SOFT X-RAY SOURCES AS A MEANS OF REDUCING MEDICAL EXPOSURE TO RADIATION

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Abstract—Medical use provides a major source of population radiation exposure. This includes exposure from the use of radium and other radioisotopes in the implant treatment of cancer. In such implants, the radio-therapist, patient, visitors, and attending staff, all typically receive some unwanted radiation.

A promising means of essentially eliminating such exposure is through the use of soft X-ray emitting radioisotopes as a replacement for radium and radon in brachytherapy. Particularly promising are the soft X-ray emitters cesium-131 and iodine-125, which emit monoenergetic 30 keV X-rays free of beta or higher energy gamma radiation. These radioisotopes, when properly encapsulated, provide a suitable substitute for use in radiotherapy. They have the marked advantage in that their radiation can be completely shielded by thin layers of heavy metals, yet they have a practical range in tissue. Physics, dosimetry, animal and clinical tests with human cancer patients have been initiated using commercially available miniature sources of ^{125}I and ^{131}Cs. Experience with these sources, called X-seeds, has now shown that they can be used to significantly reduce radiation exposure while at the same time they provide a substantially uniform tumor dose. In one instance, 970 mCi of ^{131}Cs were inserted in a leisurely series of animal implants, and, by the simple expedience of using a radiologist's lead apron, the radiotherapist kept his whole body dose under 1 mR and his hand dose under 10 mR. Recent progress and clinical experience with these sources will be described.

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DISCUSSION

T. F. JOHNS (*U.K.*):

I was interested to hear that the Riso workers had failed to find agreement between the sodium flame test and the Pollak counter for determining the efficiency of filters. At Winfrith we have found remarkably good agreement between these two methods, and as a result we are now beginning to use the Pollak counter for the routine *in situ* testing of filters. This technique is so simple that we feel that this represents a real break-through in the business of *in situ* filter testing; other methods are difficult to perform, and as a result such measurements are frequently not made at all.

D. K. CRAIG (*South Africa*):

It depresses me to hear of filter testing procedures and filter efficiencies still reported with no reference to aerosol particle size distributions. Theoretically speaking, the physical properties of aerosols are such that one must obtain a minimum filtration efficiency for a given particle size. I know that there has been a lot of controversy about this, but, for aerodynamic equivalent unit density spheres, this minimum occurs at approximately 0.3μ diameter. If results different from this are reported, then an attempt should be made to advance a theoretical explanation for the difference (e.g. there will be a shift to smaller particle diameters in the minimum as the face velocity of air passing through the filters is increased). I disagree that the Pollack counter method can give an accurate measure of the minimum filter efficiency. I still believe that the best way to measure the efficiency of filters is to use 0.3 μ diameter spheres, such as are available from the D.O.P. generator. With the use of an 0.3μ diameter D.O.P. aerosol, one is not bothered by the varying filter efficiencies as a function of particle size. What one is measuring, then, is the minimum efficiency of the filter, the parameter in which I think we should be interested.

T. F. JOHNS:

No one was more surprised than we were when we found these two methods gave agreement. The explanation appears to be that one is not measuring true penetration, but merely finding how much aerosol passes through a small number of imperfections, the latter being so big that the apparent penetration is quite independent of particle size.

D. K. CRAIG:

In reply to Mr. Johns, what he is measuring is the efficiency of installation of the filter, not the filter efficiency, and I think that this point should be made clear when reporting filtration efficiency results.

T. F. JOHNS:

I quite agree, but I would point out that the whole purpose of *in situ* testing is to measure the effectiveness of the installation.

H. FLYGER (*Denmark*):

The photoelectric nuclei counters are not easily moved around for *in situ* testing of filters. The counters are heavy and the light source is easily put out of focus. The use of the lithium test is nevertheless very easy.

D. C. LAWRENCE (*U.S.A.*):

I would like to ask the authors if they can give further details on why they feel the testing of radon is not satisfactory for leak testing of radium needles and what it is they propose or suggest.

L. B. BEENTJES:

Possibly Mason refers to sealing of the Ra needles by water using the method of carbon in water. This was pointed out at the Health Physics meeting in Los Angeles in 1964.

K. KRISTENSEN (*Denmark*):

Have any measurements been made with regard to internal contamination of personnel?

PH. C. JOHNSON:

We have been unable to find Hg^{203} in the kidneys or urine of our laboratory personnel.

D. C. LAWRENCE (*U.S.A.*):

Were the commercial suppliers advised of the problem and if so what was their explanation of the apparent contamination?

