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RADIATION THERAPY OF THE LARYNGEAL AND TRACHEAL TUMORS WITH
HIGH ENERGY ELECTRONS USING PENCIL BEAM SCANNING*

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By

MELVIN L. GRIEM, M.D., LESTER S. SKAGGS, PH.D., LAWRENCE H. LANZL, PH.D.
Chicago, Illinois

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IN NUCLEAR SCIENCE ABSTRACTS

*From the Department of Radiology, the University of Chicago, and the Argonne Cancer Research Hospital, operated for the United States Atomic Energy Commission by the University of Chicago

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In 1955, Skaggs, Nygard and Lanzl (1) described the initial experience with a 50 MeV microwave linear accelerator for electron beam therapy. The electron beam is produced in an accelerator of the travelling wave type powered by two klystrons in cascade (Fig.1). A variable energy of between 5 and 55 MeV is obtained by the proper combination of radiofrequency power level of the klystrons and the phase of the electrons with respect to the radiofrequency wave in the second section of the wave guide. After leaving the accelerator, the electrons enter a magnetic section system which produces a unique pencil beam deflecting and scanning system (2) (Fig.2). The beam is approximately 0.5 cm in diameter, and may be programmed so as to scan an area of various shapes and sizes up to 20 x 20 cm using one treatment arrangement. A second method of treatment is possible by rotating the magnetic deflection system about an axis through the center of the accelerating tube. By such rotation it is possible to do pendulum beam therapy with electrons. Films exposed in a homogeneous unit density phantom to such programmed treatment at three different energies produce a crescent shape exposure (Fig.3). On entering a water phantom at 35 MeV the pencil beam shows Cerenkov radiation (Fig.4). The beam is pulsed and has a repetition frequency of 60 cycles per second. The pulses are approximately one microsecond in duration. Because of the magnetic deflection of the electron beam and a collimator which limits the electron energy to a band, a monochromatic beam of electrons is presented for patient treatment. The intensity of the beam is established in the knowledge of the area covered by the beam per unit time and the absolute value of the electron current. A Faraday cage based on the design of Rozenfeld (3) has been used to measure the current (Fig.5). The absorbed dose is determined on an absolute basis by making use of the energy and current intensity as well as the collision energy loss formulation of Sternheimer. The absorbed dose determination has been previously reported(4). We have also reported on some of the dosimetry associated with field therapy at the different energies between 10 and 40 MeV (4). Ishida (5) has reported on the treatment of tumors of the neck with a pendulum beam produced by foil scattered electrons. Laughlin (6) has outlined the problems associated with

treatment planning with electrons in homogeneous tissue. He has pointed out the different ranges of electrons with tissue inhomogeneities.

Since the neck is a relatively homogeneous structure, we postulated that the use of electron therapy with the finite range of the electrons in tissue for a given energy might be a consideration. An anterior field covering the neck and upper mediastinum might be suited for treatment of an advanced malignancy of the larynx. Using a commercial phantom containing material equivalent to the various tissues encountered in the neck and chest, dosimetry was estimated with industrial photographic film with AA emulsion. Using scanning beam field therapy, energies between 15 and 30 MeV were investigated. 16 MeV, 18 MeV + 22 MeV seemed most suitable for the treatment of the larynx and adjacent node areas usually involved in the more advanced tumors of the supraglottic, glottic, and subglottic regions. Patients with these advanced tumors usually have lymph node metastases to the anterior cervical nodes. The anterior fields provided the U-shaped region of uniform dose seen in Figs. 6, 7 and 8. These isodose patterns were obtained at 18 MeV and show how the spinal cord is protected by this approach.

Although lung cancer is a common tumor seen in our clinic, tumors of the trachea are quite rare. Dosimetry has been completed using the heterogeneous phantom at energies between 15 and 30 MeV. Energies between 25 and 30 MeV seem to be most suitable, as is indicated in Figures 9 and 10.

CLINICAL MATERIAL

Our experience with early tumors of the larynx has been reported previously (7). These patients were treated with both orthovoltage and supervoltage, and such conventional treatment produced an 85% five-year-survival. We have not modified that treatment.

