**Health Technology and Training Task Group (HTTTG)**

(www.iupesm.org)

# Workshop on Palliative Radiotherapy for Developing Countries

**November 1, 2008**

Asia-Oceania Congress of Medical Physics 08 (AOCMP)
Cho Ray Hospital, HCMC, Vietnam

The Australasian College of Physical Scientists and Engineers in Medicine

## Workshop Chair and Convener

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## Contents

## *Asia-Oceania Congress of Medical Physics (AOCMP)*

The Asia-Oceania Congress of Medical Physics (AOCMP) was held at Choray Hospital in Saigon, Vietnam, from 30-31st October, 2008. It was followed by a one day workshop on Palliative Radiotherapy. The congress was well attended, with over 200 delegates. Speakers came from Vietnam, Korea, Thailand, USA, Japan, China, Malaysia, Canada, Austria and Australia.

The plenary sessions focused on the current status of medical physics in the Asia-Pacific region, including the training and professional development of medical physicists. Recurring issues included the need for an international assessment and certification system. Initial reports from the introduction of the IAEA clinical radiation oncology medical physics (ROMP) training scheme in Thailand were encouraging, and other member countries should benefit from IAEA guidelines to establish ROMP training programs.

The papers in the scientific sessions varied in content, with talks on planning system verification, linear accelerator QA, Gamma Knife dosimetry and IMRT, as well two talks on applications of non-ionising radiation. Some papers presented methods of overcoming challenges, such as lack of resources in the regional centres, explaining novel and cost-effective ways of carrying out routine QA and more complex measurements without expensive equipment. An example of this was the design and development on an in-house daily radiation beam checker.

The post-congress workshop was on palliative radiotherapy. This was organised by the Health Technology and Training Task Group (HTTTG), under the auspices of the International Union of Physicists and Engineers in Medicine (IUPESM). Within this task group are a series of action groups, including the palliative radiotherapy action group. The roles of these groups are to review commercially available equipment and evaluate the suitability of such equipment in rural communities in developing countries.

The workshop was arranged as a discussion forum for physicists, engineers and oncologists experienced in cancer care in such regions, with the aim of developing some recommendations for appropriate equipment and staffing levels for radiotherapy centres. Given that over 80% of cancer patients in developing countries present with incurable disease, a new approach is needed if ever rural populations are to receive adequate and appropriate cancer treatment.

The workshop was split into four sessions, to cover clinical aspects, choice of radiation modality, alternative approaches to imaging and therapy and cost-benefit considerations.

*Clinical Aspects*

The need for provincial radiotherapy centres was certainly in no dispute, but whether they should specialise in palliative care only was the centre of much discussion. The potential benefits of a dedicated palliative centre include lower cost (due to more basic equipment and the lower level of required expertise) and therefore more centres, enabling more patients to be able to reach palliative care. Arguments against dedicated palliative centres included potential lack of progression of quality of care, as well as the concern that these centres may be perceived simply as “places to die”. Whilst there is an obvious need for palliative radiotherapy, the option for simple curative treatments should not be ignored.

*Choice of radiotherapy modality*
It is usually assumed that Co60 units are more appropriate for radiotherapy in developing countries, due to the initial cost of a linear accelerator, as well as the need for reliable power supply and the level of skill required by linac technicians and physicists. The beam characteristics of both Co60 units and linac were compared and both were deemed acceptable for palliation. However, the cost of new sources and source disposal is often overlooked when evaluating the cost of a Co60 unit. When source changes are taken into account, the linac can become more financially viable, especially with the lower cost, simpler models that are now commercially available. These have been specifically designed for the developing world.

*Alternative approaches to imaging and therapy*
A number of lower cost palliative treatment solutions were presented, including the use of unsealed sources, high intensity focused ultrasound therapy (HIFU), and electroporation. The concept of telemedicine was also discussed, using mobile phones and internet communication to allow rural clinics to receive support from specialists based in the cities, as well as to send images for remote diagnosis.

*Cost-benefit considerations*
An analysis of the cost-benefit of using high technology for treating advanced disease in rural areas was presented, which concluded that high technology should be avoided to optimise treatment cost. Patients requiring complex treatment should be referred to specialised centres in based in major cities.

The desired outcome of the workshop is a set of recommendations. These were drafted by the Convener, discussed by all delegates and are given in section 6 of these proceedings.

Barry J Allen
Convener
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President IOMP
Vice-President IUPESM


## *Acknowledgements*

The success of this workshop was very much dependant on the financial support by our sponsors. Key sponsors were the Rockdale City Rotary Club in Sydney, IUPESM, IOMP, ACPSEM, Panacea Engineering Medicine and Best Theratronics. The support of VAMP and Choray Hospital is gratefully acknowledged.

However, without the dedicated skills and experience of our faculty, this workshop could have become yet another talkfest. Under the auspices of HTTTG and the IUPESM, our recommendations should become important considerations for health planning in developing countries.

## 1 Introduction

# Health Technology and Training Task Group (HTTTG)

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**Background**

The Health Technology and Training Task Group (HTTTG) was set up by the International Union of Physics and Engineers in Medicine (IUPESM) at the 2006 world congress in Seoul. The principal objectives of IUPESM are:

a) Contribute to the advancement of physical and engineering science in medicine for the benefit and wellbeing of humanity.
b) Organize international cooperation and promote communication in health-care science and technology.
c) Coordinate activities of mutual interest to engineering and physical science within the health care field.
d) To represent the professional interests and views of engineers and physical scientists in health-care.

The objective of HTTTG is to ascertain and then determine the development of appropriate technology and training needs in rural communities in developing countries. It also obtains funds from international organizations to allow this to happen. The sponsors and actions of HTTTG are shown in figure 1.

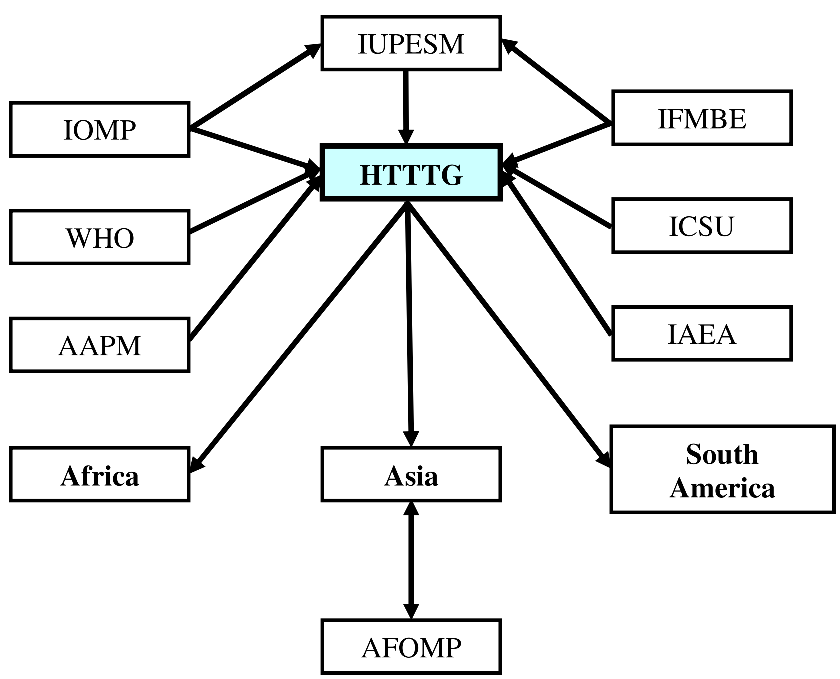

**Figure 1: HTTTG and the other organizations**

## Methods

The recent investigation of HTTTG in 2007 into the health services in the Mekong Delta of Vietnam led to the development of recommendations that call for action on several fronts. Action Groups (AG) were set up within the HTTTG to address each recommendation. These Action Groups have the task of reviewing commercially available equipment, evaluating whether such equipment is appropriate for the designated task, and if not, developing specifications and proposals new R&D that would satisfy the specifications. AGs have been formed on the following topics:

1. Telemedicine
2. X-ray source and imaging
3. Ultrasound source and imaging
4. Basic blood chemistry analysis
5. Palliative radiotherapy
6. Cervical screening

HTTTG will use these reports as independent, expert opinion on which to develop further actions in the way forward and to provide the basis for funding requests. At this stage HTTTG emphasises on telemedicine and palliative radiotherapy.

The first phase of HTTTG action was to identify key technical needs in a specific location. This has now been completed with reference to the Mekong Delta region of Vietnam, Philippines and Vanuatu. The second phase is now to recommend appropriate equipment and training to satisfy these identified needs which include

- Telemedicine between all health service levels, so as to empower each level, reducing costs and disruption of families.
- As most cancer patients are stage 4, palliative treatment is indicated.
- Palliative radiotherapy to be located in Provincial hospitals.
- The task of this PRTWS is to justify this approach.

The third phase is to fund the purchase or development of the required equipment and its installation as a demonstration model in the Mekong Delta. The widespread implementation of the technology then becomes a matter for the Vietnam Ministry of Health and international funding organisations.

## Summary

This workshop on Palliative Radiotherapy for Cancer was a first step in the development and implementation of policies of importance to the majority of mankind. The workshop was tasked to finding the best solutions to the following questions:

- Do we need provincial palliative care centres for cancer?
- How would they operate?
- How different are dose-depth distributions for Co60 and 6 MV?
- How significant is this difference for Palliative Therapy?
- Comparative capital & running costs and down time?
- Cost of maintenance and quality assurance.

- **Appropriate Technology for Palliative Radiotherapy**

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**Background**

The world is facing a crisis in cancer management that concerns developing countries in particular. Average life expectancy in developing countries is increasing in a predictable way. Data from the International Agency for Research on Cancer (IARC) indicate that cancer incidence in developing countries will increase dramatically in the first two decades of this millennium[1]. Although health is within the mandate of the World Health Organization (WHO), the International Atomic Energy Agency (IAEA) mandate includes peaceful uses of atomic energy and specifically, the use of ionizing radiation for the treatment of cancer. In response to the impending cancer crisis, the Technical Cooperation Fund (TCF) of the IAEA has been investing in the transfer of cancer treatment technology to developing countries. The IAEA is unique within the United Nation (UN) family since it has both a mandate and resources to assist developing countries directly in their cancer treatment programs.

To deal with the cancer crisis in developing countries, the IAEA symposium on dosimetry standards in 2002 was arranged with the following overviews[2]:

- IAEA potential to deal with the cancer crisis outlined in a plenary session entitled, "Meeting the Needs".
- A review of the IARC data by Sharon Whelan[3].
- A review of the equipment needs by Jake VanDyk.
- A discussion of the imaging requirements by Cari Borras et al.
- A discussion of the health economics in radiotherapy, particularly in developing countries[4].
- The executive summary of the meeting, which underlined the importance for the Agency to address the cancer crisis.

Cancer incidence in developing countries will increase by 75% in the first two decades of the 21st century[5]. Without action, the percentage of people able to benefit from treatment will decline from about 20% to only 10%.

The Programme of Action for Cancer Therapy (PACT) was created within the IAEA in 2004 to build upon the Agency's experience in radiation medicine and technology. The objective was to enable developing countries to introduce, expand or improve their cancer care capacity and services in a sustainable manner by integrating radiotherapy into a comprehensive cancer control programme that maximizes its therapeutic effectiveness and impact[6]. PACT expects an increase in incidence of 75% for developing countries whereas the increase is relatively modest in developed countries. If only 20% of patients suffering from cancer who would benefit from radiotherapy are currently being treated, the failure to act would result in only 10% of such people having access to treatment.

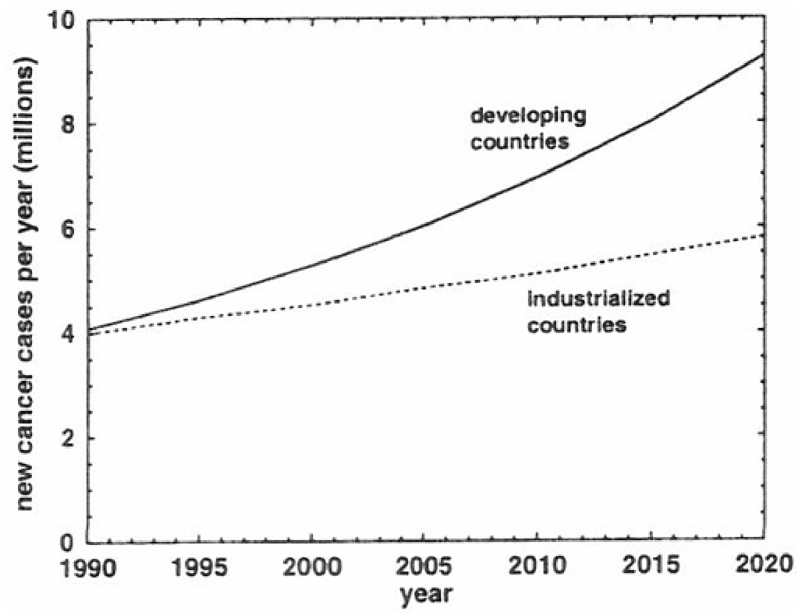


Figure 1: Estimate of cancer incidence in developing and developed (industrialized) countries. Note that in 1990 the incidence was practically the same in the two groups. In a time frame of 20 years, there will be approximately 260 million new cancer cases and nearly 150 million will be developing countries[5].

**Which countries have the right approach?**

Notwithstanding the Agency's assistance, several countries have mounted their own campaigns to enhance their citizens' access to quality radiotherapy. For example, Brazil purchased several new linacs in 2000 to address the issue of lack of access to radiation therapy facilities in their country. The Agency has several projects in Brazil to help with the transfer of high technology to improve the quality of curative therapy.

Currently, Cuba is in the process of doubling its radiotherapy capabilities. Venezuela has chosen to acquire new radiotherapy technology in a bilateral arrangement with Argentina to supply both linacs and cobalt machines.

Smaller countries in Central America have also tried to increase their capacity to deliver radiotherapy. In the case of Nicaragua, the Agency has been able to organize a demonstration site, which includes the installation of a new Equinox cobalt machine.

Many countries are constructing new cancer treatment facilities and/or expanding existing ones. Manufacturers of cobalt therapy machines have revised their designs. Manufacturers of linacs are offering more simplified and economical machines to compete in the expanding market. Here, the advantages and disadvantages of these technologies are assessed in terms of suitability, reliability and economics.

*Equipment suitability*

- The depth dose for a 6 MV linac is only slightly more penetrating than for a cobalt machine. Validating a preference for a linac over cobalt would require that a cancer therapy centre review the number of clinical cases of treating obese or exceptionally large patients who might require 5 or more fields to deliver their therapy if treated with cobalt but fewer fields if treated with a linac.
- Although the penumbra for linacs is smaller due to the smaller effective source size, this advantage is lost when multiple fields are used such as with IMRT.
- Linacs have a dose rate about twice that of cobalt, but set up time (15 min) determines throughput. Traditionally, clinics using cobalt work longer hours to get all their patients treated.
- Quality assurance issues tend to be simpler for cobalt machines, but manufacturers of cobalt machines have been slow to add new QA tools such as record and verify systems.
- The decision process in selecting one technology over another has to take into account the nature of the patient population to be treated. Typically, since 80% of patients require palliative therapy in many developing countries, the sophistication afforded by linacs may not be justifiable.

*Equipment reliability*

- A requirement of the International Basic Safety Standards (BSS)[7] is that national regulatory authorities insist that cancer clinics install only machines that are compliant with the safety standards of the IEC.
- However, equipment safety standards alone do not encourage purchasers to assess issues associated with the delivery of spare parts and the availability of qualified service personnel.
- In some developing countries, just raising a purchase order to get replacement parts may be problematic. This may tip the decision in favour of purchasing a cobalt machine due to its traditionally greater reliability.

*Economics*

- *Facility construction:* Decisions regarding the choice of teletherapy equipment should be made on the basis of the anticipated clinical benefit, costs (initial and operational) and downtime. In developing countries, the costs of treatment per patient are generally much lower with $^{60}Co$ teletherapy than with linac teletherapy (Table 1). Furthermore, experience in developing countries has shown that the downtime of a linac is considerably longer than that of a $^{60}Co$ unit. Therefore, by choosing a $^{60}Co$ unit, it may be possible to offer greater reliability and as a consequence, to treat a larger number of patients over the lifetime of the machine.[8]
- *Staff training:* Agency Member States seek help on technical matters related to infrastructure and equipment rather than on medical issues pertaining to treatment protocols for example[9]. The number and type of staff members required to support cobalt machines is less than required for linacs. In addition, the training regime to support the operation of a cobalt machine requires less time than is the case for linacs.

- *Machine costs:* Building-in repairs and servicing including replacement cobalt sources are important considerations. A treatment fraction on a linac with functionality comparable to cobalt, costs 50% more than for cobalt therapy[5].

**Table 1:** Costs of radiotherapy per treatment course (the costs incorporate local labour costs and are based on an IAEA study[10]. Costs are in US dollars at 2002 prices, and are intended for comparison purposes only.)

| | Palliative radiotherapy (Single fraction) | | Radical radiotherapy (30 fractions) | |
|---|---|---|---|---|
| Country | $^{60}$Co unit | 6 MV linac | $^{60}$Co unit | 6 MV linac |
| India | 3 | 11 | 90 | 330 |
| Indonesia | 10 | 17 | 300 | 510 |
| Netherlands | 34 | 32 | 1020 | 960 |

**Developing Country Problems**

Frequently, the basic infrastructure is too weak in developing countries to support sophisticated technologies. For example, an unstable power grid precipitated the linac accident in Poland in 2003. In Zambia in 2008, a new linac has shown a greater number of treatment days lost compared to a cobalt machine, because of unplanned power failures.

**Conclusions**

The physical characteristics of the radiation distributions produced by cobalt are not significantly different from those produced by 6 MV photons. More importantly, any physical differences may not be clinically important particularly given the preponderance of palliative cases in most developing countries. The costs to purchase and operate a cobalt machine are less than 50% of the costs for linacs. Since linacs are more complicated in principle, they suffer more lost treatment days due to unscheduled shutdowns, sometimes due to an unstable power supply. Some countries experience problems obtaining replacement parts because of difficulties to raise purchase orders and long delivery times.

Faced with the moral imperative to treat people suffering with cancer, it is necessary to select appropriate technology to optimize the impact of therapy delivery, at least to provide pain relief. It is not easy for developing countries to select the most suitable equipment for their needs. However, through its guidance documents, the IAEA provides assistance. The PACT program has created awareness of the cancer crisis in developing countries. PACT is now turning attention to raising the additional funds to help developing countries to improve their radiotherapy capabilities.

**References:**


1. Parkin D. M., Bray, F. I., Devesa, S. S., “Cancer burden in the year 2000. The global picture”. European Journal of Cancer, **37**, S4-S66, 2001.
2. Standards and Codes of Practice in Medical Radiation Dosimetry. Proceedings of an International Symposium, Vienna, 25-28 November 2002, Vol 1, IAEA, Vienna, 2003.

3. Whelan S.L. International Agency for Research on Cancer, "Cancer epidemiology in developing countries" pages 189-203, reference #2 above.
4. Levin C.V. & Tatsuzaki H. International Atomic Energy Agency, "Issues of health economics in the practice of radiotherapy in developing countries" pages 221-230, reference #2 above.
5. Salminen E., Izewska J. and Andreo P. "IAEA's role in the global management of cancer-focus on upgrading radiotherapy services". Acta Oncol., **44** 816-824, 2005.
6. www.iaea.org/Publications/Booklets/TreatingCancer/**pact**1006.pdf.
7. International Basic Safety Standards for Protection against Ionizing Radiation Sources, IAEA Safety Series No. 115, IAEA, Vienna, 1996.
8. Setting up a radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA, Vienna, 2008.
9. Podgorsak E.B. Radiation oncology physics: a handbook for teachers and students. (Sponsored by the IAEA and endorsed by the COMP/CCPM, EFOMP, ESTRO, IOMP, PAHO and WHO.) IAEA, Vienna, 2005.
10. Giessen V.D. et al. Multinational assessment of some operational costs of teletherapy. Radiotherapy & Oncology, **71**, 347-355, 2004.

## 2 Clinical Aspects

# The Role of Radiotherapy in Palliative Care

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## A. Basic Principles

**Radiation Physics**

Radiotherapy is the use of ionising radiation in the treatment of disease. Ionising radiation is so called because, when it interacts with matter, ions are created. The major types of radiation used for treatment are X-rays or gamma rays.

Electromagnetic radiation with photons of energy greater that 10 electron volts can eject orbital electrons from the target atoms creating ions. The excess photon energy is transferred to kinetic energy of the ejected electron, which further interacts with other atoms losing energy. Ultimately all the photon energy is deposited in the target material and many ions are created. The energy of the X-ray or γ-ray photon determines the physical and biological characteristics of its interaction with the target material (in medicine the target material is the cell and tissues).

Photons of ionising radiation interact with matter and lose their energy in 3 ways:

1. Photo electric effect
2. Compton scattering
3. Pair production

One or other of these processes predominate at different photon energies. The net effect of all ionising photon interactions is deposition of energy in the target tissue and the production of energetic electrons and ions. When this occurs in human tissue cells die.

**Radiobiology**

Cells die after being irradiated mainly due to damage to their DNA with the consequent loss of the ability to divide. DNA may be damaged either by direct ionisation or indirectly by chemical interaction with the free radicals formed by ionisation of water (most of the cell content).

Induction of double strand breaks in DNA is the dominant mechanism of cell killing by X-rays or γ-rays. Breaks in the DNA and misrepair of the damage to DNA, result in the cell dying when it next attempts to divide.

Ionisation produced by radiation is distributed randomly in cells; consequently cell death follows random probability statistics.

The typical single dose-cell survival curve has an initial shoulder and then becomes exponential at higher doses. The dose levels used in clinical practice are on the shoulder part of the curve.

The equation $SF = e^{-(\alpha d + \beta d2)}$ describes this curve.

Where, SF is the surviving fraction of cells, $\alpha + \beta$ are constants and d is radiation dose.

When multiple doses of radiation are given the effective survival curve is an exponential curve with a shallower slope. The fraction of cells surviving depends on, the size of each dose fraction, and α/β ratio. The α/β ratio is known to be different for different types of tissue. (Slowly proliferating cells ~ 3, compared to rapidly proliferating cells ~ 10)
The calculation of multifraction treatment programmes which use different sized dose per fraction, to result in equivalent cell survival can be made using the α/β ratio.

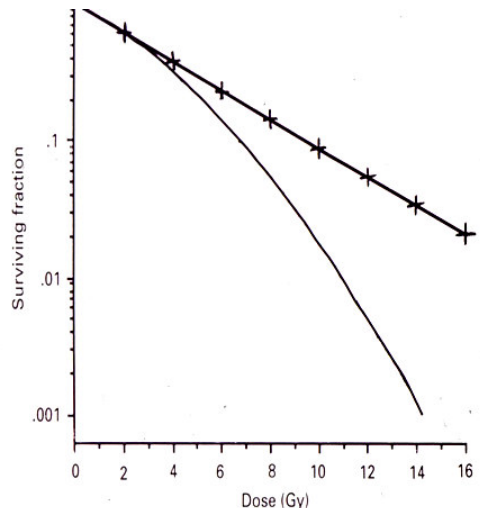

**Figure 2:** Effective Cell Survival Curve from multiple doses of radiation

**Tissue Response to Radiotherapy**
At the tissue level the response to irradiation reflects the cell survival and the regenerative capacity of the tissue stem cells.
Since the death of irradiated cells is apparent when they attempt to divide, the observed effects of radiation on tissue are largely determined by the frequency of the cell division within that tissue. As, cancer cells are generally divided more rapidly than normal tissue cells, and cancer cells cannot repair and recover from ionising radiation to the same degree as normal cells, more cancer cells are killed off than normal cells.

**Fractionation of Radiation Dose.**
Fractionation or dividing the total radiation dose into a number of smaller doses exploits the differences between the normal tissue and the cancer tissue response to radiotherapy.
Fractionation exploits the 4 R's of radiotherapy:
1. Repair of sublethal damage in normal cells
2. Repopulation of normal cells
3. Redistribution of cancer cells to more sensitive phases of the cell cycle
4. Reoxygenation of hypoxic areas in the cancer

Fractionation of the radiation dose aids the repair and recovery of the normal tissue and increases the radiation sensitivity of the cancer cells. Over a multifraction course of irradiation these differences add up, to minimise normal tissue effects and increase cancer cell kill.
Fractionation is also important for normal tissue effects. The faster turning over normal tissues like mucosa, skin and bone marrow are responsible for the observed acute effects of radiation. These are the effects seen during or soon after the

irradiation is given. The acute effects of radiation are a manifestation of the death of rapidly dividing normal cells, and always recover after treatment (for the usual doses used in treatment).

The more slowly dividing normal cells show the effects of radiation much later, e.g. kidney, bone, fibrovascular tissue. The late effects of radiation are a manifestation of depletion of the functional parenchymal cells of a tissue. Late effects are the dose limiting effects in radiotherapy.

Dividing the radiation dose into more, smaller fractions of treatment will reduce the severity of acute effects but will not alter the late effects. The total dose given is more important for determining late effects although fraction size is also important. When using radiotherapy for palliative treatment, the late effects are usually not a great concern as the patient's survival is short and they do not live long enough to manifest these effects. However, late effects do need to be considered if retreatment of an area previously irradiated is contemplated or when treating a patient who has a metastatic cancer that is compatible with a long survival e.g. myeloma, thyroid cancer, and some breast and prostate cancer.

The radiation dose which produces an acceptably low probability of late tissue damage is called the Tolerance Dose. The tolerance dose is different for different tissues, with quite a dose range from the most sensitive to the most resistant tissue. The tissue with the lowest tolerance dose, which is in the path of the radiation beam, is obviously the dose limiting tissue for a particular course of treatment.

**Modern Radiotherapy**

Most radiotherapy treatment is given using external beam radiotherapy. The modern era of radiotherapy began in 1937 with the invention of the Van der Graff generator and the availability of megavoltage energy radiation beams. The advantages of a megavoltage therapy beam compared to lower energy beams are:

1. Greater Penetration in Tissue – Co60 gives a beam penetration, and hence dose delivery equivalent to a 4 MV linear acceleration.
2. Skin Sparing – the acute skin effects no longer the limit to delivering radiation dose deep in the body.
3. Beam Definition – i.e. narrow beam penumbra allow sharp delineation of irradiated and non irradiated tissue.
4. Bone Absorption - is not increased so that bone toxicity is not a problem.

**Cancer Therapy**

Ionising radiation is a potent cytotoxic (cell killing) agent and is one of the 3 major therapeutic tools in cancer treatment:

| | |
|---|---|
| 1. Loco-regional therapies: | Surgery<br>Radiotherapy-(ionising radiation can only influence the cancer within the path of the treatment beam). |
| 2. Systemic therapies: | Chemotherapy<br>Hormone therapy<br>Systemic radioisotope therapy |

**Symptom Diagnosis**

Because external beam irradiation only produces its effect within the area irradiated, it is important that the tumour deposit responsible for the symptom is identified and then treated. Diagnostic skill is required to determine the anatomical location of the

symptomatic tumour deposit and is the essential basis for effective palliative radiotherapy.
Diagnosis requirements:
- A good clinical history and physical examination is fundamental for diagnosis and to guide further investigation.
- Plain X-rays will confirm clinical findings often.
- CT scan is particularly useful for assessing the site and extent of soft tissue cancer deposits.

**Principles of Palliative Radiotherapy**
The intention of giving radiotherapy for palliation of symptoms is improvement in quality of life by decreasing or eradicating symptoms. This will not be achieved if the treatment itself induces a lot of side effects. Also, patients with metastatic cancer have a reduced life span, this may only be months, and therefore the treatment itself should not consume a major portion of the patients remaining lifespan. The major benefit of radiotherapy is the speed with which symptom improvement develops and the certainty of response. Sufficient radiation dose must be given to ensure that the symptom response will last for the rest of the patient's life. Too low a dose means retreatment at some later time is needed.
Hence guiding principles are:
1. Accurate anatomical localisation of the symptomatic tumour deposit.
2. Simple treatment techniques and field arrangements
3. Short hypofractionated treatment regimes.
4. Moderate dose treatment to achieve a good predictable response and to keep treatment toxicity to a minimum.
5. Consider the patient's overall life expectancy when determining the treatment aims and the treatment duration.

## B. The Role of Palliative Radiotherapy in Practice

1. Bone metastasis and bone pain
2. Cerebral metastases
3. Bleeding and fungating tumour
4. Obstruction/pressure symptoms

### 1. Bone Pain and Bone Metastasis
The skeleton is one of the commonest sites for metastatic cancer of any type. Whilst cancer in the bones is not usually directly life threatening it is frequently a source of pain which is a major debility. On occasions the more disabling complication of pathological fracture, spinal cord compression and hypercalcaemia may also occur. Local irradiation of one or more painful bone deposits is associated with a high probability of pain relief.
This graph plots probability of pain relief related to time for one clinical trial of palliative irradiation of painful bone metastasis where a multifraction treatment regime was compared with a single fraction. It demonstrates that the onset of pain relief may take 2-3 weeks to occur. It also shows that a single fraction of 8Gy is as effective as 30Gy in 10 fractions for achieving pain relief.

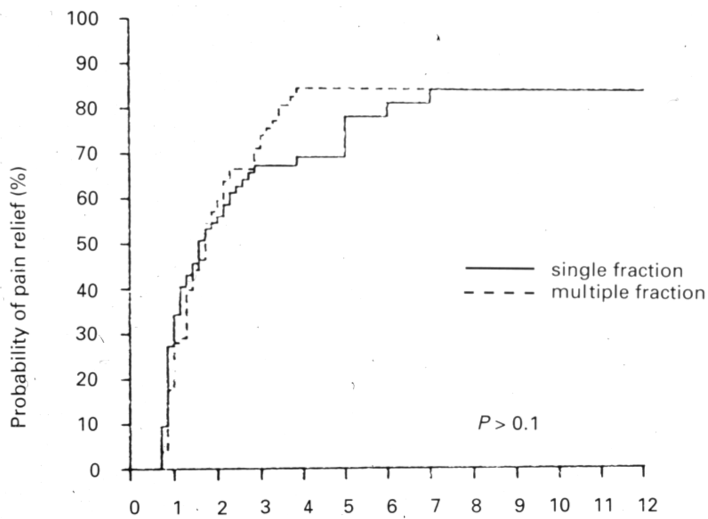


**Figure 3:** Probability of pain relief related to Time

However, other studies show that longer term pain relief, greater tumour shrinkage, and thus, fewer episodes of retreatment are achieved by a multifraction treatment program. Hence the choice of dose and fraction number needs to be tailored to the patient's general condition, expected survival and convenience of access. While single dose treatment may be adequate for pain relief, when tumour shrinkage is the goal this may not be adequate. For example, in spinal cord compression, where extension of soft tissue tumour from the vertebral bone into the spinal canal causing the spinal cord to be compressed and neurological impairment, or in a weight bearing bone, where sufficient bone destruction has occurred to reduce the mechanical strength of the bone. In these situations significant tumour shrinkage is required to relieve symptoms. So, short course fractionated treatment is preferred either 30Gy in 10 factions or 20Gy in 5 fractions at 5 fractions per weeks.

*1.1 Mechanical Strength*

In weight bearing bones (e.g. femur) bone metastases may cause enough bone destruction to reduce the mechanical strength of the bone. The bone is weak and may break. Mechanical strength will be restored if the bone can heal and repair. To enable this to occur, the tumour eroding the bone must be made to shrink. Fractionated radiotherapy causes the tumour to shrink relatively rapidly and bone healing proceeds a lot more slowly, by the normal bone healing processes. It may take 3 months or more for the mechanical strength of a bone to be restored after radiotherapy, so the bone remains at risk of facture for this time. Prophylactic surgical strengthening of the bone by an orthopaedic operation, e.g. putting in an intramedullary nail or plate, can improve the mechanical strength of the bone and prevent the trauma and disability of a fracture. Radiotherapy is still very necessary to shrink the tumour at the site to allow bone healing but the mechanical weakness and fracture risk has been remedied by the surgery.

*1.2 Wide Field Irradiation for Bone Metastasis*

When there are multiple sites of pain arising from widespread bone metastases, wide field irradiation is a useful technique for palliating pain. This is referred to as hemi-body radiotherapy. A single dose of radiotherapy is given to one half of the body. An RTOG study of 168 patient reports overall response rate 73%. Whilst the onset of pain relief may be rapid, (within 24 hours), it may take up to 6 weeks to fully develop. The duration of response is usually measured in months. No significant tumour regression is seen. It is possible to treat one half of the body and six or more weeks later treat the other half to achieve whole body pain relief. This treatment has little toxicity when the patient is pre-medicated with corticosteroids and antiemetics prior to treatment. The main toxicity is bone marrow depression which can be quite prolonged. Hence it is important to check the blood count prior to each treatment.

*1.3 Bone Seeking Radio-Isotopes*

In an attempt to deliver radiation more selectively to the site of bone metastases the use of bone seeking radioisotopes has been explored. This is a systemic form of radiotherapy to treat multiple symptomatic bone metastases. Bone seeking radioisotopes of Strontium or Samarium are selectively taken up at sites of osteoblastic bone metastasis, where they are retained enabling the delivery of significant doses of β irradiation at the sites of the metastases.

Treatment is administered as a single intravenous injection to an outpatient. The time to response may be protracted. It is primarily suitable for cancers which produce osteoblastic metastasis. Hence it has been most used to treat prostate cancer and some breast cancers. In one study of 83 patients with bone pain from prostate cancer metastases a response rate of 63% was seen.

Intravenous bone seeking radio-isotopes appear to give similar response rates to hemi body radiotherapy but there have been no trials comparing the two. The toxicity is primarily bone marrow depression, particularly with repeat treatments.

The main draw backs the significant financial cost of the isotopes.

## 2. Cerebral Metastases

Brain metastases are a major cause of symptoms and neurological disability. In general, patients present with multiple tumour deposits in the brain in the setting of widespread metastatic disease elsewhere. However as systemic chemotherapy improves, and as the brain is a sanctuary site for chemotherapy, brain metastases may be seen as the first site of metastatic disease. The median survival for patients with brain metastases varies from 1 month to several years depending on the primary cancer. Survival is related to the extent of neurological deficit at diagnosis and the extent of metastatic disease outside the brain.

Corticosteroids can palliate brain metastasis symptoms in a proportion of cases but the beneficial effect diminishes with time.

Palliative cerebral irradiation, because it kills the tumour and causes tumour shrinkage, consolidates and improves on the steroid response and maintains the response for a prolonged time.

Palliative brain irradiation is aimed at maintaining and improving neurological function and performance status until death occurs from some other metastases at another site.

Again the treatment program can be tailored to the patient's general condition and expected survival. For whole brain treatments most use 5 or 10 fractions but a single dose can be used.

## 3.Bleeding and Fungating Tumour

Bleeding, ulcerating and fungating tumour is one of the most disabling and unpleasant things for a patient. Bleeding is frightening for the patient, and the pain and smell arising from necrotic tumour are major detractors from quality of life. In advanced breast cancer this can be seen occurring on the skin. But the same thing occurs with cancer in the bladder, uterus or bowel when the mucosal surface is breached. In order to achieve any meaningful palliation, significant tumour regression must be achieved.

Radiotherapy has a major role in controlling bleeding and ulceration. Only slight tumour shrinkage is needed to stop bleeding but higher doses of palliative radiotherapy result in cancer shrinkage and this allows the surface to heal.

**4. Obstruction / Compression Symptoms.**
A range of symptoms are produced from a cancer mass developing within or around a normal structure and obstructing a hollow organ such as the bronchus or oesophagus or compressing adjacent normal tissues causing pain and functional disturbance, for example spinal cord compression or brachial plexus entrapment.
Irradiation of these cancer masses can relieve the obstruction or pressure and thus relieve the symptoms. Short courses of irradiation can achieve this e.g. bronchogenic carcinoma causing bronchial obstruction and collapse of distal lung.

