CHAPTER VI

DISCUSSION
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6.1 PHOTON BEAMS

In chapter IV experimental results of a few measurements carried out on high energy photon beams had been presented. In chapter V measurements performed on high energy electrons and their results were outlined. The measured physical parameters of 6 and 18 MV photons and electron beams of 6, 9, 12, 16 and 20 MeV energies from a dual photon energy Medical Linear Accelerator were evaluated and compiled. For understanding the physical principles co-60 beams were also studied with similar experiments. The analysis made in this study could be incorporated in the accurate treatment planning for radiation therapy. Results obtained in chapters IV and V are discussed and following inference are made out of the study.

6.1.1 MEASURED TARs, TMRs AND TPRs:

In this present work, (section 4.2) a method is presented to measure one of the basic radiation parameter TAR or TMR of the high energy photon beams. The method is simple, reasonably accurate and easily adoptable. Vatnitskij et al (1983) have measured TARs for 19 cobalt units comprising of eight different types, with a special dosimeter filled with Baldwin Farmer Chamber (Type 2505/3A, 0.6 cc) with reproducibility of charge and current measurements within 0.2%. The purpose of their study was
to evaluate the general validity of the commonly used TAR tables. In their work, the ionization chamber was fixed at 75 cms SAD using a water proof sleeve. To get the depths viz. 5 cm, 10 cm and 15 cm, previously measured volumes of water were poured in the water tank. Some tank volumes were checked by filling the tank to a known level and then measuring the volume of water used. This method had given an accuracy of 0.15 mm in the determination of depth z. Using profile measurements they had determined field sizes within 1 mm. They have discussed that differences in spectral composition of the primary beam of the cobalt-60 teletherapy is to be accounted while considering the observed deviations in measured TARs. The energy distribution of the scattered photons gets affected with source construction and the collimator system of the teletherapy head. Deviations upto 4% has been shown in the measured values of TAR. The $\mu_{\text{eff}}$ value for the effective beam was 0.071 cm$^{-1}$ for Rokus-M cobalt-60 unit instead of 0.065 cm$^{-1}$. The differences in the $\mu_{\text{eff}}$ values could be accounted by the different energy distribution of the scattered photons in the region of 0.6 to 1.0 Mev. Another interesting finding was also furnished by Vatnitskij et al (1983) that there was variation in TAR after changing source in the same unit. This effect was attributed due to the differences in the spectra of self scattered radiation from cobalt-60 sources with equal diameters but with different active lengths. They had also opined that they could not see any distribution of TAR value for any particular machine design.

In our study, it could be seen from the design that the
outer cap thickness surrounding the ion chamber is more than the optimum water equivalent build up thickness. It is felt that this would be a systematic error in the method which would not significantly alter the ratios of measured values. Because measurement at \( d_{\text{max}} \) depth needs special type of geometry in chamber positioning, the concerned department may still refer to the BJR Table values for the BSF factors which are normally used along with percentage depth dose in treatment planning calculations. Comparison of our measurements with reported values suggests good efficacy of the present method for all beam qualities viz. Cs-137, Co-60, 6 MV, 18 MV beams and advocates its use in a basic level radiation physics department to measure their own values and use for treatment planning. It is emphasized that BJR supplement 17 values (Day 1983) values are mean of a few measurements made in a fixed number of machines. Measured values at any institution is preferred for using in treatment planning. The suggested method is simpler compared to the use of radiation field analysers. This system along with appropriate electrometers could be useful for determination of TARs in diagnostic beam qualities which would be relevant in health physics and radiation safety, with appropriate electrometers and chamber design.

6.1.2 EQUIVALENT SQUARES FOR HIGH ENERGY PHOTON BEAMS:

The results of our work relating to measured equivalent squares were outlined in section 4.3. For high energy photon beams the equivalent square field size for rectangular fields estimated from measured relative output factors does not match
with the equivalent square field size obtained using BJR table
(Day 1950, 1983) and Sterling's formula (Sterling et al 1964) for
6 MV and 18 MV photon energies. When the longer axis of the field
is set by lower jaws and smaller axis with upper jaws the BJR
values holds good for both 6 and 18 MV photons with minimum
device and the Sterling's method over estimates the size. The
BJR table and Sterling's equation values under-estimates the
equivalent square size when the field is set in the reverse
order. The deviation is pronounced for rectangular fields of
higher elongation factors. We therefore recommend the usage of
BJR tables for the determination of equivalent square field for
the investigated accelerator type with the smaller dimension of
the field defined by upper jaws and the larger size by lower
jaws.