In cases of advanced tumor of the larynx however, either radical surgery or x-ray therapy has failed in a high percentage of the cases in our series. Using the high-energy electron beam with an anterior field and dose distribution as described above, twenty-four patients have

been treated. (Table I) The treatment arrangement is shown in Fig. 11. When this picture was made, the patient had received a minimum tumor dose of 5800 rads. One month after the tumor dose had reached 7000 rads, the patient demonstrated only a mild skin reaction. At no time during the treatment was a wet skin reaction observed. Six months after treatment the appearance of the neck had returned to normal.

The first several patients treated in this fashion had surgery performed subsequent to the treatment. The interesting finding in those cases was that the primary tumor bearing area was without disease. In two patients, nodes containing tumor were noted just above the angle of the mandible, a site not reached by the anterior field as we initially used it. In current treatment arrangements, we extend the neck and head to reach these tumor bearing areas.

We have also treated eight patients following laryngectomy and radical neck dissection and find our results very encouraging. Three patients are without disease two and three years after therapy. Six patients have come to autopsy. In 3 of these patients lung metastases were present, although no tumor could be found in the neck.

Two patients treated with electrons alone have died of lung cancer of an entirely different histological type from the laryngeal tumor. In these two cases no tumor was found in the neck area. Six patients treated with electrons alone are without disease between one and two years after treatment. Three of the patients in this series had had previous treatment with other forms of supervoltage. The recurrent disease responded well in one of the three cases.

We are encouraged by the results in this initial trial. We are currently doing a randomized study on these advanced lesions to see whether combinations of surgery and radiation with the electron beam will produce even a higher salvage rate.

SUMMARY

1. Electron beam therapy for advanced tumors of the larynx with lymph node metastases offers a unique and simple approach to treatment.
2. Dosimetry for such treatment and for treatment of tumors

of the trechea is presented.

3. Results of treatment are encouraging with adequate control of advanced lesions of the larynx and with evidence to suggest control of lymph node metastases in a number of cases.

4. A brief description of the pencil beam scanning electron linear accelerator at the Argonne Cancer Research Hospital is given.

FIGURE LEGEND

Figure 1. The electron linear accelerator of the Argonne Cancer Research Hospital as photographed at the High Voltage Engineering Corporation Laboratory. In the foreground three klystron stations are shown, one of them a spare. On the left is the accelerating tube.

Figure 2. A schematic diagram of the pencil beam scanning and deflecting system showing the three deflecting magnets, the rotating shield, and treatment arrangement. By motion of the magnet number 3 about axis BB' field scanning as shown in the inset can be obtained. Pendulum scanning can be obtained by rotation of the shield about axis AA' .

Figure 3. Films exposed to pendulum scans at 5, 10 and 15 MeV.

Figure 4. Water phantom exposed to 35 MeV electrons.

Figure 5. Faraday cage for absolute calibration measurements.

Figure 6, Figure 7, Figure 8. Isodose patterns at 18 MeV. Field size 12 x 13 cm. Three cross-sections of the neck are demonstrated.

Figure 16. Isodose pattern produced by the automatic dose plotter from photographic film exposed at 25 MeV. The level in the chest is 5 cm below the sternal notch.

Figure 10. Isodose pattern produced at 30 MeV, same level as Figure 12.

Figure 11. This picture demonstrates the treatment position. The patient had received a minimum tumor dose of 5800 rads at the time of this picture.

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Figure 2

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Figure 2

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figure 1

figure 3

FILMS EXPOSED
TO ELECTRONS

5 cm

5 MEV

10 MEV

15 MEV

Figure 4

Figure 5

Figure 4

ELECTRON ENERGY 18 MEV
FIELD 16 X 13cm

Figure 7

ELECTRON ENERGY 18 MEV
FIELD 16 X 13cm

Figure 8

ELECTRON ENERGY 18 MEV
FIELD 16 X 13cm

Figure 9

ISODOSE DISTRIBUTION - LINEAR ACCELERATOR
ELECTRON BEAM ENERGY 25 MEV
FIELD SIZE 17cm X 12cm
HETEROGENEOUS PHANTOM No. 109
SECTIONS 12-13

Figure 10

ISODOSE DISTRIBUTION - LINEAR ACCELERATOR
ELECTRON BEAM ENERGY 30MEV
FIELD SIZE 7cm X 12cm
HETEROGENEOUS PHANTOM No. 109
SECTIONS 12-13

Figure 11