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# The Achievement of a common standard for Dosage Statement in Radiotherapy

*Mr. Chairman, Ladies and Gentlemen,*

In my contribution to this symposium I wish to illustrate, in moderate detail, some of the contributions which a physicist can make to successful radiotherapeutic practice. To do this I have chosen to discuss the achievement of a common standard for Dosage Statement in Radiation Beam Therapy.

My remarks are intended to apply quite generally to both conventional (300 kV) and megavoltage radiations; since it is by no means certain that there is no place for 300 kV radiation in this megavoltage era. The same sort of ideas will also apply to electron beams but I shall not refer to these again as I have no personal experience of their use.

In his contribution earlier this afternoon Dr. Cohen discussed the general problems involved in prescribing and determining the desired treatment distribution. I shall now discuss some of the part played by the physicist in helping to ensure that not only is this dose distribution achieved but also that the correct magnitude of dose is delivered.

Although I shall refer to the work of the Physicist what I am really talking about is the Physics: that is the tests and measurements which must be carried out if good, consistent radiotherapy is to result. Clearly this physics is best done by a Physicist but if, for any reason, it is not possible to have the collaboration of a properly trained and qualified physicist then it will be the responsibility of the Radiotherapist to supervise this work or even do it himself. It may be possible, even if not advisable, to work without a physicist but this must not mean that the necessary Physics is neglected.

Now what needs to be done? Firstly we must ensure that the apparatus is working properly and that it continues to do so. I am not implying that the Physicist needs to be also an X-Ray Engineer - although in fact he often becomes one. But it is the Physicist who knows when the apparatus needs to be adjusted or repaired and it must be his responsibility for seeing that this is done properly.

I know that we should expect a new piece of equipment to be correctly installed and to continue to work properly. Unfortunately this is not always the case. For instance I have known 250 kV X-Ray Sets to be supplied with unsuitable and incorrect applicators: cobalt units to be left with their sources off centre and Betatrons to have beams which change their direction from day to day or even from hour to hour.

In considering whether the equipment is working properly we are concerned with such things as the X-Ray Tube Voltage and Filtration which control the penetrating power of the radiation. We also need to know that the collimating system is correct. For instance, is it defining a beam of the correct size such that if we set, say, 8 $\times$ 10 on the dials the resultant beam is of the same size as would be obtained on other equipment or even on the same equipment at different times for the same 8 $\times$ 10 setting?

It is only when we are sure of the radiation beam quality and collimation that we can use the % Depth Dose Data and Isodose Charts referred to by Dr. Cohen. The Source Skin Distance is also important but not critically so.

In addition we need to be sure that the beam is pointing in the direction we think it is.

By way of example of this type of work I would like to describe the very simple tests which can be made on, say, a Cobalt Unit to check that the beam direction and the collimators are correctly aligned and, what is equally important, remain so. These tests must be done before the equipment is used for treatment and should be repeated from time to time, say every 3 or 6 months.

The intended central axis of the beam is indicated in some way or other, usually by means of front and back pointers. These may be either mechanical or optical. The slide shows a mechanical back and front pointer being used to direct a 4MV Linear Accelerator beam through a patient. It is also useful to have a visible light beam of the same size as the X- or $\gamma$-ray beam, centred about the same axis. In addition the collimators are usually arranged to rotate about the beam central axis. The slide shows that when the unit is in correct adjustment:

1) The front and back pointers point along the axis of rotation of the collimators at all S.S.D. 's.

2) The collimator jaws are symmetrical and move symmetrically about this axis.

3) The light is (or is effectively via a mirror) on this axis.

4) The source is centred on this axis.

The technique for checking that this is so is very easy and the order in which this is done is:

a) Adjust the front and back pointers so that when the collimator is rotated the tips of the pointers remain stationary at all S.S.D. 's. The two slides show this. We can now see where the eventual central axis of the beam is.

b) Adjust the collimators to be symmetrical about this axis by observing that the edge of the light patch, defined by first one and then the other jaw remains stationary when the collimators are rotated through 180°. This can be done even if the light beam is not yet in correct adjustment.

c) Adjust the position of the light (or mirror) so that the light patch is symmetrical about the front pointer.

d) Adjust the source position so that the reading obtained on an ionisation chamber placed in the edge of the beam and fixed to one side of the collimators, reads the same when the collimators are rotated through 180°.

