Early Experience in Using an 18 MeV Linear Accelerator for Mycosis Fungoides at Howard University Hospital

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This paper describes the problems and solutions in using 18 MeV linear accelerator, with minimum 6 MeV electron capability, for total skin irradiation for mycosis fungoides. The 6 MeV electron energy can be degraded to acceptable electron energy of 3.2 MeV by interposing a plexiglass sheet of 9.6 mm in the beam. To minimize the bremsstrahlung, the degrading plexiglass should be kept away from the machine head. A wide area with uniform dose distribution over single plane can be achieved by using dual fields but homogenous dose distribution over irregular body surface cannot be achieved mainly because of self-shielding. The nails and the ocular lens can be easily shielded from the low energy electrons with 1.5 mm lead shield.

The tautologic name of this disease was used for the first time in 1806, by Alibert, the founder of modern French dermatology. Mycosis fungoides (MF) also has been known as malignant cutaneous reticulosis, granuloma fungoides, and sarcomatosis generalis. In recent years there have been increasing numbers of reports emphasizing the existence of a clinical and pathological disease spectrum which has been termed cutaneous T-cell lymphoma. Recent evidence has suggested that Sezary syndrome first described in 1938 is a part of this spectrum of cutaneous T-cell lymphomas.

The classic course of mycosis fungoides, characterized by three stages, was described by Bazin in 1851. Mycosis fungoides occasionally starts with a tumor stage, mycosis fungoides d'emblee. Mycosis fungoides is an uncommon, chronic, fatal disease which originates in the reticuloendothelial system of the skin. Primarily and predominantly, it affects the skin and may stay confined there for many years. Eventually, however, it leads to involvement of lymph nodes and internal organs.[1-3] Therefore, in both early and late stages, the major problem is to treat the whole skin.

The advantages of applying the unique properties of megavolt electrons for the treatment of superficial diseases had been suggested by Trump, Van de Graaff, and Cloud in 1940. In 1953, Trump et al[4] described certain modifications to an already available low megavolt Van de Graaff electron accelerator to produce an electron beam in downward direction through a wide slit, making it suitable for patient therapy. Following this, different machines with electron capability have been used for this purpose.

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Materials and Methods

The 18 MeV Varian linear accelerator in our department is used to treat mycosis fungoides. There are five major problems to be solved in its use for this purpose: (1) degradation of electron energy, (2) uniform dose over a wide area, (3) uniform dose over the entire skin of the patient, (4) minimum x-ray contamination, and (5) protection of the ocular lens and the nails.

Degradation of Electron Energy

The minimum electron energy that is available from 18 MeV Clinac is 6 MeV. This energy is excessive for treating the whole skin of mycosis fungoides patients. Electron energy with a maximum penetration of 10 to 12 mm is sufficient for this purpose. The most suitable electron energy for this purpose is 2.5 to 4 MeV. The degradation of 6 MeV electrons to 2.5 to 4 MeV electrons is very easily done by interposing a sheet of plexiglass along the path of the electrons. Several workers have described this either as placing the plexiglass sheet close to the machine head or placing it close to the patient and away from the machine head. Our work showed that if the plexiglass is kept close to the machine head, the electron dose rate falls markedly due to scatter and the percent of x-ray dose increases beyond acceptable ranges (Figure 1). We therefore decided to keep the plexiglass sheet close to the patient, away from the machine head. Figure 2 shows electron beam depth doses in tissue equivalent material using different thicknesses of plexiglass screen at 3 meters distance. We found that a 9.6 mm thickness of plexiglass is sufficient to degrade the 6 MeV electron energy to 3.2 MeV, which has 80 percent depth dose at 7 mm, and 50 percent depth dose at 10 mm. As we increase the thickness of the degrading materi-

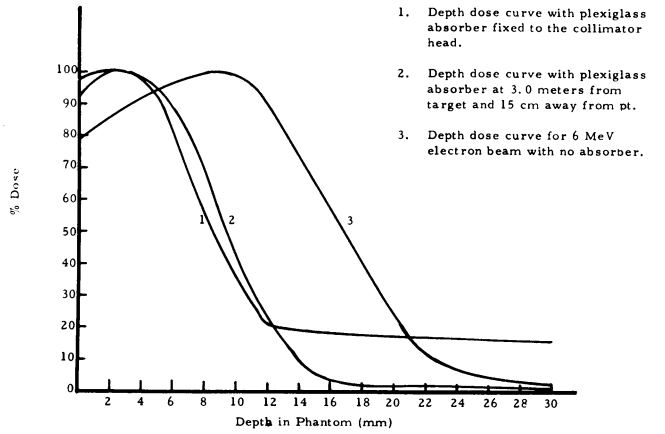

Figure 1. Depth dose curves in phantom at treatment distance (3.2 meters) without plexiglass screen and with plexiglass screen on the machine head and at 3 meters. The bremsstrahlung with the screen on the head is >15 percent and the screen at 3 meters is <2 percent.