## C. Palliative Medicine

**Control of Physical Symptoms**
While I have focussed on palliative radiotherapy in this talk, it is only one aspect of palliative care. Radiotherapy is one of the main tools used for the control of physical symptoms arising from cancer. Other tools used in addition to radiotherapy include:

1. Symptom Controlling Drugs
   - Analgesics – Aspirin, Panadol, NSAIDS, OPIATES Morphine, Codeine.
   - Antiemetics – Stemetil, Maxalon, Ondansetron
   - Corticosteroids
   - Bisphosphonates - alendronate , zolendronate, chlodronate
   - Aperients
   - Antispasmodics
2. Anticancer Systemic Therapy
   - Cytoxic Drugs
   - Endocrine Therapy
3. Aids and Physical Supports
   - Crutches, walking frames, slings.
4. Palliative Surgery
   - Laminectomy for spinal cord compression
   - Orthopaedic operations to prevent fractures
   - Stents for ureter , bile duct or bronchus

Symptom controlling drugs essentially suppress the symptoms, which is appropriate if there is no more effective treatment available or for short term relief while anticancer therapy is implemented. If it is possible to remove the cause of the symptoms, e.g. with palliative radiotherapy, much more effective palliation is achieved.
To achieve effective treatment of physical symptoms all the skills of good medicine are required:

1. Accurate diagnosis
2. Good clinical judgement
3. Patient focused and tailored treatment
4. Comprehensive knowledge of cancer and its available treatment
5. Appropriate follow up and reassessment

The control of physical symptoms is essential for effective palliative care and maintaining quality of life. Control of physical symptoms is the basic requirement of palliative medicine upon which the other aspects of the holistic care of the patient can be built, to achieve a quality palliative care plan for each patient.

In summary the Palliative Management Plan elements are listed here.

1. Recognition of the symptoms and its significance. Any symptom which interferes with or has the potential to interfere with the patients' functional state deserves attention.
2. Specific treatment for the cause of that symptom
3. Systemic treatment for the cancer
4. Non specific symptom suppression
5. Review and Reassessment

**Multidisciplinary Care and Telemedicine**

The care of the patient with metastatic cancer is just as much a multidisciplinary team activity as curative cancer treatment. However, the multidisciplinary team do not need to be physically all at the one location. Teleconferencing, video conferencing and computer links enable specialist to liaise with the local medical community and provide expert advice.

A doctor locally would need to take the history from the patient, complete a physical examination and assessment to relay the information to the specialist at a remote site, as well as be able to implement the planned treatment. Imaging can be transmitted for viewing and specialist diagnosis. Similarly computer links allow viewing of treatment planning images and field marking for radiotherapy to be done remotely.

One specialist radiation oncologist could thus support several radiotherapy treatment facilities delivering treatment to patients close to their home and assist the local medical and paramedical team care for the patient.

Telemedicine could allow a small number of specialists at a central location to assist non specialists deliver effective palliative patient care at the local level.

# Considerations in Developing a Regionalized Palliative Oncology Program in a Low- or Middle-Income Country: A Radiation Oncology Perspective

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## Abstract

Radiation is an indispensable tool for the effective palliation of advanced cancer. Numerous considerations in planning and implementing services are relevant to effectively deliver palliative radiation. Patient-related, disease-related and practice-related factors affect the need for palliative radiotherapy. Differences in national and regional cancer epidemiology will have a large impact on the most common indications for palliative radiation and other palliative services. In addition, an ongoing epidemiologic transition in Low- and Middle-Income Countries (LMICs) means a higher burden of cancer. The high proportion of late-stage presentations in these settings create a significant need for palliative services including radiation. The heavy burden of late-stage presentations also indicates significant opportunities for cancer prevention and early detection to reduce the need for palliative radiation.

Access to palliative radiation for dispersed populations is a multi-dimensional issue. Availability is a key dimension, though other factors include spatial accessibility, acceptability, affordability, accommodation and awareness. As such, improving access to palliative radiation will involve more than simply providing the right equipment and enough of it. An attractive model for accessible care provision is the hub-and-spoke model with high-complexity treatments provided in larger cancer centres in key cities and lower-complexity treatments in regional centres.

The relationship of palliative radiation therapy to other palliative care needs is important to recognize. Essential elements of a palliative care initiative include adequate access to narcotics, health care worker training, patient advocacy, public awareness and caregiver education and support. Integration of palliative services into a comprehensive cancer control plan is crucial to the success of any cancer program. Equally important is a context-specific and step-wise approach to the planning of radiotherapy services.

We would put forward that careful and informed investment in radiotherapy services is an important and irreplaceable part of effective palliative and curative cancer care in LMICs. We need further international dialogue regarding these issues, and the development through research of more cancer control strategies for LMICs specific to radiation oncology. We have the tools to prevent and ease the suffering of millions of men, women and children around the world inflicted with the heavy burden of advanced cancer. We have an unprecedented opportunity to bring relief as never before.

## Introduction

This paper will highlight some of the key considerations for planning a regionalized palliative oncology program in a Low- or Middle-Income Country (LMIC). We will provide a clinical and health services perspective with focus on the role of palliative radiation within a national palliative oncology program for a dispersed population. Although the focus will be on LMICs, many of these considerations are also relevant in High-Income countries.

Planning is 'the process of deciding how the future should be different from the present, what changes are necessary and how these changes should be brought about'.[1] This process of planning can be conceptualized as three related questions suggested by the World Health Organization: Where are we now? Where do we want to be? How do we get there?[2]

## Where are we now?

Currently, available information suggests there is often little or even no use of palliative radiation as part of palliative care for cancer patients in LMICs.[3,4] Estimating the need for palliative oncology services involves an understanding of patient-related, disease-related and practice-related factors that may interact at the individual and population level. Patient-related factors include age, performance status, comorbidity, perception of available treatment options, treatment preferences, and cultural norms. Furthermore, palliative therapy requires clinical acumen to balance potential benefits against treatment-induced toxicity. For instance, choosing a shorter versus a longer course of palliative radiation for lung cancer requires careful assessment of the patient's performance status and expected prognosis. With malnutrition and limited primary care in many LMICs, patient performance status may be worse in general than in wealthier jurisdictions and this will alter the estimated need for various palliative services such as radiation.

Cultural and individual variability in perception and preference also influence the need for palliative services. For example, investigators in Singapore have found that 85% of patients preferred a multiple day radiotherapy regimen over a single fraction for palliation of painful bony metastases.[5] In contrast, a group of investigators in Canada found that 76% of patients preferred single day radiation to a fractionated course for bone metastases using the same survey tool.[6] This contrast illustrates different valuation of the inconvenience associated with fractionated treatment visits, which is probably more burdensome for palliative patients in Canada where there is evidence that travel distances to and from cancer centres is a barrier to access.[7,8]

Disease-related factors can significantly influence the need for palliative oncology services. There is an epidemiologic transition occurring in LMICs with a rise in chronic diseases. Leading causes of death worldwide from chronic disease are cancer, cardiovascular disease, chronic respiratory illnesses and diabetes.[9-11] This is due to gradually rising life expectancy along with population growth and adoption of smoking, poor diet and lack of physical activity, risk factors for chronic disease.[11] According to WHO statistics, already 71% of cancer deaths worldwide are in LMICs and this number is projected to rise so that by 2010, cancer will be the number one cause of death worldwide.[12,13]

Regional and national cancer epidemiology varies widely and the common cancers in each area will lead to different palliative needs. As an illustration, Table 1 outlines some of the common cancers in Vietnam and the expected effectiveness of radiotherapy in palliating their common symptoms. Such a table is country-specific, given that cervical cancer, liver cancer and nasopharyngeal cancer rates vary widely globally.

Population-based prevention programs such as cervical cancer screening and tobacco control and education have brought notable reductions in incidence of related cancers in High-Income Countries.[14,15] Hepatitis B vaccination has also been found effective at reducing virus-associated cancers.[16] While cancer programs in LMICs will likely incorporate prevention strategies, the impact on cancer incidence will not likely be realized without decades of coordinated efforts. Hence attention to present country- or region-specific cancer epidemiology is vital to estimating the needs for palliative services.

**Table 1:** Some common cancers in Vietnam, their symptoms and effectiveness of symptom control with palliative radiation.

| | | **Symptom Control with Radiation (RT)** | |
|---|---|---|---|
| **Common Cancers in Vietnam** | **Common indications for palliative treatment** | **RT usually effective** | **RT usually not effective** |
| Lung | Shortness of breath, hemoptysis (mediastinal mass), pain (bone metastasis), anorexia, brain metastasis, malaise | Hemoptysis, pain, (equivocal: shortness of breath, brain metastasis) | Anorexia, malaise |
| Liver | Nausea, pain, anorexia, malaise | No established indications | Nausea, pain, anorexia, malaise |
| Colorectal | Rectal bleeding, pain, mass, bowel obstruction | Bleeding, pain, rectal mass | Other mass (lung, liver), bowel obstruction |
| Cervix | Bleeding, pelvic mass, pain, ureteric obstruction, edema | Bleeding, pelvic mass, pain | Ureteric obstruction, edema |
| Nasopharynx | Neck mass, painful bone metastases, lung, liver metastases | Mass, pain | Lung, liver metastases |

Practice-related factors can have a drastic impact on the need for palliative services. Without access to diagnostic imaging services, many cases of cancer may not be diagnosed. In most cases it will also not be possible to differentiate palliative from curative cancer cases which will lead to inappropriate under-use or over-use of palliative radiation. As mentioned, many cancers in LMICs are highly preventable. Danaei et al emphasize that about a third of cancers in LMICs are due to preventable causes.[12] Early detection through screening programs for breast and cervical cancer can reduce the number of patients with advanced incurable cancers, hence reducing the number of patients needing palliative radiation as part of their initial treatment.[17,18] Approaches appropriate to LMICs for early detection of breast and cervix cancer exist in the medical literature to guide health policy makers.[19-22] Also, policies regarding accepted indications for palliative radiation and choice of number of daily treatments for these indications will impact service needs.[23]

Evidence-based approaches using regional epidemiology and the scientific literature have produced estimates of the need for radiation in High-Income Countries but these have not been widely applied to LMICs.[24] Evidence-based estimation of the need for radiation is limited by the capacity to carry out cancer staging investigations in most LMICs. Using the Australian estimates of need for radiation by cancer type, Barton *et al* proposed that the overall need for radiation for cancer patients in regions of Africa varied between 47% and 61% of all cancer cases.[3] These are probably underestimates given the large proportion of late-presenting patients in Africa and other LMICs compared to Australia and the significant need for palliative radiation among patients with advanced and metastatic cancer.

A benchmark-based approach may also be used as an alternative to evidence-based estimation of the need for radiation. With this technique, benchmark communities are selected where radiation therapy is freely accessible and decisions regarding radiation therapy are likely to be appropriate. Benchmark radiation use rates are established based on observed practice patterns at these centres. These rates can then be used for program planning or for program evaluation at other regional centres. Benchmark sites have not been clearly defined or identified in LMICs. The efforts of the IAEA Programme of Action for Cancer Therapy (PACT) may provide useful data in this regard.[25] This noteworthy programme encompasses a number of demonstration comprehensive cancer treatment centres in various LMICs throughout the world that are designed to serve as centres of excellence. These are at various stages of development.

**Access**

Assessing need is only one part of answering the question of ‘where are we now?’. Determining current use of care and barriers to meeting care needs, or in other words access to care, is equally important. Penchansky and Thomas describe five cardinal elements of access: availability, spatial accessibility, acceptability, affordability and accommodation.[26] Mackillop adds a sixth: awareness.[27] Spatial accessibility refers to the both the distance to available services and the time it takes to traverse that distance. This time can be affected by infrastructure such as the quality of roads and modes of transportation. The dimension of acceptability is of particular note. For instance, radiotherapy may be seen to conflict with certain South African cultural beliefs regarding traditional healing methods for breast cancer.[28] Programs may also be deemed unacceptable to patients and families if they do not take into account the established cultural role of the family in care giving, decision making and communication of information to the patient.

Affordability refers to both direct and indirect costs. Indirect costs include loss of income due to sickness of the patient or the need for the family to take time off of work to bring the patient for treatment. It also includes transportation and accommodation costs if specialized services are not close by. In medical systems where equity is not a cornerstone of administrative policy, the practice of bribery would incur added costs to patients requiring multiple consultations at varying levels of specialization. The dimension of accommodation refers to organization of services to meet patient needs such as operating hours and flexibility of appointment times.

**Awareness**

Awareness as an element of access to care is of particular note. This refers to the patient’s awareness of their need for palliative services, their knowledge of affordable services to meet these needs and also to health care worker knowledge of the availability of and indications for these services. If awareness of services does not exist, a bountiful supply of equipment, buildings and personnel will not lead to truly accessible care. Building awareness in the general public may be through public service announcements by collaboration with local media, such as print, radio and television. It may also be through word of mouth or through promotion at public or community events. Building awareness among future health care workers requires the inclusion of appropriate palliative and curative oncology teaching curricula within national health care training programs. Continuing medical education (CME) is also important for experienced health care workers as many may have been trained in educational systems geared toward management of communicable diseases. CME initiatives should include primary care physicians who will be involved in palliative care and referral of patients to specialized cancer services.

**Where do we want to be?**

Following an assessment of 'where' a program is, one needs to ask 'where do we want to be?' This will involve developing means to overcome factors perceived to be limiting access to care. A centralized approach to specialized cancer services is often the norm in LMICs. Services, if available, tend to be clustered in one or a few large cities with little available beyond. Given a lack of awareness and the cost of transportation, oncology services are essentially non-existent for those outside of the larger cities. Datta and Rajesakar have suggested a three-tier model for provision of radiotherapy services for India.[29] This model is an attractive one for other limited-resource settings, though we emphasize that little research has been done to identify the optimal model for providing radiotherapy services in LMICs. They describe three levels of treatment capacity with external beam radiotherapy (EBRT) alone at primary centres, with planning and simulation done at the secondary or tertiary centres and transmitted to the primary centre electronically. EBRT, brachytherapy and simulation would be available at secondary centres and a full range of equipment and advanced technical capacity such as intensity-modulated radiation (IMRT) at tertiary centres. All three levels of centres would be linked through computer networking allowing for teleconsultation, off-site treatment planning, continuing medical education and tumour boards. Further research will need to be done to explore other models and compare it to this one to identify ways of providing the most accessible, highest quality, most sustainable and economically efficient care possible.[30]

There is little primary literature or guidelines describing the optimal role of radiotherapy in limited-resource countries wishing to provide palliative care services for geographically dispersed populations. It is crucial to note that access to opioid pain medication, education of health care workers in palliative care, advocacy on government palliative care policy that may excessively prohibit access to opioid pain medication, and education and awareness among patient's families and the general public are first priorities for any successful palliative care program.[30,31] Models of effective out-patient and community-based palliative care programs in Uganda, India and Malaysia are notable examples, emphasizing the principles discussed above in their palliative care service models.[30,32-34] Though radiation therapy is an effective modality, its maintenance and delivery requires qualified professionals, technical expertise and large start-up expense. The foundational elements of a palliative care program described above such as access to opioids, education, effective policy and awareness do not require the same level of expertise or start-up expense and can bring rapid population-level benefits to those in need of care. We will also emphasize here as we will elsewhere in this paper that any plan to implement palliative radiation services must occur in parallel with plans to concurrently build capacity to identify and treat patients with potentially curable cancers.

The WHO has outlined a number of key principles of cancer control that are applicable to planning a palliative oncology program for cancer and other diseases. These are *leadership, stakeholder* involvement, *partnership* creation, *responsiveness* to needs of people, *informed decision making,* application of a *systematic* approach, *continuous improvement* and adoption of a *stepwise* approach to meeting program goals.[2] Strong *leadership* is needed to provide clarity and unity of purpose. *Stakeholders* need to be identified and key players from all levels of the decision-making process need to be gathered as part of the planning process. *Partnerships* creating trust and capacity across disciplines and sectors are needed.

*Responsiveness* to needs of people includes building an understanding of patient and family basic needs, symptom assessment and control, addressing end-of-life issues and the financial impact of the patient's disease on the family unit. For instance, providing financial support for a family whose sole breadwinner is dying may bring relief to the whole family unit in the common situation in Low-Income Countries where life insurance and disability insurance are not commonly affordable. Surveys from in various African countries have identified hunger as often the second most common self-assessed end-of-life need after pain control.[35] If a palliative care program is not geared towards their client's key needs, it cannot succeed. *Informed decision making* means basing plans on available scientific evidence and considering social values, cost-effectiveness, sustainability and practicality. Unfortunately, there is often a lack of region-specific and resource-appropriate data to guide palliative and curative radiation practice in LMICs. This highlights the need for a broadening of the global radiation oncology research community's activities and the need for systematic, consensus-based deliberation of optimal management when resources are limited. The Breast Health Global Initiative's guidelines for the comprehensive management of breast cancer in LMICs is an example of this process applied to cancer management.[19] The IAEA's guidelines on management of lung cancer in limited resource settings provide an early example of radiation oncology considerations in LMICs.[36]

A *systematic* approach to planning involves partnerships with other programs of the local health system, creating horizontal integration rather than a stand-alone vertical program. This is important for palliative care, where other illnesses such as HIV/AIDS create other significant palliative needs beyond cancer. *Continuous improvement* implies collection of data on a regular and systematic basis so that quality can be evaluated and programmes adapted for optimal performance of palliative services. Lastly, a *stepwise* approach is key when resources are limited. A stepwise approach sets out a long-term plan for expansion and allows time to maximize service quality.

**How do we get there?**

Having decided on policy-guiding principles, a program needs to set goals to be achieved, search for possible means to achieve these and develop a timeline for the process. This planning process answers the question: 'how do we get there?'. The WHO outlines stepwise goals for a national palliative care program according to 'core', 'expanded' and 'desirable' depending on the resources available to national palliative programs. These goals are broken down into short-term (within 5 years), medium-term (5-10 years) and long-term (10-15 years) goals.[2] Timely relief of suffering from pain and other physical, psychosocial and spiritual problems and caregiver support are key goals of these stepwise objectives.[2] The question of where radiation therapy fits into this plan for LMICs remains largely unanswered in explicit terms, although in the opinion of this Working Group and the attendees of the 8th Asia-Oceania Congress of Medical Physics and 6th South-East Asian Congress of Medical Physics Palliative Radiotherapy workshop held at Cho Ray Hospital in Ho Chi Minh City, Vietnam, the long-term added value of radiation therapy in offering cancer symptom palliation well justifies its costs. To a large extent the place of radiation therapy will depend on the unique situation of each country, reflecting its values, priorities and resources. One can envision core radiation services in the short term being provided through tertiary care centres in one or two large cities of a Low-Income Country with a long term goal of establishing regional centres where low-complexity treatments, both curative and palliative are offered and more complex patients are identified and referred to one or more larger centres.

The attendees of the workshop represent physicists and radiation oncologists from all world regions and national income levels. The attendees and symposium faculty largely agreed that setting up regional radiotherapy centres in LMICs, when appropriate, should start with low- complexity treatments rather than simply palliative treatments. At first, however, the bulk of patients presenting to these sites would probably require palliative services. Diagnostic equipment to identify curative cases of cancer is crucial as are clear referral and communication channels between regional centres and larger referral centres in key cities. Expanded and desirable goals of a palliative oncology plan might include a shorter timeline for developing regional radiation treatment centres and specific goals regarding delivery of radiation to specified proportions of the population in need of services nationwide. There was also support at the workshop for the notion that Low-Income, Middle-Income and High-Income countries will have different goals and timelines for palliative oncology based on their available resources and priorities.

Ongoing dialogue is in process with key Vietnamese stakeholders, local representatives and government officials to develop a plan for palliative radiotherapy in Vietnam. Beyond this, there is a great need to develop a framework and strategy for meeting needs for palliative care and palliative radiation in the broader developing world. We hope that the ongoing work in Vietnam will serve as a model for other LMICs. We urgently need further meetings bringing together experts and decision leaders from the global oncology community, including palliative care, health policy and clinical oncology from Low-, Middle- and High-Income Countries. We need further discussion and dialogue regarding these issues, and the development of more cancer control strategies for LMICs specific to radiation oncology. This will help to dramatically improve cancer control in Low- and Middle-Income Countries.

**Concluding Recommendations**

To summarize, palliative radiation is one important component of an effective palliative care program even in a limited-resource country, though fundamentally a successful initiative must start with adequate access to narcotics, health care worker training, patient advocacy, public awareness and caregiver education and support. Cancer epidemiology specific to the region or country of interest greatly affects the extent and type of palliative care needs and must be borne in mind when planning services. Cancer prevention and early detection have crucial roles to play in reducing the need for palliative radiation in the long term. Access to care requires coordinated planning beyond treatment machine availability and staffing. There are multiple important considerations for effective program planning and we have highlighted some of the key ones in this article.

Optimal technology needs cannot be determined without a greater understanding of the local and regional context, but it was affirmed by workshop attendees that careful and informed investment in radiotherapy services in LMICs is important and irreplaceable. As demand for services grow through regional centres, treatment objectives that are predominantly palliative, low-complexity will broaden in scope as case mix changes and centre's technical experience matures.

We have the tools to prevent and ease the suffering of millions of men, women and children around the world inflicted with the heavy burden of advanced cancer. We have an unprecedented opportunity to bring relief to them as never before. We strongly urge for further meetings bringing together experts and decision leaders from the global oncology community, including palliative care, health policy and clinical oncology from Low-, Middle- and High-Income Countries. We need further discussion and dialogue regarding these issues, and the development through research of more cancer control strategies for LMICs specific to radiation oncology. This will help attain informed action for cancer control in Low- and Middle-Income Countries in all parts of the world.

**References**

1. Lee K, Mills D: Policy making and planning in the Health Sector. London, Croom Helm, 1985
2. World Health Organization: Cancer control: Knowledge into action: WHO guide for effective programs; Module 5. Palliative Care. Geneva, World Health Organization, 2007
3. Barton MB, Frommer M, Shafiq J: Role of radiotherapy in cancer control in Low-Income and Middle-Income Countries. Lancet Oncol 7:584-95, 2006
4. Hanna TP: Radiation Oncology in the Developing World, in Perez CA, Brady LW, Halperin EC, et al (eds): Principles and Practice of Radiation Oncology Fifth Edition. New York, Lippincott Williams & Wilkins, 2007
5. Shakespeare TP, Lu JJ, Back MF, et al: Patient preference for radiotherapy fractionation schedule in the palliation of painful bone metastases. J Clin Oncol 21:2156-62, 2003
6. Szumacher E, Llewellyn-Thomas H, Franssen E, et al: Treatment of bone metastases with palliative radiotherapy: patients' treatment preferences. Int J Radiat Oncol Biol Phys 61:1473-81, 2005
7. Huang J, Zhou S, Groome P, et al: Factors affecting the use of palliative radiotherapy in Ontario. J Clin Oncol 19:137-44, 2001
8. Mackillop WJ, Groome PA, Zhang-Solomons J, et al: Does a centralized radiotherapy system provide adequate access to care? J Clin Oncol 15:1261-71, 1997
9. Omran AR: The epidemiologic transition. A theory of the epidemiology of population change. Milbank Mem Fund Q 49:509-38, 1971
10. World Health Organization: Preventing chronic disease: A vital investment. Geneva, World Health Organization, 2005

11. Lopez AD, Mathers CD, Ezzati M, et al: Global and regional burden of disease and risk factors, 2001: Systematic analysis of population health data. Lancet 367:1747-57, 2006

12. Danaei G, Vander Hoorn S, Lopez AD, et al: Causes of cancer in the world: comparative risk assessment of nine behavioural and environmental risk factors. Lancet 366:1784-93, 2005

13. World Health Organization. Pinchuk M. Ed.: World Health Statistics 2007. France, World Health Organization, 2007

14. Cervical cancer screening programs. II. Screening for carcinoma of the cervix. Can Med Assoc J 114:1013-26, 1976

15. Jha P, Chaloupka FJ, Corrao M, et al: Reducing the burden of smoking world-wide: Effectiveness of interventions and their coverage. Drug Alcohol Rev 25:597-609, 2006

16. Chang MH, Chen CJ, Lai MS, et al: Universal hepatitis B vaccination in Taiwan and the incidence of hepatocellular carcinoma in children. Taiwan Childhood Hepatoma Study Group. N Engl J Med 336:1855-9, 1997

17. Daly MB, Rader JS: Cancer Screening- Section 3. Gynecologic Cancers, in DeVita VT Jr, Lawrence TS, Rosenberg SA (eds): DeVita, Hellman, and Rosenberg's cancer: principles & practice of oncology (ed Eighth). Philadelphia, Lippincott Williams & Wilkins, 2008

18. Dershaw DD: Cancer Screening- Section 4. Breast Cancer, in DeVita VT Jr, Lawrence TS, Rosenberg SA (eds): DeVita, Hellman, and Rosenberg's cancer: Principles & practice of oncology (ed Eighth). Philadelphia, Lippincott Williams & Wilkins, 2008

19. Anderson BO, Shyyan R, Eniu A, et al: Breast cancer in limited-resource countries: An overview of the Breast Health Global Initiative 2005 guidelines. Breast J 12 Suppl 1:S3-15, 2006

20. Garland SM, Cuzick J, Domingo EJ, et al: Recommendations for cervical cancer prevention in Asia Pacific. Vaccine 26 Suppl 12:M89-98, 2008

21. Munoz N, Franco EL, Herrero R, et al: Recommendations for cervical cancer prevention in Latin America and the Caribbean. Vaccine 26 Suppl 11:L96-L107, 2008

22. World Health Organization: Early detection. Cancer control: Knowledge into action: WHO guide for effective programmes; Module 3. Geneva, World Health Organization, 2007

23. Dixon P, Mackillop W: Could changes in clinical practice reduce waiting lists for radiotherapy? J Health Serv Res Policy 6:70-7, 2001

24. Delaney G, Jacob S, Featherstone C, et al: The role of radiotherapy in cancer treatment: estimating optimal utilization from a review of evidence-based clinical guidelines. Cancer 104:1129-37, 2005

25. International Atomic Energy Agency: PACT: Building partnerships to stop the global cancer epidemic. Austria, International Atomic Energy Agency, 2006

26. Penchansky R, Thomas JW: The concept of access: Definition and relationship to consumer satisfaction. Med Care 19:127-40, 1981

27. Mackillop WJ: Health Services Research in Radiation Oncology: Towards achieving the achievable for patients with cancer, in Gunderson LL, Tepper JE (eds): Clinical Radiation Oncology 2nd Edition. New York, Churchill Livingstone, 2006

28. Wright SV: An investigation into the causes of absconding among black African breast cancer patients. S Afr Med J 87:1540-3, 1997

29. Datta NR, Rajasekar D: Improvement of radiotherapy facilities in developing countries: A three-tier system with a teleradiotherapy network. Lancet Oncol 5:695-8, 2004

30. Clemens KE, Kumar S, Bruera E, et al: Palliative care in developing countries: What are the important issues? Palliat Med 21:173-5, 2007

31. Stjernsward J: Instituting palliative care in developing countries--an urgently needed and achievable goal. J Pain Palliat Care Pharmacother 17:xxix-xxxvi, 2003

32. Livingstone H: Pain relief in the developing world: The experience of hospice Africa-Uganda. J Pain Palliat Care Pharmacother 17:107-18; discussion 119-20, 2003

33. Rajagopal MR, Kumar S: A model for delivery of palliative care in India--the Calicut experiment. J Palliat Care 15:44-9, 1999

34. Devi BC, Tang TS, Corbex M: Setting up home-based palliative care in countries with limited resources: A model from Sarawak, Malaysia. Ann Oncol 19:2061-6, 2008

35. Sepulveda C, Habiyambere V, Amandua J, et al: Quality care at the end of life in Africa. British Medical Journal 327:209-13, 2003

36. Macbeth FR, Abratt RP, Cho KH, et al: Lung cancer management in limited resource settings: Guidelines for appropriate good care. Radiother Oncol 82:123-131, 2007

# The Case for Provincial Palliative Radiotherapy Centres in Vietnam

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## Background

Cancer kills 7.9 million people globally each year, among these 72% occur in low and middle income countries which places a tremendous burden on human suffering, health systems, health budgets and efforts to reduce poverty. WHO called on all member states to develop national cancer programs (NCCP), included four basic components- prevention, early detection, diagnosis with treatment and palliative care. In general, some 80% patients in developing countries present with incurable disease, and need palliative therapy.

Vietnam (VN) is a developing country in Southeast Asia with land area 329,600 sq km and 84 million populations. The GDP per capita is 3100 USD. According to the National Registry of Cancer, in 2006, VN had 150,000 new cases of cancer in a population of 84 million. Among these, more than 80% patients came to hospitals in their late stages. Therefore, palliative treatment, including palliative radiotherapy, plays an important role here.

## National Cancer Control Plan (NCCP) of Vietnam

The VN government approved the NCCP from 2006 to 2010 with two objectives:

a) reducing the cancer incidence rate and b) improving quality of life for cancer patients.

The national cancer control planning focused on the strengthening of the cancer control network from central to provincial levels, extending population based cancer registries, screening and early detection of cancer, especially breast and cervix cancer. Knowledge transferring and rising awareness of public on cancer were included in the control planning to strengthen the effect of treatment and palliative care. The most common cancers in VN are lung and liver in males and breast and cervix in females, as shown in Table 1.

**Table 1:** The common cancers in Vietnam

| Ranking | Male | Female |
|---|---|---|
| 1 | Lung | Breast |
| 2 | Liver | Cervix |
| 3 | Colorectal | Lung |
| 4 | Stomach | Colorectal |
| 5 | Larynx | Liver |
| 6 | Lymphoma | Stomach |
| 7 | Nasopharynx | Ovary |
| 8 | Esophagus | Thyroid |
| 9 | Prostate | Lymphoma |
| 10 | Skin | Skin |

There is a shortage in radiotherapy (RT) facilities and these are located in the major cities. The available RT equipments in Vietnam are Brachytherapy units 10, Simulator 7, Co-60 Teletherapy Units 14, LINACs 8, Gamma Knife 3 and Cyber Knife 1; well down from the IAEA recommendation of at least 1 machine per million populations. Most of Co-60 Units are too old and dosimetry systems are in short supply at many RT centers. At present, palliative radiotherapy shares the same facilities with curative radiotherapy treatment and most of this equipment is located in big cities such as Hanoi, Hue and Hochiminh city. This means that many patients have to travel very long distances for care in the company of their families. This results in a considerable cost to the hospitals and to the patients' families.

**Cho Ray Hospital**

This hospital is a government teaching hospital with more than 30 clinical wards, surgical departments for almost every kind of cancer, strong diagnostic imaging (US, CT, MRI, DSA) and nuclear medicine (SPECT, PET, CT) facilities. The Department of Oncology was established in 2002 and the Department of Palliative Care in 2003. The Gamma-knife was installed here in 2006.

The Department of Oncology has 2 sections, Radiotherapy and Chemotherapy with 6 Radiation Oncologists, 4 Medical Oncologists, 6 Medical Physicists, 13 Radiation Therapy Therapists and 6 Nurses. This department is well equipped with 2 LINACs, 1 Simulator, 2 Treatment Planning Systems (DSS and Leibinger). The available RT techniques are 2D, 3D, conformal radiotherapy and radiosurgery. About 1200 patients in RT and 1000 patients in CT are treated at this Hospital each year. Patients have to wait for RT treatment around 3 – 4 weeks. The treatment rate per machine per day is 70 – 80 patients. Some 23 of patients with stage 4 disease percentage rate receive palliative radiotherapy. Only 24% of patients are from HCM city, others are from distant provinces. From the above mentioned statistics it is obvious that overloaded machines and overworked staff often give rise to suboptimal techniques, inadequate care in patient set up, and a greater possibility of treatment errors.

The objectives of the Department of Palliative Care is taking care of the end stage cancer patients, pain management and establishing & developing home care services. This department has a 35 bed facility with 6 Doctors and 12 Nurses. The total number of patients treated from this department in 2007 was 1795.

**Problems with possible solutions**

The major problems of Cho Ray Hospital and other central cancer centers relate to overburdening with cancer patients. Patients have to travel very long distances for care in the company of their families. Many of them are have end-stage disease. So there is a considerable cost to the hospital and to the families as well.

Palliative Radiation therapy differs substantially from radical treatment. Because any toxicity against the limited potential benefit must be avoided, a small number of larger radiation fractions is used. This simplifies the treatment for a patient with limited life expectancy. Palliative therapy planning should involve the best estimate of subsequent possible sites of metastasis.

Palliative RT centers are not only giving pain relief and palliation for cancer sufferers but also help identify more curative patients at earlier stages of disease and send them to the city. Its establishment cost is low, just enough technology for palliative therapy but not curative therapy. There could be perhaps 4 – 5 such centers for the cost of one curative centre in the city.

## Conclusion

The treatment cost for the patients could be much reduced if palliative radiotherapy centres were available closer to their home. This means setting up palliative radiotherapy centers in the provincial hospitals to care of patients in their own regions. By separating palliative radiotherapy objectives from those for curative treatment and by locating these palliative radiotherapy centers in the provinces, we can give our patients more chances to get appropriate treatment. Further, these centres can be used for screening and early detection for curative treatment. Their lower cost means that spare resources can be used more effectively in the appropriate treatment of more patients.

## 3 Choice of Radiotherapy Modality

### Is Cobalt 60 Therapy Still Needed For Developing Countries?

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**Introduction**

Photon beams (electromagnetic wave) and particle beams (particle) are the two mode of radiation. In particle beam therapy, heavy particle and proton are used; and in conventional radiation therapy, X-ray and gamma ray are used for cancer treatment.

In 2006 survey, it was found that in China the Radiation Oncology Centres excluding Hong Kong, Macao, Taiwan gradually increased for the 5 different years – 1986, 1994, 1997, 2001 and 2006. In year 1986 the number of centres was 264 and in 2006 it increased to 952[1] as shown in figure 1. The corresponding Radiation Therapy equipments for the same 5 different years are also shown in the figure 2. From figure 2 it is shown that in the year 2006, maximum number of radiation therapy equipments were linear accelerator (LA) – 918. Table 1 shows the other radiation therapy equipments like Co-60, Brachytherapy, X – Knife, Simulators, TPS, Dose Meter, Deep – X ray, CT Simulator and γ - Knife number, available in china in the year 2006.

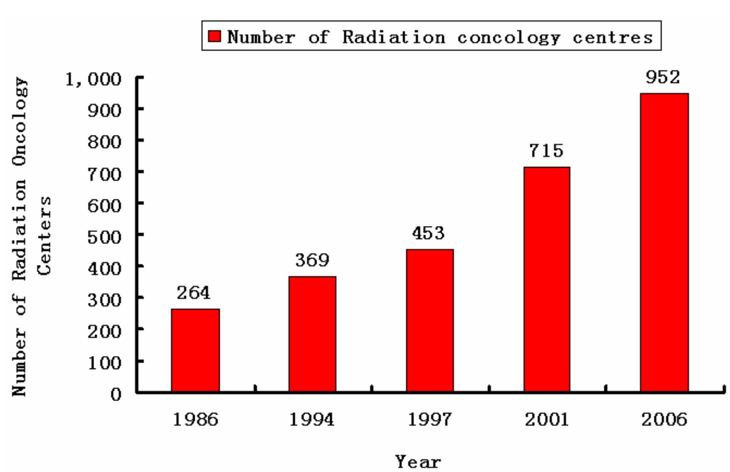


**Figure 4: Number of Radiation Oncology Centres in China[1].**

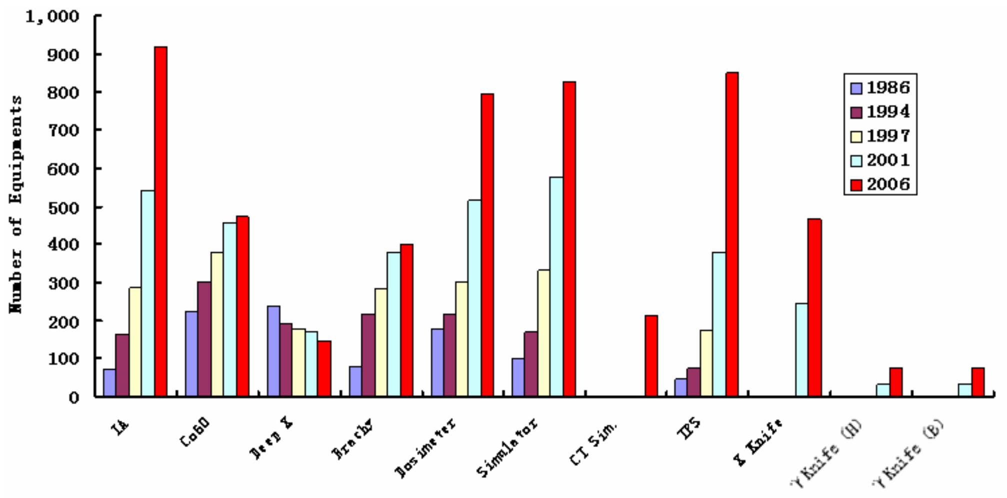


**Figure 5: Radiation Therapy Equipments in China[1].**

**Table 1:** The most available radiation therapy equipments in china in 2006[1].

<table>
<tr><th>Equipment name</th><th>Number</th><th colspan="2">Equipment name</th><th>Number</th></tr>
<tr><td>Linear Accelerator (LA)</td><td>918</td><td colspan="2">Co-60</td><td>472</td></tr>
<tr><td>Brachytherapy (Brachy)</td><td>400</td><td colspan="2">Deep – X ray</td><td>146</td></tr>
<tr><td>Simulator</td><td>827</td><td colspan="2">CT Simulator</td><td>214</td></tr>
<tr><td>X – Knife</td><td>467</td><td rowspan="2">γ - Knife</td><td>For Head (H)</td><td>74</td></tr>
<tr><td>TPS</td><td>851</td><td>For Body (B)</td><td>75</td></tr>
<tr><td>Dose Meter</td><td>796</td><td colspan="3"></td></tr>
</table>

Out of 952 Radiation Therapy Centres 903 centres reported that 409,440 new patients were treated in 2006. Estimated 431,657 new cancer patients were treated within the whole country that counts only 20% of 2.2 millions new cancer patients population who had chance to do Radiotherapy (RT). About one million cancer patients lost the chance to see radiation oncologist if say 65% of cancer patients needs RT. Only 0.41 million populations were actually treated by RT in 2006.