The increase in output factor when the lower jaw position is
fixed and the upper jaw varied continuously could be due to more
scatter photons and electrons arising from the larger surface
area of the lower collimator reaching the detector. The effect is
pronounced for more elongated fields. The equivalent square fields
for 6 MV and 18 MV photon beams obtained from BJR tables and
Sterling's formula over estimates the output factor for rectangu-
lar fields defined with longer axis in the upper collimator and
the shorter axis in the lower collimator (Fig.4.5(a) &
Fig.4.5(b)). The variation in output factor is more for maximum
elongated fields (5x40 cm). Minimum variation in output factor
using BJR table values is noticed when the elongation factor
approaches 0.5 for 6 MV and 18 MV photons (Fig.4.4(a) &
In practical circumstances it is difficult to individualize patient portal set up in terms of upper and lower jaws and the present work has outlined the expected deviations in extreme circumstances.

6.1.3 ENTRANCE AND EXIT DOSES:

In earlier chapter (section 4.4) our results relating to measurements of entrance and exit doses were brought out. The increase in surface dose with field size for both photon energies is due to the electron scattering from flattening filter, monitor chambers, primary and secondary collimators and the air column between the distal collimator and the phantom surface. The effect has been measured and calculated earlier (Ahnesjo and Andreo 1989, Biggs and Ling 1979, Horton 1983, Petti et al 1983). The tray perturbation factor variation with SSD indicates that the introduction of perspex tray acts both as a contributor and an absorber of scattered electrons. The increase in TPF for 6 MV beam indicates that the increase in scattered electrons in the polycarbonate tray is more compared to the amount of an absorbed scattered electrons by it. Whereas for 18 MV photon beams the decrease in TPF at extended distances proves that the polycarbonate tray absorbs more secondary electrons compared to that of the secondary electrons produced. These effects depend on the range of secondary electrons generated from the collimator and the blocking tray. This could be due to the limited range of scattered electrons from the polycarbonate tray. The use of wedge filters
absorbs low energy scattered electrons significantly and hence, relative Surface Dose (RSD) is always less than unity. The increase in dose enhancement percentage with graphite compared to perspex supporting assembly indicates that the electron backscatter is proportional to the atomic number of the medium. When the depth dose tables are used to assess the dose at the exit surface, the dose due to loss of backscatter and the enhancement due to patient support devices should be considered. When the patient is treated, mostly the loss in dose due to the loss of the backscattering medium is compensated by the dose enhancement from the supporting devices. The skin reactions observed on the patients posterior body surface when the anterior portal is treated is due to the backscatter electron dose from the patient supporting devices. Similar results was shown by Sathiyanarayanan et al (1992) in cobalt-60 photon beams.

6.1.4 HEAD SCATTER FACTORS:

Head scatter factors at extended distances for Clinac 1800 photon beams were studied (section 4.5). The increase in head scatter factors for 18 MV photon beams compared to 6 MV photons could be due to the increase in scatter volume of the target and the beam flattening filter which interfere in the path of the beam, but the percentage increase in H(s) for 18 MV compared to 6 MV is very small. In CLINAC-1800 accelerator when 6 MV X-ray energy is selected the thin area of the target is inserted directly into the electron beam path by means of air flow through the low energy inlet. Selection of 18 MV X-ray energy automati-
ally allow air to flow through the high energy inlet to the air cylinder, thereby moving the thicker target area beneath the beam path. The beam flattening filters are brought into the position depending on the energy of the photon beam by means of the motor driven plate. By making use of these head scatter factors, the overall improvement in the accuracy of dose delivery is marginal, but the above concept is more relevant for the multileaf collimators and blocked fields. The small deviations observed in the present study from that of Khan et al. (1996) could be due to differences in scatter patterns from the upper and lower jaws of the collimating systems of different machines.

