[Reprinted from RADIOLOGY, Vol. 146, No. 2, Pages 531–532, February, 1983.]

Robert F. Moyer, Ph.D.[2]
W. R. McElroy, Ph.D.
Joan E. O'Brien, R.T.
Charles C. Chamberlain, Ph.D.

A Surface Bolus Material for High-Energy Photon and Electron Therapy[1]

The authors describe a useful bolus material for therapy with high-energy photons and electrons (>1 MeV). Qualities evaluated included flexibility, transparency, tissue equivalence (*re* radiation interactions), stability at high doses, durability, lack of toxicity, ease in cleaning, low flammability, and cost. Using a parallel-plate ionization chamber and ^{60}Co, 4-, and 10-MV photons as well as 6- and 18-MeV electrons, maximum deviation from water-equivalent values was approximately 2 mm for 6-MeV electrons. The material comes in large sheets of precise thickness (±0.5 mm) which can be cut and layered to form more complex shapes.

Index term: Therapeutic radiology, instrumentation

Radiology 146: 531–532, February 1983

In radiation therapy, *bolus* is defined by the International Commission on Radiation Units and Measurements (ICRU) as "tissue equivalent material placed around the irradiated object to provide extra scattering or build-up or attenuation in the beam" (1). In addition to tissue equivalence, bolus material should be transparent enough to show the location of the beam, flexible enough to conform to the surface contours, available in variable configurations, unaffected by high dose levels, durable, nontoxic, easy to clean, nonflammable, and available at reasonable cost. One substance that appears to meet several of these requirements was found to be currently in use in mattresses and wheelchair pads under the name Elastomeric.[3] We conducted quantitative and qualitative tests on specially constructed samples of this substance to evaluate its usefulness as a bolus material in high-energy radiation therapy.

MATERIALS AND METHODS

Variable thicknesses of Elastomeric bolus, alone or in combination with polystyrene, were evaluated with an electron chamber[4] at various depths in a polystyrene phantom. Polystyrene thickness was adjusted to a water-equivalent value based on electron density (actual thickness × 1.015), but bolus thickness was not. The average value of readings made with both collection-potential polarities was used to measure near-surface density of ^{60}Co,[5] 4-, and 10-MV photons and 6- and 18-MeV electrons.[6] Fractions by weight, calculated from constituent chemicals, are shown in TABLE I.

RESULTS

Figures 1–3 show relative measurements. Those made with bolus material for photons and 18-MeV electrons were within precisional uncertainty (typically <0.5%) of expected values based on measurements in polystyrene (adjusted for electron density difference relative to water) and clinical depth-dose data in water. Depth-dose values in the Elastomeric bolus for 6-MeV electrons deviated from adjusted polystyrene data by approximately 2 mm. Density of several samples from different batches was 1.03 g/cm as determined by mass per unit calculated volume and by Archimedes' principle. The "effective" density relative to water was 1.02 based on electron density (2) and 0.993 according to the method of Datta *et al.* (3).

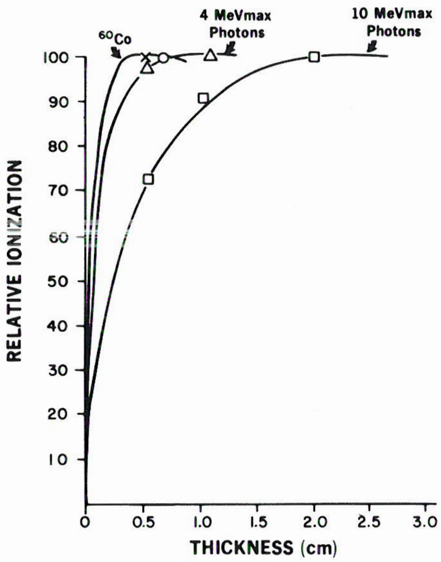
Localization marks on the skin surface were readily visible through a 1-cm layer of Elastomeric bolus and marginally through two 1-cm layers. Figure 4 illustrates the flexibility and transparency of a 0.5-cm sheet. Although not specifically tested by scientific methods, thickness did not appear to be affected by sharp curves; however, the protective skin induced wrinkles <1 mm in depth.

A small sample was irradiated to a dose of 1 Mrad (10 kGy) with no qualitative changes in color or elastic properties. In addition, the basic matrix material was found to be free of skin irritants (4) and resistant

---

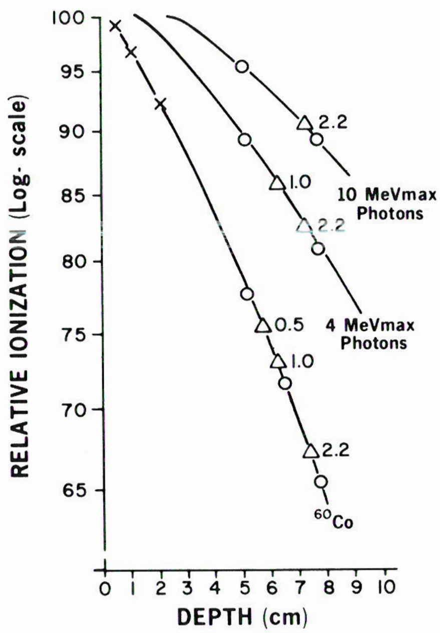
[1] From State University of New York/Upstate Medical Center, Syracuse, N.Y. (R.F.M., J.E.O., C.C.C.), and Action Products, Hagerstown, Md. (W.R.M.). Received March 2, 1982; revision requested May 17; revision received May 25 and accepted June 29.
Presented at the Twenty-third Annual Meeting of the American Association of Physicists in Medicine, Boston, Mass., August 9–13, 1981.
[2] Present address: Radiology Department (Physics Section), Reading Hospital and Medical Center, Reading, Pa. 19603.
[3] Action Products, Hagerstown, Md.
[4] Markus PTW, Nuclear Associates, Carle Place, N.Y.
[5] Picker V-9, ATC Medical Technology, Sunnyvale, Calif.
[6] Clinac 4 and Clinac 18, Varian, Palo Alto, Calif.
sjh