This technique works if the light bulb remains stationary as the collimators rotate. If it moves with them then the light-adjustment and collimater must be done in the reverse order.

Having now satisfied ourselves that the Unit is correctly aligned we can either use appropriate published % D. D. data and isodose charts with confidence or set about measuring our own data knowing that our efforts will not be wasted. Even if we intend to use published data it is probably worthwhile and advisable to check the %. D. Doses for one or two conditions of beam size and S.S.D. to confirm the data.

Let us now consider the problem of how shall we determine the absolute magnitude of the dose.

Although absolute accuracy in our statement of dose delivered to the patient is desirable, it is even more important that all radiotherapists, in all centres and at all times should mean exactly the same thing when they state that a particular patient was given a dose of 5,500 rad, say. It is only if this is so that previous experiences at the same and different centres may be profitably exchanged and used to improve techniques. In other words it is vitally important that a common language should be adopted by all radiotherapists and that the standard

adopted shall remain constant over the years. To do this two things are required. Firstly we must decide what our language or standard is to be and secondly we must apply it correctly.

In view of the limited time I shall restrict my remarks to the determination of the dose at the 100% point of the Depth Dose Data for a single beam in water. It is useful to define the Output for a single beam as the dose rate at this 100% point. The actual value of the Output will, on a given unit, depend upon such things as beam size and source skin distance. The output is usually expressed in terms of a monitor dose meter reading or, in the case of a teleisotope unit, a time. Even for an isotope unit the outputs must be measured, it is not possible to calculate them.

Once we know the Output for each of the beams employed in a treatment we can then determine the dosage inside the patient by the use of appropriate depth dose data together with correction factors appropriate to the actual shape and composition of the patient. Exactly how this is done was described by Dr. Cohen in his comprehensive review earlier this afternoon.

In determining the Output there are two distinct problems:

1) The choice of a suitable dosemeter and the selection of a suitable standard for the calibration of this dosemeter and
2) The selection of a suitable technique for the actual Output measurement.

In 1957 the Hospital Physicists' Association published a Code of Practice for the measurement of x-rays in the quality range 0.5 to 5.0 mm.Cu.H.V.T. More recently they formulated a code for use over the Megavoltage range extending from Caesium 137 $\gamma$-rays to 8 MV X-rays. The ideas which I am describing this afternoon have been incorporated in these Codes.

Although there are now many possible types of dosemeters available, for instance the various solid state devices and the ferrous sulphate system already described today by Professor Dutreix, I am certain that for many years to come the thimble ionisation chamber dosemeter will continue to be the instrument of choice for this type of work. Its reliability, consistency and reproducibility are too well known and appreciated for it to be discarded yet. This applies for both conventional and megavoltage radiations.

Now let us consider the Standard which we should adopt for conventional quality x-rays. The one which has been in use

for very many years is, of course, the roentgen, as measured by a Free Air Chamber. During this time many changes have been made in both its definition (or even meaning) and in its experimental realisation. I think that it is now fairly certain that both have settled down and that dosemeters calibrated at the various National Standardising Laboratories are in good agreement and that the standard will be constant in time.

As a result of the calibration, we are given a factor, $N\lambda$, which varies with radiation quality. The product of this factor and the instrument reading (corrected for temperature, pressure and humidity) equals the exposure in roentgens at the position of the centre of the chamber.

It is important that the calibration of the dosemeter should be checked from time to time for changes in both overall sensitivity and in its response to different qualities of radiation. This is best done by returning the instrument to the standardising laboratory but since this cannot conveniently be done at intervals of less than 2 or 3 years some other intermediate checking of the dosemeter is essential. The overall sensitivity can be checked very simply by means of a radio-strontium source into which the chamber can be fitted in a very reproducible position. All that is required is to check that the reading per minute (corrected for strontium decay) stays constant in time. Unfortunately this does not check either the variation of sensitivity with wavelength nor any change in the electrical saturation properties of the dosemeter which could affect its response to different dose-rates. The wavelength response can really only be checked by a recalibration, but a comparison of two or more chambers attached to the same or different electrical systems at a soft and a hard quality is useful. The change in wavelength response is most likely to occur, if at all, with a new chamber in the first 2-3 years and for the soft, i.e., up to 0.5 mm Cu h.v.t. qualities.