6.1.5 FORWARD DOSE PERTURBATION FACTORS:

In the earlier part of this thesis (section 4.6) the effect of metallic inhomogeneities in photon beams were quantified. The rapid increase or decrease in FDPF initially depending on the energy is due to the effects of electron transport across the interface. The slow increase in FDPF for larger thicknesses of the metallic inhomogeneities is due to the contribution of scattered photons. When the FDPF curves are extrapolated to zero thickness of inhomogeneity, it gives the value of the FDPF with the scattered photon dose contribution removed with the inhomogeneity thickness more than the range of secondary electrons. The slight slope in the saturation region of the curve is due to the change in the scattered photon contribution with the change in the position of the inhomogeneity. This FDPF was found to be
more when the thickness of the homogeneous polystyrene medium \( d' \) is more, which could be due to the beam hardening (Werner et al 1987). For thin layer of inhomogeneities for low energy beams especially for cobalt-60 gamma rays the FDPF falls considerably. This could be due to secondary electrons that would have been scattered out through the beam entrance side of the inhomogeneities for the thin layers. With the thicker layers of the inhomogeneities these secondary electrons would have internally reflected back to reach the chamber. The hypothesis of this phenomenon was explained by Das et al 1988). Differences in dose due to loss of internal backscatter would be most important for low energy beams for which the scattering power of the medium is greater and for which secondary electrons are set in motion at larger angles to the beam axis.

6.1.6 BACKSCATTER EFFECT INTO BEAM MONITOR CHAMBERS:

Measurements of backscatter of photon beams into monitoring chamber were outlined in section (4.7) of this thesis. The Clinac-1800 in our institute is equipped with a Kapton beam monitoring chambers which has no finite thickness of metal coating at the exit window level as observed with the mica beam monitor chambers. A similar study conducted with Mica chamber fitted Clinac-1800 accelerator shows a decrease in output by less than 1% and 2% for 6 MV and 18 MV photon beams. This could be due to the attenuation of low energy backscatter radiation by the aluminium exit window present in the Mica monitor chamber (Kubo and Lo 1989). A maximum reduction of 4.3% and 4% in dose delivery for
6MV and 18 MV photon beams are observed due to backscattered radiation originating mainly from upper collimator reaching the beam monitor chamber. Also, a maximum of 1% difference in backscatter effect is observed between the upper and lower collimators. Hence, whenever an asymmetric field is used instead of assuming a simple relationship between the off-axis ratio for large symmetric field and the output at the central axis, it is felt direct output measurement for asymmetric field is more reliable to avoid radiation backscatter effect into beam monitor chambers.

Though the ion chamber used for telescopic technique measurement is fitted with large build-up caps, the fact that beam size is not large enough to cover the chamber volume does not arises, as the chamber monitors only the primary photon fluence. Also the results noticed in our study is different from that of Kubo’s study (1989) where the fixed jaw was maintained at 2 cm compared to 40 cm opening in the present study. For Clinac-2100C accelerator equipped with Kapton beam monitor chamber a reduction in output of 2.5% and 4% are reported for 6 MV and 18 MV photon beams (Duzenli et al 1993).

6.2 ELECTRON BEAMS:

6.2.1 DOSE OUTPUT FACTORS IN ELECTRON BEAMS:

In earlier chapter, the experimental measurements on dose output factor for high energy electron beams were made (Ref. section 5.2). The more output factor variation at lower energies
(Fig.5.3) could be due to more electrons scattered through large angles by the scattering foils on to the fixed collimators than at higher energies. When larger cones are used the photon collimator opening increases as shown in Table.5.1, when the collimators are wide open more of the fixed collimator is made visible to the phantom and also the photon jaws intersect that part of the electron beam that is scattered at larger angles. When larger cones are used, area of the photon jaws exposed also increases. Hence the stronger field size dependence of the output factors at lower energies is noticed as reported earlier (Biggs et al 1979, Bruinvis et al 1983, Choi et al 1979, Mills et al 1972, 1985).