**Medical Physics Education in China**

There is a big demand of Medical Physicists (MP) in Chinese Radiation Oncology Community. Table 2 shows the MP number in comparison with the Radiation Oncology Centres for 5 different years (as mention earlier). From this table it is clear that there was a lacking of the Medical Physicists in each of the year for the Oncology centres[1]. According to the demands there was a lacking of 1127 MP for the year 2006.

**Table 2:** Numbers of Radiation Oncology Centres and Medical Physicists[1].

| | 1986 | 1994 | 1997 | 2001 | 2006 |
|---|---|---|---|---|---|
| Number of Radiation Oncology Centres | 264 | 369 | 453 | 715 | 952 |
| Teletherapy Units (T Units) | 363 | 685 | 929 | 1375 | 2308 |
| Medical Physicists | 80 | - | 423 | 619 | 1181 |
| Ratio of MP per Centre | 0.303 | - | 0.934 | 0.866 | 1.241 |
| Number of MP demand<br>(1 MP per T. Unit) | 363 | 685 | 949 | 1375 | 2308 |

**Shortage of Equipments**

World Health Organization (WHO) suggested 2 – 3 LA / million populations. In China, 2006 survey reported 0.7 LA / million populations and 0.36 Co-60 / million populations. This figure shows a huge shortage of the equipments according to the WHO guideline.

So, Radiation Therapy facilities demand a big market in China because

- 1.1 million new cancer patients need RT
- Insufficient of Centers, Personnel, Equipment in proportion to the total population (1.3 Billion)
- Insufficient Training of radiation oncologists, physicists, and radiotherapists
- Insufficient of adequate Quality Assurance (Quality Control) systems

**A comparison study of Cobalt-60 and 6MV Linac**

Considering the basic features such as beam energy, depth-dose value, available wide range field size, dose rate, beam penumbra, radiation source replacement and spent source disposal as mentioning in table 3, a Cobalt 60 therapy unit is inferior to 6MV X-ray linear accelerator. However, a Cobalt 60 therapy unit offers, compared with 6MV X-ray linear accelerator, more reliability, less need for a good power supply system, less need for skilled persons for maintenance as shown in table 4. These are essential criteria for developing countries, and for vast remote areas in China and India where there is a shortage of qualified medical physicists and engineers who are essential for 6MV X-ray linear accelerators.

The initial capital cost and after-installation maintenance cost in 5 years running time of a Cobalt 60 therapy unit are less than that of a 6MV X – ray linear accelerator. Though in 10 years running time both costs are almost equal due to the cobalt 60 source must be replaced every 5-7 years, the lifespan of a modern 6MV-X ray linear accelerator is getting shorter and shorter as the modern advanced technology changes ever faster than before. Figure 3, 4, 5, 6, 7 and 8 show a comparison treatment planning of both Co-60 and 6MV X – ray for different organs like Nasopharynx, Lung, Cervix and Prostate Cancer.

**Table 3:** Main features' comparison of Cobalt-60 and 6MV Linac.

| Items / Unit | Energy (MeV) | Source Diameter (mm) | $D_{max}$ (cm) | Dose rate (cGy/min) | PDD at 10cm | Minimum Field Size (cm) | Penumbra (mm) | Source Replacement (wave guide) |
|---|---|---|---|---|---|---|---|---|
| Co-60 | 1.33<br>1.17 | ~ 20 | 0.5 | ≤ 200 | 55% | ≥ 5 × 5 | ≥ 10 | ~ Every 7 years |
| 6MV Linac | 6MV X-ray | ~ 2 × 3 | 1.5 | ~ 600 | 67% | 0.5×0.5 | ≤ 7 | Depends on patient load ~ 2-3 years (1500 HT hrs) |

**Table 4:** Factors impact on cost-effect of Cobalt-60 unit vs 6MV Linac.

| Items / Unit | Source replacement | Reliability | Power required | Skilled person |
|---|---|---|---|---|
| Co-60 | ~ 400,000R MB/7years<br>(Source disposal included) | ≥ 98% | Much less | Less need |
| 6MV Linac | ~ 600, 000R MB/2~years | ≥ 95% | Much high | Much need |

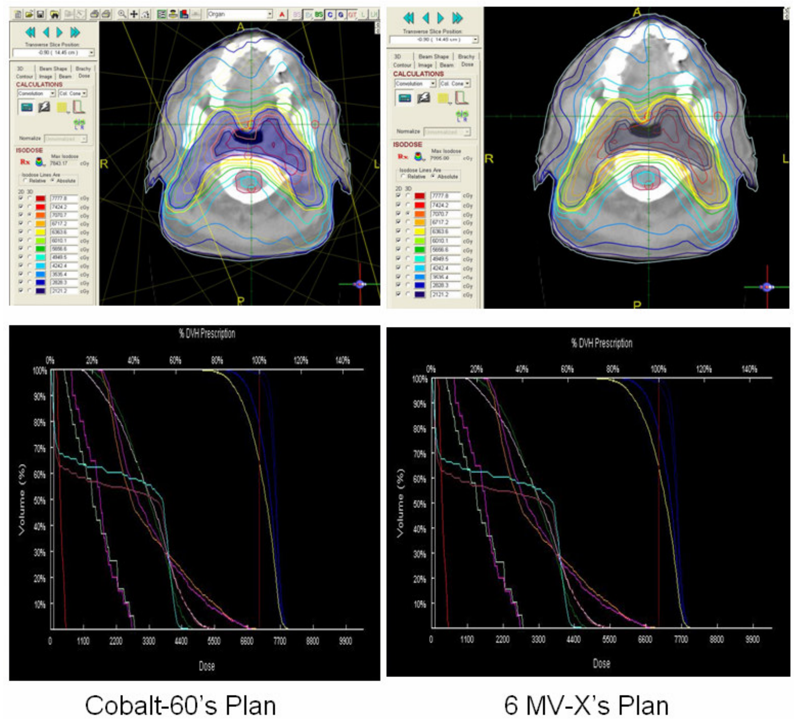


**Figure 6: Co-60's plan vs 6MV X-ray's plan for Nasopharynx Cancer (9 Beam's IMRT plan).**

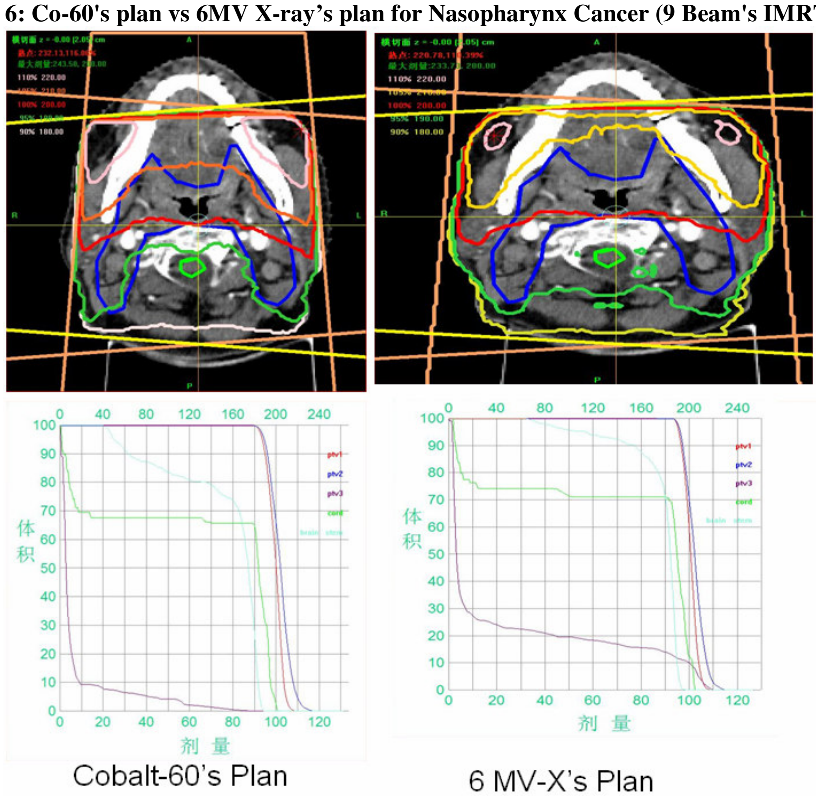


**Figure 7: Co-60's plan vs 6MV X-ray's plan for Nasopharynx Cancer (2 Opposing Beam)**

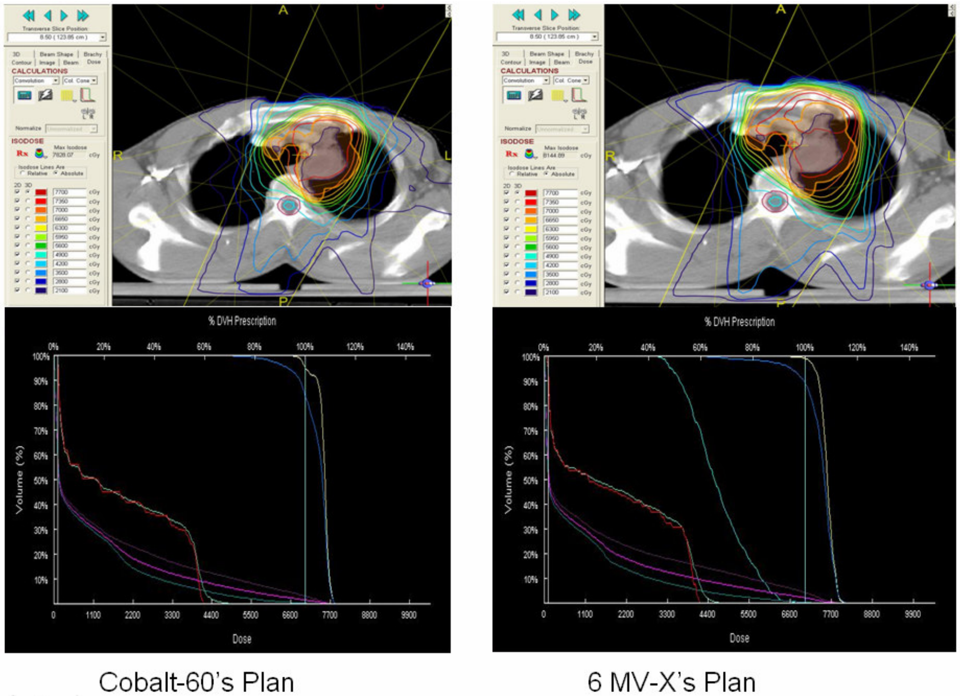


**Figure 8: Co-60's plan vs 6MV X-ray's plan for Lung Cancer (7 Beam's IMRT plan).**

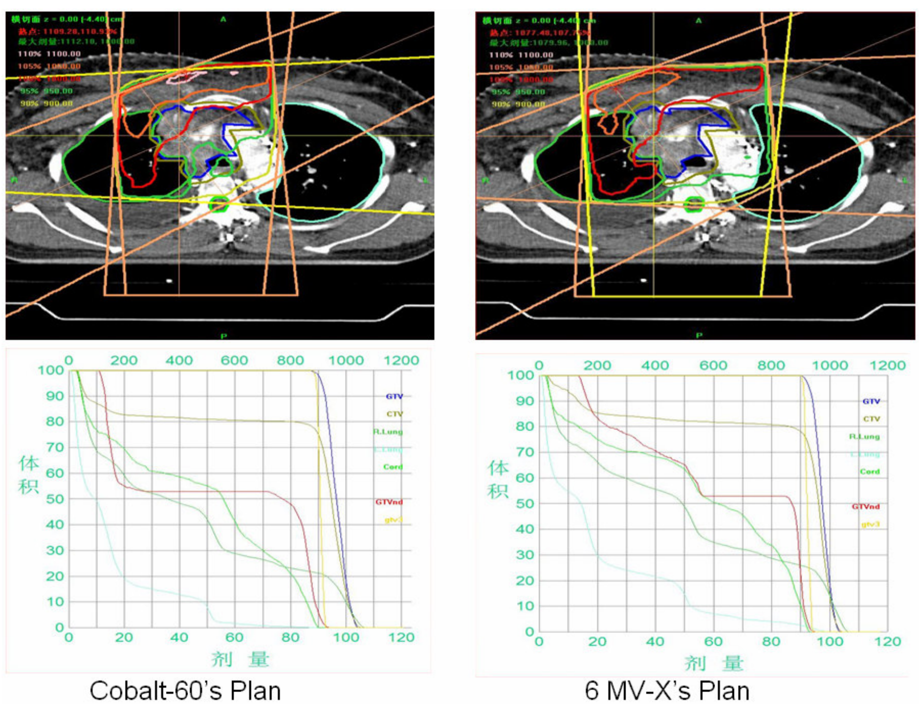


**Figure 9: Co-60's plan vs 6MV X-ray's plan for Lung Cancer (3 Beam's 3DCRT plan).**

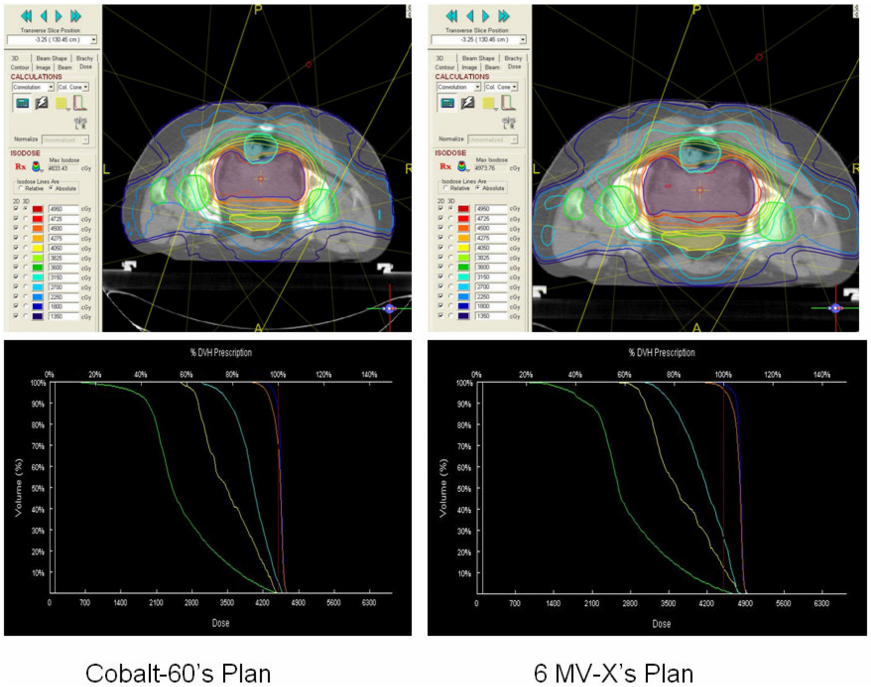


**Figure 10: Co-60's plan vs 6MV X-ray's plan for Cervix Cancer (7 Beam's IMRT plan).**

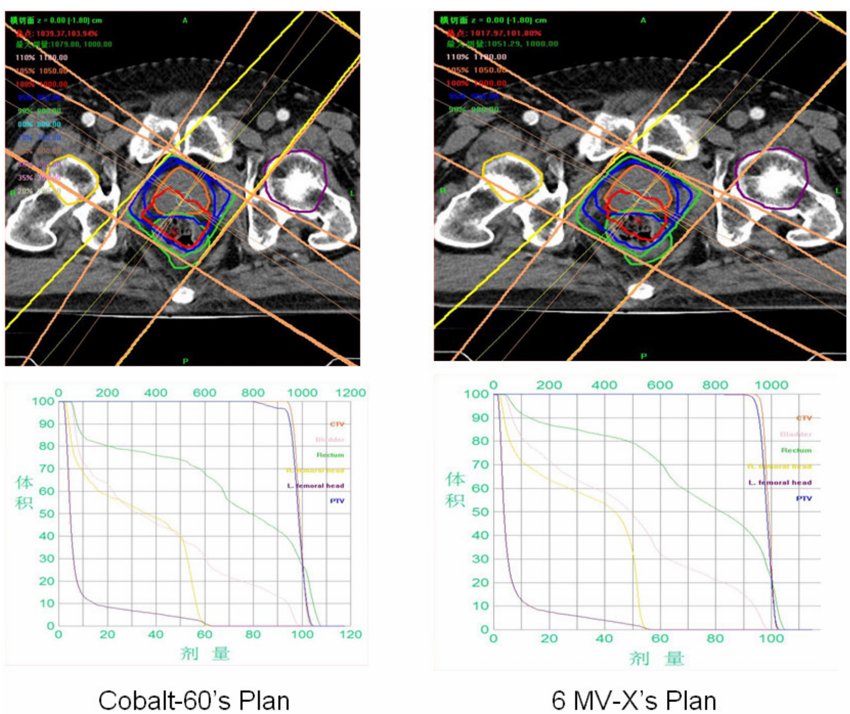


**Figure 11: Co-60's plan vs 6MV X-ray's plan for Prostate Cancer (4 Beam's 3DCRT plan).**

## Conclusion

The Cobalt 60 therapy unit provides 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. Even with modern Cobalt 60 therapy unit equipped with Multi Leaf Collimator (MLC), they are suitable for treatment of more deep seated tumours like lung and liver cancers, though the plans are more complicated. The Cobalt 60 source emits mono-energetic gamma rays that are very suitable for using the compensator technique to do advanced treatment with beam intensity modulation (IMRT).

## References:

1. Yin W, Chen B, Tian F, Yu Y and Kong FM. The Growth of Radiation Oncology in Mainland China during the last 10 Years. Int J Radiat Oncol Biol Phys 2008, 70(3):795-798.

# Radiation Therapy with Cobalt-60 vs. 6 MV Photon Beams for Palliative Care: Comparison of Beam Characteristics

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## Introduction

According to estimates and projections by WHO, the number of new cancer cases worldwide per year by the year 2015 is expected to approach about 15 million. About two-thirds of these cases will be from developing countries, and the non-availability of proper radiation treatment facilities need to be of grave concern. Radiation Therapy is a well accepted treatment modality for palliative care, which accounts for about two-third of the cancer patients in developing countries.

## Comparison of Co-60 with other Photon beams

Most patients in developing countries receive radiation treatments with simple approaches, mostly two parallel opposed beams, assuring that the target volume receives adequate dose even if some normal tissues will receive higher doses than desired. There have been several presentations, over the years, on the advantages and disadvantages, for and against the use of Co-60 machines and low energy linacs, for delivery of palliative radiation treatments. However, Co-60 machines are well suited for this application and are commonly used in a large number of developing countries, since they have acceptable features. Isocentric machines with treatment distances of 100cm. and very reproducible photon beam characteristics are now commonly available. They provide a level of reliability that has not been matched by other machines, like linear accelerators. Their ease of use and much lower servicing and maintenance requirements have established the Cobalt Machine as the machine of choice in most developing countries.

The beam characteristics of the Co-60, 4 MV and 6 MV photon beams that will be compared, with emphasis on palliative care, are:

a) Surface Dose
b) Dose Build-up depth
c) Penetration – Depth Dose at 5cm and 10cm
d) Beam Flatness & Symmetry
e) Stability of Dose-rates

Additionally, dose distributions for some simple clinical cases, for Lung, Breast, Maxillary Sinus, Oesophagus and Cervix, generated using beam data for both Co-60 and 4 or 6 MV will be compared, showing that the Co-60 treatments are satisfactory for the most part. The differences are small when multiple beams are used, even though the single beam characteristics show a slight advantage for use of the 4 or 6 MV beams.

The differences in the surface dose and build-up region, between Co-60 and 6 MV beams, show an advantage in using the Co-60 beams in treating Breast and Head & Neck cancers. Good skin sparing is achieved and adequate dose is delivered to the superficial tissues, which are part of the clinical target volumes.

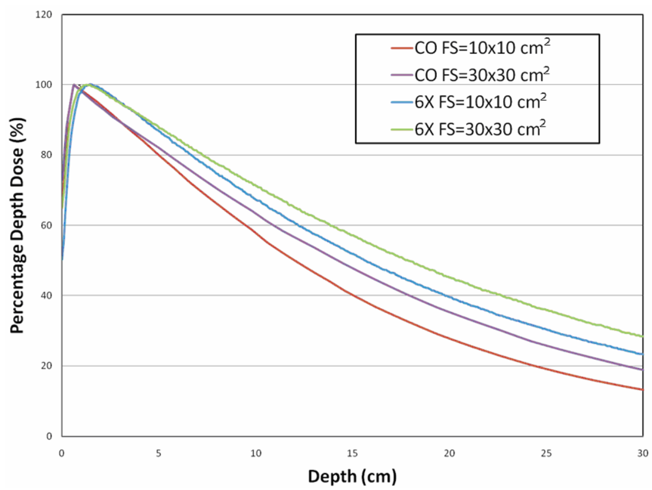


**Figure 12: Co-60 vs 6 MV Photon Beam Percentage Depth Dose**

With the increase in depth for different field size (FS), the percentage depth dose for Co-60 decrease exponentially rapidly in compare to 6 MV Photon beam as shown in figure 1. The percent depth dose differences between Co-60, 4 MV and 6 MV, at 5cm and 10cm depth, for a 10cm × 10cm field at a Source to Surface Distance (SSD) of 100cm are:

| Radiation Therapy | 5cm | 10cm |
|---|---|---|
| Cobalt-60 | 80 | 59 |
| 4 MV Photon Beam | 85 | 65 |
| 6 MV Photon Beam | 87 | 67 |

Most palliative treatments are delivered with two parallel opposed beams, for a total dose of 30Gy in 10 fractions. When treating thin body sections, about 10cm thick, the Co-60 beams are preferable to ensure adequate dose delivery even at shallow depths. The build-up zone of higher energy beams can be a disadvantage. If one considers thick body sections, like in the pelvic region, as for example cervix (figure 2), then there is a gradual improvement in the dose to subcutaneous tissues when one treats with the higher energy beams. However, a more used technique for such situations is the use of multiple beams, 3-field or 4-field ‘box’, and the dose distributions between these different beams are very similar, recognizing that more normal tissue is being irradiated with slightly higher doses with Co-60 beams. Overall, for palliative treatment Co-60 beams are more than adequate.

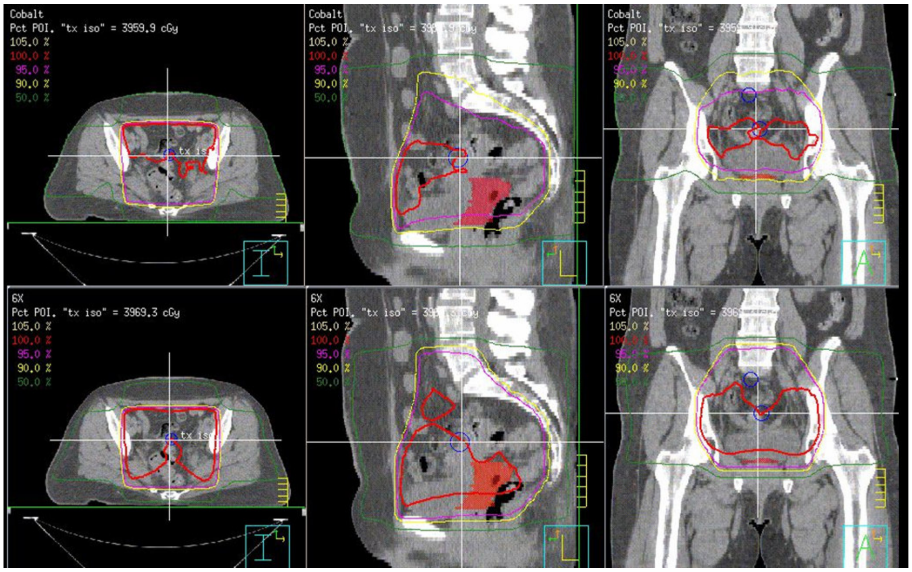


**Figure 13: Comparison treatment for cervix**

## Conclusion

More care and good planning is necessary in cases where one has to consider treating areas that have already received some radiation. Treatments delivered with multiple Co-60 fields provide satisfactory dose distributions, with good skin sparing, and as such for palliative care, the need for photon beams with slightly higher energies, in developing countries cannot be justified.

# Cobalt-60 versus Linear Accelerators: A Review

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**Abstract**

Cobalt-60 remains a useful megavoltage radiation modality in spite of the tendency for the developed world to use linear accelerators. This review will consider the advantages and disadvantages of the use of cobalt-60, especially in the context of the developing world and its use for palliative radiation therapy.

Issues for comparison include:

a) radiation beam characteristics (e.g., beam edge sharpness, beam penetration, scatter/dose uniformity, contour and inhomogeneity corrections, dose to bone),
b) machine characteristics (e.g., dose rate, patient to collimator distance, isocentre height, gamma rays vs x-rays),
c) service/maintenance issues,
d) safety considerations, and
e) cost considerations.

Considering that palliative radiation therapy can generally be performed with simple techniques and simple technology, cobalt-60 provides a strong option for improving the quality of life of cancer patients. Indeed, its low cost, easy maintenance and relative ease of availability may provide a treatment option versus no treatment at all.

**Introduction**

According to recent estimates of the International Agency for Research on Cancer (IARC) and the World Health Organization (WHO) approximately nine million new cancer cases are detected annually worldwide [1]. Over half of these are in developing countries. It is estimated that by the year 2015 the number of new cases will increase to 15 million, of which 60-70% will occur in developing countries.

An advisory group in 1993 estimated that "approximately 2,300 megavoltage teletherapy units are currently installed in developing countries, primarily cobalt-60 units. By the year 2015, barring a dramatic and unforeseen cure for cancer, a total of 10,000 machines will be needed to provide treatment for an estimated 10 million new cancer cases per year in developing countries". Currently 5% of resources are spent on 60-70% of cancer cases in the developing countries. Nearly half of all cancer patients receive radiotherapy during the course of their disease. It is therefore important to have affordable, reliable, low cost radiotherapy to meet the needs of those patients, especially those needing palliative treatment.

In developing countries the most common types of cancers are head and neck, cervix, esophagus and breast cancer, mostly presenting at advanced stages (T3-T4) of their disease. These account for close to 80% of cases and can usually be treated with cobalt therapy units. In contrast, for developed countries the majority of cases are colon, prostate, and early stage (T1-T2) breast cancer. Forty to fifty percent can be treated with cobalt teletherapy.

Over the years, there have been many arguments for and against cobalt-60 machines. A general consensus appears to exist in the developed world that linear accelerators are the treatment machine of choice. However, these machines are often not affordable in the developing world. Furthermore, societal infrastructure may make it difficult to operate such complex technology for a whole variety of reasons. This paper reviews some of the arguments both for and against linear accelerators with a special consideration being given to the needs of palliative care in the developing world.

## Radiation Treatment Process

The radiation treatment process is complex and consists of multiple steps. These are broadly summarized in a simplified form in Figure 1. The steps are not always necessarily in the same order nor are all the steps always needed. The latter is especially true for palliative radiation therapy where CT scanning and target volume delineation are not always required, particularly when a large fields are used to treat systemic disease or pain.

## Radiation Therapy Equipment

When setting up a radiation therapy facility, even if it were to be set up specifically for palliative radiation therapy, the equipment necessary for all the steps in the radiation treatment process must be considered, not just the radiation therapy machine alone. See, for example, the recent report by the International Atomic Energy Agency that describes the requirements for setting up a new facility [1]. Thus, consideration should be given for the acquisition of appropriate diagnostic equipment required for defining the target volume. Patient immobilization devices are particularly important for treating patients who have disease close to critical structures such as the eyes, kidneys, spinal cord, and lungs. This is an important consideration since the treatment should not create any morbidity or additional suffering for the patient. Patient external contouring devices may also be needed to determine dose delivery with some accuracy. Most radiation therapy facilities also have CT scanners and/or radiation therapy simulators for tumour and normal tissue location to aid with the treatment planning process. The contour or CT data are then entered into a treatment planning computer, which is used to determine the optimal treatment plan and to determine the actual treatment settings that are to be used on the machine to treat the patient. A treatment machine, whether a cobalt-60 unit or a linear accelerator, is then used to deliver the radiation dose to the target region while restricting doses to normal tissues at acceptable levels. As part of the treatment process, treatment verification tools, either in the form of port films or *in vivo* dosimetry may be required to confirm the accuracy of the plan prior to actually delivering the radiation dose.

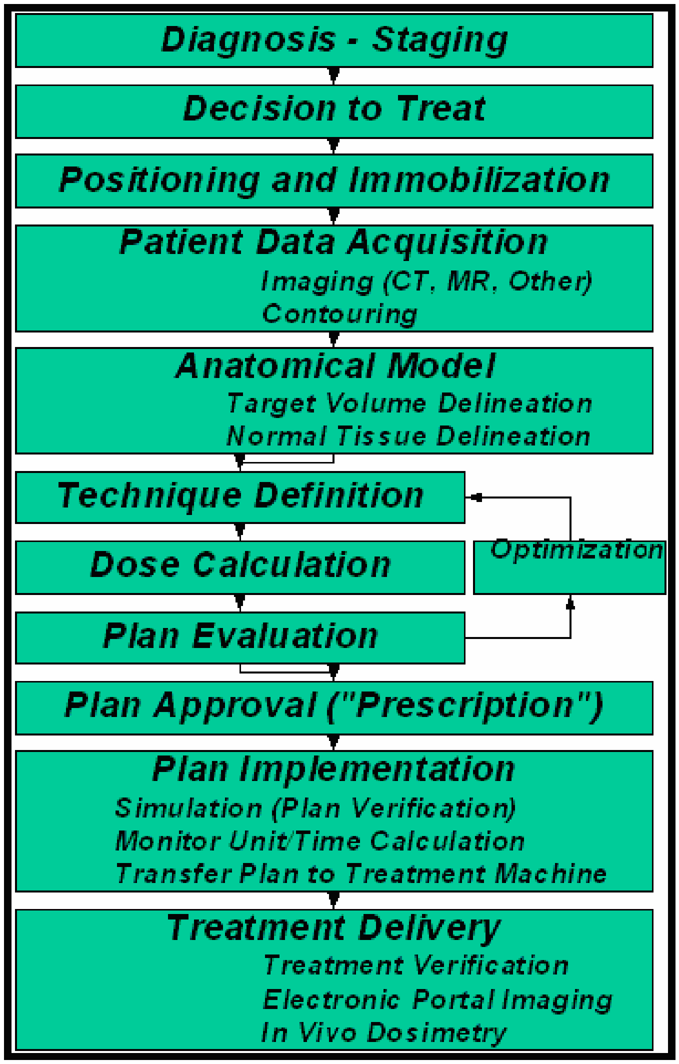


**Figure 14: Schematic block diagram demonstrating the multiple steps in the radiation treatment process.**

The main message of this section is that setting up a radiation therapy facility requires more equipment than only a radiation treatment machine. The resources available, the local infrastructure, the type of patients to be treated and the available professional staff will dictate the type of facility and the type of technology that should be purchased.

**Radiation Beam Characteristics**

There are a number of ways of describing the characteristics of a radiation beam used in radiation therapy. In this section we will expand on the following characteristics that have an impact on the clinical quality of a radiation treatment:

- Beam penetration (energy)
- Scattering conditions and dose uniformity
- Beam edge sharpness (penumbra)
- Contour and inhomogeneity corrections
- Dose to bone *versus* soft tissue

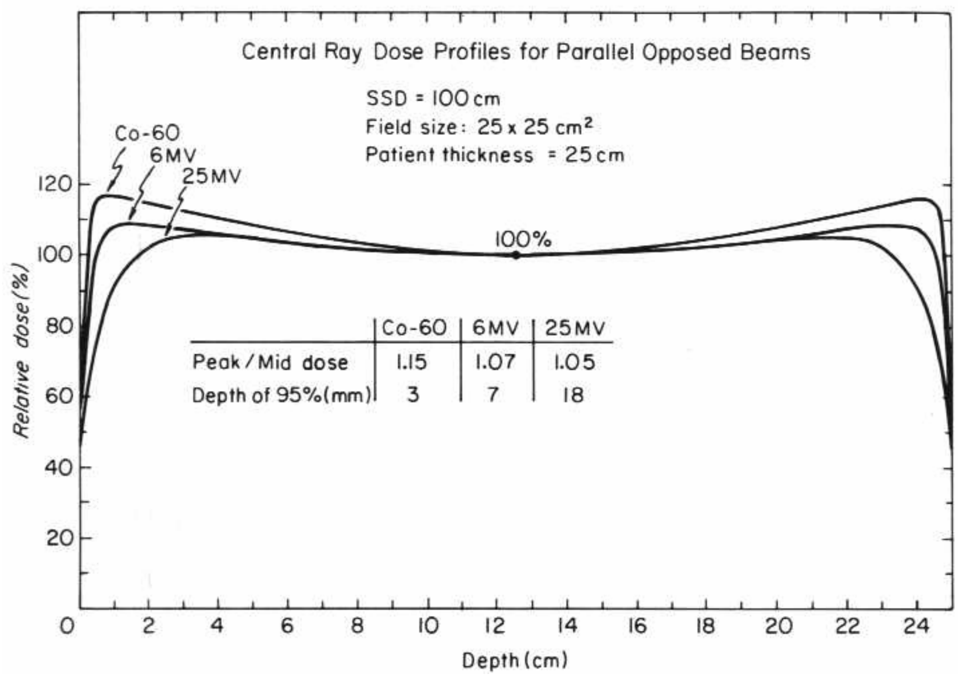


**Figure 15: Central ray dose profiles for parallel-opposed beams with energies of cobalt-60, 6 MV and 25MV for a large patient with thickness of 25 cm and a large field size of 25 × 25 cm2. The inset shows the ratios of maximum to mid-plane dose as well as the depth at which the dose near the surface reaches 95%.**

*Beam penetration (energy):* Beam penetration, or beam quality, from a patient's treatment perspective is best described by percentage depth doses. Any energy in the megavoltage range has a relatively low surface dose and builds up quickly to a maximum dose. This "skin sparing" is the great advantage of megavoltage radiation treatments and is provided by any beam with energy of cobalt-60 (equivalent to 1.25 MeV) or higher. The depth of maximum dose increases with increasing energy and the remainder of the depth dose curve is also higher with higher energies. Generally, when only one to four beams are used to treat a tumour at a depth, the higher energies tend to provide more uniform dose distributions with lower doses outside of the target regions. Figure 2 is an example of central ray dose profiles for a parallel-opposed treatment technique. As the number of fields increases the difference between the normal tissue doses outside of the target region decreases. In many of the developing countries, where poor nutrition is often the norm, the older patient population tends to be small and therefore the need for higher energy radiations decreases and cobalt-60 is quite adequate to treat a majority of patients.