As we once found to our dismay, it is possible for the central electrode of a chamber to move especially if the cable is mishandled. This resulted in a loss of sensitivity at high dose-rates but not significantly so at low dose-rates because of a change in the collection of ionisation. We now radiograph our chambers at 2 monthly intervals in order to confirm the constant position of the electrode.

A separate check on the electrical system may be made by means of a standard cell and this is useful in differentiating between a change in the sensitivity of the chamber and one in the associated circuitry.

I would emphasize that the calibration of a dosemeter is a fairly costly business and that for this and other reasons it

cannot be repeated too frequently. But it is our responsibility to do sufficient intermediate checks to allow us to be reasonably certain that the calibration factors which we are using are correct.

Assuming now that we have an instrument whose calibration factor we know, how do we make the measurement on the X-Ray Unit? There are three main methods - and probably hundreds of others.

1) A measurement at a point in Air.
2) A measurement at a point on the surface of a Water Phantom.
3) A measurement at a point inside a Water Phantom.

I would remind you that we are ultimately interested in the Output, that is the dose rate at the 100% point of the Depth Dose Data. Provided we have available direct experimental information about the relationship between the Output and the dose rate at our chosen measuring point there is little to choose between these methods and personal opinion of convenience is likely to dictate the choice.

It is when we look at the relationship between our measured dose and the depth dose data that the difficulty becomes apparent. It is very well known that the air dose varies with beam size and in a very different way on different designs of X-Ray Unit. This must, therefore, mean that, although the value of and variation with beam size of the Back Scatter Factor in substantially the same on different units operated at the same quality, the variation of surface dose with beam size is peculiar to the particular unit used because of the variation in the Air Dose. The net result is that if either an air dose measurement or a surface dose measurement is chosen, then we have to take very great care that the %D.D. data, subsequently used, is compatible with it. The only way in which this can be ensured is to measure the %D.D. data on the particular unit in use - or at least one identical to it.

The third method of making the calibration measurement at a depth, however, allows us to use published data for both %D.D. and Back Scatter Factors and yet achieve high accuracy of statement of nominal dose to the tumour. This type of calibration is the one recommended by the I.C.R.U. The method suggested is a follows:

The dose at as depth of 5 cm inside a water phantom is determined by direct measurement. We then evaluate the Output or dose at the 100% point by

$$O_1 = \frac{\text{Measured dose at 5 deep}}{\%\text{D.D. at 5 deep}} \times 100$$

This is for one particular size of beam and ideally, the relative doses at 5 deep should be measured over the range of beam sizes of interest and hence all the required Outputs determined.

However, it is possible to write

$$O_2 = O_1 \times \frac{\text{B.S.F.}_2}{\text{B.S.F.}_1}$$

where 1 and 2 refer to different beam sizes.

The advantage of this method is that since the measurement is made at a depth then the highest accuracy is obtained at this depth, which is after all where the tumour is. More importantly, perhaps, it allows us to achieve accuracys, of dose to the tumour even though we use published data for our % depth doses. Of course, it is essential to use the same publication for the % D. D. data used throughout and also to use compatible B. S. Factors. If several different S.S.D. 's are used then separate measurements will have to be made for each.

In this scheme the measured dose rate at 5 cm deep is the only absolute measurement required and therefore great care can be taken to make sure that it is done properly.

The depth dose data used may be locally measured but in view of the known difficulty of making these measurements and of the very slight differences between the results obtained by different workers, except near the surface, the common adoption of this method of measurement at 5 cm deep, coupled with the use of common published data, will lead, I think, to a much greater uniformity of dosage statement from centre to centre than I suspect in the present case.