The decrease in output factors for the shaped fields at smaller field sizes (Fig.5.4) could be due to the decrease in scatter dose contributions reaching the detector from the fixed collimator. When the field size is more the variation in output factor is not pronounced as there is a limitation of the range of electrons scattering from the fixed collimator reaching the field centre, to contribute to the scatter dose.

6.2.2 VIRTUAL SOURCE POSITIONS FOR STANDARD AND CERRO-BAND CUT-OUT APPLICATORS

Our results of measurements on virtual source positions for high energy electron beams were listed in section 5.3. The measured virtual source position in space was observed to change with beam energies and the dimension of the applicator defining the
size of the electron beam at the treatment surface. These observed variations in virtual source positions are due to the change in electron scatter for different energies and beam sizes. Since the scatter contribution from the larger applicator size is less towards the central area of the beam, the virtual source is getting shifted more towards the scattering foil for larger standard applicators for all electron energies (Table 5.2). It was found that there is a difference in virtual source position between the same field defined by the standard applicator and the cerroband block (Table.5.2 & Table.5.3). It was also observed that the VSSD is more for the field sizes defined by the cerroband inserts in the standard 20*20 applicator for all energies. The difference tends to become minimum as the cerroband cut-out field size approaches the field size defined by the standard applicator (Table.5.3). The observed difference could be due to the variation in photon jaw setting between the 20*20 applicator and the other standard applicators. When the cerroband cut-outs are introduced close to the chamber the scattering conditions will likely to get altered introducing change in the virtual source position. A similar observation have been made by several investigators earlier (Faermann et al 1983, Ghazi and Lingman 1991, Jamshidi et al 1986, Sharma et al 1992).

6.2.3 DOSE LINEARITY AT LOW MONITOR UNITS SETTING:

We have attempted to quantify dose linearity effects at low monitor units setting in the Clinac 1800 medical linac (section
5.3). Dose Linearity Ratio (DLR) has been defined with reference to a standard dose rate of 200 MU/min and ideally the DLR should be unity over a wide range of MU settings for all electron beam energies at different dose rate settings. In our study DLR as high as 1.40 for 20 MeV electrons for 400 MU/min dose rate for very low MU setting (1 MU) was observed.

The above results obtained for electron beams is in similar lines as with 6 MV and 18 MV X-ray photon beams in an identical study (Das et al 1991, Sharma et al 1994). They have attributed the effect due to the control of electronics design for achieving varying dose rates. Ion chamber theory for integrating 1 or 2 MU vis-a-vis 200 MU at same applied potential for the monitor chamber needs careful documentation. We have brought out clarifications on the above point by measuring very low integrated exposures at extended distance in a telecobalt machine, where no similar effect was demonstrated, indicating that the reported phenomenon is only in the linear accelerator. This problem is relevant for low dose radiobiological experiments when low monitor units may be in use and therefore proper corrections in arriving at absolute doses are essential.

6.2.4 PHYSICAL ASPECTS OF TOTAL SKIN ELECTRON THERAPY (TSET):

In chapter 5 (section 5.4) the physical parameters relating to TSET were outlined. For Total Skin Electron Therapy a careful study of degraded electron beam energy at surface and at dose
maximum is necessary as many other dosimetric parameters depend on these energy values (AAPM 23 1988, IAEA TRS 277 1977, ICRU 35 1984). The estimation of optimal perspex degrader thickness is required for proper implementation of TSRT. If the degrader thickness is more, the beam energy would drop down drastically and the output at calibration point would reduce to a greater extent. Though the literature suggests the beam angle of $\pm 10^\circ$ to $\pm 25^\circ$ relative to the horizontal it depends upon the energy of the electron beam and geometrical conditions which should be established prior to the treatment. The dose due to the X-ray background is mostly peaked in the forward direction and falls rapidly for off-axis points (Karzmark 1960,1964). As we had a facility for longer treatment distance (4.6 m), an angulation of $8^\circ$ of the field was found sufficient to cover the entire patient's body surface with an acceptable uniformity in dose.