*Scattering conditions / dose uniformity:* For small fields the scattering conditions or the dose uniformity is minor but for larger fields scattering condition can be reduced with flattening filters, compensators, and clever treatment planning.

*Beam edge sharpness (penumbra):* The beam edge sharpness (penumbra) varies from 90% to 10% from the centre of the beam to its edge for a specific field size. The penumbra also depends on the treated area density. Figure 3 show this variation in water with density 1.00 gm/cc and lung with density 0.20 gm/cc for a field size 5 × 5 $cm^2$, The equivalent dose is shown at a distance 10 cm for Co-60 and 4 MV linac. For Cobalt-60, the surface to axis distance (SAD) is 80 cm.

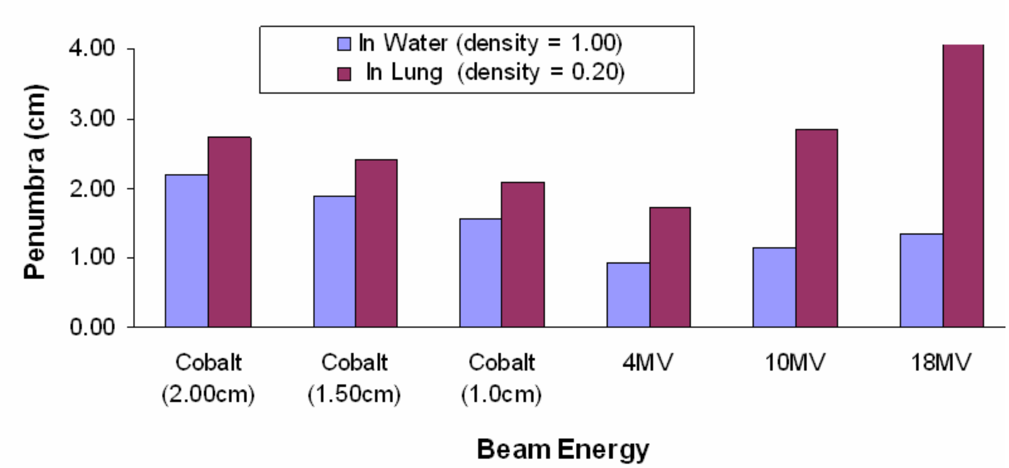


**Figure 16: Penumbra in Water and Lung**

*Contour / inhomogeneity corrections:* Electronic disequilibrium is observed for high energy photon beams in the lung because of larger penumbral effects and possible reduced dose on central axis.

*Dose to bone versus soft tissue:* Tissue/bone (or tissue/prosthesis) interface effects cover a larger volume in higher energy photon beam. There is a small difference in dose to bone for MV energies with small fields and a large difference for large fields.

**Machine Characteristics**

The following characteristics should be considered when comparing radiation therapy machines:

- Dose rate
- Patient-collimator distance
- Isocentre height
- Radioactive source versus x-rays

**Cost Considerations**

In view of economic considerations the costs of interest are:

- Capital costs of equipment
- Capital costs of treatment room
- Operating costs
- Maintenance costs
- Training costs
- Dosimetry & Quality Assurance equipment
- Eventual disposal costs of technology

A number of studies (Table 1) indicate that on an annual basis Linacs cost 2 to 3 times as much as Cobalt. The International Atomic Energy Agency (IAEA) studied 50 machines (20 Cobalts, 30 Linacs) for 1 year (2002) in 16 institutes of 11 countries and found that Linacs cost 1.4 to 2.6 as much as cobalt per fraction [2].

**Table 1: Annual operational costs for Cobalt and Linacs (normalized to Co-60)**

| | **Cobalt** | **Low Energy Linac** | **High Energy Linac** |
|---|---|---|---|
| Rawlinson, 1986 | $ 38.1 K<br>1.0 | $122.8 K<br>3.2 | $181.8 K<br>4.8 |
| Glasgow, 1990 | $ 62 K<br>1.0 | | $100 K<br>1.6 |
| Van der Giessen, 1991 | $ 23.3 k<br>1.0 | $48.1 k<br>2.1 | $61.8 K<br>2.7 |
| Van der Giessen, 2002<br>Old Machines | $ 31.5 K<br>1.0 | $70.7 k<br>2.2 | $64.4 k<br>2.0 |
| Van der Giessen, 2002<br>New Machines | $ 49.0 K<br>1.0 | $116.9 k<br>2.4 | $111.3 k<br>2.3 |
| Average Costs | 1.0 | $2.5 \pm 0.4$ | $2.7 \pm 1.2$ |

***Service/Maintenance Issues***

The most important issue with radiotherapy machines is the availability for patient treatment. In the context of infrastructure, stable power supply and efficient service personnel are essential. Up-time in the developed world for Cobalt-60 is more than 99.5% and for a Linac more than 97%.

The break-down time for Linac is near about 8% and for Cobalt 1% [2]. Some times repairs are delayed because of a lack of resources. A Cobalt machine in Nigeria was out of service for 2 to 3 months in the years 1980, 1984 and 1986, 4 months in 1985; and 6 to 8 months in year 1987, 1983, 1981 and 1988 [3].

**Safety Considerations**

Radiation safety is an important issue not only for the patients but also for the radiation therapy staff, radiotherapy professionals and the environment. This should strictly be maintained by the regulation of the radiation safety.

**Special Palliative Care Considerations**

Providing palliative radiation therapy (PRT) it is not just treatment equipment alone but the total context of other issues:

- Regional and national physical and societal infrastructure
- Financial
- Numbers & types of diseases
- Professional staff available
- Treatment planning technologies
- Treatment machine technical issues
- Maintenance and parts availability
- Safety issues

Radiation oncologists, medical physicists, radiation therapists and technical maintenance support with on-going training of professionals and continuing education is required for palliative care. In addition, palliative care also requires physical infrastructure such as a constant source of electrical power, constant source of cooling water and appropriate air circulation & air conditioning for accelerators.

***Large Field Radiation Therapy***

Half body irradiation for palliation of widely disseminated disease

- Replaced by drugs in developed world
- Drugs too expensive & not available for developing world
- 6 - 10 Gy in single fraction for 1st half
- 2nd half 4-6 weeks later
- Recovery of hematopoietic system
- Limit lung dose to <7.50 Gy for single fraction
- Dose to bone higher by 19% to small fields for Co-60 vs 14% for 6 MV

**Cobalt vs Linac**

Choice of either Cobalt-60 or Linac depends on infrastructure, resources availability, professional staff availability, radiation safety regulatory control (decommissioning source disposal control) and type of institution (palliative care centre vs palliative plus radical care centre). A comparison between Cobalt and Linac sources according to these parameters for three different environments is shown in table 2.

**Table 2: Comparison between Cobalt and Linac for different environments**

| **Environment** | **Poor** | | **Moderate** | | **Excellent** | |
|---|---|---|---|---|---|---|
| | Cobalt | Linac | Cobalt | Linac | Cobalt | Linac |
| Infrastructure | N | N | Y | N | Y | Y |
| Resources | N | N | Y | N | Y | Y |
| Professional Staff | N | N | Y | N | Y | Y |
| Radiation Safety | N | N | Y | N | Y | Y |
| **Type of centre** | | | | | | |
| Palliative only | N | N | Y | N | Y | Y |
| Palliative and Curative therapy | N | N | Y | N | Y | Y |

**Conclusions**

Palliative radiotherapy is simple for both modalities in techniques and technologies. Cobalt-60 provides the practical option for palliative radiation therapy such as low cost, easy maintenance, minimal personnel and strong option for improved quality of life, and is superior to no treatment at all.

**References**

[1] INTERNATIONAL ATOMIC ENERGY AGENCY. Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, International Atomic Energy Agency, Vienna, Austria 2008.

[2] Giessen V.D. et al. Multinational assessment of some operational costs of teletherapy. Radiotherapy & Oncology, 71, 347-355, 2004.

[3] Durosinmi-Etti FA. An overview of cancer management by radiotherapy in Anglophone West Africa. Int. J. Radiat Oncol. Biol. Phys. 19(5), 1263-1266; Nov 1990.

# Cobalt verus Linacs: A Technical Perspective. Benefits and Drawbacks of These Two Modalities - Time to Change?

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## Introduction

Cancer is the second most common cause of death in the industrialized world and is considered to be a global problem. Worldwide, more than 6 million people die of cancer and 10 million people cases are diagnosed with cancer every year. Estimated cancer patients in 2020 will be more than 15 million. Most of the patients with cancer (>70%) are over 60 years old. Demographic shifts cause cancer incidence rates to increase.

Radiation therapy is the fastest growing and the most cost-efficient treatment for cancer. Chemotherapy is 3 – 5 times the cost and surgery is twice as expensive as radiation therapy. In Asia (excluding China and Japan), Taiwan and Korea installed the maximum number of Linear Accelerators, 130 and 110 respectively in comparisons with Co-60 teletherapy units, only 3 – 5 both of the countries. Thailand installed sixty Linacs and is the next radiation therapy facility user country in Asia. Honk Kong, Myanmar and Indonesia installed near to the same number of Linear Accelerators, 30 – 35. Both Thailand and Indonesia installed twenty Co-60 units of each. Philippine and Vietnam installed 20 and 18 Linacs respectively. Out of these nine Asian countries Singapore installed the least number of Linacs, (Only 10 Linacs). Overall, it is obvious from the column chart (figure 1) that the Linac is more popular than Co-60 units in these nine Asian countries.

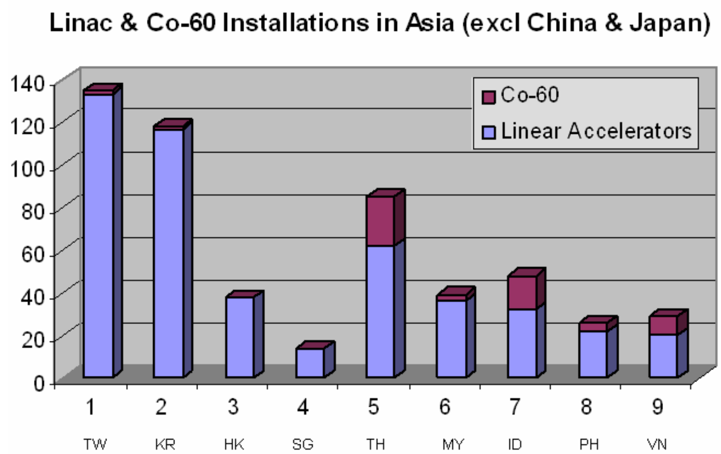


**Figure 17: Competitive overview - Asia region**

This discussion will offer some comparisons about the efficiency and technical applications of Cobalt-60 versus comparable current medical linear accelerators on the market today and how end users might consider their choices and the results of their decisions. The current state of Cobalt and Linac supply in Vietnam will be reviewed.

**Comparative study between Co-60 and Linacs**

In 1978 World Health Organization (WHO) recommended Cobalt 60 Teletherapy Units (Vertical and Isocentric Units) for the next 5 – 10 years. In 2008, the WHO recommendation is still for Cobalt 60 Teletherapy Units, as follows:

"A patient requiring radiotherapy may be treated using two broad groups of techniques: teletherapy and brachytherapy. External beam radiation therapy or teletherapy is usually administered in a tertiary hospital on an ambulatory basis. The treatment takes place in an enclosed shielded room (bunker) and no anaesthesia is needed for adult patients. It may be administered by cobalt machines or by medical linear accelerators. For the majority of patients with curable cancers or cancers that are treatable but not curable, cobalt machines are the more cost effective option in low- and middle-income countries (WHO, 2002; Barton et al. 2006). This is not simply because the capital and maintenance costs of a cobalt machine are much lower than those for a linear accelerator, but also because a linear accelerator is easily damaged by an unstable electric supply, a common hazard in low-income countries (Van der Giessen, 2002)".

WHO predicts that for the next 30 years the Asia-Pacific region will continue to primarily rely on Cobalt Teletherapy for cancer programs in the developing countries.

In response of a question such as "if one's mother had a curable parotid tumour would they want her treated on cobalt or linac with what they know?", raised to the radiation therapists of the developed countries; the answer was "Many rich patients and government officials from developing countries still fly to the West for cancer treatment. They are treated on linear accelerators not cobalt units. Only fair their citizens should get similar quality treatments".

Lenox Hill Hospital, ranked among America's best hospitals, still only uses Cobalt. The machine's circuitry suffered major damage on two occasions because of power surges and the machine went down multiple times over 9 years. The cost of repair was about 50% of a Linac cost in New York at the time (1989-1998). But the problems were similar to Linacs regarding rescheduling, patient inconvenience and staff dissatisfaction. So the only benefit would be cost effectiveness? In the early 1990's the Joint Review Committee for Hospitals reviewed the department and strongly urged the physicians not to use cobalt for any of their radical cases since linacs are easily accessible in New York City. The Cobalt machine still exists in the hospital with 95% of the referral patients sent to outside sites for treatment. The Theratron 780 is only used for in-patients that cannot be treated elsewhere or clinic patients who cannot afford private treatments. The room now is primarily used for a high dose after loading machine for gynecology cases. The hospital has lost millions of dollars in revenue over the past 20 years because of this policy.

On the other hand Harvard J.C.R.T. switched from Cobalt and a Van der Graff machine to all Linac departments in 1970 under the guidance of Bengt Bjorngaard Ph.D. and Samuel Hellman MD. Dr. Bjorngaard still supported Cobalt for developing nations (since 1983) and Dr. Hellman supported all an Linac Department at Harvard (since 1970). The available equipment was:

- 3 Varian 4MV80 Isocentric Units
- 2 Siemens Mevatron 100FSD ISO Units

- 1 GE Maxitron Unit
- 3 Philips Contact 50KV Machines
- 1 Philips Intraop Prototype Machine
- 1 Picker Simulator
- 1 Odelft Simulator

This equipment ran for 10-15 years and treated 220 patients per day. About 70% of the cases were curable by 1980 standards. Therapists in DEAC treated patient loads of 90 cases or more from 7am to 2pm and over 70 years from 7am-7pm daily. The J.C.R.T. was well organized with the following efficient staff:

- Machine Shop with full time master machinist
- 3 fulltime Engineer
- Block Rooms
- 11 Ph.D. Medical Physicists
- 3 full time dosimetrists
- 14 Attending Physicians
- 10 Residents
- 40 Therapists
- Additional Research Staff, Labs etc….

In 1980 average treatment time for patients from door to door was:

- 3-Field Hanging Block Technique for Breast Cancer – 10 minutes
- Medulloblastoma Treatment – 15 – 20 minutes
- 4 Field Prostate (all fields) – 8 minutes
- 3-Field Head and Neck Treatments – 8 minutes.
- Single Palliative Field – 6 minutes

All fields were treated daily and had custom blocking and any wedging, custom compensators, bolus etc. if needed. Normally 2 Therapists with a rotating supervisor were always standing by with each machine. Normal machine load was more than 50 patients per day. Total body electrons and photons was given after normal working hours.

For a good quality external beam radiation therapy treatment one should consider the accuracy, efficiency, precision, penetration & optimum X-ray output, clinical result and optimum equipment operation & ease of maintenance. Depending upon these properties there is a comparison of new Linac and Co-60 as shown in table 1.

The Elekta Compact™ is the latest member of the Elekta Linear Accelerator family. It offers:

- Cost-effective solution for a variety of conventional radiation therapy applications.
- Accurate and easy set-up and delivery of radiotherapy
    - Treat all areas of the body
    - Deliver accurate treatment prescriptions
- Compatible with a range of products from the stereotactic portfolio
- Small footprint – ideal for small treatment rooms (figure 2)
    - Isocentre to Back Wall distance (D), < 2650 mm
    - Fascia to Back Wall distance, < 1000 mm

- Isocentre to Front Wall distance (C)
  - Allow 2400 mm
  - Allows full extension of table top
- C + D = 5050 mm

In comparison, a Cobalt 60 machine bunker has entry width 1170 mm, back wall to maze wall distance 4380 mm, width 4520 mm, height 2530 mm. Challenges are height of machine 2800 mm, height of 'A' frame 3600 mm, back wall to maze wall 5050 mm; additional shielding required.

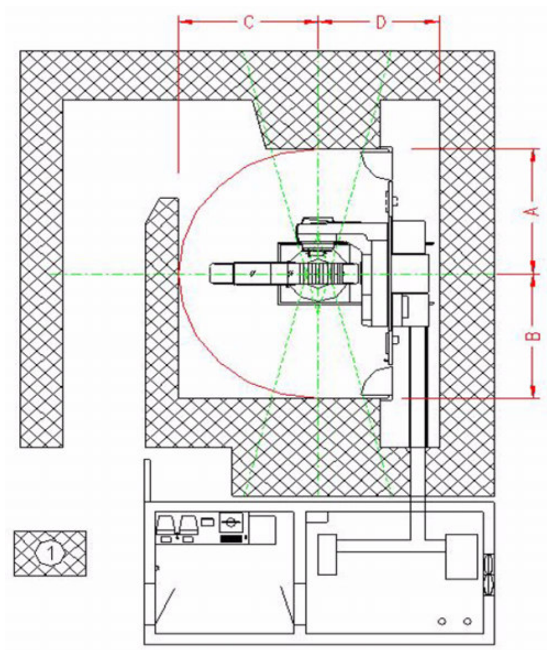


**Figure 18: Ideal for small treatment rooms of LINAC**

**Table 1:** Comparison of new LINAC and Cobalt 60 machine.

| LINAC | Cobalt 60 machine |
|---|---|
| Continuing progress in technology, design & utility | New machines have improved beam capabilities. |
| 6MV – adequate penetration to treat very vast majority of tumors | Does not give ideal depth dose, but adequate for palliative therapy. |
| Platform that allows for advanced curative treatment. | Primarily used for palliative treatment. |
| Upgradeable for advanced treatment modalities to improve the accuracy & quality of treatment. | Continuously depleting sources mean longer treatment times – compromised treatment efficiency & quality. Cumbersome exchange & disposal of sources |
| Standard of external beam therapy in Developed Countries. | |

**Solution for Vietnam**

Based on the historical shift of Institutions to Linacs from Cobalt and their journey into the use of medical linear accelerators and the problems faced by Co-60 users in the current marketplace, the possible solution for Vietnam could be the following:

- Establish regional Palliative Centers
- One Linac Plus one simulation tool.
- 2 Therapists plus 3 Technical aids
- Online Dosimetry
- Radiation Oncologist covering 3-5 Departments.

A vendor is currently offering similar pricing for Linac and Cobalt facilities. Engineering issues between Cobalt and Linac have been resolved in modern times; a simple dehumidifier and power surge adaptor are now installed by Linac vendors in Asia. A Linac can now run on the same current as a diagnostic unit.

**Conclusion**

Doctors and Administrators in developing countries should look at time and motion studies, staff efficiency, transfer of knowledge and not choose equipment based on old thinking. Patients can be treated faster and more efficiently and more effectively with Linacs. Radiation Therapy is the least expensive modality and is used now in 70% of cases.

Leading clinicians still consider Cobalt-60 a viable alternative for poorer economies. How to convince investors or government agencies to make the change to medical linear accelerators and what will be the outcome? Faster treatments, a push for modernization, more sophisticated use of linacs and overall patient satisfaction.

# Radiation Oncology Medical Physicist Status In Vietnam And Recommendations

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**Abstract**
Most of us understand well that Medical Physicists (MPs) play an important part in the safe applications of radiation in medicine. MPs collaborate with clinicians in radiation oncology, diagnostic radiology and nuclear medicine. They are also engaged in research, training and radiation protection, in development and implementation of Quality Assurance (QA) as well as Quality Control (QC) protocols.
Radiation Oncology Medical Physicists status in Vietnam is a big problem. We are in shortage not only of trained medical physicists but also of quantity as well.
How to deal with this matter to meet current demands and to future developments will be discussed in details of this presentation.

## Introduction

Vietnam's population is approximately 87 millions. Cancer is the second rank, after cardiovascular diseases. There are about 120 000 - 150 000 people suffer from cancer each year and only 10% of these are treated by radiation. Radiotherapy in Vietnam is in a very difficult situation. To date, in the nationwide, radiation therapy net work exist two main Cancer Center: K Hospital (National Cancer Hospital) in Hanoi and the Oncology Hospital in HCM City. Besides, there are 2 Cancer hospitals, they are: Hanoi Cancer Hospital and CanTho Cancer Hospital. A few Oncology Departments in general hospitals, such as: 1- Nuclear Medicine and Radiation Oncology Dept., Bach-Mai General Hopst, (Hanoi); 2- Radiation Oncology and Nuclear Medincine Dept., 103 Army Hospital (Hanoi); 3- Military Institute for Nuclear Medicine and Radiation Oncology (Hanoi); 4- Oncology Dept. at Haiphong General Hospital; 5- Oncology Dept. in Thai Nguyen Central Hospital; 6- Oncology Dept. in Hue Central Hospital; 7- Oncology Dept. in Da nang General Hospital; 8- Oncology Dept. in Cho Ray Hospital; 9- Oncology Dept. in Khanh Hoa (Nha Trang). In the private sector, HCM City: Prench-Vietnam Hospital and PhuTho Hospital.
Radiation therapy facilities are also in poor conditions. In the nationwide, there are total 14 Cobalt Units (two-third of them are second hand and too old); 9 Linacs; 3 HDR Brachytherapy machines (only two of those are new). Radiation Therapy professionals are involved: 63 Radiation Oncologists, 38 Medical Physicists, and 64 Technicians (table 1).

**Table-1:** Distribution of Radiation Therapy Facilities and ROMP in Vietnam.

| Radiation Oncology Institutions | RT Facilities | | | ROMPs |
|---|---|---|---|---|
| | Cobalt-60 | Linacs | HDR | |
| National Cancer Hospital (K Hospital) | 3 | 2 | 1 | 7 |
| Oncology Hospital, HCM City. | 3 | 2 | 1 | 8 |
| Hanoi Cancer Hospital | 1 | 1 | 0 | 1 |
| Bach Mai Hospital | 1 Gamma Knife | 1 | 0 | 1 |
| CanTho Cancer Hospital | 1 is expected in 2009 from IAEA | 0 | 0 | 2 |

| | | | | |
|---|---|---|---|---|
| 103 Army Hospital | 1 | 0 | 0 | 1 |
| Military Institute (Hanoi); | 0 | 0 | 0 | 3 |
| Oncology Dept.(Hai Phong ) | 2 | 0 | 0 | 1 |
| Oncology Dept.(Thai Nguyen) | 1 | 0 | 0 | 1 |
| Oncology Dept. (Hue) | 1 | 0 | 0 | 2 |
| Oncology Dept.(Da Nang) | 0 | 0 | 0 | 0 |
| Oncology Dept.(Khanh Hoa) | 1 | 0 | 0 | 1 |
| Cho Ray Hospital | 1 Gamma Knife | 2 | 0 | 9 |
| Phu tho Private Hospital (HCM City) | 1 | 0 | 1 | 1 |
| French-Vietnam | 0 | 1 | 0 | ? |
| Total | 14 | 9 | 3 | 38 |

**Comments:**

- The amount of equipment used in the field of radiotherapy is too few to deal with the situation comparing to developed countries, where exist at least one or two radiation therapy facilities per one million people. Cancer patients are always overload in most of RT institutions.
- At the institutions where Cobalt-60 Units have been using, RT techniqiues are quite simple due to lack of TPS, Simulator/CT Sim as well as dosimeters. Furthermore, almost of these Cobalt Units are too old and the activity of the radiation sources are so weak that the treatment time per one fraction is rather long. Therefore, treatment quality is hardly improved.
- To date, there is not a university to train Medical Physicist (officially). Only a few Medical Physicists have qualifications in Nuclear Physics, the few others are electronic engineer and obtained jobs in hospitals. Their knowledge of medical physics is limited.
- A few Radiation Oncology Centres have no Medical Physicist at all.
- 

**Table-2:** Ten Common Cancer Diseases in Hanoi and HCM City
(Age standard Rate-ASR/100 000 persons)

| Male | | | Female | | |
|---|---|---|---|---|---|
| Type of cancers | ASR | | Type of cancers | ASR | |
| | Hanoi | HCM City | | Hanoi | HCM City |
| Liver | 17.0 | 38.2 | Cervix | 6.3 | 35.0 |
| Lung | 38.8 | 32.3 | Breast | 26.7 | 17.1 |
| Stomach | 34.5 | 24.3 | Colorectal | 8.0 | 11.8 |
| Colorectal | 13.3 | 14.8 | Stomach | 16.4 | 10.3 |
| Esophagus | 3.4 | 6.1 | Lung | 5.6 | 8.8 |
| Nasopharynx | 9.5 | 5.5 | Liver | 6.6 | 8.3 |
| Pharynx | 2.6 | 4.9 | Skin | 4.2 | 4.0 |
| Prostate | 2.2 | 4.6 | Ovary | 5.9 | 3.8 |
| Skin | 5.0 | 4.2 | Uterus corpus | 2.1 | 3.4 |
| Pancreas | 1.0 | 3.8 | Lymphoma | 3.2 | 2.9 |

**Comments :** Registration data indicated that,

- In male: common cancers are similar to region in the whole country, such as: Lung, Stomach, Liver, Nasopharynx, Colorectal. But liver cancer in the south is much higher than that in the North of Vienam.
- In female: Cervix cancer in the South is much higher than that in the North of Vietnam. In contrast, Breast cancer in the North is much higher than that in the South.

- Common cancer in Hue, Da nang are similar to Hanoi and HCM City.
- Comparing with cancer statistic data in the world showing that, some cancers in Vietnam such as Nasopharynx, Liver, Stomach, Cervix... are much higher.

The other cancers such as Prostate, Breast, Skin, Colorectal... are lower than those elsewhere in the world.

**Recommedations for 2009-2012**

- Radiotherapy in Vietnam is facing to very difficult conditions. To deal with these problems, a significant budget for Cancer control in general and for Radiotherapy in particular needs to be funded by the Vietnam Government.
- Strengthen International Co-operation with IAEA/WHO as well as NGOs.
- The too old Cobalt units should be replaced and the weak Co-60 sources should be changed soon.
- The main Cancer Centres should purchase Linear Accelerator(s).
- Establish new Radiation Oncology Department(s) in provinces.
- Carryout a National Program for QA in radiotherapy.
- Organise National workshops and conferences on RT with assistance of the IAEA's Experts to train professionals who are working in the field of RT in the Nationwide.
- Establish two centers for Training and Education of ROMP in Hanoi and in HCM City.

**Recommendations to 2015**

- Establish Radiation Therapy Network in Vietnam
- Establish National Radiation Therapy Center (from National Cancer Hospital, Hanoi)
- Establish National Institute for Nuclear and Radiation Therapy (in Bach Mai Hospital, Hanoi).

# The Bhabhatron: an Affordable Solution for Radiation Therapy

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## Abstract

Radiation therapy as a mode of cancer treatment is well-established. Telecobalt and telecaesium units were used extensively during the early days. Now, medical linacs offer more options for treatment delivery. However, such systems are prohibitively expensive and beyond the reach of majority of the worlds population living in developing and under-developed countries.

In India, there is shortage of cancer treatment facilities, mainly due to the high cost of imported machines. Realizing the need of technology for affordable radiation therapy machines, Bhabha Atomic Research Centre (BARC), the premier nuclear research institute of Government of India, started working towards a sophisticated telecobalt machine. The Bhabhatron is the outcome of the concerted efforts of BARC and Panacea Medical Technologies Pvt. Ltd., India. It is not only less expensive, but also has a number of advanced features. It incorporates many safety and automation features hitherto unavailable in the most advanced telecobalt machine presently available. This paper describes various features available in Bhabhatron-II. The authors hope that this machine has the potential to make safe and affordable radiation therapy accessible to the common people in India as well as many other countries.

## 1. Introduction

Radiotherapy is one of the established treatment methods of localized cancer. External beam therapy started with kilo-volt systems, and later radioactive isotope based high energy systems were developed. Most of the research and development on these systems occurred during the initial few decades. Although, the telecobalt and telecaesium units were effective and played important roles, there was little effort for further improvements of these designs. In the electronic era, most of the enhancements and developments have come across in linear accelerator based systems. Similar developments have not been found for tele-cobalt machines. The linear accelerator based systems are versatile and offer more options for treatment delivery, but these are very expensive. The lack of resources required for such complex systems is another concern.

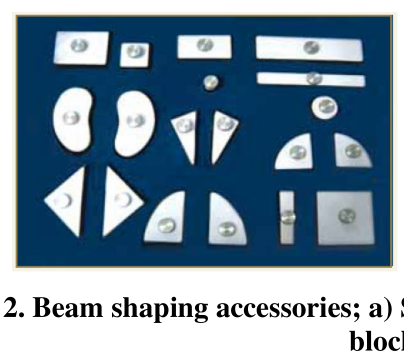
In India, it is estimated that, there are more than two million cancer cases at any point of time, and more than one million new cancer cases are detected every year. Additionally, incidences of cancer are expected to rise significantly due to aging population, environmental degradation, changing lifestyle etc. Although, the treatment using cobalt-60 is most cost effective and relevant in a developing country like India, till 2005, all the operating cobalt machines in the country were imported. There are only 422 teletherapy units (282 telecobalt and 140 medical LINACs) available against the modest immediate requirement of at least 1000 machines. Also, the existing facilities are located in urban areas while the vast rural areas remain largely untouched. To meet this shortfall, Bhabha Atomic Research Centre, Trombay, Mumbai has developed a new generation telecobalt unit named Bhabhatron-II [1]. It is a computer-controlled, isocentric external beam therapy machine with a number of advanced features, viz. full collimator closure, asymmetric collimation, motorized wedge filter, collimator auto setup, battery backup for regular operations during power cuts etc. The important features of this unit are described in brief.

**Figure 1: Bhabhatron-II tele-cobalt machine**

## 2. Bhabhatron-II: Brief Description

Bhabhatron-II is an isocentric, external beam radiation therapy system with source to axis distance of 80cm. It houses a Cobalt-60 radioisotope of high activity (15KCi max.). The source capsule is mounted in a pneumatically driven source drawer which toggles the source between shielded (beam-OFF) position and treatment (beam-ON) position. All the motions in the main unit and the treatment table are motorized. The collimator assembly controls the size and orientation of the radiation beam. During patient setup, the area to be exposed can be visualized using a light beam. Two sets of trimmers are provided to reduce the radiation penumbra. Bhabhatron-II is provided with various beam shaping accessories like breast block and shielding blocks. Shielding block protect vital organs in the path or near the radiation field.

a)



b)

**Figure 2. Beam shaping accessories; a) Standard shielding blocks, b) Breast block**

The counterweight is placed at the rear side (behind the partitioning wall). Large area is now available for the operator, resulting in increased flexibility to ensure proper visual feedback for accurate positioning.

The patient positioning table or couch consists of a turntable mounted eccentrically with the isocentre. The couch has four motorized motions: Isocentric rotation and translations in longitudinal, lateral and vertical directions. The motions are controlled through keypads attached on either side of the couch body. Salient features of the couch are high stability, noise-free motions and high precision.

**Figure 3: Couch of Bhabhatron-II**

The operator interacts with the system using the mouse and keyboard located at the control console (Figure 4). For normal operation of the machine, highly skilled operator is not required. Inside the treatment room, two keypads are used. Simple, ergonomic, backlit keypads (Figure 5) are located on either side of the patient positioning table for quick patient set-up. Digital readouts on the keypads make the positioning job simpler. Machine parameters (both set values and actual values) and patient specific set-up notes are available on the wall-mounted display monitor inside the treatment room.

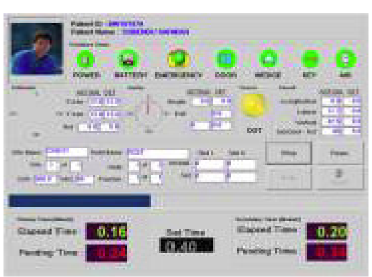
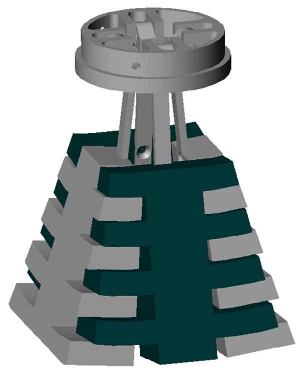



**Figure 4. Control console outside the treatment room**

**Figure 5. Keypads on either side of the couch**

*2.1 Enhanced Safety:* In case of any emergency, the control system pushes the source automatically to the beam-OFF position thus ensuring safety against over-exposure. One of the unique features of Bhabhatron-II is its fully closable collimator. During any emergency, the collimator closes fully to limit unplanned exposure to the patient. Intermeshing leaves as shown in Figure 6.(a), are commonly used in telecobalt units to define the radiation field size, and it is not possible to close the radiation beam fully using such mechanism. However, Bhabhatron-II uses parallel jaw pairs (Figure 6.(b)) in different planes facilitating full closure of the radiation beam. In addition to physical key, the system allows selective access to operation, machine parameters, and patient/treatment data through password protection. Thus unauthorized exposure as well as access to treatment/patient data is prevented.

a)



b)

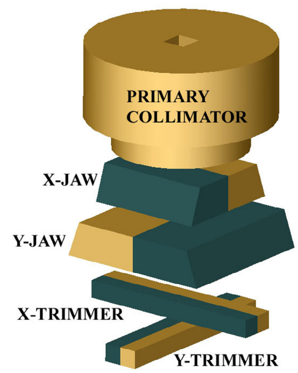



**Figure 6. Collimator design: Typical telecobalt unit vs Bhabhatron-II**

*2.2 Motorized Universal Wedge Filter:* Wedge filters are frequently used to provide wedge-shaped dose distributions inside the target. Although, multiple choices are available for generating wedged dose profiles, individual physical wedge filters are typically used in telecobalt units. In addition to the physical wedge filters viz. 15, 30, 45 and 60deg., Bhabhatron-II is equipped with a motorized wedge filter [2] designed to generate maximum wedged field size of 15Wx20cm$^2$, and maximum wedge angle of 60deg. The axes of the physical and motorized wedge filters are perpendicular to each other, facilitating complex dose distributions. In motorized wedge, a wedged beam is combined with the open beam in proper combination to achieve the desired wedged profile. In this way any wedge angle up to the angle of universal wedge filter can be generated. The potential advantages of motorized wedges are often to speed up the patient setup because it is no longer necessary to handle physical wedges. Additionally, motorized wedge filters can generate any arbitrary wedge angle instead of the limited standard angles available with the physical wedge filters.

*2.3 Asymmetric Collimation*: Telecobalt units typically provide radiation fields symmetric along both the axes. However, in many instances, asymmetric fields can provide improved conformity. For example, physical handling of heavy shielding blocks during breast treatment can be avoided. In Bhabhatron-II, the shielding jaws (for defining the radiation field) corresponding to one axis move independently facilitating asymmetric fields with respect to the radiation beam central axis.

*2.4 Collimator Auto Set-up:* Typically, for telecobalt units, sets of buttons are provided on or close to the patient positioning table (couch) for setting the radiation field parameters prescribed for any patient. In Bhabhatron-II, the operator can opt for automatic set-up after providing the radiation field details at the control console located outside the treatment room. In auto set-up mode, the computer instructs the control hardware and sets the required field setting automatically. This facilitates fast and accurate patient positioning. Reduction in patient positioning time is very important, particularly for multi-field treatments. Any saving in treatment setup time is directly related to the number of patients can be treated in a shift/day.

*2.5 Battery Backup:* The system consumes low power (1.2KW). In remote locations where either electric supply is not available or erratic, it is possible to operate this machine using a low-capacity generator. Additionally, the (rechargeable) battery backup facilitates continuous treatment (~six hours) during power-cuts.

*2.6 Remote Monitoring:* The telecommunication network has covered almost all the regions of our country. An SMS based communication system is developed for reporting the machine status continuously to the service center. This permits remote diagnosis, and timely corrective actions, ensuring reduced downtime of the machine.

*2.7 Security and Data Management:* The machine, patient and treatment data are password-protected and accessible to authorized staff only. Since the machine is computer controlled, it is possible to manage the patient and treatment related parameters easily.