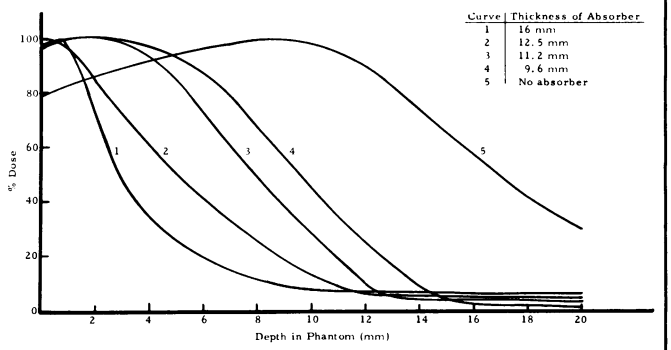

Figure 2. Depth dose curves in phantom at treatment distance (3.2 meters) with different thicknesses of plexiglass screen at 3 meters. With increasing thickness of the screen the electron energy falls and the percentage of bremsstrahlung increases because of the fall in dose rate.

al, not only does the energy of the electrons fall, but the dose rate also decreases, resulting in an increase in the percent of x-ray dose as shown in Figure 2.

Uniform Dose over a Wide Area

At a treatment distance of 3.2 meters, the field size is 115 cm x 115 cm. This field size can cover the width, but not the length of the patient. Therefore, dual fields are used to cover the entire length of the patient on each side. However, the electron beam field does not correspond to the light field as is true in x-ray beams. For this reason cones are used to confine the electron beam to the area of interest. Cones cannot be used while treating the patient at longer distances as in mycosis fungoides therapy. Therefore, to achieve uniformity of dose while using dual fields, one has to leave a gap between the dual light fields and match the dual fields at 50 percent of dose line. This is achieved by rotating the machine 17 to 20 degrees on either side of the horizontal axis, which is at the level of the umbilicus, the calibration point in our setup. The vertical and the transverse planar dose distributions at the treatment distance are shown in Figures 3 and 4.

Uniform Dose over the Entire Skin

The most difficult problem in treating mycosis fungoides with total skin electron beam is to achieve uniform dose over the entire skin surface. Since Trump started electron beam therapy for superficial malignant diseases in 1951, various techniques have been used (Bagshaw and Eltringham, 1968;[5] Fuks and Bagshaw, 1971;[6] Grollman, 1966;[7] Kitagawa, 1962;[8] Smedal et al, 1962;[9] and Szur et al, 1962[10]) to achieve effective and uniform dose distribution over the entire skin surface. We would like to emphasize here that the dose distribution within ±7 percent achieved on phantom studies cannot be reproduced over the patient. Two major reasons for this are inability of the patient to stand in a particular position for long periods, and self-shielding at anatomical locations like axillar, gluteal, and perineal regions. Both these problems result in areas of hot and cold spots in an actual setup. The arrangement which we used and found satisfactory incorporates four dual fields. The only way to correct the problem of underdosing and overdosing is to monitor the skin dose at multiple points with thermoluminescence detectors (TLDs) during the entire treatment and correct the problem by shielding the overdosed areas and boosting the underdosed areas. Our initial experience with TLDs on patients shows a variation of ±15 percent, (Figure 5), except in the perineal region where there is 60 percent underdosing.

Minimum X-ray Contamination

Page et al[11] discussed the problems of associated x-ray contamination in electron beam therapy and described four possible sources. X-ray contamination could be due to electrons striking the primary scattering foil within the accelerator, the various components of the collimating system, the intervening air, and the tissue being irradiated. Because of the low atomic number involved, the last two factors are negligible. Edelstein et al[12] reported that x-ray contamination can

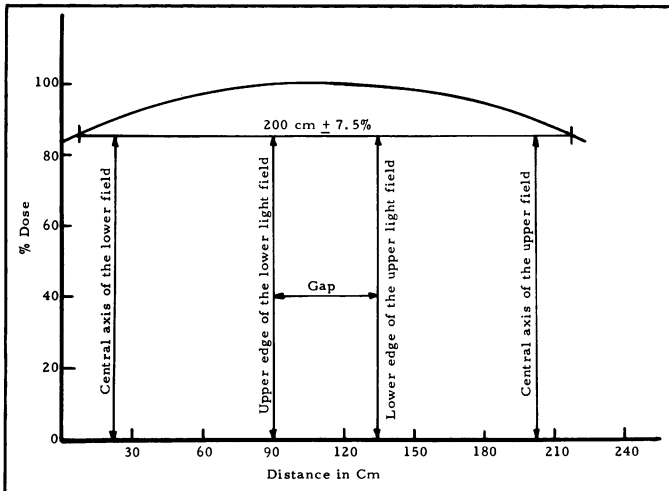

Figure 3. The dose along the vertical plane with dual fields matched at 50 percent isodose line, with a gap of 45 cm between the lower and upper light fields showing ± 7.5 percent variation over 2 meters.