PH. C. JOHNSON:

We notified the manufacturers. Their response was, essentially, to deny that it occurs. However, at least one supplier has begun to wash his bottles with acid prior to shipment.

D. C. LAWRENCE:

If the Chairman would permit, I would like for a minute to discuss another approach toward solving the problem of radiation exposure from interstitial therapy.

Essentially the problem which was outlined in the last paper is one of a radioactive patient after he has received interstitial therapy, and the patient must be handled with extreme care in order to prevent exposure of visitors, the person who has installed the radioisotope, and even the nursing staff.

Ideally what is desired is to install the radioisotope and have the radiation exposure uniformly distributed and yet remain within the tumour volume. One way of achieving this can be shown in Table I, which shows several radioisotopes now being used for radiotherapy, including Ir^{192}, Rn, and Au^{198}, the isotopes which were mentioned by the last author. If you look over to the last column, the shielding requirements as characterized by the lead half-value layers for Au^{198}, radon, and iridium range from 0.13 to 0.53 inches and they have a half-value layer in water of 7 to 9 centimeters. Now, if we look at the last three isotopes, I^{125}, Cs^{131} and Xe^{133}, you will note that these have varying half-lives from 5.3 days to 60 days and emit only soft X-rays. This results in the fact that a very small amount of lead can be used to shield these isotopes (Pb HVL = 0.001[11]) and yet they still have a reasonable range in tissues of 2 to 5 cm.

Table I. *Radioisotopes for Permanent Implants*

Radioisotope	Half-life	Gamma radiations	Other	Half-value layer Pb	Half-value layer H_2O (tissue)
Au^{198}	2.7 days	0.411 & 0.680 Mev	0.97 Mev β	0.13 inch	$\simeq$ 7 cm
Rn^{222}	3.8 days	0.24–2.43 Mev (many)	Alpha (2) & 0.65 Mev β	0.53 inch	$\simeq$ 9 cm
Ir^{192}	74.2 days	0.2–1.1 Mev (many)	0.54 & 0.67 Mev β	0.14 inch	$\simeq$ 7 cm
I^{125}	60 days	28 & 35 Kev	None	0.001 inch	$\simeq$ 2.1 cm
Cs^{131}	9.7 days	29.4 Kev	None	0.001 inch	$\simeq$ 2.1 cm
Xe^{133}	5.3 days	32 and 80 Kev	0.35 Mev β	$\simeq$0.01 inch	$\simeq$ 5 cm

We have approached the problem of radiation safety in interstitial implantation by incorporating these isotopes, primarily I^{125} and Cs^{131} in small seeds. By incorporating these isotopes in the small seeds, we noted the following advantages in interstitial therapy. First of all, by use of a radiologist's lead apron, we can eliminate the radiation exposure to the therapist. He can handle these isotopes using only a thin lead foil for radiation protection. Second, we have found an improved tumour dose distribution and therapeutic ratio over seeds of Au^{198} and Rn. Third, the reduction in exposure makes the implant therapy of very large tumours possible. We have also found it possible to protect healthy adjacent tissues by the use of thin metallic foils, particularly gold foils, which are non-toxic, and I^{125} seeds permit simple out-patient treatment, because the dose is retained within the tumour. It also makes possible the use of such isotope therapy in remote areas, because the sources can be carried safely by air in a very small lead container. The complete protection of the nurses and other patient associates also becomes a reality. The I^{125} seeds thus developed have now been used to treat over a dozen cancer patients. We have been able to see in actual practice all of the desired advantages, and we are going on with clinical testing.

This is just one way of solving the problem which was outlined in the last papers.

S. LIN (*Italy*):

Desidero ricordare un semplice dispositivo che viene impiegato nel nostro Laboratorio, costituito da un ago da anestesia tipo Olorson-Gohrd, il quale permette di iniettare il radionuclide, attraverso la piccolo camera chiusa da una membrana di gomma, dopo aver proceduto all'immissione dell'ago in vena.

Vorrei chiedere anche all'autore se ha esperienza del grado di contaminazione dell'aria ambientale, determinata dall'espirazione di pazienti sottoposti a terapia con alte dosi di radioiodio.

Vorrei infine richiamare l'attenzione su di una apparecchiatura costruita in Italia dalla SORIN-Saluggia, la quale permette non solo di eseguire a distanza l'infissione di sferule di materiale radioattivo, ma anche di contarne il numero per mezzo di n dispositivo elettromagnetico.