## 3. Telecobalt Source and Disposal of Decayed Source

The Co-60 radioisotope is produced from natural cobalt-59 by the thermal neutron capture reaction in a reactor and fabricated in required geometry for the end users. The source capsule is remotely assembled to the source drawer (part of the Bhabhatron-II unit) inside hot-cell (facility for handling radioactive substances inside shielded room remotely). Subsequently, the source drawer assembly is transported to the installation site, and loaded into the machine. Similarly, the decayed source is brought back along with the drawer to the hot-cell for decommissioning. Sometimes, the decayed source capsule is recycled for further fabrication or securely preserved for long-term interim storage. The block diagram of Cobalt-60 life cycle is shown in figure 7.

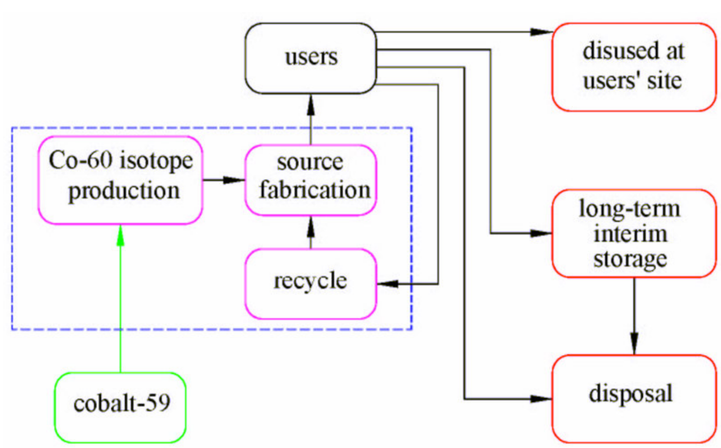



**Figure 7: Cobalt-60 life cycle**

## 3. Telecobalt Source Transportation

The strength of the radioactive cobalt-60 source decays with time and after few years, the radiation source needs to be replaced. A transportation flask is a shielded container used to transport the source capsule from the manufacturer's site to the location of the teletherapy unit (typically a hospital). It is also used to return the decayed sources from hospitals to designated facilities for final disposal. Since, the transportation flask containing the radiation source is to be transported through public domain; utmost care and safety are essential to protect people and the environment from the harmful effects of radiation. As per the safety regulations [3] of IAEA, the integrity and effectiveness of the radiation shielding is must during normal as well as accident conditions of transport.

**Figure 8. Teletherapy Source Transportation Flask**

The source transportation flask (Figure 8) is designed for this purpose and approved as type B(U) package. It has a sacrificial piped structure to protect the containment from mechanical damage during accident conditions of transport. It also contains thermal shield to protect the shielding against excessive heating during accidental fire.

## 4. Quality Assurance

Like other radiotherapy systems, the main objective is to deliver prescribed dose to the target while limiting the exposure to the surrounding healthy tissues. Regulatory requirements are quite stringent to protect the patient, staffs and the environment from the harmful effects of radiation. This machine conforms to the requirements as per the International Electrotechnical Commission (IEC) [4,5] applicable to this type of equipments. It also has CE marking conforming to the requirements of the Medical Device Directive 93/42/EEC.

## 5. Bhabhatron-II Future

Although the present trend is in favour of linear accelerator based systems, Bhabhatron-II is gradually becoming popular due to advanced features at much lower cost. We feel that Bhabhatron-II will play significant role in coming years in improving the cancer care in India as well as other developing countries [6].

## 6. Developments in Progress

Like all commercially available telecobalt units, this machine also provides rectangular field. But, the collimation systems using multiple leaves (MLC) offer excellent conformity to complex targets. Such systems are typically used for Linear Accelerator based systems. Till now, this feature is not available for any telecobalt machine due to limitations arising from space availability and other operational complexities. The collimator system of Bhabhatron is different from other telecobalt systems. Preliminary studies show that MLC is possible to implement in Bhabhatron. Work has already started in that direction, and it will be a significant development enabling affordable yet high precision radiation therapy.

## 7. Conclusion

The indigenous development of Cobalt-60 teletherapy machine has the superior features in terms of safety, user-interface and security. Moreover, the cost of Bhabhatron-II is significantly lower than imported machines of similar capacity. The technology is already transferred for its mass production. Bhabhatron-II development is improving the access of cancer patients to treatment facilities and reducing treatment cost not only for Indian but also for the rest of the world.

### References


1. Jayarajan K., Kar D.C., Sahu R and Singh Manjit, "Bhabhatron: An Indigenous Telecobalt Machine for Cancer Treatment". Founder's Day Special Issue, Issue No 297, October 2008, page 27-34. www.barc.ernet.in/publications/nl/2008/20081003.pdf

2. Rajesh Kumar, D C Kar, S. D. Sharma, and G. V. Subrahmanyam (2009), Design, Implementation and Validation of Motorized Wedge Filter for Bhabhatron-II Telecobalt Machine. *30th International Conference on Medical Physics* (to be held), November 22-25, Hyderabad, India.

3. *Regulations for the Safe Transport of Radioactive Material,* Safety Series No.TS-R-1, 2005 Edition, IAEA, Vienna,

4. IEC 60601-1 – Medical Electrical Equipment- Part 1: General Requirements for Safety, Edition 2. *International Electrotechnical Commission,* Geneva.

5. IEC 60601-2-11 - Medical Electrical Equipment- Part 2: Particular Requirements for the Safety of Gamma Beam Therapy Equipment, Edition 2, rev. 2004. *International Electrotechnical Commission,* Geneva.

6. K. Jayarajan, D. C. Kar, and M. Singh, (2009), Role of Bhabhatron in cancer care in India. *International Conference on Peaceful Uses of Atomic Energy.* September 29- October 01, New Delhi.

# Management of a basic radiation therapy center

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## Abstract

Radiation therapy services can be organized in two levels of complexity and in some large countries, depending on the distribution of the population, in three. The functional links between centers of differing degrees of complexity should be clearly established in order to ensure smooth referral and counter referral processes and guarantee continuity of care for patients who require it. Most critical is the initial evaluation of the patient and his/her tumor to decide whether the treatment's goal is cure or palliation, and whether other treatment modalities should be employed, especially for pain control. The management of a radiation therapy center comprises financial, administrative and technical issues regarding the type of services to be offered (outpatient vs inpatient), the facility requirements in terms of space and structural shielding, the technical characteristics of the needed equipment (with accessories and supplies), and the hiring of on-site and off-site personnel. A "Basic Radiation Therapy Center of Technological Complexity Degree I" should have at least one cobalt-60 teletherapy unit, brachytherapy at least for gynecological treatments, a superficial x-ray unit for skin lesions and a radiodiagnostic unit for tumor and radiosensitive organ localization. A personal computer with Internet connection, as well as some quality control (QC) test tools, are essential. A quality assurance/quality control (QA/QC) program that monitors clinical and technical aspects should be developed jointly by a radiation oncologist and a medical physicist but may be carried out by local personnel using telephone or personnel computer communications. For the cobalt unit, adherence to the set of maintenance steps recommended by the manufacturer is critical to ensure patient safety and prolong the life of the machine.

## Introduction

The number of global cancer deaths is projected to increase from 7.9 million in 2007 to 11.5 million in 2030, due in part by an increasing and aging global population, and new cancer cases are estimated to jump from 11.3 million in 2007 to 15.5 million in 2030. In most industrialized countries, cancer is the second largest cause of death after cardiovascular disease, and epidemiological evidence points to this trend emerging in the less developed world. This is particularly true in countries in "transition" or middle-income countries, such as in South America and Asia. Already more than half of all cancer cases occur in developing countries (1).

Thanks to medical advances, one-third of all cancers are now preventable and another one-third, if diagnosed early enough, are potentially curable. Moreover, appropriate palliative care of the remaining one-third of cancer patients can bring about substantial improvements in the quality of life.

It is estimated that radiation therapy, alone or in conjunction with surgery or chemotherapy, is required for more than half of all cancer patients. The 2008 UNSCEAR report estimated that there were 4.6 million patients treated annually with radiation therapy during the period 1997–2007, up from an estimated 4.3 million in 1988. About 4.3 million were treated with teletherapy and 0.3 million with brachytherapy. However, the 24% of the population living in health care level I countries received 76% of the total radiation therapy treatments! (2). In some parts of the world, such as large regions of Africa and South East Asia, there may be only one high-energy radiation therapy machine for 20-40 million people, and one machine may be used to treat more than 600 new patients per year. Many cancer patients have no access to radiotherapy services. Yet, increases in life expectancy, means there will be even a greater demand of radiation therapy.

The major factor that currently limits radiation therapy in the developing world and that will stand in the way of meeting future needs is the shortage of equipment and personnel for operation and maintenance. People in many areas of Africa and South East Asia have virtually no access to this beneficial treatment modality. Essential services must therefore be developed; these services may often be offered within a comprehensive palliation center.

**The Organization of Radiation Therapy Centers (3)**

There are three types of radiation therapy services: teletherapy, brachytherapy, and treatment with radionuclides. They should be planned according to the levels of health care, after performing an analysis of morbidity and mortality in the community and reviewing the utilization patterns of the various radiological procedures. They should be categorized based upon their complexity, and located taking into consideration the geographical distribution and mobility of the population.

In the organization of these services, stratification in two categories of facilities or centers with clearly differentiated technological complexity is generally considered sufficient. In some large countries, depending on the distribution of the population, it may be advisable to consider establishing centers which would eventually constitute a third level of technological complexity. The centers of degree of complexity III would be the ones with have IMRT and IGRT treatments and have radiation oncologists and other staff with high levels of specializations (i.e. head and neck, gynecological…). Degree II would have conformal therapy equipment at various energies, with linear accelerators and high dose-rate brachytherapy devices (HDR), and staff consisting on on-site radiation oncologists, medical physicists, dosimetrists, radiation therapy technologists – called in some countries radiation therapists– oncology nurses and biomedical engineers.

A “Basic Radiation Therapy Center of Technological Complexity Degree I” should have at least one cobalt-60 teletherapy unit, some form of brachytherapy at least for gynecological treatments (manual, low-dose rate brachytherapy device, HDR or electronic brachytherapy depending on patient workload and budget), and an adequate radiodiagnostic unit for tumor and radiosensitive organ localization. A personal computer with Internet connection as well as some quality control (QC) test tools and at least one survey meter are essential.

Preferably, this basic radiation therapy center would be located in a general hospital of intermediate complexity, but it could be a stand alone facility with some beds for in-patient treatment or it could be part of a palliation center. It should be interconnected with a radiation therapy center of degree-II technological complexity for the development of treatment protocols and the advanced training of specialists.

Degree-II technological complexity centers should be located in referral hospitals or in tertiary care hospitals specifically equipped to provide treatments with specialized techniques and to carry out research. These degree-II radiation therapy centers could meet the needs of a population of approximately one million inhabitants. A center of degree-III technological complexity should definitely be part of a university teaching hospital or a dedicated cancer center with comprehensive diagnostic and treatment facilities.

The functional links between centers of differing degrees of complexity should be clearly established in order to ensure smooth referral and counter referral processes and guarantee continuity of care for patients who require it.

**Installation and Operation of a Basic Radiation Therapy Center**

In the selection of equipment, it is fundamental to consider both the initial investment and the operating costs. For the cobalt unit, they include the purchase of the radioactive source (185 TBq of activity and 2 cm of diameter?), its initial calibration (by a medical physicist), its periodic replacement (every 5 years?), and the eventual disposal of the whole unit (after 20 years?). Table 1 lists procurement considerations. If brachytherapy is to be done with radioactive sources, their storage requires a properly shielded area and their eventual disposal must be carefully planned and budgeted. An alternative to radionuclide manual or automatic brachytherapy is the use of electronic brachytherapy, miniature x-ray tubes that can yield similar dose distributions to LDR with I-125 and similar dose rates to HDR with Ir-192. At least one manufacturer of such devices is exploring a model which can be used for gynecological treatments (4).

In the selection of the radiation therapy staff, their qualifications and training will depend on the center complexity; their number, on patient workload. Table 2 lists the minimum human resources needed for a Complexity I Center. A critical person within the facility is the manager who has to take and implement administrative decisions.

**Radiation Therapy Process**

The destruction of tumors by ionizing radiation is a complex process, which requires the collaboration and interaction of personnel trained in various disciplines. The process encompasses the following steps: clinical evaluation, therapeutic decision, tumor localization, treatment planning, treatment, periodic evaluation and follow up evaluation.

A most critical step is the initial evaluation of the patient, where the diagnosis is established and the tumor staging is determined. Ideally, patients should be diagnosed at a Radiation Therapy Center of Complexity II or III, the referring facility. It is at this point when the radiation oncologist seeing the patient decides whether the treatment's goal is cure or palliation, and what other treatment modalities, if any, should be employed. When the patient lives at a great distance from such a Center, he/she could be referred to a Basic Radiation Therapy Center for treatment, especially if the goal is palliation. To simplify matters, tumor localization and treatment planning could also be done at the referring center. If not done at the time of patient evaluation, treatment planning can be done locally with simple point dose calculation programs running in a personal computer or remotely using suitable software. In the latter case, the communication between the facility performing the dose distributions and the center treating the patients is of paramount importance and requires the local technical personnel to be trained in the interpretation of the plans very carefully. The requirements for remote treatment planning are listed in Table 3.

The local (basic) center has to verify the treatment, both in terms of volume treated and dose delivered. The treated volume can be ascertained with the same cobalt-60 unit, but brachytherapy treatments will require at least one AP (or PA) and one lateral radiographs. The possibility to use computed radiography for this imaging should be carefully considered, as it would eliminate the need for a darkroom and it would facilitate the transmission of the data to the center doing the dose calculations. Patient treatment charts can be done electronically, but patient doses within the facility should be calculated by one person and checked manually by another one. Special attention should be given to field matching when large field sizes are used, requiring careful calculations of gaps. The coincidence of the light field and the radiation field should be determined by the medical physicist and the calculations checked by the dosimetrist.

The local center should evaluate patient progress during treatment and keep the statistics on treatment outcome in order to adjust protocols after discussion with the referring center.

**Quality Assurance/ Quality Control**

A quality assurance/quality control (QA/QC) program that monitors clinical and technical aspects should be developed jointly by a radiation oncologist and a medical physicist. In a basic radiation therapy center, the clinical aspects of the QA program can be carried out by the local physicians in frequent consultation via telephone or personnel computer with the supervising radiation oncologist, who should visit the center on a periodic basis. QC tests involving mechanical, dosimetric and radiation safety checks of the imaging, treatment, dosimetry and treatment planning equipment can be carried out with simple instruments by the local technical personnel, trained by a medical physicist who should perform the initial radiation safety survey and the calibration of the treatment unit. The frequency of the tests will depend on the complexity of the center. The same medical physicist should be available for consultation and should visit the center at least yearly to perform a full evaluation of the cobalt unit, check the maintenance tasks performed, review the clinical dosimetry and assess the adequacy of the technicians' treatment procedures. For the cobalt unit, adherence to the set of maintenance steps recommended by the manufacturer is critical to ensure patient safety and prolong the life of the machine.

The most critical function is that of the facility manager who should assign functions and responsibilities, among them who in the staff will become the radiation safety officer, and the dosimetrist, when and how will the clinical consultations take place (will the local physicians participate in tumor boards by internet or telephone?), facilitate treatment planning communications, schedule the visits and telephone consultations of the preventive maintenance engineer and the medical physicist. Table 4 lists the radiation safety officer functions; Table 5, the QC tests to be performed by the dosimetrist, and Table 6 the overall coordinating responsibilities of the facility manager.

**Radiation Safety / Replacement and Disposal of Cobalt-60 sources**

Co-60 sources require replacement every 3-5 years and Ir-192 used for HDR, every 3 months. Manufacturers will remove the old sources when purchasing new ones, but if the facility decides to buy a linear accelerator or close the center, the disposal of Co-60 sources is very expensive. Disposal costs should be budgeted at the time the equipment is first purchased. Irresponsible disposal or abandonment of teletherapy units can result in severe radiation accidents such as those occurred in Ciudad Juarez and Goiania.

**Conclusions**

It is possible to operate a basic radiation therapy center that provides high quality treatments with simple radiotherapy equipment and without on site specialized personnel such as radiation oncologists, medical physicists and maintenance engineers, provided the facility: a) follows the clinical and technical protocols established by these specialists, b) is in constant communication with them through scheduled and unscheduled visits and via telephone and Internet and c) has a committed manager that supervises the financial, administrative and technical issues and insists on implementing and monitoring a rigorous QA/QC Program.

**Bibliography**


1. World Health Organization. *Are the number of cancer cases increasing or decreasing in the world?* Features, On-line Question and Answers, 1 April 2008. http://www.who.int/features/qa/15/en/
2. United Nations Scientific Committee on the Effects of Atomic Radiation. S*ources and effects of ionizing radiation: UNSCEAR 2008 Report to the General Assembly, with Scientific Annexes*. New York: United Nations. In press.
3. C. Borrás, ed. *Organization, Development, Quality Control and Radiation Protection in Radiological Services - Imaging and Radiation Therapy*. Pan American Health Organization/World Health Organization. Washington DC (1997)
4. Xoft, Inc. *Personal communication*. http://www.xoftinc.com/Press-Releases/press-releases.html. (November 2008).

**Table 1. –Procurement Considerations**

**Equipment Costs**
- New or used – Refurbished?
- Donation or purchase
- Payment facilities

**Warranties / Maintenance**
- Spare Parts
- Down Time

**Facility Conditions**
- Space
- Shielding

**Permits / Regulations**
- Import? - Customs
- Building Codes
- Ministry of Health
- Ministry of Labor
- Radiation Regulatory Authority
- Local Ordinances

**Time Line**
- Building Modifications?
- Equipment Access?
- Temporary Storage?

**Medical Physics Expertise**
- Facility
- International?

**Manuals** (Available in a local language acceptable to the user?)
- Operation
- Service

**Replacement parts**
**Accessories**
**Software upgrades**

## Table 2

### Radiotherapy Department Complexity I

#### Minimum Human Resources ON Site

| | |
|---|---|
| Treatment Physicians | 1 / 250 New Patients / Year |
| Dosimetrist | 1 / Center |
| Radiotherapy Technologists | 2 / Treatment Unit |
| Diagnostic Imaging Technician | 2 / Imaging Unit |
| Radiotherapy Assistance Nurse | 1 / Center |

#### Human Resources OFF Site - On Contract (Periodic Visits)

Radiation Oncologist(s)
Maintenance Engineer/Technician
Medical Physicist
Information Technology Expert

## Table 3

### Remote Treatment Planning Requirements

- Patient contouring capabilities
  - Manual
  - CT
- Imaging for tumor localization
- Good broadband connection
- Excellent personal communication
- Well-trained and supervised
  - Technologists
  - Dosimetrist
- Periodic validation
- Frequent consultations
- In vivo dosimetry (diodes?)

## Table 4

### Radiation Safety Officer Functions

**Verify**
- Radiation Warning Signs
- Door Interlocks
- Radiation Emergency Controls

**Perform Periodic Radiation Safety Surveys**

**Maintain Inventory of all Radioactive Sources**
- Receipt
- Use
- Disposal

**Table 5**

**Quality Control Tests - Dosimetrist**

**Daily checks**
- Safety Interlocks
- Motions / Displays
- Isocenter
- Light Field Size

**Monthly tests**
- External Beam Outputs
- Brachy Source Inventory
- Light/Radiation Field Size

**Table 6**

**Overall Coordinating Responsibilities of the Facility Manager**

**Maintenance Program**
- Mechanical checks done locally
- Follow up periodic preventive maintenance visits

**Medical Physics Program**
- Tests done locally
- Follow up medical physicist recommendations

**Radiation Safety**
- Reports for Regulatory Authority
- Investigation accidental medical exposures

# The Educational Requirements for Technologists in the Fields related to Palliative Radiotherapy

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**Abstract**

The radiological technologist is a health care professional who manages the details of the radiation process in diagnostic radiology, nuclear medicine, radiation therapy and other applications**.** Since these professionals are using ionizing radiation, which is potentially harmful to living cells, most countries have strict regulations and certifications regarding the practice of this profession. The education of a radiological technologist varies worldwide. Usually their basic educational qualifications may include a diploma after secondary schooling or a three year to four year bachelor's degree or master's degree. However, with the rapid development of health technologies and radiation applications, the skills of technologists in developing countries need be qualified and continuously developed by appropriate educational programs to meet the demand of increasing quality and safety for healthcare services.

This paper contributes to the evaluation of current educational requirements for technologists in the fields related to palliative radiotherapy.

**The role of radiological technologists in radiotherapy**

The radiological technologist who is working in radiotherapy or in palliative radiotherapy is normally called radiation therapist. The technologist is an essential member of a team of professionals including radiation oncologists, medical physicists and nurses. The technologists are involved in variety of works in radiation therapy such as the mould room, simulation, treatment planning and dose delivery.

In the mould room, technologists can manufacture immobilization devices, prepare blocking, create patient positioning devices and work with power tools. In simulation, technologists can work with doctors and medical physicists in real time and computer localization of target volume. In treatment planning, the technologists can define the target; prepare patient data, treatment details and dose calculations for treatment units. They can work in conjunction with dosimetry and mould room staff to provide a homogeneous dose distribution to the target volume while limiting the dose to normal tissues using the various computer applications.

In radiation treatment, technologists can position the patient accurately, deliver the treatment dose, verify the prescribed radiation, operate linear accelerators, Cobalt-60 and computers, monitor the patient’s physical and emotional needs, assess and record treatment reactions, advise patients on the appropriate care plans, provide overall care of the patient on a daily basis.

In addition, the technologists should have characteristics such as a strong desire to serve humanity, empathy and compassion, patience, consideration and acceptance for patients regardless of their age, race, gender, culture or social standing, team player, integrity and responsibility.

**The educational requirements**

The technologists require education and training in or in combination with community schools, universities and hospitals for the duration of 2- 4 years. The basic program should include didactic courses in classroom and clinical education in clinical treatment areas for clinical experience.

One example of didactic courses includes the following subjects:

- Applied Anatomy and Physiology
- Clinical Radiation Therapy
- Clinical Palliative Radiation Therapy
- Professional Practices (Patient Care)
- Radiation Physics
- Equipments ( Imaging & Therapy)
- Radiobiology
- Radiation Protection
- Treatment Planning
- Telemedicine

In which, the students should be required to:

- Attend all classroom lectures
- Submit assignments on time
- Write scheduled examinations
- Submit a research project

One example of clinical education models should include:

- scheduled clinical rotation sites
- scheduled labs
- clinical written assignments and care plans
- simulated workshops
- oral reviews and/or testing situations
- research project
- article review classes
- patient rounds

In which, the students should be required to:

- Demonstrate a gradual increase in clinical skills
- Be a team player
- Interact with the patient
- Demonstrate competence in clinical areas

For graduation requirements, students should:

- Complete the didactic and clinical components of the program
- Maintain the academic standard on didactic and clinical components of the program (min. 70%)

**Comparing the intents of Curative Radiation Therapy with Palliative Radiation Therapy**

To understand the intent of Curative Radiation therapy and Palliative Radiation therapy, it is better to go for the treatment procedure individually:

***a) Curative Radiation Therapy***

- Precisely and reliably define and treat the target tissue.
- Influence the biology of treatment by optimizing the treatment approach
- Reduce normal tissue dose and/ or increase target tissue dose
- Minimise the incidence of side effects
- Increase tumour control and achieve cure
- Daily treatment fractions, prescribed in Gy
- Five days per week, six to eight weeks
- Cumulative side effects
- Treat tumour and risk areas
- Eradication of all tumour cells

***b) Palliative Radiation Therapy***

- Used in Advanced cancer where cure in not possible
- Hypofractionation (1or few fractions, low dose )
- One day to two weeks (treatment course is short)
- Less concern about long term side effects
- Treat only site requiring palliation (treat symptoms: bleeding, obstruction, pain), forego risk areas
- May purposely miss known areas of tumour

However, both intents are of Radiation Therapy, it is the use of ionizing radiation in the treatment of patients with disease and applying the same procedures: consultation, simulation, defining target, treatment planing, verification, and dose delivery. Both intents could be carried out by the same LINAC, except special techniques (i.e. radiosurgery).

In reality, at school, I think it's difficult to give two separate educational programs for two kinds of technologists: curative radiation therapy and palliative radiation therapy. The same basic Educational Training program on Radiation Therapy for technologists is possible and available. Technologists can get more training on Palliative or Curative from "on the job training" after graduation.

**Current situation of education and training of technologists in Vietnam**

At present, there are some models of education and training for technologists as follows:

- University education for radiological radiographer plus additional training (hospital based training, on job training) needed for technologists who are working in radiotherapy.
- Certificate required in additional training of radiation safety for some kinds of special radiation activities (such as operation of linear accelerators, Cobalt-60, gamma knife).

**Recommendation**

It is recommended to establish official Academic Education in University or Community School and qualified Education & Training Centres based on "Training Hospital" for radiation therapists. The role of Medical Physicists in Education & Training could be increased. An advanced training program could be arranged for radiation therapy trainers. Continuing Education and Training could also be applied for the current employed radiation therapists. The advantage of Telemedicine and Distance Education & Training could be taken to providing the latest service in radiotherapy by the radiation professionals.

# 4 Alternative Approaches to Imaging and Therapy

## Palliative Treatment by Unsealed Sources of Radiopharmaceuticals for Bone Metastases of Cancer

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**Abstract**

Bone metastasis is a common site of most cancers (breast cancer, prostate cancer, lung cancer). Sometimes bone metastases can be the first symptom of cancer. The application of nuclear medicine techniques such as bone scan can help to detect early metastasis and to diagnose disease stage earlier than other diagnostic imaging at 6-12 months.

Bone metastases often cause severe pain, skeletal related events and reduce the quality of life. Many opioid or non-opioid medicaments cannot give a good effect on palliative treatment and drugs can be habit-forming or cause severe complications. In those cases bone seeking radiopharmaceuticals with beta radiation nuclides such as P-32, Sr-89, Sm-53, Re-188 etc. will be an appropriate treatment to reduce pain and to improve the quality of the patient's life.

The principle of using several radiopharmaceuticals for treatment is reviewed with emphasis on therapeutic indications, clinical practice and some experiences with this method.

**Introduction**

Almost all primary malignancies can result in bone metastases. Bone metastasis is very common in patients with carcinomas of prostate, breast and lung. It is predicted that 95 – 100% myeloma cancerous patients can result in bone metastases. In case of breast, prostate cancer and thyroid cancer, some 65 - 75% and 60% of patients progress to bone metastases. The proportion and prediction of bone metastases percentage rate in a survey time duration for different cancerous patients are shown in table 1. There is often increased bone destruction (Osteolytic), increased bone formation (Osteosclerotic) or both. Pain is one of the commonest symptom, fractures and vertebral compression are not rare, and hypercalcemia occurs in 5 – 10% of patients with later stages of disease. Bone metastases result is a worse quality of life and even death.

**Table 1:** Proportion and Prediction of Bone Metastasis

| Cancer | Proportion (%) | Median of Survey (months) | Survival Proportion (%) of 5 years |
|---|---|---|---|
| Myeloma | 95 – 100 | 20 | 10 |
| Breast | 65 – 75 | 24 | 20 |
| Prostate | 65 – 75 | 40 | 25 |

| | | | |
|---|---|---|---|
| Lung | 30 – 40 | < 6 | < 5 |
| Kidney | 20 – 25 | 6 | 10 |
| Thyroid | 60 | 48 | 40 |
| Melanoma | 14 – 45 | < 6 | < 5 |

Clinically the most prominent symptom of bone metastasis is pain. The analgesic drugs may have a short term effect and may not be quite effective after a long time use. Opioids may be toxic or lead to patient addiction.

WHO (1990) define the pain relief treatment as; "Palliative medicine is active total care of the patient, whose disease is not responsive to curative treatment. The control of pain and other symptoms and care of psychological problems are paramount. The goal is achievement of best quality of life".

Local bone metastasis increased bone destruction (Osteolytic) and formation (Osteosclerotic) – macroscopically no qualitative difference, in most cases new bone formation takes place long side destruction. Radiologic / Scintigraphic appearance merely reflects the process that predominates. 50 - 60% of patients with bone tumour causes of bone pain. The other causes for bone pain are tumour infiltration, expansion of periosteal membranes (richly innervated nociceptors), simulation of endothelial nerve ending by prostaglandin, mechanical instability (resulting from osteolytic tumour, weakened bones) including bone pathological fractures, spread of tumour bone to contiguous neurological structures (spinal cord, nerve roots etc).

Overall pathological bone fractures (BF) occurs in about 8% of cases, especially in osteolytic lesions. BF can occur in breast 53%, kidney 11%, lung 8%, thyroid 5%, lymphoma 5% and prostate 3%. Hypercalcemia occurs in 5-10% of bone metastasis, commonly in breast (30%), multiple myeloma, non-small cell lung carcinoma (NSCLC).

Bone metastases can be detected by X ray, CT Scanner, MRI, Gamma camera, SPECT, SPECT/CT, PET, PET/CT. Skeletal scintigraphy is also used for its simple performance, economical examination, whole skeletal scan and early detection of micrometastases. The main radiopharmaceutical for skeletal scintigraphy is Tc-99m labelled MDP. Other radiopharmaceuticals are Gallium (Ga-67), Thallium (Tl-201) or Tc-99m-MIBI.

There are 3 phases of skeletal scintigraphy. Phase 1 known as the vascular phase, which is the early dynamic phase for arthritic and soft tissue inflammations. Phase 2 is the early static phase and Phase 3 is the later static phase, which is the standard static phase (2-3 h after injection) for the status of bone metabolism. All those hot radioactive uptakes are suspicious.

Although skeletal scintigraphy is not a specific method but it is the preferred one for evaluation of metabolic status of the skeletal system. It has high sensitivity (> 95%) and can early detect bone metastases, 3-6 months earlier than X rays). It is standardized for the diagnosis of Osteosarcoma, Ewing Sarcoma and Chondrosarcoma. It can better differentiate the lesions of infections (arthritis, osteochondritis), rheumatism and others. It is very valuable for assessment of osteochondrodystrophy, algodystrophy, bone infract and trauma.

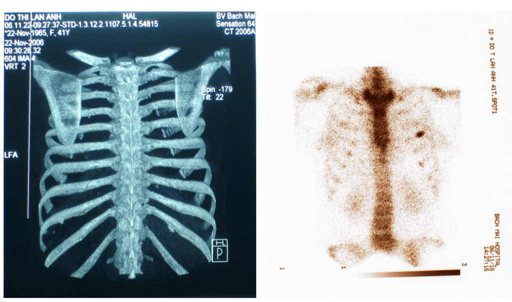
PET is used for cancer because of:

- Whole body imaging
- High resolution
- High sensitivity
- Quantitative measurement abilities with Standardized Uptake Value (SUV)
- Early detection of tumours
- Staging of cancer
- Distinction of residual active tumour from scar
- Detection of recurrence
- Assessment of therapeutic response
- Monitoring post-therapy

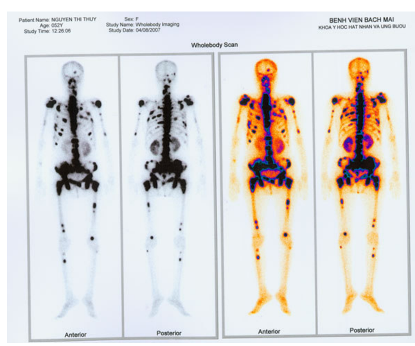
PET is useful in making decision in 89% - 96% of cancer treatments. Treatment method was changed in 45% - 60% patients based on PET scan. Doctors can predict treatment outcome and response i.e. after 1 cycle of chemotherapy, PET (+) means 90% relapse and PET (-) means 85% remission [*Kostakoglu L. et al. JNM(2002)*]. Table 2 shows the comparison of the sensitivity and specificity of skeletal scintigraphy by SPECT and $^{18}$FDG-PET in detection of Bone Metastasis.

**Table 2:** Sensitivity (Accuracy) and Specificity of Skeletal Scintigraphy by SPECT vs $^{18}$FDG- PET in detection of Bone Metastasis

| | **SPECT** | | **$^{18}$FDG - PET** | |
|---|---|---|---|---|
| | Accuracy | Specificity | Accuracy | Specificity |
| Vertebra | 84% | 29% | 87% | 82% |
| Ribs | 80% | 12% | 85% | 77% |
| Pelvis | 100% | 13% | 100% | 88% |
| Others | 91% | 60% | 89% | 50% |
| Total | 87% | 21% | 90% | 77% |



**Bone metastasis from lung cancer**
MSCT (-), Bone scintigraphy (+)



**Bone metastasis from Gastric Cancer**

The strategies of cancer treatment are primary prevention, early diagnosis, curative therapy and palliative care (pain relief). Palliative care includes chemotherapy, surgery, analgesics, external beam radiotherapy, and systemic radiotherapy. Overall anti-cancer treatment adopted for each type of primary cancer is always the first step in the management of metastatic bone pain. The key objectives are to relieve or remove pain and improve quality of life. External beam radiotherapy is highly effective in reduction of tumour size or removal of the entire gross tumour burden. It is also effective in pain relief by providing better quality of life and enhancing functional performance. Biphosphonate (BP) is used to treat bone fractures, bone compression and hypercalcemia and impacts on skeletal-related events.

The World Health Organisation (WHO) has a 3 step pain relief method for medicaments:

1. Non-opioid drugs, eg aspirin and paracetamol.
2. Non-opioid and opioid drugs eg codeine, cyclizine and amitriptyline, benzodiazepines.
3. Opioid drugs eg morphine, hydromorphine and pethidine for moderate and severe pain.

Bone seeking radionuclide therapy relies on the uptake of Ca and P during the osseous metabolism, so they and their analogues can incorporate into the DNA of rapidly proliferating cells of the bone marrow as well as in the trabecular and the cortical structures of the bone. Therefore, the beta emitter radioisotopes can be used to treat bone metastasis of cancers.

The advantages of bone seeking radionuclide therapy are its simplicity, effectiveness in ameliorating bone pain over a few months to years depending to radionuclides, especially for multifocal metastasis. However, this treatment is not readily available in many developing countries because of high cost and non-availability. The pain may be increased after given dose but the effect of pain relief can appear after 1 week. The side effects may appear in the hemopoietic system but this is not severe and can ameliorate and recover in weeks.

**Table 3:** Radiopharmaceuticals with $\beta$-energy and $\gamma$-energy used in therapy

| Radioisotope | $T_{1/2}$ (hours) | Energy $\beta$ MeV | Energy $\gamma$ keV | Compound |
|---|---|---|---|---|
| Arsenic - 76 | 26.3 | 2.97 | 559 ( 43 ) | Phosphonate |
| Holmium - 166 | 26.8 | 1.84 | 806 ( 6 ) | Chelate |
| Iodine -131 | 193 | 0.61 | 365 ( 81 ) | NaI |
| Phosphorus- 32 | 343 | 1.71 | — | Phosphates |
| Rhenium -186 | 90.6 | 1.07 | 137 ( 9 ) | Phosphonate |
| Rhenium -188 | 17.0 | 2.12 | 155 ( 10 ) | Phosphonate |
| Samarium- 153 | 46.7 | 0.8 | 103 ( 28 ) | Chelate |
| Tin -117m | 327 | — | 159 ( 86 ) | Chelate |
| Strontium - 89 | 1212 | 1.46 | — | Ionic |
| Yttrium - 90 | 64 | 2.27 | — | Citrate |

The most used unsealed sources of radiopharmaceuticals are I-131, P-32, Sr-89, Sm-153-EDTMP, Re-188-HEDP and Zn-117m-DTPA. Most applications (90%) are for I-131 for thyroid cancer; 20% of applications for bone palliation with the radioisotopes P-32 and Sm-153; 5% of applications for liver cancer with Re-188. Figure 1 shows these distributions of radioisotope applications in therapy.