Figure 1



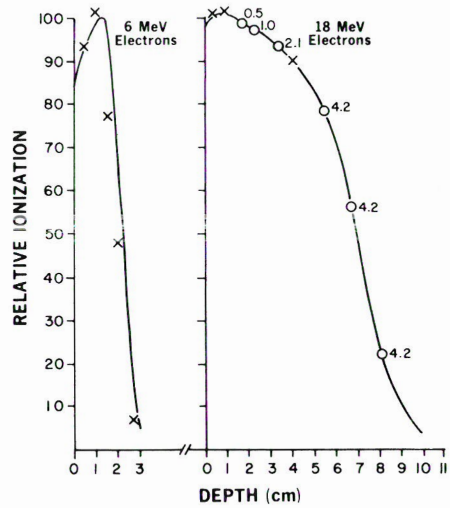
Relationship between thickness and ionization at a fixed source-to-chamber distance. Solid lines are based on concomitant measurements in polystyrene, which were adjusted to compensate for differences in electron density between it and water. x = ^{60}Co bolus only; O = ^{60}Co bolus and 0.16 cm polystyrene; Δ = Clinac 4 bolus only; □ = Clinac 18 (10X) bolus only.

Figure 2



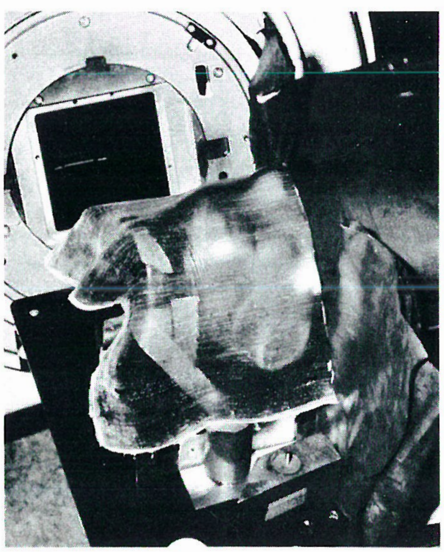
Relationship between depth and ionization when evaluating photon attenuation by a surface bolus. Solid lines are based on clinical data in use. The chamber position was fixed for 4- and 10-MeV photons (TMR; 80- and 100-cm source-to-axis distances) and variable for ^{60}Co measurements (% depth dose; 80-cm source-to-surface distance). O = water-equivalent polystyrene thickness; x = actual thickness of bolus only; Δ = bolus and polystyrene (numbers indicate thickness of bolus in cm).

Figure 3



Relationship between depth and ionization for 6- and 18-MeV electrons. Solid lines are based on concomitant measurements in polystyrene (water-equivalent thickness is shown). x = bolus only; O = bolus and polystyrene (numbers indicate thickness of bolus in cm).

Figure 4



Multiple-field treatment of facial skin with 9-MeV electrons. The sample has prototype skin with slightly less transparency and more flexibility than the final product.

TABLE I: Fraction of Elastomeric Bolus Elements by Weight

Element	Fraction
Carbon	0.639
Oxygen	0.252
Hydrogen	0.0992
Nitrogen	0.00922
Tin	0.00026
Silicon	0.00053

to fungi (5) and fire (6). Repeated cleaning with soap and water or ethanol produced no qualitative changes in physical properties.

Elastomeric bolus can be cast precisely with less than 0.5-mm variation over an area of at least 30 × 30 cm. The price of the cast material with protective plastic covering is approximately 20¢ per cm^3 in sheets suitable for a surface bolus.

DISCUSSION

Due mainly to its tissue equivalence (1–18 MeV), flexibility, and transparency, Elastomeric material has proved to be an excellent surface bolus for radiation therapy. We have used it for this purpose for more than a year and have also found it to be useful in dosimetry for (*a*) phantom shaping and (*b*) build-up for surface TLD measurements. The material can be cut easily and layered to form complex shapes, as in chest wall thickness compensation and construction of special phantoms. Probably it would also make an excellent transparent phantom material, but this possibility has not been fully explored.

Radiology Department
Physics Section
Reading Hospital and Medical Center
Reading, Pa. 19603

References

1. Determination of absorbed dose in a patient irradiated by beams of x or gamma rays in radiotherapy procedures. ICRU Report 24. Washington DC: ICRU, 1976:51.
2. Procedures in external radiation therapy dosimetry with electron and photon beams with maximum energies between 1 and 50 MeV. Recommendations by Nordic Association of Clinical Physics (NACP). Acta Radiol Oncol Radiat Ther Phys Biol 1980; 19:55–79.
3. Datta R, Datta S, McDavid WD, Waggener RG. Electron beam depth dose scaling by means of effective atomic number reconstructed from CT scans. Med Phys 1979; 6:526–529.
4. Schwartz patch test. Standard method ASTM D1924-63. Letter from U.S. Testing Co., Hoboken, N.J., Dec. 9, 1969.
5. Mildew resistance test. Standard method ASTM D1924-63. Letter from U.S. Testing Co., Hoboken, N.J., Sept. 12, 1969.
6. Flammability test. Standard method ASTM D1692-68. Letter from Lancaster Laboratories, Lancaster, Pa., Feb. 6, 1980.

M5014-000