There is a difficulty, of course; the insertion of the chamber into the water will disturb the dose we are trying to measure. The instrument reading indicates the dose at the position of the centre of the chamber. This, in principle, is different from the dose at the corresponding point in the complete water due to the replacement of a certain volume of water by the ionisation chamber. Fortunately, for the chambers usually used at least in Great Britain (for instance the Farmer-Baldwin, the Victrometer and the Victoreen) the increase due to extra transmission is almost exactly balanced

by the reduction in scatter and the overall effect is negligible. Clearly, however, the smaller chamber is to be avoided.

A second difficulty is that we need to know the quality of the radiation at a depth in water in order to know what correction factor to apply to the instrument reading. Fortunatly the magnitude of the doubt is small since most ionisation chambers have a factor which changes only slowly with quality in this range. We need to know the quality for other reasons, of course. Although I have not been too specific my previous remarks have really been about the determination of exposure dose in roentgens. What we need to know is the absorded dose in rads. For water and soft tissue this is easy for again the change with quality in the factor relating rads in these materials to roentgens is small. Knowledge of the quality is much more important, however, when we come to consider other materials such as bone.

Turning now to megavoltage radiation. Here there are several difficulties. The first is that the only widely used dosemeter calibration service is the British National Physical Laboratories 2 MV one. The second is that in order to determine roentgens, the chamber must be fitted with a thick cap and that the effects caused by the insertion of such a fat chamber into the phantom are potentially much greater than at 250 kV.

It is important to remember, however, that just as at 250 kV, our determination of the roentgen is only an intermediate step to the determination of rads. If the use of the roentgen leads to difficulties then we can discard it.

However, we would still like to use an ionisation method of measurement in view of the known reproducibility, accuracy and convenience of ionisation chambers.

We are all well aware that the observed ionisation in an air cavity is a measure of the absorbed energy in the surrounding medium or, in brief, the ionisation dosemeter reading is proportional to the absorbed dose (rads) in the thick wall of the chamber. In the suggested scheme for megavoltage dosimetry it is this fact which is utilised.

The method which is recommended is as follows.

1) The ionisation chamber is calibrated at 2 MV by the N.P.L. and for this calibration it is fitted with a perspex cap 4.6 mm thick. The resulting calibration factor is $N_{2MV}$.
2) The ionisation chamber, still fitted with its perspex cap of 4.6 mm, is placed with its centre at 5 cm deep in water.

3) The dose at the point 5 cm deep in water is given by

$$D_5 = R \cdot N_{2MV} \cdot C\lambda \text{ rads in water.}$$

where R is the in strument reading correted for temperature, pressure and humidity and $C\lambda$ is an overall conversion factor. This factor allows for:

a) The fact that we are measuring now at a quality other than 2 MV.

b) The disturbance caused by the presence of the chamber and cap.

c) The change from 2MV roentgens to rads.

$C\lambda$ is of course, a very important quantity. The value of $C\lambda$ which I shall be giving in a minute have been calculated by Bernard over the range Cs 137 $\gamma$-rays to 8 MV x-rays. They are substantiated by the calorimetric work of Bewley and of Law.

The slide shows the experimental arrangement and the next slide shows a measurement being done. The water phantom extends at least 5 cm outside the edges of the beam and at least 5 cm behind the chamber position.

The recommended values of $C\lambda$ are shown on the next slide. I would emphasize that no further factors are needed. Although strictly speaking these values of $C\lambda$ apply only if a 4.6 mm perspex cap is used for measurement in water, this is not critical. A change in the thickness of the cap means that water is being replaced by perspex or viceversa. The effect of this on the observed ionisation is slight. This has the result that the *same* factors apply for other reasonable thicknesses of perspex or even no extra perspex. These factors are for the Farmer and Victrometer chambers. Measurement on these and on a Farmer chamber constructed entirely of perspex show that these same factors will apply to all chambers of these types.

The factor for other types of chambers may of course be significantly different and I have no information about them.

Having now determined the dose at 5 deep for one beam size, the dose at the peak for this and other beam sizes may be evaluated using depth dose data and back scatter factors in exactly the same way as for 250 kV.