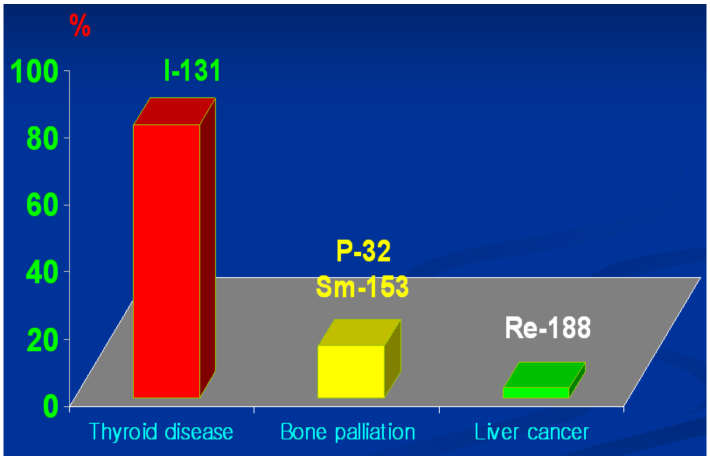



**Figure 19:** Distribution of radioisotopes in therapy

**Clinical Practice**

Entry criteria for patients with palliative treatment by unsealed sources of radiopharmaceuticals are as follows:

- Positive bones scan. Abnormalities corresponding to sites of bones pain.
- Require analgesics for control of pain.
- WBC > 3,500 cells/mL
- Platelet counts > 100,000/mL
- Absolute granulocytes >1,500
- Serum creatinine < 1.5 mg/dL.
- Patient is on stable hormone regime for not less than 3 months.
- No external RT within the past 6 weeks
- No chemotherapy within the past 6 weeks
- No treatment with inactive phosphorates during past 6 weeks
- No signs of spinal compression
- Patient can return to clinic for follow-up
- Life expectancy greater than 6 weeks
- Not pregnant or nursing, if the patient is female
- Patient is not in another clinical trial
- Informed consent is obtained.

**Therapeutic Procedure**

Radiopharmaceuticals for the treatment of pain relief for bone metastasis are:

*a. Phosphorus – 32 ($^{32}P$):*

- $^{32}P$ solution: $Na_2H_32(PO_4)$.
- $T_{1/2}$ is 14.3 days.
- Average beta energy is 0.695 MeV.
- 3 to 5 times more uptake in the metastatic lesion than in normal tissue.
- Patients should be treated with parathyroid hormone.

- Dose: 37 - 250 MBq (1 - 6.75 mCi) for 1 oral dose or 4 consecutive doses, each dose of 111 MBq (3 mCi) for each day. The total dose may reach to 444 MBq (11.89 mCi).
- The toxic effect in blood appears from 4 - 5 weeks after given dose.
- The haematological components can recover without intervention at 6 - 7 weeks post-treatment with $^{32}P$.

*b. Strontium – 89 ($^{89}Sr$), Metastron:*

- Chloride de Strontium ($^{89}SrCl_2$ solution)
- Metabolism is the same as calcium,
- Beta energy is 1.53 MeV.
- $T_{1/2}$ is 50.5 days.
- Vein Injection.
- Indication: multifocal bone metastases.
- Dose: 150 MBq (4 mCi) which may be repeated after 3 months.

*Métastron:*

- Often is associated with HEDP (Hydroxy ethylidene diphosphonate)
- Dosage: The total dose 1.2 - 1.5 MBq/kg weight (0.3 - 0.4 mCi/kg weight) can be up to 150 MBq (4.05 mCi).
- Slow intravenous injection.
- Efficacious in 80% of patients. A good response in 60% - 70% of cases.
- Complications: temporary reduction of platelets, recovery after 3 - 6 weeks. Toxic effects for disappear at 7 - 8 weeks post-therapy.
- Many scientific papers found that $^{89}Sr$ is less toxic than $^{32}P$.
- Pain may increase temporarily in 10% of the treated patients.
- The average effect time is 4 months.

*c. Rhenium – 186 ($^{186}Re$)*

- $\beta$ energy 1.07 MeV, $\gamma$ energy 137 keV.
- Scintigraphic images to detect metastasis by the gamma rays.
- $T_{1/2}$ is 89.3 hours.
- The ratio of radioactive concentrations between metastatic and normal tissue is 20:1.

*d. Rhenium – 188 ($^{188}Re$)*

- Generator $^{188}W/^{188}Re$
- $T_{1/2}$ of $^{188}W$ is 69.4 days and $T_{1/2}$ of $^{188}Re$ is 16.9 hours.
- Strong $\beta$ rays (2.1 MeV) is attached to EDTMP (ethylene diamine tetra methylene phosphonate) or DTPA (diethylene triamine penta acetic acid) for treatment.
- The average dose 1147 $\pm$ 222 MBq (31$\pm$ 6 mCi).
- Results are very good.
- Less toxic for bone marrow.

*e. Samarium – 153 ($^{153}Sm$)*

- $T_{1/2}$ is 46.8 hours.

- Beta energies are 0.64 Mev, 0.71 Mev and 0.81 MeV, range in tissue 3 - 4 mm. Gamma energy is 103 keV.
- Injection dose 37 MBq/kg weight (1 mCi / kg weight).
- Can repeat after 2 months.
- Results: reduced pain in 70% patients after 1 week and is maintained to 4 months.

IAEA conclusions with respect to P-32 & Sr-89

- Both isotopes give effective pain relief.
- No significant difference between the efficacy of P-32 and Sr-89.
- Overall 60-75% responded to radionuclide therapy.
- If a patient responded, duration of response was dependent of given dose.
- With respect to safety of treatment (in haematological parameters) P-32 was worse in comparison with Sr-89 because, proportion of patients who showed a fall in WBC and platelet counts was more in P-32 treated patients. But none of treated patients needed any medical intervention as result of fall in blood cells.
- P-32 is effective as Sr-89.

So P-32 should be accepted as an effective alternative to Sr-89 for bone pain palliation in situation when Sr-89 is not easily available and cost is a consideration. This is an important factor in the choice of radiopharmaceuticals.

*IAEA Recommendation*

- Sm-153 and P-32 vs Sr-89 showed good results although there are toxic side effects.
- Calculation of patient dose depends on the general condition of patients.
- P-32 can be applied in the developing countries.

**Radiation protection in therapy**

*Patient safety*

The patient needs to be diagnosed and the disease identified prior to treatment. An appropriate radiopharmaceutical should used and the required dose determined.

*Employee safety*

The rules of radiation protection with unsealed sources must obey completely. Radioisotopes must be handled with gloves in a glove box. Reduce radiation dose by 3 ways: distance, barrier and exposure time. Individual radiation dose monitors to be used when working and health check periodically. Pay attention to avoid the risks arising from regular small radiation doses.

*Environment safety*

Avoid accidents by correct management of radioactive waste and the patients according to regulations on radiation safety. Isolate patients for the appropriate time to ensure the patient's family is not exposed to radioactivity. Limit contact between patients and visiting persons. The patient room is covered with appropriate shielding material.

**Results in Bach Mai Hospital**

In a study of 206 treated patients treated with P-32, 87% patients show a good response and 13% no response. The highest rate of pain relief in the first 2 weeks was 67%. Most patients (85%) had a good response in the first month. The earliest effect on pain relief was in the first 24 hours after treatment. The effect of pain relief was observed on 94 % of treated patients for 1 month, 85 % for 2 months, 75% for 3 months and 46% for more than 3 months.

The average time of maintaining pain relief was 2.23 ± 1.1 weeks. Pain returned for all treated patients at 4 months post-therapy. The toxicity was slight and under control. Red blood cells and platelets were slightly decreased, returning to baseline at 6-8 weeks post-therapy. White blood cells and the bio-chemical parameters (Bilirubin, GOT, GPT, Creatinine, Urea, A. Uric, Glucosemia, lipid and protein) were stable. Clinical complications were not observed in any of the 206 patients after P-32 treatment.

**Conclusions**

Palliative treatment by unsealed sources of radiopharmaceuticals for bone metastases of cancer is a promising method because of its low cost, convenient use and suitability. It overcomes the limitations of other analgesia methods for advanced cancer patients in Vietnam.

**References:**


1. Phan Sü An: Text Book of Nuclear Medicine (Vietnamese). Nhµ xuÊt Ed. Medicine , Hµ néi – 2002.
2. Phan V¨n DuyÖt: Nuclear Medicine – Basic and Clinical (Vietnamese). Ed. Medicine Hµ néi – 2001.
3. A. M. Friedman : Radionuclides in therapy. Boca Raton, Florida, America, 1987.
4. O. Enrique et al. ( 2002): Efficacy and toxicity of Sm-153 EDTMP in the Palliative Treatment of painful Bone Metastases. WJNM vol.1, No 1.pp 21
5. B. Petelenz.1999 " International seminar on therapeatic applications of radiopharma ceuticals Hyderabad, India 18 – 22 January 1999. IAEA, SR – 209 pp 182.
6. Tuner JH (2003), a report on the 5th International Radiopharmaceutical Therapy Colloquium and The Final Planning Meeting of the Radiopharmaceutical Therapy Council held at Santiago, Chile, 29 september, 2002, WJNM, vol.2.No 1, pp. 67.
7. World Journal of Nuclear Medicine (2002), Abstract of the 8th Congress of the world Federation of Nuclear Medicine & Biology, Santiago, Chile, 29th Sept – 2nd Oct. Vol.1, Supplement 2.

# Technique of Non-Ionizing Radiation therapy – Ultrasound therapy & Laser Therapy

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The present paper introduces the techniques of Non-Ionizing Radiation therapy. Non-Ionizing Radiations are the radiations with less energy than that required to cause ionization in the irradiated material, typically including Ultraviolet radiation (UV, except the high energy end), Visible light, Infrared radiation(IR), Micro waves(MW), Radio frequency waves(RF), Extremely low frequency (ELF), Ultrasonic waves, and Static magnetic field. Since most of non-ionizing radiations are not deep tissue-penetrating rays, therefore once their medical application were limited. Owing to the recent advance of technology, by integrating modern engineering technology and medical sciences, nowadays, non-ionizing radiation therapy not only offers an important potential alternative or adjunct to radiation therapy, but also promises improved outcomes and faster recovery for tumors and other conditions. The major non-ionizing radiation therapies broadly used at the present are: Sound and ultrasound therapy/lithotripsy, Laser therapy, Thermotherapy (hyperthermia and cryogenic therapy), Electrotherapy and Photodynamic therapy. In this paper, we mainly introduce Ultrasound Therapy and Laser Therapy, including the technical features of the therapies, and their medical applications.

**The feature of HIFU Therapy**

The most attracting feature of HIFU Therapy is that it is a non-invasive or minimally invasive therapy, with capacity to generate in-depth precise tissue necrosis using an external applicator, without ionizing damage and effect on the surrounding structures. Guided by MRI or color ultrasound imaging, high intensity extracorporeal ultrasound beams can be precisely focused at the treatment area, the significant energy deposition at the beam focus thus instantly destroys the cancerous cells in the area. Nowadays, MRI or color ultrasound imaging guided high intensity focused ultrasound can not only used for precise "ablation" of diseased tissues from malignant to benign tumors such as liver cancer, uterine fibroids, bone tumors, but also used to seal blood vessels or dissolve clots obstructing blood flow in arteries, temporarily break up the blood-brain barrier, allow an influx of drugs into the brain. Meanwhile, it requires no anesthesia, almost has no infection and a low rate of complications, no limitation on lesion size, no limitation on the number of treatments, and no secondary tumors. The advantages of HIFU over the traditional radiation therapies are: it can be used for the patients who are not suitable for open surgery or not responsive to conventional treatment. The treatment is flexible in that it is able to treat both small and large tumors ( > 8cm or more). The focused ultrasound only kills cells at its focused point. It will not affect cells along the path of the ultrasound, side effects are thus reduced. HIFU has lower relapse rate as anti-cancer immunity cells is increased after treatment. This means lesser need for continuous medication to reduce relapse. HIFU can destroy the tumor in situ, the destroyed cancer cells lose their activities and change into solidified tumor vaccine, which may activate the hosts' local and systematic anti-cancer immunity in the course of degeneration and re-absorption. Therefore, HIFU help to prolong lives of patients in advanced cancer stages.

**The history and development of HIFU**

The first investigations of HIFU for non-invasive ablation were reported by Lynn et al in the early 1940s. Extensive important early work was performed in the 1950s and 1960s by William Fry and Francis Fry. Throughout the 1970's and 80's the study of high intensity ultrasound was orientated toward focused ultrasound and studies using HIFU to eradicate experimental tumors followed. In 1989, Dr. ZB Wang started the research of biological effects of ultrasound and use HIFU on treating malignant tumors since 1996. Since then, HIFU had been widely used in clinical application for the treatment of human malignant and benign tumors in China, UK, Korea, and Japan. In 2000, HIFU was approved in China. The first commercial HIFU machine was developed and launched in Europe in 2001 after receiving CE approval. MRI-guided treatments of uterine fibroids have been approved in Europe and Asia, and were granted FDA approval in the US in 2004. HIFU treatment of prostate cancer is currently an approved therapy in Europe, Canada, South Korea, Australia, and elsewhere. Clinical trials in the United States began in 2006.

**The principle of HIFU therapy**

In HIFU therapy, multiple intersecting beams of ultrasound are used and the concentration of the beams is focused by a magnifier on a target tissue. The focus is as small as one millimeter in diameter therefore it can be achieved deep in tissues. There are several effects generated by the focus sound wave in tissue. The first one is heat effect, the heat generated by the sound wave is:

$$Q = 2\alpha_a It$$

Where $I$ is the intensity of the wave, $\alpha_a$ is the absorption coefficient, $t$ is the exposure time. So when $Q$ increases, the temperature of the tissue is raised, thus the tissue is thermally coagulated.

The second effect is Cavitation, it occurs at high enough acoustic intensities. Inside the bubbles it generates, very high temperatures occur, and their collapse is associated with shock wave, which, can mechanically damage tissue. In HIFU therapy, mainly the heat effect is used, when the temperature within the tissue rises to 65°C to 85 °C, it would destroy the diseased tissue by coagulation necrosis. By focusing at more than one place or by scanning the focus, a volume can be thermally ablated.

Usually, in HIFU therapy, 0.8MHz—2.4MHz ultrasound is used, the focus length of the beams of ultrasound is □140mm, the focal region is □1.1mm×3.3mm—1.4mm×5.6 mm. Their intensities are from 5000W/cm$^2$ -25000W/cm$^2$. The Exposure time at each point is 1-2 s, correspondingly, the instant tissue temperature is ≥ 70□. Due to the significant energy deposition and temperature rising at the focus of the beam, the cancerous cells in the target area can be destroyed instantly. The HIFU technology can achieve precise "ablation" of the diseased tissue. Since the treatment destroys the diseased tissue non-invasively, it is known as "Non-invasive HIFU surgery". Unlike conventional methods, healthy tissue is not affected by HIFU treatment.

**Methods and applications of HIFU therapy**

Conventionally, HIFU therapy was guided by diagnostic ultrasound. However, due to its acoustic properties, a diagnostic ultrasound beam is difficult to direct through some specific organs such as bone and only echo changes of treated region is used as the scale to guide and evaluate treatment effects. Therefore, Magnetic resonance imaging, which imaging quality was good enough to visualize tiny lesions, has been widely used in HIFU clinical applications. The temperature mapping of the treatment region can be also used to guide the treatment process. Therefore, magnetic resonance can guide focused ultrasound treatment in treating tumors located at organs such bones and brain.

Guided by MRI/Real-time diagnostic ultrasound, HIFU can perform point—line scanning, 2D scanning and 3D scanning, thus precisely ablate/destroy the whole tumors and other tissues while leaving the normal surrounding structures unaltered.. Current clinical applications have reported encouraging results in the treatment of malignancies. The most significant clinical experience with therapeutic ultrasound has been in treating benign prostate prostatic hyperplasia and in the treatment of uterine fibroids. HIFU has been proved to be a therapy which treats the tumor without having significant effect on normal tissues. Its indications include: Breast cancer, Malignant bone tumor, Liver cancer, Sarcoma of soft tissue, Kidney cancer, Carcinoma of bladder, Tumor in pelvic cavity, Retroperitoneal tumor, Pancreatic cancer, Tumor metastasis, Palliative treatment for advanced malignancy, Recurrence of solid tumor after conventional surgery, Residual tumor after failed surgery, which is not suitable for a repeat surgical procedure, Superficial tumors, Uterine fibroid, Benign breast neoplasm, Benign tumors of solid tissues.

It was demonstrated that HIFU beams can be also used to seal/ block blood vessels, or used to rapidly dissolve clots obstructing blood flow in arteries, including those associated with stroke and related diseases, minimizing or even eliminating their destructive effects on normal tissue. It can be used to alter the blood-brain barrier to increase the permeability from the bloodstream into the brain of a variety of therapeutic agents. Furthermore, it can be used to deliver drugs such as chemotherapy agents, genes, antibiotics, or growth factors in high concentrations specifically to the needed tissue site, thus avoiding the systemic toxicity associated with other delivery methods.

There are few contraindications like the tumors in air-containing viscera, such as lung, stomach, and bowel, mediastinal tumors, and spinal tumors. The limitation of HIFU: it is not suitable for the lesion behind bone or in air-containing viscera; about 20% - 25% of patients would suffer from mild fever or skin burn for less a week after treatment

**Features of modern HIFU systems**

For a modern HIFU system, it is equipped with 3-D conformal technique to ensure complete targeting and ablation of solid tumor deposits. It is also with real-time diagnostic ultrasound to provide high-quality images for the location and targeting of the selected tumor. Multi-dimensional motion transducer is readied to enable a great variety of anatomical sites to be treated. A degassed water system is used to provide an acoustic coupling medium. The ultrasound therapeutic frequency is adjustable to ensure the treatment effectiveness for various tumors.

In summary, patients can be clinically benefited by HIFU as it is a non-invasive outpatient procedure, no hospitalization needed, and next day return to normal activity. It is limited conscious sedation, no ionizing radiation, low rate of complications, and high precision and superior tissue differentiation.

**Advance of laser therapy**

Laser therapy, includes laser induced thermotherapy, photodynamic therapy, low level laser therapy and laser surgery. The reason to use laser therapy is that lasers are more precise than standard surgical tools (scalpels), so they do less damage to normal tissues. Patients usually have less pain, bleeding, swelling, and scarring in laser therapy. Operations are usually shorter, can often be done on an outpatient basis. It also takes less time for patients to heal after laser surgery, and they are less likely to get infections.

Its current development emphasizes using minimal or non-invasive techniques such as optical fiber, endoscopy and wave guide to lead the laser beam to the in-depth diseased tissues to perform intracorporal and interstitial treatments without or with little effect on the surrounding tissues. Such as the techniques of Laser-induced interstitial thermotherapy (LITT), in the technique, an optical fiber is inserted into a tumor by the aid of probes or needles percutaneously, guided by ultrasound imaging. Laser light at the tip of the fiber raises the temperature of the tumor cells and damages or destroys them. The advantage of laser-induced interstitial hyperthermia over traditionally used heat sources such as ultrasound, microwave, or radiowave radiation lies in: better ability to focus heat localization to the specific tumor tissue site; simple, safe, and minimizes the potential for thermal injury to the adjacent tissue; can preserve the organ (breast, prostatic urethra, etc); no effect on overlying normal tissue; no cumulative toxicity, and no surgical wound to heal so recovery is rapid.

Another modern technique of Laser therapy is called interstitial photodynamic therapy (IPDT). The technique involves light delivery through thin optical fibers inserted into the tumor mass could eliminate the limitations of PDT and allow treatment of solid, thicker and deeper-lying tumors. In the treatment, photosensitizer or photosensitizing agent is injected into a patient and absorbed by cells all over the patient's body. After a couple of days, the agent is found mostly in cancer cells. Needles are then positioned in the tumor under the guidance of CT/MRI. Fibers from a laser inserted through the needles, laser light is therefore used to activate the agent and destroy cancer cells. Since IPDT uses low power laser so there is no increase in tissue temperature. By the therapy, connective tissues (collagen, elastin) are largely unaffected, much less risk to the mechanical integrity of hollow organs. The healing takes place with more regeneration and less scarring.

# Potential of electrical techniques in imaging and therapy for palliative care of cancer patients

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## Introduction

Palliative care of cancer patients involves monitoring (including some diagnosis too), therapy and rehabilitation, and electrical techniques have possible application in all these areas in future. The attraction for electrical techniques is that unlike conventional ionizing radiation based techniques, these are potentially of much lower cost, and even may be designed, fabricated and maintained in the Third World. Besides, these are free from the radiation hazards which are associated with all ionizing radiation techniques. Since this is a relatively new area, this paper will describe and explain some electrical techniques from the very basics and discuss their possible application in palliative care, as well as in the diagnosis and therapy of cancer, as charted below.

1. Diagnosis and monitoring:
    a. Tissue impedance basics and relevance to cancer
    b. Tetra Polar Impedance Measurement (TPIM)
    c. Electrical Impedance Tomography (EIT)
    d. Focused Impedance Measurement (FIM) – 6 electrode FIM
    e. 4-electrode FIM
    f. Application of Impedance systems in cancer detection
    g. Application of FIM in monitoring of cancer therapy
2. Therapy: Electroporation
3. Rehabilitation: TENS for pain reduction

## 1. Diagnosis and monitoring

### *a. Tissue impedance basics and relevance to cancer*

Electrical impedance is a term used to represent resistance offered by an object to electrical currents which has both frequency dependent and frequency independent elements. When the measurements are made using ac signals of different frequencies these properties show up which may be utilized judiciously to identify the properties of particular tissues. Measurement of electrical impedance provides a means for characterisation of tissue properties which may be utilized in diagnosis and monitoring. The impedance (Z) is given by Ohm's law, $I = V/Z$ where I is the electrical current passing through the object of interest and V is the potential dropped across it. From the above we can get the impedance as, $Z = V/I$.

Certain cancer cells have frequency dependent impedance variations which are significantly different from that of normal cells, hence electrical impedance measurement at different frequencies provide a means of diagnosis and of monitoring of such cancerous organs, which may be useful in palliative care as well.

Body is, simplistically stated, a fluid having mobile ions – both positive and negative. Whenever a voltage is applied between two points the ions start to move due to the electric field (force on a unit positive charge) created by the voltage. The positive ions flow towards the negative electrode and vice versa. Thus for body tissues current is mainly due to ions, which are essentially charged atoms or molecules. This is different from the current in a metallic conductor such as copper where the current is entirely due to the flow of negative electrons of the outermost orbits of the atoms, the atoms themselves remaining fixed in positions in the solid.

The above description talks about a direct current (dc). However, there are some basic problems associated with measurements using such a simple direct current (dc) which arise at the contact interface between the metallic electrodes and the fluid body, in the form of contact potentials and of building up of charge layers which tend to mask the internal parameters that one intends to measure. Besides, a dc will contribute to a redistribution of charges inside the body which might interfere with natural body functions. Therefore usually alternating currents (ac) are employed for electrophysiological measurements. This opens up newer avenues since body cell membranes are basically thin sheets of insulators sandwitched between conducting fluids inside and out, forming individual capacitors. With ac, a capacitor allows current to pass through it through charging and discharging, although with some opposition which varies with frequency. Such resistance to current offered by a capacitor is called 'Reactance' and decreases with increasing frequency. On the other hand the 'Resistance' of the body fluid (and that inside the cells too) does not change significantly with frequency of the ac. A biological body may be considered as a sea of ionized conducting fluid having a simple resistance and a host of cells distributed in 3D inside it contributing to an overall capacitance. A popular simple electrical equivalent circuit of a biological body is shown in Fig.1. The equivalent circuit parameters may be approximately related to physical parameters as follows. The resistance of the extra-cellular fluid is given by R; C is the overall capacitance of the cellular membranes, and S is the intracellular resistance. The equivalent circuit has both resistive and reactive components, i.e., having frequency independent and frequency dependent terms, and the combination is said to have 'impedance' as mentioned before.

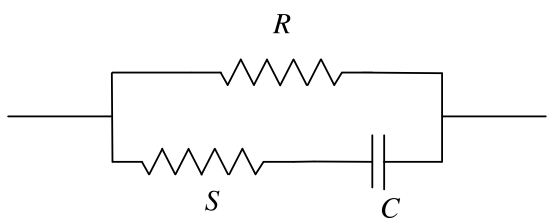


Figure 1: A simplified 'Cole-Cole' model of biological tissue

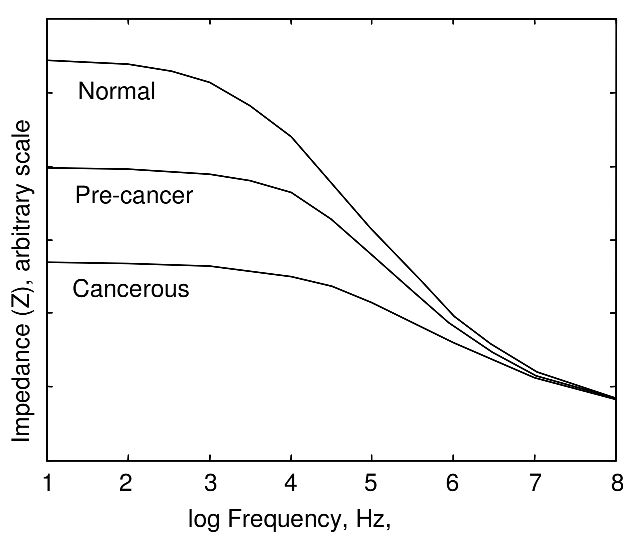


Figure 2: Variation of electrical impedance of epithelial cells in the female cervix with frequency, for normal and cancerous situations (Brown et al[1] )

Again the cell membrane thickness and its electrical properties, the size of the cell, the size of the nucleus inside, the packing density of the cells, all of these will contribute to the measured impedance and its variation with frequency. Such information has been used to characterise tissue from the gastric and oesophageal mucosa and from the cervix with the aim of differentiating between cancerous and non-cancerous tissues. Figure 2 shows the results of such a modelling of epithelial cells of the cervix by Prof B H Brown's group of Sheffield, UK[1]. It shows the frequency dependence of electrical impedance of i) normal squamous cells in Cervix, ii) cells in the pre-cancerous phase of Cervical Intra-epithelial Neoplasia (CIN), and iii) cancerous columnar cells. They have also been able to demonstrate such difference experimentally using a Tetra Polar Impedance Measurement (TPIM – described below) probe operated at different frequencies of ac. Cancer of the cervix is the second most common cancer affecting women in the world and the most common cause of cancer related death. However, death may be prevented if the disorder is diagnosed early through screening tests, in the precancerous phase (CIN). Although this prevention scheme is well established in the economically developed countries, it is not so in the Third World. Therefore impedance measurements have the potential to diagnose such cancerous cells and an electrical impedance based screening test would be cheap and quick (result obtained almost instantaneously).

In the above case the cancer ridden cells were somewhat exposed and could be measured using contact electrodes at the tip of a probe. However, it may be possible to identify cancerous tissue underneath the skin surface, at a certain depth, through various focused impedance techniques or Electrical Impedance Tomographic techniques, under development at present.

For cancerous cells the electrical properties may vary significantly from that of normal healthy cells. However, one needs to identify which electrical parameter is particularly involved in a particular type of cancer, and how to measure this variation from outside without being cluttered by neighbouring body organs and their movement in functional studies. Besides theoretical or numerical modeling, one may also need in-vitro measurements of particular cancerous cells in order to have a preliminary assessment of the characteristics, although it should be appreciated that the characteristics may be different within a live body having the presence of moving fluids.

***b. Tetra Polar Impedance Measurement (TPIM)***

From the expression of the Ohm's law mentioned above, a basic impedance measurement would involve passing a known electrical current through the object via two electrodes and measuring the voltage developed across the electrodes as shown in figure 3. However, this method has a problem for biological measurements. The electrode-skin interface has a large impedance compared to that inside the body, and it appears in series with the target impedance of the inner bulk (they are algebraically added) in this measurement. Therefore the small target impedance is mostly masked by the large skin-electrode impedance.

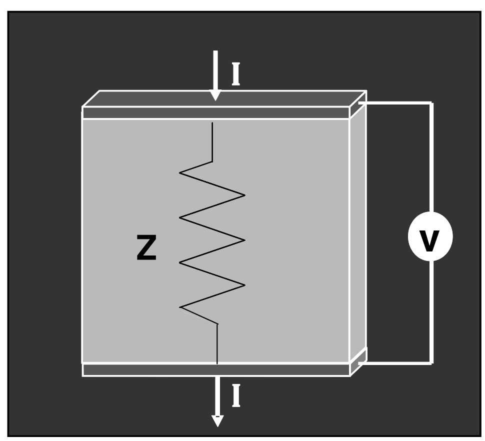


Fig 3: Basic 2-electrode impedance measurement, Z=V/I

This problem has been eliminated by the Tetrapolar Impedance measurement technique as shown in figure 4 which uses four electrodes. Current is passed through the two outer electrodes while potential (voltage) is measured across the inner two. A voltmeter used to measure potential has very high input impedance and takes a very negligible current (almost zero). Thus the voltage across the electrode-skin impedance of the voltmeter circuit is almost zero [Voltage = current x resistance(R) ≅ 0 x R ≅ 0] and the measured voltage truly represents the voltage across the inner bulk of the biological material. The current passing through the outer electrodes contributes to voltage drops across the respective electrode-skin impedances, however, these do not come in the voltage measuring circuit, and are thus eliminated.

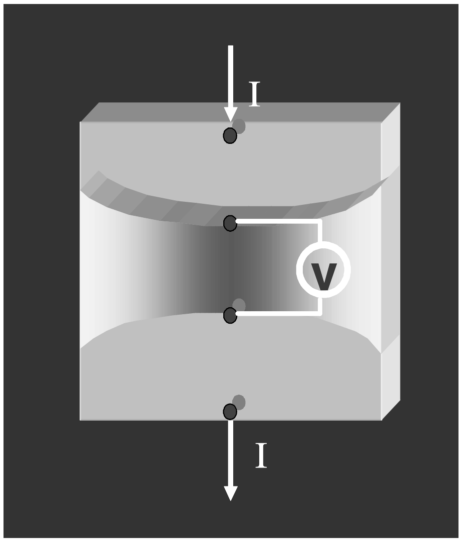

Fig.4: Wide sensitive zone in traditional TPIM

However, the application of TPIM in the human body, which is a volume conductor, is rather limited. In most applications we are interested in a single target organ like a mass of cancerous cells, but the sensitive zone of a TPIM system is rather wide as shown by the horizontal shaded zone in the middle of figure 4, in between the two equipotential lines passing through the potential measuring electrodes (An equipotential line has the same potential at all points).

***c. Electrical Impedance Tomography (EIT)***

The above limitation of TPIM was removed by a significant development in the eighties through the development of EIT[2, 3]. The basic principle is explained with the help of a typical 16 electrode EIT in figure 5. The electrodes (represented by black dots) are shown fixed around a 2 dimensional circular area, which could be across a transverse plane of the thorax in a typical application. In this technique first a current is passed through two adjacent electrodes while the potential is measured across the rest 13 adjacent pairs. This scheme is then repeated in steps by passing current through all the 16 pairs of adjacent electrodes and measuring potential across the remaining pairs in each step. All these data are then analysed using a computer and a 2 dimensional image is produced, similar to that in a CT scan. However, the images are of low resolution, and objects outside the electrode plane affect the image rendering it less accurate. Therefore EIT has not been very useful clinically so far, particularly in getting information at pixel level resolution. For most application using EIT so far, a rather large region of interest is marked out and the temporal variation of the sum of all the pixels within this region is studied. Currently 3D EIT is under development and one has to wait till this development is successful. An alternative technique of using state of the art 2D EIT has been suggested by the author's group[4] in which an isolated object like that of a cancerous zone may be localized in 3D using EIT measurement in two planes. This may be useful in monitoring of cancerous regions in palliative care, during the application of therapy.

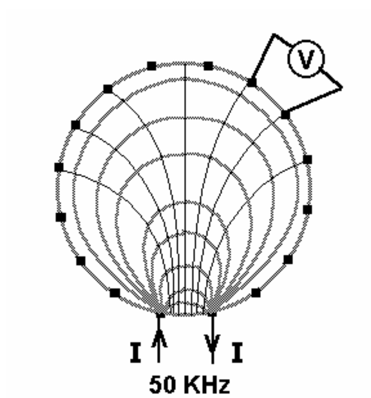

Fig 5: Basics of 16 electrode EIT

EIT is a sophisticated technique employing many electrodes and needs a computer to analyse and display the images. However, it has been shown by the author's group that it is possible to monitor the changes in a localized zone using a much simpler technique which they have developed and named as "Focused Impedance Method".

Again two methods have been developed – one with 6 electrodes, and the other using 4 electrodes as described below[5, 6, 7].

***d) 6-Electrode FIM***

The basic concept may be explained with the help of Fig.6 described for a 2D conductor. Black dots indicate electrodes. Following conventional TPIM method, a constant current (ac) is first driven through electrode pair A&B while potential is measured across electrode pair u & v. The impedance of the bulk region is proportional to the above potential since current is constant. This essentially gives the impedance of the region bounded by the equipotential lines aa′ and bb′, the sensitivity decreasing away from the centre. Then the same measurement is performed at $90^0$ by driving current through the pair C&D, and measuring the potential across the same electrode pair u & v. In this case the sensitive zone is bounded by the equipotential lines cc′ and dd′, at a right angle to the previous sensitive zone. If now these two impedance values are summed, the almost square region at the centre formed by uv as the diagonal will have a dominant contribution compared to the neighbouring zones and an impedance focusing effect will be obtained. The focusing effect was experimentally verified with success through sensitivity mapping in a 2D phantom. Although it is described in 2D, using such electrodes on the body surface one can also probe the 3rd dimension since current flows in 3D. Using innovative electronic techniques it has been possible to get the FIM output directly in a meter though a single measurement without the use of computer or of sophisticated circuitry. Further work is being carried out to make a small portable system integrating all the electrodes. One advantage of this system is that the size of the focused zone may be increased or decreased by changing the separation of the diagonal potential measuring electrodes while the depth sensitivity in the 3rd dimension may be changed by changing the separation of the external current driving electrodes.

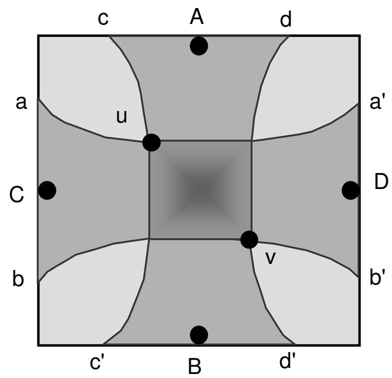

Fig.6: Basic concept of 6-electrode FIM

***e) 4-Electrode FIM***

With respect to figure 7, the 4-electrodes are represented by the dots marked 1, 2, 3 & 4. First current is passed through electrodes 1 & 2 when potential is measured across electrodes 3 and 4. The sensitive zone is the horizontal shaded region $E_1F_1H_1G_1$, between the equipotential lines passing through electrodes 3 and 4. Next current is passed through electrodes 2 and 3 and potential is measured across electrodes 1 and 4 when the vertical shaded region becomes the sensitive zone. When the two measurements are combined the dark shaded region at the centre dominates resulting in a focused zone at the centre. The 4-electrode system requires less electrodes and can be applied on the thorax both in the transverse plane and in the frontal plane. However, the size of the focused zone and the 3D depth sensitivity

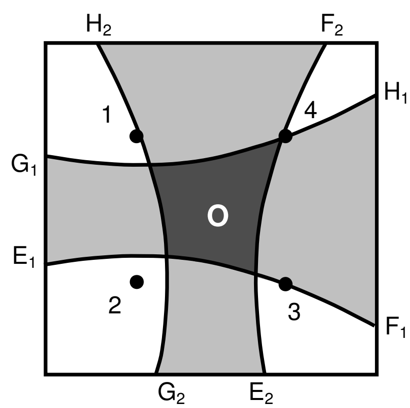

Fig.7: Four electrode FIM basics

cannot be adjusted independently as possible using the 6-electrode system.

The FIM systems appear to offer immediate clinical applications. Being simpler than EIT, multifrequency systems may be implemented without much difficulty at low cost and may become useful tools in the monitoring of cancerous zones, whether for diagnosis or for monitoring during therapy.

***f) Application of Impedance systems in cancer detection***

As mentioned before, Professor Brown's group has already succeeded in obtaining diagnosis of cervical cancer using a simple tetrapolar impedance probe as shown in figure 8. The differentiation of normal and cancerous tissue as described in a previous section has been observed experimentally using this probe and a commercial prototype as shown in figure 9 has been developed for clinical trial. As against previous techniques like pap smear which needs further processing to give a result, this impedance system gives instantaneous outputs. Of course the probe has to be moved and placed at several locations on the cervix to ensure that the location of the cancer is not missed.

