ACCIDENT IN A LINEAR ELECTRON ACCELERATOR FOR MEDICAL USE

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ABSTRACT

Early in 1993, at a medical centre located in a north-eastern city in Argentina, the first 32 patients treated with a 6 MV photon beam electron linear accelerator, were accidentally irradiated for a total five weeks period at about twice the expected daily dose rates.

The accident occurred as a result of an erroneous calibration of the ionization chamber dosimeter of the medical centre causing an incorrect calibration of the accelerator's photon beam. Due to abnormal clinical effects shown by some patients, the radiotherapist took some actions that avoided an extension of the accident.

Fifty percent of the patients showed local injuries, while the severity observed in a patient's evolution could be associated with the received doses.

INTRODUCTION

During the commissioning in late 1992, the dosimetric acceptance tests of the linear accelerator were performed with a dosimeter owned by the supplier, because the ionization chamber dosimeter of the medical centre was only available in early 1993.

The radiotherapist had 8 year's experience in telecobaltherapy and had just finished his training in electron beam therapy, while the physicist who had been part of the operating team as required by the Argentine regulations, had completed his training in 1990. Since then the physicist had had further experience in telecobaltherapy without any additional performance in photon beam calibration.

INITIAL ACCIDENT CONDITIONS

1 - Situation before the photon beam calibration

The accelerator's physicist did with the following data before calibrating the photon beam: 1) The calibration certificate of the ionization chamber dosimeter, on whose accuracy the physicist did not doubt at all; 2) The results of the dosimetric acceptance tests performed by the supplier, indicating a value of approximately 1.4 m.u./cGy for the ratio between the readings -in monitor units (m.u.)- provided by the dose monitor installed in the radiation head of the accelerator and the doses to water delivered by the accelerator.

2 - Situation after the photon beam calibration

A beam calibration factor of Dw=2.3 m.u./cGy was obtained (absorbed dose in water phantom under standard irradiation conditions). This value could not be adjusted to the usual value of about 1 m.u./cGy and, consequently, an unsuccessful attempt was made to obtain advice from another physicists in Buenos Aires. The Dw value was not compared with the results of the accelerator acceptance tests, no double independent beam calibration was requested (1) and no inter-comparison of the medical centre's dosimeter and other dosimeter was made.

DEVELOPMENT OF THE ACCIDENT

1. The calibration factor for exposure in air of the medical centre's ionization chamber dosimeter, used to calibrate the photon beam when therapy started, was:

$$N_X = 47.41 \text{ Roentgen /digit}$$

2. Between the mid-second and late-third weeks in operation, some of the patients showed radiation induced early effects (diarrheic defecations, radiodermitis). Considering this situation, therapy was discontinued for the most compromised patients.
3. At such time, another physicist was called in and he verified that the doses planning was correct. An inter-comparison of dosimeters was planned but was not performed.
4. During the fourth week, treatments were restarted for some patients and treatments was started for some new ones. By the end of the fifth week, this second group of patients showed early clinical effects. Consequently, an inter-comparison of dosimeters was performed and the conclusion was reached that the doses received by the patients in the accelerator were 2.3 times higher than planned. At that time, all the treatments involving the use of the linear accelerator was discontinued.
5. A third physicist was called in and he assessed that the correct value of the calibration factor for exposure in air of the ionization chamber dosimeter was:

$$N_X = 109 \text{ Roentgen/digit.}$$

6. A total number of 32 patients were treated with dose rates higher than planned, before the dosimeter's calibration error was corrected.
7. Two weeks later, the accelerator's operation was restarted after reprogramming the treatments and since then no other patients have shown any unusual effects.
8. With decreasing frequency, an external physicist supervised planning work and doses administration with the accelerator.

RADIOPATHOLOGIC FEATURES AMONG THE AFFECTED PATIENTS

On the basis of the received doses, most of the patients showed early effects, particularly in their skin and mucosa, that is compartimental and high mitotic indexes tissues. Both the skin and the intestine are tissues with high α/β ratio values (10 Gy), in which the variation of the isoeffect dose with fractionating is weak (2); this fact explains the acceleration of the appearance of early effects and the increase of their severity with the administration of higher doses per fraction.

Table I shows the time **T** before appearance of early effects as of the initiation of the treatment and the doses received by the organs under treatment; Fig. 1 shows the excess of doses received by the patients with respect to that planned for the organs under treatment. The doses are indicated in terms of the instantaneous equivalent dose **De** given by Walinder's expression (3):

$$\mathbf{De(T) = \int_0^T 0.568\ \dot{D}(t)\ (T-t)^{-0.29}\ dt}$$

	Radiodermitis	Enterocolitis	Esophagitis
De (Gy)	13 to 26	14 to 24	17 to 21
T (days)	8 to 28	10 to 16	7 to 21

Table I: Instantaneous equivalent dose **De** received in organs under treatment and time T before appearance of early effects

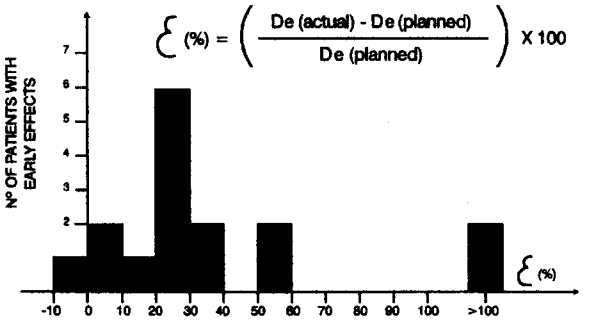

Fig. 1: Excess (%) of instantaneous equivalent dose **De** received, with respect to that planned for the organs under treatment

Concerning late effects, one of the patients showed radio-induced fibrosis and another one died after an intestinal resection a few months after receiving an instantaneous equivalent dose **De**=25 Gy. In the second case, there were early proctorrhage and symptoms compatible with those of a gastrointestinal syndrome. This involves the possibility of causality between this late effect and the cause of death.

The geographical isolation of the site, as well as the previous vital commitment of these patients and the scarce completeness of the clinical records of the patients, hinder in this accident the assessment of an unequivocal causality between late effects and the morbimortality associated with the treatments.

CONCLUSIONS AND LESSONS LEARNED

The accident was caused by an error in the calibration of the medical centre's ionization chamber dosimeter. The professionals involved did not perceive the hazard, in spite of the strong indications found (paradigm (4) of the accuracy of the calibration of the dosimeter).

The initial doubts were focused to the physicist's work; however, later on, considering the chronology of early signs and symptoms, suspicion arose that the doses being used might not be that foreseen and the decision was taken to inter-compare dosimeters. This confirms the relevance that the clinical follow-up of the patients has in order to early detect accidental situations, as it was pointed out in previous cases (5).

In order to prevent the occurrence of these type of accidents, a double and independent initial dosimetric calibration must be implemented (1) for electron linear accelerators, while technical training for the personnel must be intensified and made compatible with the complexity of the system they must use.

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