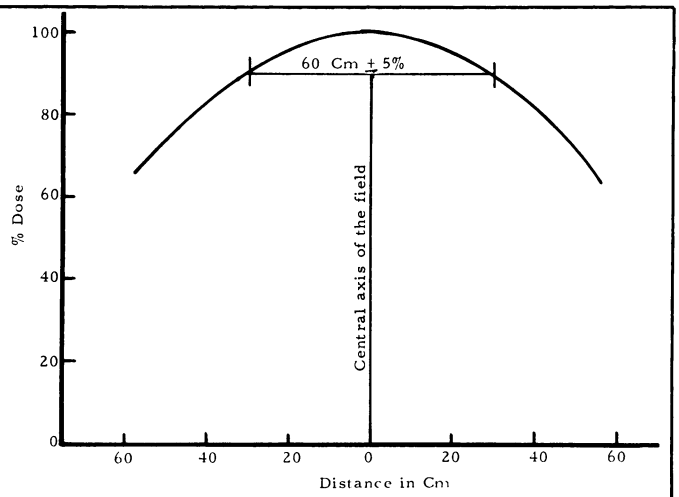

Figure 4. The dose along the transverse plane showing ± 5 percent variation within 30 cm on either side of the central axis.

be cut down considerably by lining the high atomic number Z collimator material with low Z material (eg, aluminum). We did not find this to be true with our machine. The major component of x-ray contamination comes from the primary scattering lead foil, and this can only be altered by changing the primary scattering lead foil with a low Z material. Since the x-ray contamination originates primarily from within the machine and its total dose is directly dependent upon the total exposure time, its relative proportion to the electron dose increases when the degrading plexiglass sheet is placed over the machine head. This increases scatter, and thus, decreases dose and increases total exposure time.

In our setup, with a 9.6 mm degrading plexiglass screen at 3 meters, and the patient 15 cm from the plexiglass screen, the x-ray contamination is <2 percent and is uniform throughout the body. This is confirmed by placing TLDs in the nasopharynx, stomach, and rectum in males and in the vagina in females. There is no evidence of more x-ray contamination at the axis of the beam as reported by Grollman et al.[13]

Protection of the Ocular Lens and the Nails

The lens and the nails can be effectively shielded from 3.2 MeV electron beam by lead shields of 1.5 mm thickness (Figures 6 and 7). This was confirmed by placing TLDs behind the lead shields, which gave a reading equal to the TLD readings in the nasopharynx, stomach, and rectum or vagina (readings due to x-ray contamination).

Discussion

The present linear accelerator with a minimum of 6 MeV electron capability can be used to treat mycosis fungoides. The 6 MeV electron energy can be easily degraded to 2.5 to 4 MeV electron energy by interposing a 9.6 mm thickness of plexiglass screen. If the screen is placed on the machine head for this purpose, the electron beam scatters after hitting the screen and the dose rate falls remarkably. Since the x-ray contamination of the electron beam is inherent, the percentage of x-ray dose increases with the fall in dose rate. Therefore, we found that when the screen is kept near the patient and away from the machine head, the percent of x-ray dose remains <2 percent, which is within acceptable limits. We also found that lining the high Z collimator material with low Z materials like 6 mm aluminum or 6 mm masonite cones did not change the x-ray dose of the electron beam as reported by Edelstein et al.[12]

Dose measurements both with TLDs and with ionization chamber in a single plane at the treatment distance (15 cm from the plexiglass screen) showed a deviation of ±5 percent along the transverse plane and ±7.5 percent along the vertical plane. The