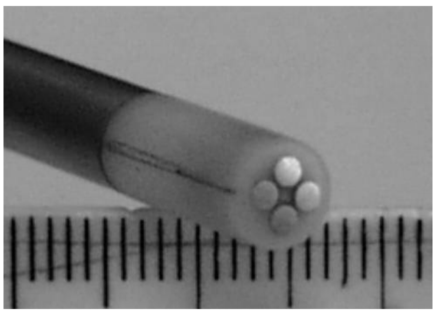

Fig.8: Prof Brown's probe for cervical cancer detection


Fig.9: Prototype of tetrapolar probe for the detection of cervical cancer (by Zilico) in collaboration with Prof Browns's group.

The Focused Impedance system described above may also be applied for cervical cancer detection with improved localization. With a little modification the same systems could be used to diagnose oral cancer, though not much work in this direction has been initiated yet. There is a possibility of using such techniques in the diagnosis of skin, colorectal oral and duodenal cancers where the affected regions may be accessed from outside directly or through endoscopy.

***g) Application of FIM in monitoring of cancer therapy***

During therapy of a cancerous tissue, FIM or 'EIT at two planes' may be used to monitor the temperature raised since tissue impedance changes with temperature. Again the quality of healing may also be monitored using the above systems since the tissue properties change during the healing process. An effort into this direction has been taken up at the University of Warwick, UK.

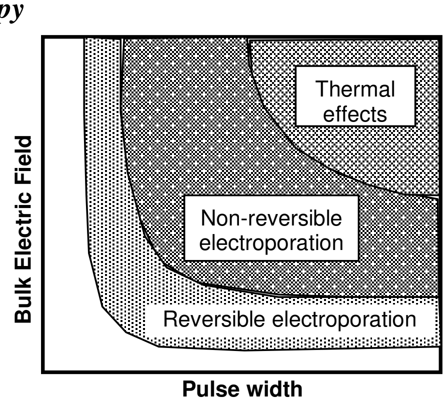


Fig.10: Concept of non-reversible electroporation

**2. Therapy using non-reversible electroporation**

There is a potential for therapy using an electrical technique known as electroporation, which has been tried out on animal models successfully by

Professor Rubinsky's group in the USA[8]. Pulsed bursts of high currents are focused onto the tumour region using multiple needle electrodes inserted to reach the neighbourhood of the target area. This work is based on the well known electroporation technique used in Genetic Engineering. On the application of bursts of electrical pulses with certain amplitudes and width, cell pores open when DNA or other chemicals are introduced into the cells. On withdrawal of the electrical stimulation the cell pores close and the desired changes in the cells are achieved. However, Prof Rubinsky's group has found out that by increasing the pulse width and the electric field it is possible to reach a stage where the cell pores do not close on withdrawal of the electrical stimulation, and the cells then are destroyed. Within this non-reversible electroporation zone, thermal effects do not come into play and the target area can be defined very well using multiple electrodes. A schematic of the reversible and non-reversible electroporation zones is shown in figure 10. Once everything including the semi-invasive electrodes is set up for this treatment, the actual therapy takes only seconds when all the cells within the target zone are destroyed. Another advantage of this technique is that collagen fibres and nerve cells are not damaged and this allows new healthy tissues to grow later. Professor Rubinsky has already demonstrated the success of this method through animal models, and recently by treating 17 patients with cancer of the prostate gland[9]. The technique does not need the use of sensitizing medicines and is free from ionizing radiation hazards. However, one needs to ascertain that damage to healthy tissues is a minimum, and the instrument is safe to both patient and the user against electrical hazards. Similar therapeutic applications may be thought of for cervical, skin, colorectal oral and duodenal cancers.

The destruction of cancer cells through the above technique may be monitored using FIM techniques where the same electrodes used for the therapy may be employed. EIT or FIM using surface electrodes may also be used for such monitoring.

### 3. Pain reduction

Transcutaneous nerve Stimulation (TENS) is an age old technique in the alleviation of pain. Although the mechanism is not well understood it is assumed that pain signals through the nervous system are blocked because of the presence of the electrical stimulation of other nerves in the neighbourhood[10, 11], also known as 'gate control theory'. However, TENS does not work in every situation and it may be researched whether it can be of any use in the reduction of pain in cancer patients. Apart from the above, biofeedback may also be tried in the alleviation of pain due to cancer.

## Discussion

From the overview presented above, electrical techniques appear to have a great potential in both diagnosis and therapy of cancer, and there should be application possibilities in palliative care too. Electrical techniques do not pose radiation hazards though some techniques have the usual electrical hazard as posed by domestic electrical equipment as well. Besides, electrical equipments are potentially cheap and offer their widespread use, even in the poor countries of the world.

### References

1. B H Brown, J A Tidy, K Boston et al, The relationship between tissue structure and imposed electrical current flow in cervical neoplasia, *The Lancet,* 355(892-895)2000.
2. Barber D C and Brown B H Applied Potential Tomography. *J Phys E Sci Instrum* 17(723-733)1984.

3. Brown BH, Barber DC and Seagar AD Applied potential tomography: possible clinical applications *Clin. Phys. Physiol. Meas.* 6(109-21)1985
4. Rabbani K S, Hassan M, Kiber A, 3D object localisation using EIT measurement at two levels, *Physiological Measurement,* 17(189-199)1996.
5. Rabbani K S, Sarker M, Akond M H R and Akter T, Focused Impedance measurement (FIM) - a new technique with improved zone localisation, *Proceedings of X International conference on Electrical Bioimpedance, Barcelona, Spain,* (p.31-34)1998
6. Rabbani K S, Sarker M, Akond M H R and Akter T, Focused Impedance measurement (FIM) - A new technique with improved zone localisation, in *"Electrical Bioimpedance methods", Annals of the New York Academy of Sciences,* 873(408-420)1999.
7. K S Rabbani and M A S Karal, A new four-electrode Focused Impedance Measurement (FIM) system for physiological study, *Annals of Biomedical Engg,* 36(1072-1077)2008.
8. P Rubinsky, G Onik, and P Mikus, Irreversible Electroporation: a new ablation modality – clinical implications, *Technol Cancer Res Treat*, 6(37-48)2007.
9. P Rubinsky, *Personal communication* (2008).
10. P D Wall and R Melzack, On nature of cutaneous sensory mechanisms, *Brain*, 85 (331)1962
11. R Melzack and P D Wall, Pain mechanisms: A new theory, *Science*, 150(171-179)1965.

# Telemedicine with Wireless Enabled Distributed Network Cloud Computing

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## Abstract

The majority of world's population has no access to high-quality medical care. This can be related to high costs of medical equipment and lack of qualified personnel to operate and maintain such equipment even if it is present. We introduce the concept of distributed network cloud computing technology in which the cost and complexity of medical devices are substantially reduced by placing in the vicinity of the patient only the minimally required raw data acquisition components, transferring *the raw data* through telecommunication to a central (cloud) processing facility for processing and sending for the patient use the processed data through telecommunication. Using cellular phone as the wireless communication link between the patient's site and the remote processing station further reduces the complexity and thus the costs of technology (both hardware and software) on the patient site, which makes medical equipment more available to economically disadvantaged communities. This work provides an overview of using distributed network cloud computing cellular technology in telemedicine, and presents imaging as a possible example of medical technology made available to the developing countries due to the availability of cellular connection. Specifically, two medical imaging modalities: (EIT) Electric Impedance Tomography and 3D US (Three dimensional Ultrasound) are employed to illustrate the benefits of using wireless cellular connection to link the raw data acquisition (patient) site with the central cloud computation processing station. In addition we show other uses of the concept with a cellular phone based classifier for tissue biopsy diagnostics.

## Introduction

World Health Organization studies find that a majority of the world's population has no access to advanced technology based medical care [1]. This can be attributed to multiple factors including the prohibitive initial cost of medical equipment. Another limiting factor is the lack of high quality technological expertise required to maintain and operate the equipment [1, 2].

One of the most important technological advances of modern medicine is medical imaging, e.g. X-Ray, US (Ultrasound), CT (Computer Tomography) or MRI (Magnetic Resonance Imaging). In the current reality, most developing countries and economically disadvantaged parts of the world experience a severe lack of adequate imaging services *(i.e. basic X-ray and ultrasound)*. The scarcity of resources also results in missing or inappropriate equipment, lack of available parts and poor maintenance of existing equipment and lack of qualified technical maintenance personnel. In many areas of the world, imaging facilities are simply not available, or not functioning. Yet, even when medical imaging facilities are available and functioning, the devices are often of poor quality and therefore the images produced cannot be used or are misread. In parts of the world lacking medical imaging there is also a lack of adequately trained medical specialists, including radiographers and technologists.

Medical imaging is required for the adequate treatment of 20% to 30 % of the diseases. The lack of medical imaging is obviously detrimental to the delivery of health care in economically disadvantaged parts of the world. Because of that the goal of the WHO in the context of diagnostic imaging is to: a) make safe and reliable diagnostic imaging services available to as many people as possible; b)advise, guide and support those working in the field developing and maintaining diagnostic imaging services and c) promote the importance of safe and appropriate diagnostic imaging services, [3,4,5]. .

Traditional advanced medical technology, including telemedicine, cannot exist in the absence of a well maintained technological infrastructure, in particular electricity and telecommunication. However, as of 2000, 14% of the urban households and 49% of the rural households had no electricity available. The population growth adjusted calculations show that since 2000 the drop in non-electrified population is only 0.4% per year. It is predicted that in 2030 about 600 to 700 million people will be without access to electricity in each, South Asia and Sub Saharan Africa. Since traditional telecommunication requires land based infrastructure, it is no wonder that cellular phones have become the main means of telecommunication in developing parts of the world. In Africa, the number of cell phone subscribers has increased from 7.5 million in 1999 to 76.8 million in 2004 [6]. One in 11 Africans is now a mobile subscriber.

While the number of medical care cases requiring massive palliative treatment is decreasing in parts of the world with a medical care infrastructure, they do occur in the rest of the world. Medical imaging for diagnostic could facilitate earlier diagnostic, similar to the use in economically advanced parts of the world. Furthermore, minimally invasive surgery such as cryosurgery or irreversible electroporation is ideally suited for palliative treatment. Irreversible electroporation, in particular, can operate from car batteries and cryosurgery requires liquid nitrogen or argon gas containers. However, minimally invasive surgery requires medical imaging for optimal use. Between two thirds and three quarters of the world population does not have access to medical imaging. This is the population that does not have access to electricity but may have access to cellular phone technology.

For over a decade, our group is focused on providing solutions for medical technology problems in the economically disadvantaged regions of the world. We have noticed that most of today's medical devices are stand-alone units with three major components: a) data acquisition device, b) data processing system, c) results display module. In most medical devices, these three components are physically located in the same location, thus adding to the complexity and redundancy of the overall system. Recent technology is even more complex in both its hardware and software components thus making the task of maintaining this technology even more challenging, especially in the developing countries where trained personnel is scarce. In the recent years, advances in computer science, telecommunication and the Internet made information technologies available to the most remote places of the world such as rural Africa. Cellular infrastructure finding its way into the most isolated corners of the planet has inspired us to come up with a novel concept which leverages the cellular connection to provide a higher-quality medical care for the disadvantaged populations of the world. In order to make medical imaging available to as wider population as possible, we see the ultimate goal of cellular phone powered telemedicine as a minimization of technological requirements in the vicinity of the patient.

The central paradigm we advocate is the separation between the three-abovementioned components of the medical system, namely the data acquisition device, the processing server, and the display module that is a part of the mobile console. We refer to this system architecture paradigm as the Distributed Network Cloud Computing (DNCC) system and in the context of medical imaging; Distributed Network Cloud Computing Imaging (DNCCI). The paradigm is presented schematically in (Fig. 1).

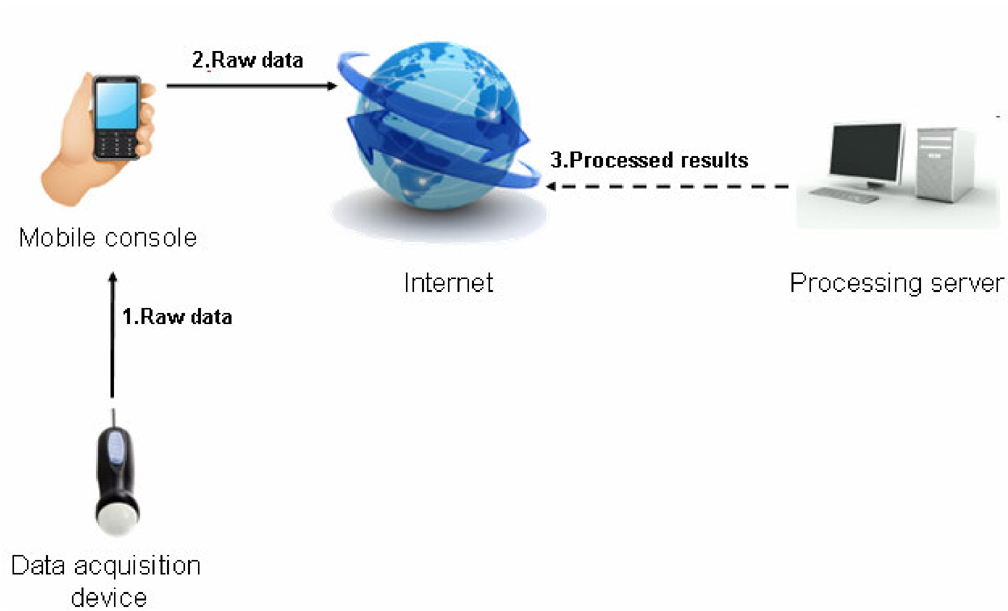



**Figure 1:** DNCCI Architecture

We envision the data acquisition device on the patient side to be as low-cost, and as simple to maintain as possible. The cellular phone will be used as a communication link in a geographically distributed system in which the main data processing server is located in a central (cloud computing) facility. This central facility is capable of serving a virtually unlimited number of cellular phone users. According to the Distributed Network Cloud Computing paradigm, the communication link, such as a cellular connection, is used to transmit the raw, physical data to the processing station. Cellular phones have inherent means to preserve the quality of the data they transmit. Therefore, when the raw data arrives at the central processing facility, the most advanced processing methods and algorithms can be applied to it. *We emphasize this* *point to make a distinction between the proposed DNCC/DNCCI paradigm and conventional telemedicine where the data is being sent after it had been already processed.*

In this work we present several medical technology applications adapting the DNCC paradigm in which the processing of the raw data is performed in a central location that serves a large number of distributed users. Medical imaging systems for monitoring minimally invasive surgery as well as two medical diagnostic imaging modalities are presented. The modalities discussed include EIT (Electrical Impedance Tomography) and US (Ultrasound). In addition this paper also reviews a recent study in which a system used to detect internal bleeding had been developed and successfully tested. The patient with the data acquisition device attached was located in Mexico and a remote data processing server was located in Israel. The raw data from the data acquisition device to the processing server was transferred over the cellular telecommunication infrastructure.

## Applications of distributed network cloud computation (DNCC) systems.

### Electrical Impedance Tomography (EIT) example.

Minimally invasive surgery has become highly dependent on imaging. For instance, the effectiveness of cryosurgery in treating cancer depends on placing the minimally invasive probes under imaging monitoring in the tumour and knowing the freezing extent, and relies on real-time imaging techniques for monitoring. However, medical imaging is often very expensive and therefore not available to most of the world's population. The concept of distributed network computer cloud imaging (DNCCI) can make medical imaging and minimally invasive surgery available to all who need these advanced medical modalities. It was demonstrated through the concept of electrical impedance tomography (EIT) during cryosurgery [7]. The central idea is to develop an inexpensive data acquisition device (DAD) at a remote site and then to connect the DAD apparatus to an advanced image reconstruction server, which can serve a large number of distributed DADs at remote sites, using existing communication conduits (Ethernet, telephone, satellite, cellular, etc.). These conduits transfer the raw data from the data acquisition console to the server and the reconstructed image(s) from the server to the console. EIT is an imaging modality which utilizes tissue impedance variation to construct an image. The EIT acquisition device that consists of electrodes, a power supply, and means to measure voltage was designed to be inexpensive, and therefore suitable for DNCCI. EIT is also very well-suited for imaging cryosurgery since frozen tissue impedance is much higher than that of unfrozen tissue. In this case, we first developed numerical models to illustrate the theoretical ability of EIT to image cryosurgery. We began with a simplified two dimensional model, and then extended the study to the more appropriate three dimensional models. Our simulated finite element phantoms and pixel-based Newton-Raphson reconstruction algorithms were able to produce easily identifiable images of frozen regions within tissue. Then, we have demonstrated the feasibility of the DNCCI concept in a case study using EIT to image an *in vitro* liver cryosurgery procedure through a modem (Fig. 2). It was found that the acquired raw data packets are less than 5 Kbytes per image and the resulting images, using compression, do not exceed 50 Kbytes per image.

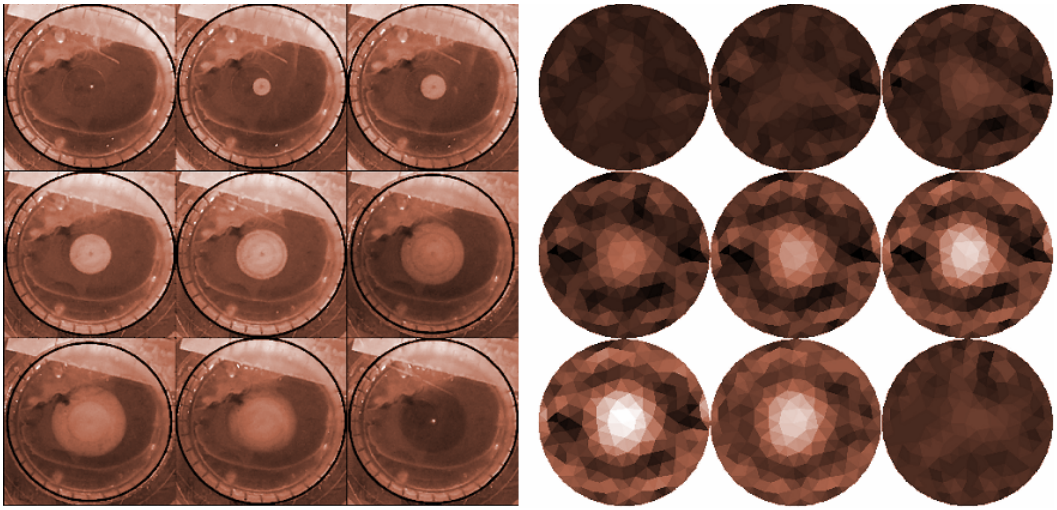


**Figure 2:** The process of freezing as a function of time in the liver (white area in the center of each panel) as seen with optical photography (left nine panels) and with DNCCI using EIT (right nine panels) [7].

EIT is an imaging technique in which the inexpensive hardware can be easily separated from the expensive software. If the measuring device is inexpensive this can be used for a low cost system of distributed medical imaging with many devices and one central processor. However, as we have described before, this concept is applicable to any imaging technique when the need arises to separate between data acquisition and interpretation. This paradigm leverages the off-site processing abilities and medical expertise thus rendering the X-ray machine usable whereas before it was grounded due to lack of trained specialists to interpret the measurements.

The Generic Remote EIT Components as presented in block diagram (Fig. 3) are

- User-end Hardware
  - Electrode array/chamber
  - Measurement electronics
  - Computer interfacing
- User-end Software
  - Low-level data acquisition device (DAQ) driver
  - Data acquisition
  - User Interface
  - File Transfer Protocol
- Image Server Software
  - File Transfer Protocol
  - Reconstruction Algorithm

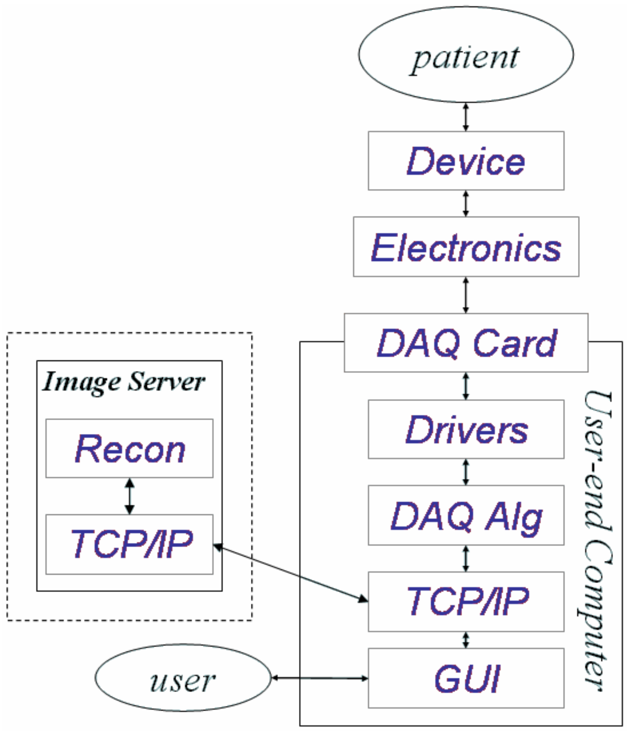



**Figure 3:** EIT Components

A natural extension of the remote medical imaging concept can be used as a cancer home screening device (such as breast cancer and prostate cancer). Such device could be purchased by an end-user and used to acquire the data, which will be sent to remote processing station. Once the data is processed, the result arrives to the remote device in a form of a text message notifying the user, for example: *"Healthy"* or *"Thorough test is required"*. Alternative ways for breast cancer detection include mammography and self-examination. In comparison to those two methods, remote imaging is inexpensive, more sensitive than self-examination and less than mammography, safe and easy to use. Self-examination is notoriously insensitive. Mammography, while providing high sensitivity, is not mobile, expensive, and painful and uses ionizing radiation.

During the imaging procedure, the data is being acquired by the data acquisition hardware, namely a sensor attached to the patient's body collecting raw, physical measurements. The raw data is prepared for transmission by the file transfer software on the patient side. Once the data acquisition is over, the raw data is being sent to the remote processing server where it is processed and an image is generated. This image is then made available for an expert doctor for review. Since our system adheres to the Distributed Network Cloud Computing Imaging concept, the expert doctor can reside in any physical location as he gains access to the scan results over the internet. Once the expert doctor has reviewed the scan results, he inputs a diagnostic recommendation which is then sent to the patient site and immediately appears on his console which can be a mobile phone such as the popular iPhone or a personal computer or a NetBook. The data flow diagram of a proposed system is presented (Fig. 4).

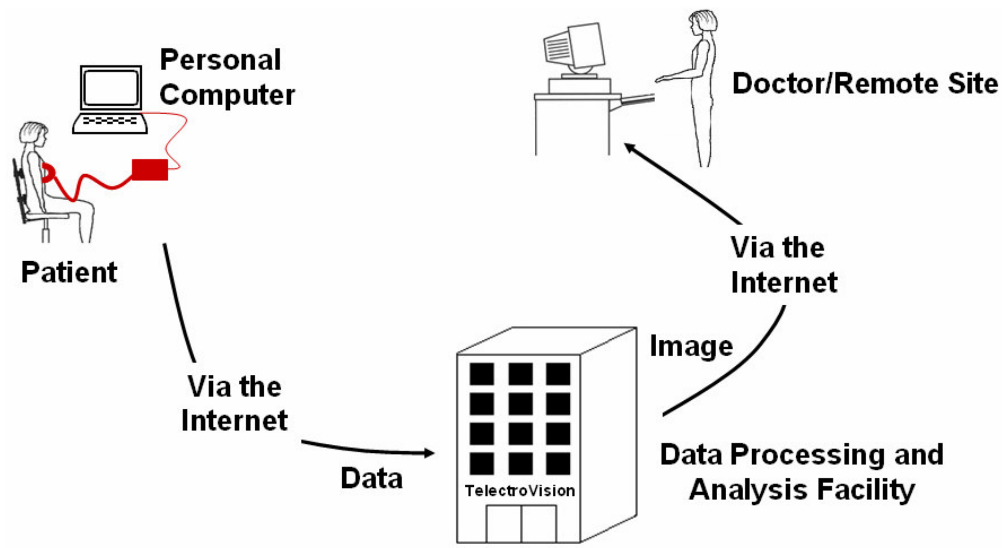



**Figure 4:** Distributed Network Cloud Computing Imaging System : data flow

Additional possible applications include remote imaging applications designed specifically with developing countries and rural areas in mind, as well as imaging for field use (for emergency service).

It is important to note that the proposed Distributed Network Cloud Computing Imaging paradigm is independent of the specific underlying connection medium used in a particular system. This means that cellular technology can be efficiently used in remote areas where conventional wired infrastructure is not available. For example the systems described in [8,9] use wired connections for telecommunication, whereas the studies described in [10,11] utilize cellular connection for transferring the raw data and the results.

Our work with EIT over the cellular channel permits selective visualization of tissues on the cellular phone screen. An oncologist can see the tumor in isolation through his cellular phone via the Internet. Based on the images the expert can then decide to use a combination of electroporation and drugs, observe the effect of treatment in real-time and choose to repeat the procedure immediately if required. Figure 5 illustrates the images obtained in a phantom simulating a breast tumor using EIT and the DNCCI concept [10].

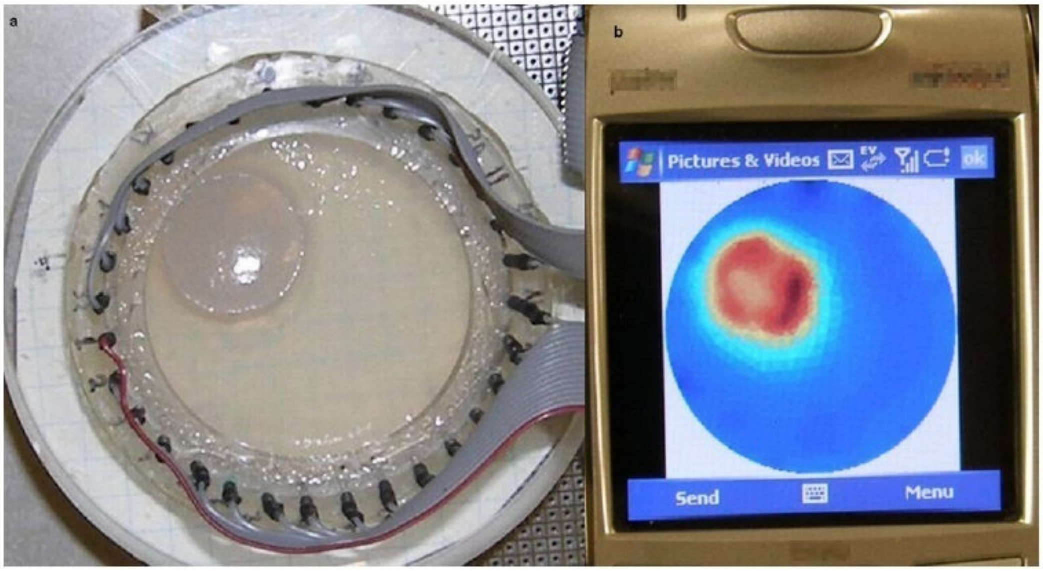



**Figure 5:** Real-Time DNCCI EIT Images of a phantom simulating a breast tumour in breast tissue (tumour darker circle). Left real data image, right image produced through DNCCI using the paradigm in Fig 4 and displayed on the cellular phone [10]

**Ultrasound Imaging**

Another application of the DNCCI concept was built by our group to create a low-cost ultrasound system which performs the processing on a remote processing server. Ultrasound imaging utilizes acoustic waves for the mapping of internal organs and tissues from changes in acoustic impedance between the tissues. Ultrasound works by sending acoustic pulse waves towards the mapped organ and then reconstructing the echoes of those waves into a visual image used for medical diagnosis. Due to the relatively compact size and low power consumption, ultrasound provides an important alternative to other medical imaging modalities such as CT and MRI. The cost efficiency of ultrasound systems makes them a viable medical imaging modality for low-income communities in both developing and developed countries. Nevertheless the classic ultrasound machine usually comes with a dedicated computer and complicated processing hardware and software requiring high level of technical expertise to operate and maintain. Our goal was to simplify the system by physically separating the data acquisition module from the processing module. We have used a standard, very inexpensive 3.5 MHz abdominal ultrasound probe manufactured by Interson Corporation [12].

Our system is based on Google's Android mobile platform which we chose because it is fully open source and capable of utilizing all the modern features provided by cellular operators. We have tested the system in two configurations: a) running on HTC G1 mobile phone and b) running in an emulator environment on Asus EEE 1000HE netbook computer. To facilitate medical expert review, we have integrated our system with OpenMRS [13] which is a popular open source medical records system.

Schematic architecture of the console (Fig. 6a) and the server (Fig. 6b) modules is presented. For the data acquisition phase, we have implemented a basic software mechanism which collects the raw data from the ultrasound probe and sends it as is to the processing server where the raw data is being processed into an image. The resulting image can be reviewed by a medical expert over the internet and then returned to the mobile console to be displayed with the diagnostic recommendations.

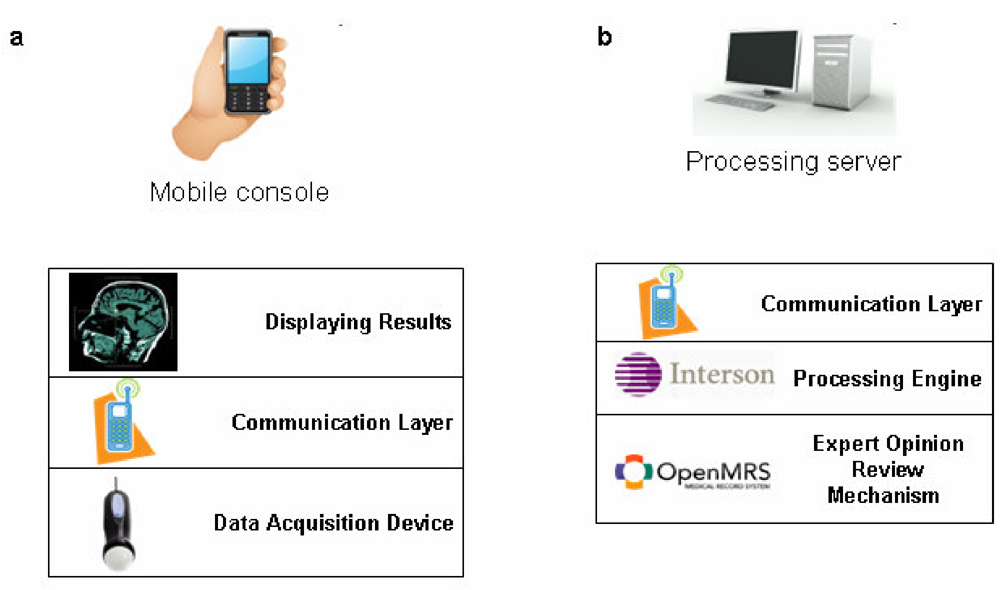
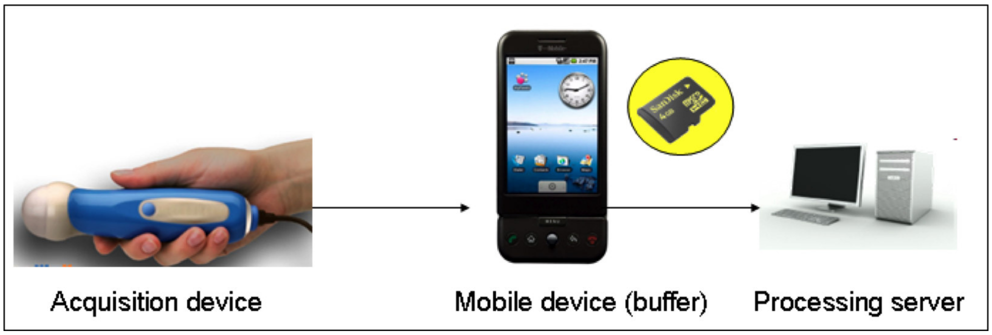



**Figure 6:** Ultrasound system architecture

By designing our system in adherence with the Distributed Network Cloud Computing Imaging paradigm, we were able to separate the data acquisition module from the data processing module. As a result we have effectively reduced the cost of a complete ultrasound system since we have eliminated the need in a dedicated computer at the patient's site.

Figure 7 illustrates the results that we have obtained with ultrasound. We were successful in acquiring free hand 2-D ultrasound raw data with the low-end transducer transfer the raw data through the cellular phone to a central processing facility and process the raw data into a 3-D image, which was returned through the cellular phone to the user. This illustrates the value of the DNCCI concept in medical imaging. It shows that a low-end data transducer can produce images that are similar in quality to those produced by devices that are at least an order of magnitude more expensive.



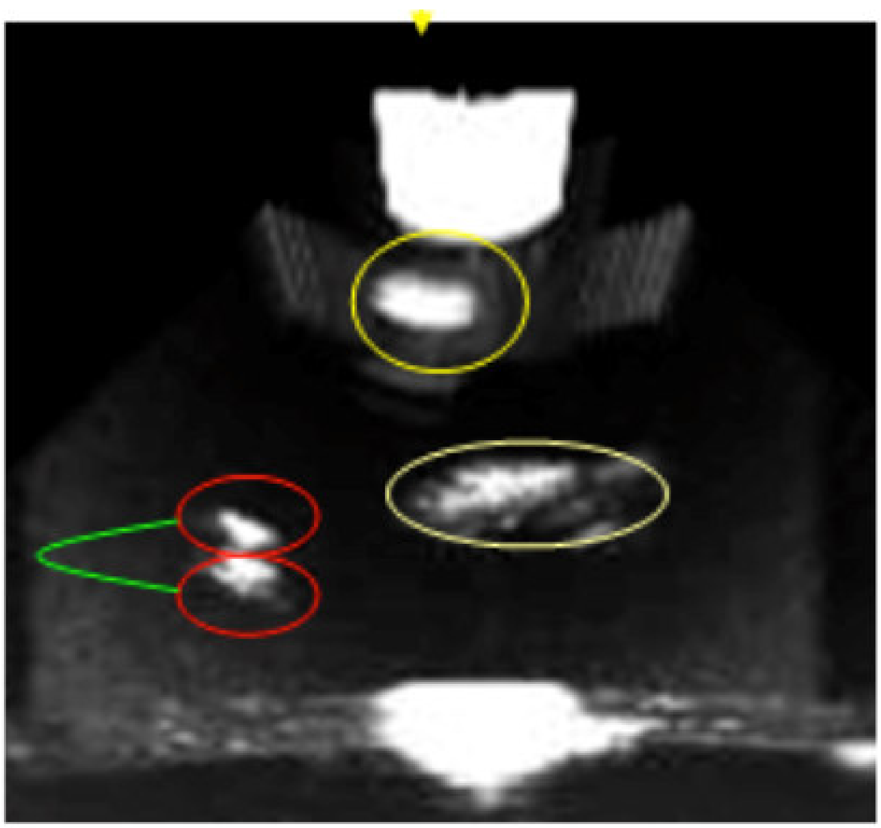



**Figure 7:** Real components used in the DNCCI ultrasound system. Note only the ultrasound transducer and the cellular phone need to be in the vicinity of the patient. Bottom, a snapshot from a 3D reconstructed image obtained using DNCCI from free

hand acquired 2-D raw data. The image is from a gell ultrasound phantom with four distinct acoustic impedance inhomogeneities (marked) embedded in the phantom.

## Internal Bleeding Detection

According to UNDP report [14], in 2005 more than 500,000 women died during pregnancy, childbirth or within the six weeks after delivery. Ninety-nine percent of these deaths occurred in developing regions. The probability of death at childbirth is one in 22 in Sub-Saharan Africa and one in several thousand in the industrialized world. According to WHO report "undetected internal bleeding is the cause of one in four maternal deaths worldwide"[15]. It is obvious that developing affordable medical technology for diagnosing internal bleeding could make a major impact on the efforts to reduce maternal mortality.

