Acta Radiologica Oncology 21 (1982) Fasc. 3

FROM THE INSTITUTE OF RADIATION PROTECTION, SF-00101 HELSINKI, FINLAND, AND THE NATIONAL INSTITUTE OF RADIATION PROTECTION, S-104 01 STOCKHOLM, SWEDEN.

INTERCOMPARISON OF NORDIC THERAPY LEVEL EXPOSURE SECONDARY STANDARDS FOR ^{60}Co GAMMA RADIATION

H. JÄRVINEN and L. LINDBORG

As a part of a Nordic cooperation on standardization of dosimetry, an intercomparison programme of exposure standards was started in Helsinki, in connection with the third Nordic Meeting on Clinical Dosimetry and Standardization of Dosimetry (JÄRVINEN et coll. 1981). Because of its importance to radiation therapy (NACP 1980) it was decided to begin with an intercomparison of therapy level secondary exposure standards for ^{60}Co γ radiation. All the Nordic countries, Denmark, Finland, Iceland, Norway and Sweden, took part in the intercomparison.

The Nordic countries have adopted different laboratories as their primary calibrating laboratories (Bureau International des Poids et Mesures, Sèvres, France, BIPM, National Physical Laboratory, Teddington, England, NPL, and National Bureau of Standards, Washington, USA, NBS). It is well known that differences of about ±0.3 per cent exist between primary exposure standards (NIATEL 1975). Other reasons for discrepancies could be the different calibration procedures established in the different countries. An intercomparison between secondary standards in a secondary standard laboratory gives an opportunity to check these systematic uncertainties, which could have consequences for the clinical dosimetry work.

Method

The intercomparison was carried out in the calibration hall of the secondary standard dosimetry laboratory (SSDL) at the Institute in Helsinki. The radiation beam was a collimated ^{60}Co γ beam from an AECL Theratron 60 unit with an exposure rate of about 80 μA kg^{-1} at 1 m.

The exposure rate in the beam was determined with each of the standard ionization chambers using the technique normally applied at the SSDL Helsinki. The measurements were prepared and carried out mainly by the local staff which usually performs the calibrations.

The ionization chambers were positioned one at a time in the beam free in air at a distance of 1 m from the source. The positioning was made with an alignment telescope to ensure that the distances from the source to the centres of the chambers were the same within 0.1 mm. The chamber axes were perpendicular to the beam axis which coincided with the centres of the chambers.

The ionization currents from the chambers were measured using the equipment and the method normally used by the SSDL Helsinki. The equipment comprised of a Keithley 640 vibrating capacitor electrometer as a feedback-type current integrator, a standard air capacitor (1 000 pF) as the feedback capacitance, and a digital voltmeter (Solartron) for measuring the feedback voltage.

This voltage was taken at constant intervals and the ionization current was calculated from a series of voltage values by a computer programmed to correct for the cable capacitance, the stray capaci-

Accepted for publication 2 February 1982.

Table 1

Summary of intercomparison data and results. The exposure calibration factors for the secondary standards obtained from the primary standard laboratory are denoted by N_X

	Denmark	Finland 1	Finland 2	Iceland	Norway	Sweden
Secondary standard						
Chamber	Exradin T2	NE 2561	Exradin T2	NE 2505	NE 2561	Shonka Sh
(serial No.)	(180)	(062)	(179)	(445)	(143)	(1057)
Collecting potential (V)	−270	−200	+300	−250	−200	−400
N_X (kg)$^{-1}$	$1.480 \cdot 10^6$	$2.590 \cdot 10^6$	$1.659 \cdot 10^6$	0.2538*	$2.575 \cdot 10^6$	$0.2343 \cdot 10^6$
Primary standard laboratory	BIPM	NPL	NBS	NPL	NPL	BIPM
Radiation quality	^{60}Co γ	2 MV rtg rays	^{60}Co γ	2 MV rtg rays	2 MV rtg rays	^{60}Co γ
Measurement results						
$\bar{I}$ (pA)	50.739	28.994	45.324	56.598	29.201	321.34
S_m (%)	0.05	0.04	0.03	0.03	0.06	0.01
$\dot{X}$ (μA/kg)	75.075	75.137	75.192	76.004	75.183	75.287

* The calibration factor is given for the ionization chamber together with the electronic sub-assembly NE 2502 (10231) and the units are mC (kg 'R')$^{-1}$.

Table 2

Comparison of results. Each column gives the difference in per cent of the result of the stated standard from the result of any other standard

	Standard					
	Denmark	Finland 1	Finland 2	Iceland	Norway	Sweden
Standard						
Denmark		0.08	0.16	1.22	0.15	0.28
Finland 1	−0.08		0.07	1.14	0.06	0.20
Finland 2	−0.16	−0.07		1.07	−0.01	0.13
Iceland	−1.24	−1.15	−1.08		−1.09	−0.95
Norway	−0.15	−0.06	0.01	1.08		0.14
Sweden	−0.28	−0.20	−0.13	0.94	−0.14	

tance of the electrometer and the leakage currents of the electrometer. For each chamber a total of 5 identical current measurement series was carried out, to reduce the random uncertainty.

The types of the secondary standard ionization chambers appear in Table 1, together with information on the names of the primary standards laboratories and the irradiation qualities which were used for the primary calibration. The exposure calibration factors, N_X, given by the primary calibration laboratories for a temperature and a pressure of 0°C and 101 325 Pa, respectively, are also shown. Finland had two chambers in the comparison, all the others had one.