By using these recommended techniques which refer back to an N.P.L. standardisation there is no difficulty in all workers expressing their doses to exactly the same standard. Only one question remains. We have a Free Air Chamber Standardisation at 250 kV and a Carbon Thimble Chamber 2 MV Standardisation plus calculated factors, $C\lambda$ for 6 MV say. Do the final statements of dose in rads at the two different qua-

lities measured by reference to different standards both represent identical amounts of energy absorded per gramme?

The answer is yes, they do.

At the N.P.L. Barnard and Aston have intercompared at 250 kV the measurement of an exposure by (a) the Free Air Chamber and (b) the Carbon Chamber used for the 2 MV calibration. After initial difficulties due to metallic contamination of the carbon chamber which was very important at 250 kV although unimportant at 2 MV, they found that the two methods agreed to better than 1% which can be interpreted as meaning that the two standards, Megavoltage and Conventional, agree.

In parenthesis I should perhaps remind you that although 1,000 rads in water at 250 kV and at 4 MV represent the same amount of energy absorbed per gramme, the biological effects are not the same. The R.B.E. of 4 MV compared with 250 kV is about 10% less.

The present position is therefore that the physicist has available standardisation facilities at both conventional and megavoltage qualities up to 8 MV and that by the use of these recommended techniques there is no reason why nominal dosage statements of rads in water should not be uniform from centre to centre and from year to year and from country to country.

This afternoon I have been attempting to illustrate the way in which a Physicist can contribute to good Radiotherapeutic Practice.

I have done this in order to emphasize the fact that the physicist has an essential role in good radiotherapeutic practice. We must remember that the ultimate aim is to render the best medical aid to the patient and to do this in the most efficient manner. If the physicist can help in this — and I hope that there is no one here to-day who doubts whether he can — then the physicist should be allowed and be prepared to help.

As has been said already the greatest part of any clinician time is spent in doing routine work. The physicist must not be frightened of doing his share or feel that it is undignified or intellectually unsatisfying to play his necessary part.

From this a further point arises. The Physicist must be brought into the actual clinical atmosphere and must himself become aware of the problems. A good medical physicist is not one who sits in his « ivory tower » waiting for the problem to be brought to him. I would remind you that the actual and correct formulation of a problem is the most difficult aspect — the solution is often comparatively easy.

It is at the stage of the asking of the question that the physicist can and must start to be involved. Perhaps the most important questions are those which the clinician does not know exist. The physicist may be able to help him to recover some of these.

Hence, although the physicist is useful in actually doing or supervising the necessary tests and measurements of the type I have described to-day, I would suggest that his main importance lies in his knowing what tests and measurements need to be done. As has been pointed out by many previous speakers this can be done effectively only if the physicist is invited, allowed and willing to collaborate fully in all aspects of radiation work.

## INTERVENTI SULLA RELAZIONE

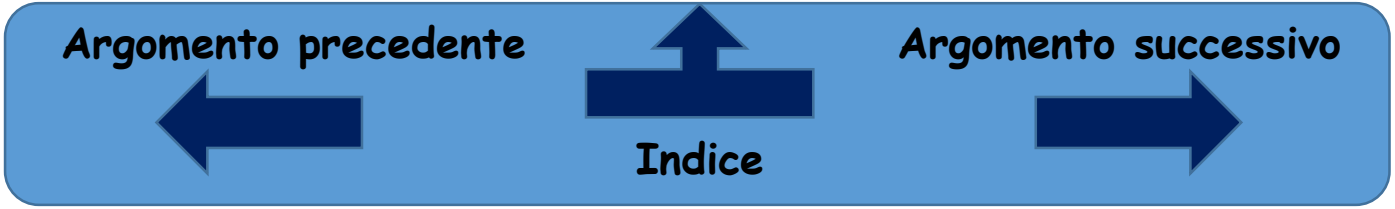
F. ELLIS

I should like Dr. Massey to say whether he considers 8MV — peak voltage as in the text, or 8MV, photon energy, as he said, to be the upper limit of the range for using his plan of dose measurements.

## RISPOSTA DEL RELATORE

J. MASSEY

The intended limit is as in the text, viz., it applies to radiation from an X-Ray machine having an equivalent peak voltage of 8 MV.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