In collaboration with the laboratory of Professor Cesar Gonzalez at the Universidad del Ejército y FAM/EMGS-Laboratorio Multidisciplinario de Investigación, DF, México, a new system was developed for internal bleeding detection [16]. This system uses Magnetic Induction Spectroscopy (MIS) technology coupled with Wearable Body Sensors to design a simple, mobile device which can be used to detect internal bleeding. Bleeding usually cannot be detected by vital signs such as pulse rate or blood pressure which can be obtained by ordinary body sensors. Magnetic resonance imaging (MRI) and Computer Tomography (CT) can monitor changes in the tissue fluid content but those modalities are not portable and are prohibitively expensive for the developing communities we are targeting. Electromagnetic induction measurements with noncontact electrical coils, such as Magnetic Induction Spectroscopy, are a valuable alternative to contact electrode measurements [17]. Inductive measurement does not require galvanic coupling between the electrode and the skin or the tissue under measurement. The change in bulk tissue electromagnetic phase shift over time is a particularly good indicator of tissue bleeding and is useful for medical diagnostics [18-21]. We [16] have integrated the MIT based sensor with a Wearable Body Sensor that controls its operation and reads out the physical measurements. These raw physical data is then sent to a cellular phone over short range transmission protocol such as 802.15.5 (BlueTooth) or 802.15.4 (ZigBee) and the cellular phone relays the raw data to the central processing station where it is processed and analyzed. Based on the results of the processing, the system is able to continuously monitor the patient and alert the medical expert in case an increased hydration level (bleeding) is detected. A schematic description of the system is presented. (Fig. 8).

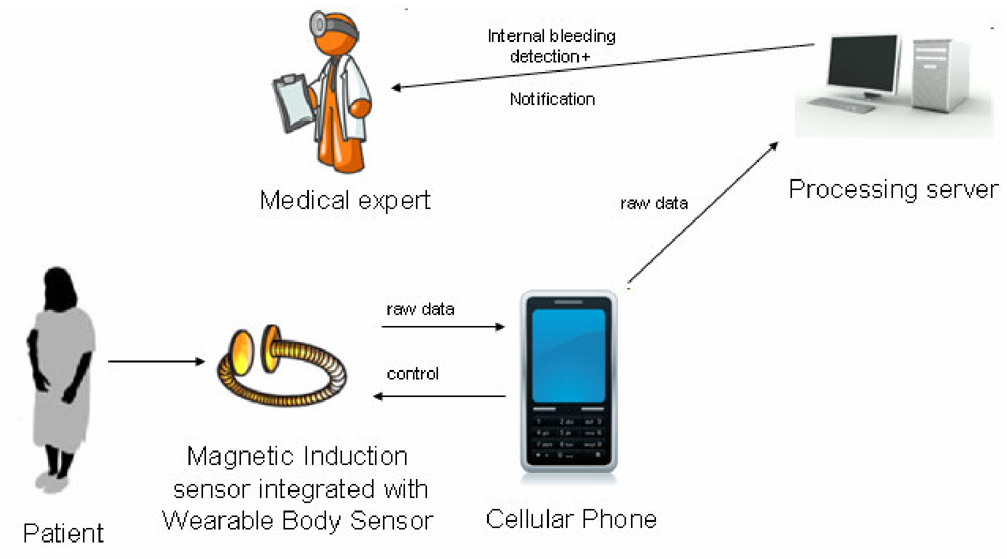



**Figure 8:** Internal Bleeding Detection System

To test the system, experiments were performed in a distributed manner. The "patient" was physically located in Mexico City and the raw physical measurements were transferred through the mobile console unit (Nokia N75 cellular phone) as a text message to a central processing unit in Jerusalem. Occasionally we have changed the environment on the patient's site which triggered a change in the raw measurements acquired by the MIS sensor. Only the raw data (phase shift measurements) was transferred to Jerusalem. These raw measurements were analyzed in Jerusalem and the results of the analysis returned to Mexico City through the cellular phone, in real time, for confirmation. The central processing server had successfully detected the change in the patient's environment which simulated internal bleeding [16].

Another related work in our lab had applied conceptually similar technology for the purpose of non-invasive monitoring system for the brain. The motivation for this is the fact that head injury causes more deaths and disability than any other neurological condition under the age of 50 and occurs in more than 70% of accidents. It is the leading cause of death in males under 35 yr old. The immediate injury may not lead to a fatality. Rather, progressive damage to brain tissue develops over time. In response to trauma, changes occur in the brain that requires monitoring to prevent further damage [22]. Applying cellular phone technology to the low-cost MIT sensor makes the brain hydration level monitoring system affordable and accessible everywhere where cellular infrastructure is enabled [23].

**DNCC based Tissue Classification**

Having the raw data processed in a centralized facility has multiple benefits. As has been already emphasized, separating the processing from the data acquisition simplifies the patient side device thus makes it simpler and cheaper to maintain. But in addition to that, having all the raw data collected in a single central facility enables the design and application of sophisticated processing algorithms which cannot be used in a standalone mode of medical imaging devices. One possible application was developed in our lab for tissue classification purposes. During cancer treatment surgery procedures, it is important to remove all cancerous tissue from the patient's body. To insure that all cancer tissue has been successfully removed, large hospitals in developed countries employ a dedicated pathologist who is physically present in the immediate vicinity of the operating room. When the cancer tissue is removed during surgery, the surgeon takes a biopsy from the surrounding area and sends it in real-time to the pathologist for analysis. The pathologist's responsibility is to classify whether the tissue is cancerous or not. For obvious reasons, smaller clinics in developed countries and even large hospitals in developing countries do not possess the resources or the expertise to perform such a classification procedure on-site. What they do instead is take a few biopsy samples and send them to the lab, to get the results after several weeks. This waiting period is usually very stressful for the patient and even if the result comes back negative for cancer, the physician often takes another biopsy just to rule out his initial suspicions. This causes huge inefficiency in treatment and causes major pain to the patient. Attempting to solve this problem, our group has developed a system based on electrical impedance spectroscopy technology and machine learning algorithms which classifies the tissue as benign or malignant [11]. The basic idea is that if the data processing is performed in a centralized facility, the processing server can "learn" the characteristics of benign and malignant tissues over time and thus act as an automatic classifier. It is interesting to note, that in many senses this emulates the behaviour of a human medical expert who acts essentially in the same way. The expert sees many different patients with the goal of training himself to detect specific patterns which can help him diagnose and then treat patients more efficiently over time. By leveraging the data aggregation in the central processing facility the technology developed in [11] can provide smaller clinics expertise that they didn't have access to until now.

## Summary

We have presented several applications which are united by the common thread of their adherence to the Distributed Network Imaging paradigm. The EIT, the ultrasound and the internal bleeding detection system all strive to minimize the technological complexity and thus the cost of the patient side device. The automatic tissue classification system leverages the central data processing facility to apply machine learning for tissue analysis. Having designed those systems with the needs of developing, low-income communities in mind, we have managed to build fully functional medical technology which provides the local health worker with valuable input at a price that he can afford.

EIT should be able to image the result of any ablative procedure whose effect on the low frequency electrical conductivity of tissue is dominated by the disruption of cell membranes, a consideration which argues for increased effort to establish widespread clinical use of the impedance imaging technique. An affordable ultrasound system means that more local clinics in both developing and developed countries can afford purchasing and operating a fully-functional medical imaging system. Transmitting medical images through cellular phone means that Ultrasound, X-ray and other medical imaging technology will literally be in the palm of a doctor's hand. Developing medical technology based on the cellular phone minimizes the technological requirements from the patient side devices therefore making it possible to build inexpensive and accessible systems for the developing countries depending upon their local, specific needs.

We envision in the future a general-purpose sensor, used by the health worker on site to scan the patient and collect raw data about his medical conditions. The raw data will be delivered to the central processing server where it will be processed, analyzed and sent back with diagnostic recommendations back to the patient's site where the local health worker can administer the appropriate care. The applications we are building work through the same basic paradigm where the various sensors (EIT electrodes, US probe, Magnetic Induction Sensors) act as the medical scanner and they are integrated with the cellular phone which is being used as the communication and display module.

## Reference:


1. WHO report (2003) Essential Health Technologies Strategy 2004–2007. World Health Organization. http://www.who.int/eht/en/EHT_strategy_2004-2007.pdf (last visited August 31, 2009)
2. WHO report, Health Technologies- the backbone of Health Services. World Health Organization. http://www.who.int/eht/en/Backbone.pdf (last visited August 31, 2009)
3. WHO report, Essential Diagnostic Imaging. World Health Organization. http://www.who.int/eht/en/DiagnosticImaging.pdf (last visited August 31, 2009)
4. WHO report, About diagnostic imaging. World Health Organization. http://www.who.int/diagnostic_imaging/about/en/ (last visited August 31, 2009)
5. WHO report, Diagnostic imaging. World Health Organization. http://www.who.int/diagnostic_imaging/en/ (last visited August 31, 2009)
6. Sharon La Franiere, Cellphones Catapult Rural Africa to 21st Century, New York Times August 25, 2005.
7. Otten, D.M., Rubinsky, B., "Cryosurgical monitoring using bio-impedance measurements - a feasibility study for electrical impedance tomography" IEEE - Trans of Biomedical Eng, vol. 27, No 10, pp 1376-1382, Oct 2000
8. Rubinsky, B., Otten, D., "Method and apparatus for remote imaging of biological tissue by electrical impedance tomography through a communication network" US Patent # 6725087, April 20, 2004.
9. David M. Otten, Gary Onik, Boris Rubinsky, "Distributed Network Imaging and Electrical Impedance Tomography of Minimally Invasive Surgery." Technology in Cancer Research and Treatment. Vol. 3, No. 2 April 2004, pp 1 – 10.
10. Yair Granot, Antoni Ivorra, Boris Rubinsky, "A New Concept for Medical Imaging Centered on Cellular Phone Technology" PloS ONE, 3 (4) e2075, 2008
11. Laufer, S, Rubinsky B, 2009 Cellular Phone Enabled Non-Invasive Tissue Classifier. PLoS ONE 4(4): e5178. doi:10.1371/journal.pone.0005178.
12. Interson Corporation, http://www.interson.com
13. OpenMRS, http://www.openmrs.org
14. UNDP Report on Millenium goals progress http://www.undp.org/mdg/basics_ontrack.shtml (last visited August 31, 2009)
15. WHO Report on maternal health, http://www.who.int/topics/maternal_health/en/ (last visited August 31, 2009)
16. G.Blumrosen, C.A.Gonzalez, B.Rubinsky. "New wearable body sensor for continuous diagnosis of internal tissue bleeding " Proceedings IEEE BSN Conference, , Berkeley, CA May 2009

17. Griffiths, H.: ‘Magnetic Induction tomography’, Meas. Sci. Technol., 2001, 12, pp. 1126-1131
18. Gonzalez, C.A., and Rubinsky, B.: ‘The detection of brain oedemawith frequency-dependent phase shift electromagnetic induction’, PhysiolMeas, 2006, 27, (6), pp. 539-552
19. Flores, O., Rubinsky, B., and Gonzalez, C.A.: ‘Experimental sensitivity study of inductive phase shift spectroscopy as non-invasive method for hypo perfusion vs. bleeding volumetric detection in brain’, EMBS 2008. 30th Annual International Conference of the IEEE, 2008, pp. 678-681
20. González, C.A., Rojas, R., and Rubinsky, B.: ‘Circular and Magnetron Inductor/Sensor Coils to Detect Volumetric Brain Edema by Inductive Phase Shift’: ‘13th International Conference on Electrical Bioimpedance and the 8th Conference on Electrical Impedance Tomography’ (2007), pp. 315-319
21. Gonzalez, C., and Rubinsky, B.: ‘Volumetric Induction Phase Shift Detection of Edema and Ischemia Patent application USA (application number: 028726-047)’, 2005
22. J.A. Langlois, W. Rutland-Brown and K E. Thomas. “Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths”. Atlanta (GA): Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2005.
23. Gonzalez C.A. and Rubinsky B. 2006b Detection of brain oedema with frequency dependent phase shift electromagnetic induction, Physiol. Meas. 27 539–52

# Achieving Proper Health Care through Telemedicine

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## Introduction

Telemedicine (TM) connects health care professionals to each other through technology in the evaluation, diagnosis and treatment of patients in other locations. It can help patients within a country or even across the world. Medical devices are enhanced through the use of telecommunications technology, network computing, video-conferencing systems and CODECs (A **codec** is a device or computer program capable of encoding and/or decoding a digital data stream or signal. The word *codec* is a portmanteau (mistakenly) of '**co**mpressor-**dec**ompressor' or, most accurately, '**co**der-**dec**oder'). The key components of the TM infrastructure are specialized application software, data storage devices, database management software, and medical devices capable of electronic data collection, storage and transmission.

TM customarily uses two methods to transmit images, data and sound - either "live", real-time transmission where the consulting professional participates in the examination of the patient while diagnostic information is collected and transmitted, or "store and forward" transmission, where the consulting professional reviews data asynchronous with its collection. Many programs employ both transmission capabilities, to maximize efficient use of resources appropriate to the medical services being provided.

## Who will benefit from TELEMEDICINE?

There are populations in underdeveloped countries who still do not have minimum standard medical facilities due to geographic isolation, natural disasters, ethnic conflicts or permanent inaccessibility. TM could save lives in rural areas where health care facilities are difficult to access, and would be a cost effective method applicable in both developed and underdeveloped countries. Figure 1 point out the condition of the traditional rural clinic from where more than 100 patients are treated a day and where a doctor comes once in a month.

**Figure 1:** Rural Clinic treating more than 100 patients a day and where doctor comes once a month

A pilot study is proposed to show that improved service can be achieved with a pyramid structure based on TM as shown in fig 2. We can use this practice in pre-designed settings by implementing new technology compatible with mobile phone networks and internet telephone services, such as Skype. Here we are going use protocols on common selected problems.

**The effectiveness of TM**

Important outcome of TM in health care include early detection of cancers, proper follow-up for patients with chronic illnesses, decrease maternal and child motility, control of medical emergencies, and tertiary care facilities for rural populations.

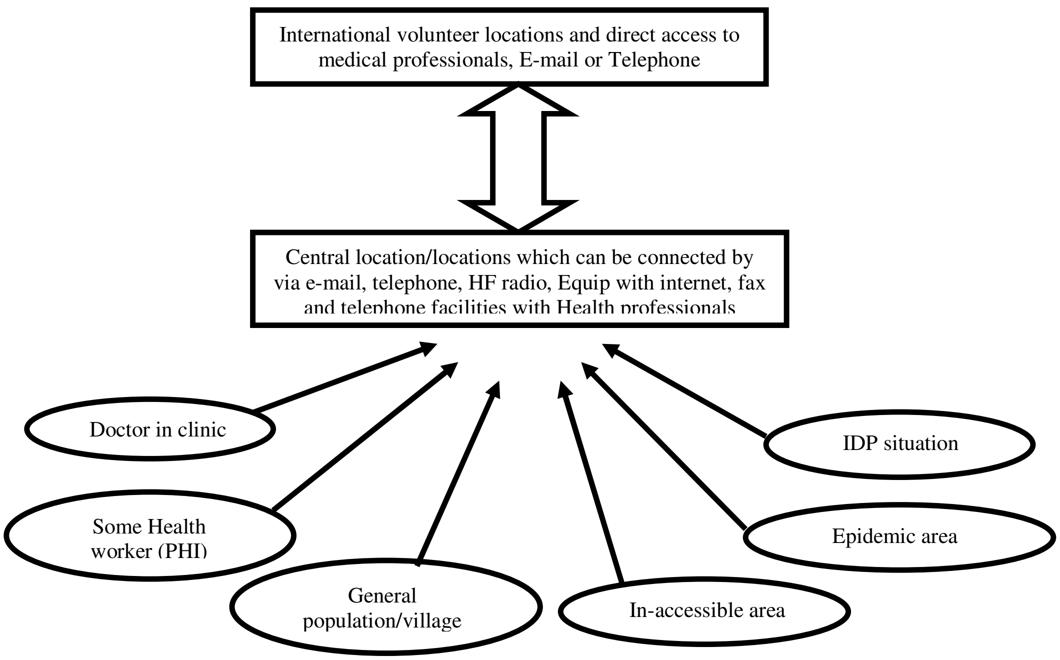


**Figure 2:** Pyramid structure based on TM

This study will utilize information from a variety of sources and focus on underdeveloped countries. It may then expand to a global scale as a way to achieve cost-effective counselling/referral systems health systems everywhere. TM would be an asset for volunteered medical support groups such as Medicine Sans Frontiers.

**Conclusion**

The TM system should not by-pass or interferes with the existing health system, but complements the system. The TM system, although it will be a common system, should have some different branches which would support different situations. Properly developed TM techniques are expected to reduce the overall cost for health care facilities for both underdeveloped and developed countries. Telemedicine can assist people to change their lives for the better tomorrow.

## 5 Cost-benefit Considerations

### The Cost Benefit of High Technology in the Treatment of Advanced Disease at Small Radiation Oncology Centres in rural areas.

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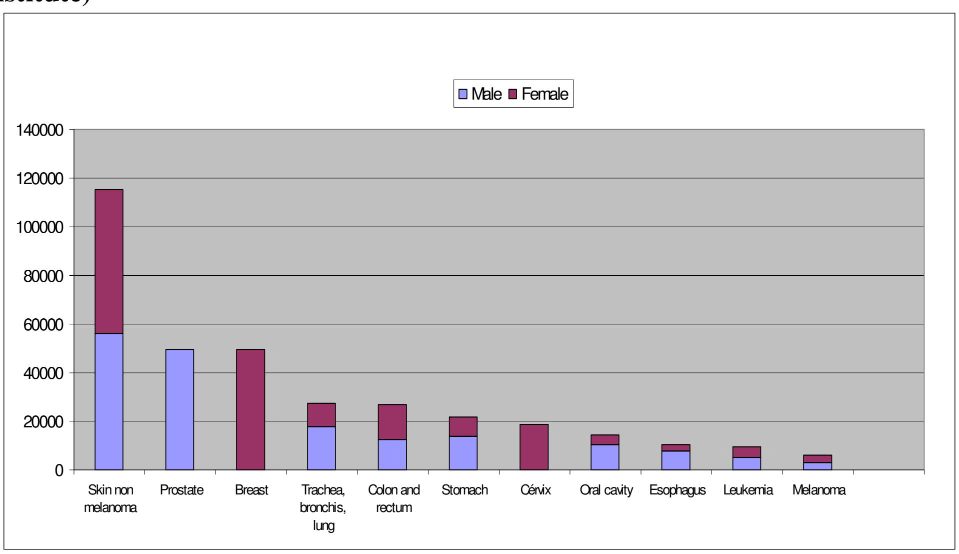
**Introduction:**

Health care in developing countries is confronted with a number of problems with no easy solution. Among these problems are the parasite diseases (malaria, sehistosomiasis, onehocereiasis, etc.), the birth rate, infant mortality, and malnutrition. In addition, increasing continuously in a number of countries the health problems of the industrialized world are added to these, such as cardiovascular diseases and cancer. In emerging countries such as Brazil the patterns of cancer incidence are still undefined though, approaching the ones of industrialized nations. The main reason is that there is still a large amount of sub-notification i.e. lung cancer, misdiagnosed as tuberculosis and the epidemiological data are yet full of flaws. This is even more confusing in less developed regions.
The data presented in the Table 1 below give a broad perspective of the cancer estimates in Brazil for the year 2008.

**Table 1. Estimates of cancer incidence in Brazil – 2008 (National Cancer Institute)**




Typical numbers of cancer patients that require palliative care involving advanced disease, as shown in Table 2 make up for a large component of the patient workload in radiation oncology centres in rural areas.

**Table 2. Typical data on the treatment staging strategy gathered in different centers.**

| | Center 1 | Center 2 | Center 3 | Center 4 | Center 5 |
|---|---|---|---|---|---|
| Advanced tumors | 50% | 40% | 40% | 50% | 50% |
| Localized Tumors | 50% | 60% | 60% | 50% | 50% |

The main reasons associated to this scenario are:

- The difficult access to diagnostic centres,
- Lack of patient awareness of the symptoms and the fear of publicizing the disease,
- Lack of cancer prevention and early detection programs, result on the diagnosis of advanced stages of various tumors leading to indications for palliative treatment.

The main objective of this paper is to analyze the present situation of cancer centers in rural areas, considering the impact and use of high technology for treatment. The concepts used are: cost-minimization, cost effectiveness, cost utility and cost benefit to critically analyze the planning and operation of radiation oncology centers in rural areas, and to relate that to the general aspects involved in treating of advanced diseases.

**Material and Methods:**

The cancer epidemiological data available from cancer centers from different geographical rural areas as shown in Table 3, the predominant cancer cases are: prostate, breast, head and neck, lung, cervix, GI, skin non melanoma being the largest.

To broader this view one should also bear in mind the treatment options and possible combinations to be exercised by the clinical judgment.

**Table 3: Frequency of Chemotherapy and Radiotherapy in advanced cases**

| | RT alone | Chemo and/or Hormone | RT + Chemo/Hormone | Others |
|---|---|---|---|---|
| Prostate | -- | 30% | 70% | -- |
| Breast | -- | 40% | 50% | 10% |
| H&N | 50% | 10% | 40% | -- |
| Lung | 20% | 40% | 40% | -- |
| Cervix | 15% | 5% | 80% | -- |
| GI | <10 | 20% | 70% | -- |

In the specific case of radiation oncology, the decision to incorporate a particular technology or the implementation of' a clinical procedure must be based primarily on the clinical needs and/or the potential improvements in treatment efficiency. In reality, it is very clear that the question of tumor control in general and especially palliative treatments are not related only to high technology but also to tumor biology. Nowadays, it is clear that technology is far ahead of tumor biology through, the new trends in radiation biology, getting away from the five R's concept and using more and more the molecular biology tools are indeed very promising. This new path might in the future allow the efficient use of predicative assays of tumor response prior to its treatment.

The most important set of questions that should be addressed when considering the incorporation a particular high technology are:

- Which patients will benefit by this technology, the clinical sites, the clinical staging for each site, the likely number of patients per year by clinical site and stage?
- Will the new technology provide cost savings over the old techniques for the same disease site and stage?
- Are the patients treated with the new technology, patients that otherwise would not have been treated by the institution?

- Would it be better to refer patients to a more comprehensive cancer center?
- Can the technology (infrastructure) regarding qualified staff maintenance and downtime be clearly handled?
- What are the costs involved in installing and maintaining a center with different technological options?

The reflection made in this paper, deals specifically with advanced cases and is based on the data gathered from several rural radiation oncology centers, and follows modern cost assessment concepts, such as:

- The cost minimization, analyses different treatments aiming the same results
- The cost effectiveness, measures the impact of the overall costs on final results such as additional years of life and distance disease avoided.
- The cost utility, measures the possible increase in quality of life or in this case, reduction of morbidity.
- The cost benefit, measures the costs and its consequences. It is related also to the performance on each treatment chosen.

Those parameters when applied to the treatment of advanced tumors can be a very useful and educational tool to guide the decision makers and the clinicians into the economic concepts related to the clinical benefits especially when a new treatment strategy needs to be assessed.

It is rather frequent to observe high tech equipments being purchased without considering the premises mentioned above either by governmental institutions or by private groups in this case pressured by local competition. In those situations, the logic behind the economic considerations may be seriously compromised.

For the purpose of this study it was only considered advanced tumors and cases with doubtful prognosis such as brain metastasis, cavo syndrome, bone metastasis and large inoperable H&N tumors. Although the decision to pursue a treatment involves not only clinical and ethical aspects but also the emotional and family pressure demanding care one has to bear in mind the potential benefit to the patient in terms of increasing survival and or reducing morbidity.

The mains objectives associated to the treatment of advanced tumors are: pain relief, bleeding control, and improvement of vital functions impairing normal breathing or GI obstruction. In the case of metastasis, though the chances to increase survival are slim, it may however be influence strongly by the quality of life i.e. breast cancer.

There are however, advanced cases that can benefit from high tech if available i.e. internal mammary recurrence with the potential to benefit from chemo, post surgery chest wall recurrence and spinal vertebra with good chance of survival.

The final question relates to the decision to whether or not one should make use of the high tech equipment already existent in the center. One may ask, the fact that it is there justify the use for this purpose?

It is not the intention of this paper to answer this question but to raise it, aiming those who are designing new centers and making the clinical decision.

When one consider the pro-rata cost based on the life expectancy of major components, the depreciation of the investments and the maintenance contracts, the estimated operational costs on a yearly basis of a simple Co-60 machine is considerably smaller than to ones for a simple 6 MV Linac as shown in Table 4.

However, interesting conclusions may also be drawn when other specific ingredients are added to the comparison. It is clear that the machine and the installation cost as well as the staff needed for a Co-60 installation are smaller than for a Linac, but the reimbursements fees practiced may be considerably different. For instance, in Brazil, the reimbursements for Co-60 treatments are 15% less than ones for a single energy

Linac. In addition, for a dual or a single photon energy Linac but both with electrons, the reimbursement fees for either beam are 15% higher than for a single energy Linac.
In this case, if one considers a patient workload of 50 new patients a month, being 30% advanced cases the overall differences in cost may be reduced substantially by the extra revenue.
Furthermore, for the Brazilian case where the reimbursement for conformal or IMRT treatments are not covered by the Social Security Health System a realistic cost benefit analysis related to the use of high equipment in radiotherapy in favorable cases may be seriously compromised.

**Results**

Based on patient data with advanced stages of the disease and with palliative treatment intention registered in five centers in operation for more than 5 years, and the costs described in Table 4, the following comments must be made:

- The cost minimization is related to the differences in the result among the alternatives (in this case a single energy machine with 2D capability versus a machine with 3D) considering the same objective, i.e. palliation. If the result is the same for both, this parameter favors 2D. In addition, hypo fractionation, when applicable, reduces the cost.
- The cost effectiveness seeks the possibility of gain using 3D focusing in the final result, i.e., enhanced time of life. As we are dealing with advanced and potentially incurable disease, it favors 2D versus 3D radiation therapy. Exception is made in very special situations where very sensitive early-responding tissues are near the radiation field and the patient life might be endangered or it may increase the risk of acute complications.
- The cost utility, which measures, in this case, the possible increase in quality of life, is very much in dispute. Apparently there are no data from multi-institutional clinical trials that would support this parameter. It is clear however, that in patients with good prognosis the morbidity may be reduced.
- The cost benefit, which measures costs and consequences, may be the most complicated concept, since it depends on the capital investments made, cost and requirements of staff, the revenues generated by each procedure which are likely to be different from country to country and a comparison with other possibilities. The conclusion of this parameter was seriously compromised by the lack of possibility to reimburse the 3D procedures.

**Conclusions**

1) Preliminary analysis indicates that the use of high technology in the treatment of advanced disease must be used with caution or avoided, if one wishes to optimize the overall treatment cost.
2) It is strongly advisable to the decision makers to consider the concepts of cost analysis when designing new centers.
3) Whenever the equipment is already available, good judgment must be exercised if there are no other alternatives.
4) Research into molecular biology through genomics and proteomics assays might be the key point to develop individualized risk adapted radiotherapy with a potential impact in the dose strategy for advanced tumors

**Acknowledgments:** The authors are thanks Prof. Barry Allen for having taken his time to make the oral presentation during the conference.

**Table 4: Cost Estimates of acquisition, installation and maintenance of a radiation oncology facility without considering the costs of staff, consumables and taxes.**

| Basic Equipment | Equipment Cost (US$) | Room Cost (US$) | Maintenance & Parts (Yearly Costs) (US$) | |
|---|---|---|---|---|
| Superficial | 150 000,00 | 20 000,00 | Tube: [10] | 3 000,00 |
| X- ray | | | Maintenance contract | 5 000,00 |
| ( 30-150 kVp) | | | Others; | 1 000,00 |
| | | | Depreciation[15] | 10 000,00 |
| | | | **Total:** | **19 000,00** |
| Telecobalt | 450 000,00 | 100 000,00 | Source: [5] | 30 000,00 |
| 12 000 Ci source | | | Others: | 2 000,00 |
| | | | Maintenance contract | 12 000,00 |
| | | | Depreciation [15] | 30 000,00 |
| | | | **Total:** | **74 000,00** |
| 6 MV Linac | 600 000,00 | 150 000,00 | Thyratron [2]: | 5 000,00 |
| | | | Magnetron: [4] | 10 000,00 |
| | | | Ion chamber:[4] | 2 000,00 |
| | | | Target: [4] | 2 000,00 |
| | | | Wave guide: [10] | 7 000,00 |
| | | | Others: | 5 000,00 |
| | | | Maintenance contract | 60 000,00 |
| | | | Depreciation [15] | 40 000,00 |
| | | | **Total:** | **131 000,00** |
| Dual Energy | 1 000 000,00 | 200 000,00 | Thyratron [2]: | 5 000,00 |
| Linac | | | Klystron: [8] | 5 000,00 |
| | | | Ion chamber:[4] | 2 000,00 |
| | | | Target: [4] | 2 000,00 |
| | | | Wave guide: [10] | 15 000,00 |
| | | | Others: | 15 000,00 |
| | | | Maintenance contract | 70 000,00 |
| | | | Depreciation [15] | 65 000,00 |
| | | | **Total:** | **169 000,00** |
| Linac | 1 300 000,00 | 200 000,00 | Thyratron [2]: | 5 000,00 |
| with IMRT | | | Klystron: [8] | 5 000,00 |
| Capability | | | Ion chamber:[4] | 2 000,00 |
| | | | Target: [4] | 3 000,00 |
| | | | Wave guide: [10] | 25 000,00 |
| | | | MLC [10] | 20 000,00 |
| | | | Maintenance contract | 75 000,00 |

| | | | |
|---|---|---|---|
| | | | Others 15 000,00 |
| | | | Depreciation [15] 80 000,00 |
| | | | **Total: 230 000,00** |
| Brachy HDR | 250 000,00 | 70 000,00 | (4) Sources 25 000,00 |
| | | | Applicators [5] 8 000,00 |
| | | | Maintenance contract 12 000,00 |
| | | | Others: 3 000,00 |
| | | | Depreciation [15] 12 000,00 |
| | | | **Total: 48 000,00** |

Numbers in brackets [ ] are estimates of the component half life in years, including taxes.

**References**


1) J.Van Dyk and J. Purdy, The Modern Technology of Radiation Oncology. Vol. 1, Medical Physics Publishing. 1999.
2) C. Manso and R. Caetano. Economic Analysis as a tool in the Process of Health Technology. Cadernos Saude Coletiva, Rio de Janeiro, 13 (3): 747-765. 2005.
3) Economical Evaluation in Health. How to Conduct and to Interpret. Minister of Health- Brazil 2008.
4) M. Mills, W. Spanos and R Esterhay. Considerations of Cost-effectiveness for new Radiation Oncology Technologies. J.Am Coll Radiol; 3:278-288.2006
5) S. Bentzen. High-Tech in Radiation Oncology: Should there be a ceiling? Int. J. Radiation Oncology Biol. Phys. 58, No 2, pp320-330, 2004.

# Comparative Cost Analyses for Co-60 and Linacs in Developing Countries

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## Introduction

In developing countries, more than 80% of patients present with advanced cancer that cannot be cured in the West, but require palliative therapy to maintain quality of life and relive pain. Of course, this result does not include cancer patients who do not present at all, as access to therapy is too far away to be considered as an option. Yet, many developing countries are keen to install the latest radiotherapy equipment in city hospitals, although such facilities may not serve the interests of the vast majority of potential patients.

The reviews of rural health technology in the Mekong Delta, Vietnam, several provinces in the Philippines and in Vanuatu[1] pointed out that the rural populations of these countries would continue to be denied palliation for cancer and other diseases unless a change of philosophy was introduced.

This workshop examines the sociological, medical physics and clinical basis for palliative therapy. However, this paper is restricted to comparative costs for Co-60 and Linacs in such developing countries.

## Comparative costs for C0-60 and Linac

Relative to linacs, the following statistics need to be reviewed[2]:

- Capital costs ~ 4 times lower for Co 60.
- Running costs are ~10 times lower.
- Down time ~ 8 times lower.
- Maintenance and QA ~ 7 times lower.
- Cost per dose fraction 2-3 times lower.
- Power costs ~ 10 times lower.

These factors may not represent the situation in the Western city hospitals or in rural locations in developing countries, but are based on median values. Power costs are not an important consideration in the West, but this may not be the case in the Provincial hospitals serving rural communities. Down-time from equipment failure may be much worse than stated above, depending on available funds for repairs and availability of replacements and engineers.

The availability of trained radiation oncologists, medical physicists, radiologists and engineers will be quite poor in rural centres, such that a balance between expertise, on site skills and training and telemedicine must be achieved. Telemedicine may provide an important element in spanning the knowledge gap between the city specialist and rural radiotherapist.

**Comparative radiotherapy technical costs in USA**

Four types of external beam radiation therapy (XBRT) are available in the United States of America (USA)[3]:

- Palliative simple, 10 Fractions in 1 field
- Palliative complex, 10 Fractions in 2 fields
- Curative 30 F in 1 field + β boost for breast cancer treatment
- Curative 35 F in 4 fields for prostate cancer treatment

Using the average of Medicare cost to charge ratios (CCR) and cost accounting systems (CAS) that includes labour, capital equipment, overheads, the technical costs for each type of radiotherapy was found as table 1. Palliative radiotherapy costs are 3.5 to 7 times lower than curative costs in the U. Michigan. The costs of treatment per patient in developing countries are generally much lower with Co-60 teletherapy than with Linac (Table 2).

**Table1:** Technical costs for cancer treatment.

| XBRT Type | Cost (US $) | Ratio |
|---|---|---|
| Palliative simple | 1250 | 1 |
| Palliative complex | 2000 | 2 |
| Curative Breast | 5800 | 5 |
| Curative Prostate | 8500 | 7 |

**Table 2:** Costs of radiotherapy per treatment course (the costs incorporate local labour costs and are based on an IAEA study[2]. Costs are in US dollars at 2002 prices, and are intended for comparison purposes only.)

| | Palliative radiotherapy (Single fraction) | | Radical radiotherapy (30 fractions) | |
|---|---|---|---|---|
| Country | $^{60}$Co unit | 6 MV linac | $^{60}$Co unit | 6 MV linac |
| India | 3 | 11 | 90 | 330 |
| Indonesia | 10 | 17 | 300 | 510 |
| Netherlands | 34 | 32 | 1020 | 960 |

**Conclusions**

The cost of palliative therapy is reported to be 10-30% less than that of curative therapy. Professional staff requirements for palliative therapy are 60% lower (one Radiologist, one Physicist and one Engineer) than for curative therapy (one Radiologist, two Physicists and two Engineers)[2]. Palliative therapy with Co-60 costs 20% of that for the equivalent Linac. The same curative therapy facilities are not cost-effective for palliative therapy.

**References**


1 HTTTG reports at www.iupesm.org.

2 Van der Giessen PH, Alert J, Badri C, Bistrovic M, Deshpande D et al. Multinational assessment of some operational costs of teletherapy. Radiotherapy & Oncology, 2004: 71; 347-355.

3 Hayman JA, Lash KA, Tao ML, Halman MA. Comparison Of Two Methods for Estimating the Technical Costs of External Beam Radiation Therapy. Int J Radiation Oncology Biol Phys 2000: 47; 461-7.

## 6 Summary

### Consensus

- Some 80% of cancer patients in the developing world present with incurable stage 4 cancer. However, the fraction of cancer patients that do not present is unknown.
- Opiates are not generally available for pain relief injetnam.
- Radiotherapy is a cost-effective means of reducing pain and improving quality of life.
- The availability of palliative therapy is grossly inadequate in Vietnam.
- Co60 and 6 MV linac photon sources provide similar and adequate dose-depth distributions for palliative radiotherapy.
- Co60 has important operational and cost saving advantages for developing countries.
- The annual running costs for low complexity palliative radiotherapy are a small fraction of those for complex curative radiotherapy.
- Palliative care centers can be upgraded for curative applications.

### Recommendations

- Provincial hospitals should set up palliative care centers.
- These centers should offer multidisciplinary support and opiates as required.
- Telemedicine should be introduced between provincial and city hospitals first, then with district hospitals and health stations.
- Low complexity radiotherapy should be offered initially to the palliative care centers.
- Co60 sources are the preferred source for palliative radiotherapy in rural areas.
- The palliative care centers should also become centers for breast and cervical cancer screening.
- The palliative care centers should also screen for curative cancer patients, for whom treatment would be indicated at the city hospitals.
- In the longer run, palliative care centers should evolve to provide curative treatment care closer to home.
- Research into the further development of telemedicine and low cost bioimpedance tomography should be encouraged.

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