A correction (0.11%) for general recombination was applied to the Swedish chamber, a Shonka chamber. For the other chambers no corrections were considered necessary by the participants.

The ambient temperature was measured with a quartz thermometer (HP 2804 A), calibrated by the manufacturer. The atmospheric pressure was measured with an air pressure meter with an accuracy better than 0.1 per cent. The consistency was 0.02 per cent from a comparison with a value given by the Finnish Metrological Office.

Results and Discussion

In Table 1 the following results are given: The mean value $\bar{I}$, of the measured ionization currents corrected to 0°C and 101 325 Pa, the standard deviation of the mean, s_m, and the calculated exposure rates, $\dot{X}$.

The results are compared in Table 2, where the difference in per cent between each result and any other result is given.

In a calibration at a primary standards laboratory the systematic uncertainty usually dominates and is in the range of one to two per cent (REICH 1976) depending on the technique used for summing the

Table 3

Table of uncertainties

Influence quantity	Maximum systematic uncertainty (per cent)	Random uncertainty one standard deviation (per cent)
Temperature	0.1	0.01
Distance	–	0.01
Current (mean value from Table 1)	–	0.04
Pressure	–	0.02
	0.1	s_m=0.05

Table 4

Calculated ratio of the calibration factors for the Danish chambers determined at Stockholm and at the BIPM

Type of ionization chamber	$N_{X,SSI}/N_{X,BIPM}$
Exradin T2 (180)	1.008
Shonka (1042)*	1.002
N.E. (068)	0.999

* The stem of the chamber had been broken and repaired between the two calibrations. The Shonka chamber current was corrected for general recombination at the Stockholm calibration.

individual errors. The random uncertainties are small in comparison with this.

The differences between the measured exposure rates (Table 2) are a few tenths of one per cent with the exception of the result obtained with the Icelandic instrument where the difference became one per cent.

In order to be able to evaluate the significance of the differences observed in the intercomparison, the experimental uncertainties in the technique were estimated. Random uncertainties from the usual influence quantities were considered, while only systematic errors from such physical effects that might have been different in the measurements with the different ionization chambers and which were not compensated for were taken into account. The only effect of this kind that may have been present was a temperature effect, due to the short warming up time in the laboratory for some of the chambers.

The influence quantities along with their uncertainties are given in Table 3. The total maximum systematic uncertainty became 0.1 per cent and the quadratic sum of the random uncertainties expressed as one standard deviation was estimated to 0.05 per cent.

There is no generally accepted method to combine random and systematic uncertainties. However, the International Atomic Energy Agency (1979) has recommended a method which can be used and which can illustrate the overall uncertainty. The overall uncertainty, u, at 95 per cent confidence level, can be written as

$$u = [(2.8\ s_m)^2 + 1.13\ \Sigma(\Delta x_j)]\ ½$$

where 2.8 s_m is the total random uncertainty at 95 per cent confidence level (Table 3) and Δx_j is the estimated size of the jth systematic error. With these values u becomes 0.2 per cent.

In the intercomparison with the Icelandic chamber 2 further systematic errors occurred; the build-up cap was not identical to the one used during the calibration at the NPL although in both cases a perspex cap was used and the current was measured with an electrometer (NE 2502) from Iceland instead of the Finnish system due to technical reason.

In order to check the accuracy of the Finnish current measuring device the current from one of the ionization chambers was measured with an electrometer (Keithley 610 C) brought from Sweden. This was done immediately after the measurement with the Finnish electrometer. The current ratio became 1.001, which is not significantly different from 1.000. (Immediately before and after the visit to Helsinki the Swedish electrometer was calibrated in Sweden and no change in sensitivity was observed.) The differences between the Icelandic standard and the others are thus not introduced by the Finnish calibration technique.

The Swedish standard is about 0.2 per cent higher than the others—except the Icelandic (Table 2). Such a difference is usually not significant but could be influenced by systematic differences between the different primary standards (NIATEL) used by the Nordic countries.

From Table 1 is seen that both the Danish and the Swedish standards are traceable to the BIPM standard. The difference, 0.3 per cent, was somewhat larger than expected.

Three secondary standards (Table 4) from the Danish laboratory were therefore brought to Sweden and were calibrated against the Swedish standard. The ratios of the calibration factors obtained in Stockholm ($N_{X,SSI}$) to those obtained at the BIPM ($N_{X,BIPM}$) are given in Table 4.

Two of the secondary standards showed good agreement with the Swedish standard, while the third chamber, which was the one used in Helsinki, deviated by as much as 0.8 per cent.

These further measurements confirmed that the initially reported difference of 0.3 per cent was a significant difference and the close relation between the Danish, Finnish and Norwegian standard shown in Table 1 was just by chance.

Of interest to note are also the small, not significant, differences between the standards calibrated primarily in the 2 MV roentgen beam at the NPL and those calibrated in ^{60}Co γ beams. Obviously the choice of radiation beam is of little importance in comparison with other uncertainties.

SUMMARY

An intercomparison of therapy level exposure secondary standards from the Nordic countries was made at ^{60}Co γ radiation at the secondary standard dosimetry laboratory in Helsinki. One standard seemed to be in error by about one per cent and another was found to be unreliable. From the analysis it was concluded that intercomparisons of secondary standards can be made with an overall uncertainty of about 0.2 per cent. This uncertainty is of the same size as the difference between primary standards, which may therefore play a role in the evaluation of differences between secondary exposure standards.

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