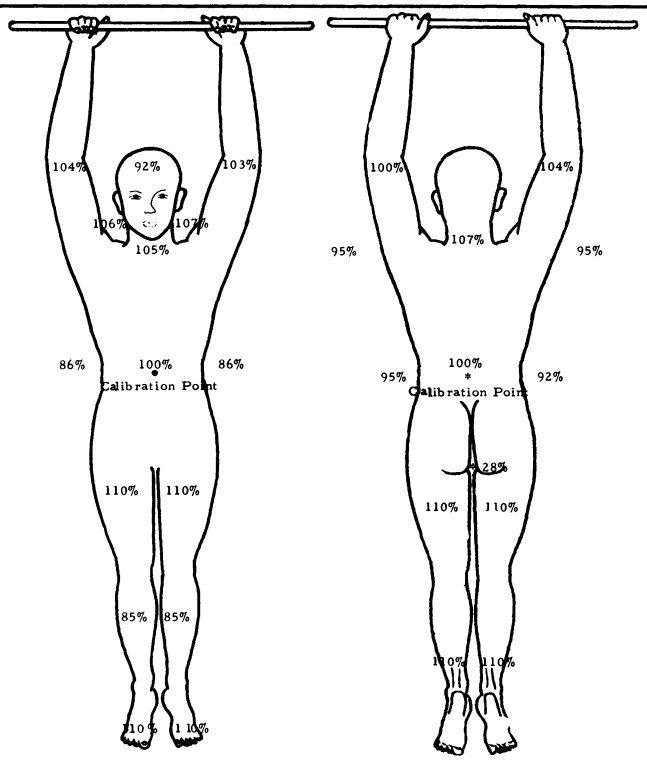

Figure 5. Actual dose measured on patient's skin using TLDs and standardized to the calibration point. There is a variation of ± 15 percent except in the perenial region where the dose is 30 to 40 percent of the total dose.

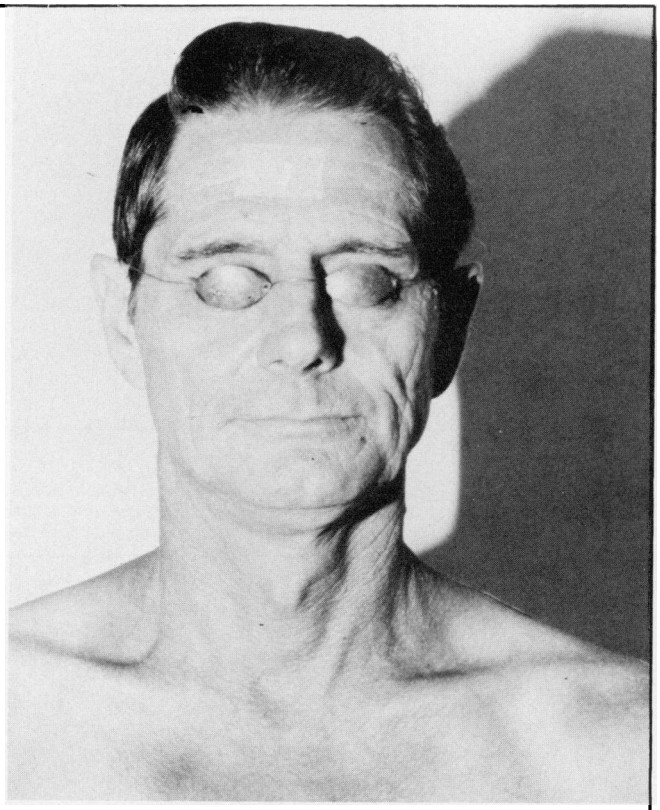

Figure 6. 1.5 mm lead shields protecting the eyes.

phantom measurements over the entire surface, however, showed ±10 percent variation. Actual measurements on patients showed a dose variation of ±15 percent, except in the perineal region, where the dose is about 30 to 40 perpercent of the total given dose due to self-shielding. Dose measurements behind the lead shields for the eyes and nails showed that 1.5 mm lead is sufficient to cut off 100 percent of the electron dose, but does not affect the x-ray dose. Repeated midline body dose measurements with TLDs in the nasopharynx, stomach, and rectum in males and the vagina in females, showed that the total body exposure due to x-ray dose is <2 percent and is within acceptable limits.

Our initial studies show that further improvement in dose distribution over the skin can be made by using rotation technique. This will be further studied and reported later.

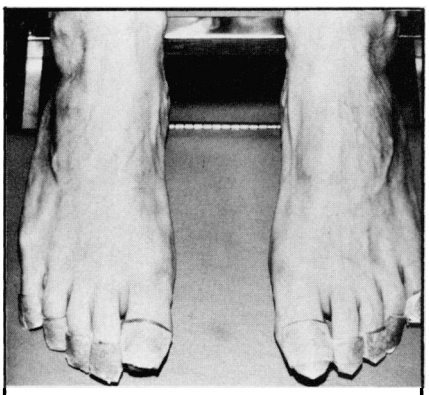

Figure 7. 1.5 mm lead shields protecting the toenails.

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