OCCUPATIONAL BETA RADIATION EXPOSURE DURING RADIOSYNOVIORTHESIS

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1. ABSTRACT

Measurements, in particular of the personal dose $H_p(0,07)$, were carried out at workplaces in the Radiosynoviorthesis (RSO). Practices in these field are characterised by handling of high activities, very small distances between source and skin, high risk of contamination and unsatisfactory area and personal dose measuring technique.
Highly sensitive thermoluminescence detectors (TLD, LiF:Mg,Cu,P) were used to determine the beta exposure especially of the skin of the hands. Contamination measurements indicated that additional exposure of the skin was to be expected.
In the RSO in some cases exposures of the hands due to direct radiation of more than 100 mSv per working day were estimated. Skin doses caused by contamination were in the same order of magnitude. Radiation exposure could be reduced drastically by simple radiation protection measures, e.g. use of manipulators and syringe protectors.
The introduction of authorised beta partial body dosimeters (finger ring dosimeters) is proposed.

2. INTRODUCTION

In the last years RSO has been used more frequently in Germany. It is a therapy for effective local treatment of chronic inflammatory joint diseases by injection of beta emitters (Y-90, Er-169, Re-186) [1].

Beta emitters are increasingly used in medicine in unsealed and sealed form. Medical therapeutical applications gain from the fact that beta energy can be totally absorbed in a small delimited tissue volume. Whole body irradiation which is unavoidable in use of photon emitters does not occur in most cases when beta emitters are used. The higher effectiveness of beta emitters can be explained by the values of the beta ray dose functions at short distances that are high compared to gamma ray constants. Beta emitters may cause doses which are two orders of magnitude higher than doses caused by gamma emitters of equal activity at short distances.

This fact which is favourable in therapies also causes, however, an increased risk of partial body exposure of the personnel, especially since very high activities are frequently handled in vessels (e.g. vials or syringes) which are not shielded enough. Often personnel are not aware of the risk they are exposed to.

Contamination measurements are carried out rarely and often in a not enough qualified way. Moreover, due to the lack of suitable area and personal dosimeters no proper workplace or partial body dosimetry was performed.

Beta personal dosimeters (finger ring dosimeters) were not used at surveyed workplaces. In Germany the introduction of authorized beta personal dosimeters has just started.

3. SUBJECT OF MEASUREMENTS

Three beta exposed fields of work can be differentiated in RSO:
- ‘Preparation’ (preparation of the syringes in the radiochemical laboratory)
- ‘Application’ (injection, additionally there is X-ray control or scintiscanning)
- ‘Assistance’ (typical scope of an assisting nurse).

Occupational radiation exposure may occur by:
- Beta radiation (direct radiation and contamination)
- Bremsstrahlung
- X-ray radiation (fluoroscopy during treatment)
- Incorporation.

Important data of the nuclides used is listed in Table 1.

Table 1: Relevant nuclide data

Nuclide	**$E_{\beta, max}$ in keV**	**Probability of emission in %**	**$E_{\beta, mean}$ in keV**	**E_{ph} in keV**	**Probability of emission in %**	**Half-life in d**
Y-90	2,284	100	934			2.67
Er-169	352	58	103	110	<1	9.40
Re-186	1,075	74	338	137	8	3.78

4. MEASURING TECHNIQUE

In the measurements thin-layer thermoluminescence detectors (TLD) of the MCP-Ns™ type, material: [LiF:Mg,Cu,P], area mass of the sensitive layer <10 mg/cm^2 were used.

The used dosimeter probes consisted of TLD welded in a foil bag with a foil thickness of 4-5 mg /cm^2, fixed on the measuring point with perforated adhesive tape (see Figure 1).

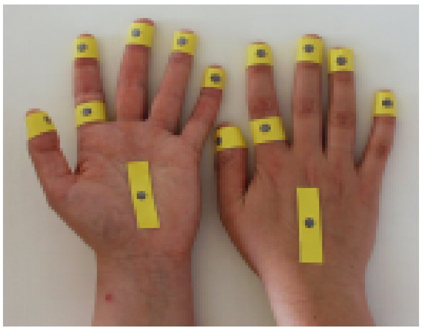

Figure 1: Fixed TLD probes at the hands

It was measured at the spots with the expected highest exposure (finger tips) inside and outside at the 3rd phalanx of the index finger, the possible spots where the ring dosimeter could be worn. In some cases additional probes were stuck at the back of the hands to estimate X-ray scatter radiation.

For area dose rate measurements a beta dosimeter DL 1™ and an X-ray/gamma dosimeter of the 27040™ type, for contamination measurements a monitor of the FHT 111 M™ type with a butane counter were applied.

5. RESULTS

Although RSO is a well established and approved method, it is carried out differently in some details that have considerable influence on the radiation exposure of the personnel. Therefore measurements were made at different institutions. At one institution (“A”) it was measured on six therapy days, at the other institutions at one or two days each. In some measuring campaigns dosimetry could be carried out nuclide specifically, to be able to assess the significance of the three nuclides for exposure.

Measurements and calculations showed that the main part of the exposure is caused *by direct beta radiation* from Y-90. Er-169 has hardly any effect on radiation exposure and the dose caused by Re-186 is only a few percent of the total dose on a typical therapy day. In the case of *skin contamination*, however, all three nuclides contribute to a comparable degree to the dose of the skin, see e.g. [2].

Accompanying photon components were negligible. Incorporations were not examined.

Table 2: Maximum exposures of the skin of the hands (daily doses) during RSO

Measurement cycle	**Maximum dose $H_p(0,07)$ in mSv/day**			**Given Y-90 [MBq]**	**Specific dose [µSv/MBq]**
	Preparation	**Application**	**Assistance**		
A-1	82	43	5	805	53
A-2	**101**	**132**	10	1675	79
A-3	16	16	2	620	26
A-4	18	33	Not measured	1480	22
A-5	Not measured	**1***	Not measured	555	1.8
A-6	Not measured	**1***	Not measured	1110	0.9
B-1	108	27	Not measured	2035	13
C-1	14	41	Not measured	555	74
F-1	7	62	9	460	**135**
F-2	8	**1***	36	2005	0.5
G-1	15	5	1	180	28
G-2	4	11	2	360	31
H-1	55	**207**	No „Assistance“	888	**233**
I-1	8	31 (Doctor 1)	No „Assistance“	1332	23
I-2	Not measured	84 (Doctor 2)	No „Assistance“	2442	34
I-3	6	**1*** (Doctor 1)	No „Assistance“	1554	0.6
I-4	Not measured	**1*** (Doctor 2)	No „Assistance“	1332	0.8

***** use of forceps during application of radionuclides

In Table 2 the maximum skin doses measured *on one workday* are listed. Usually, in the case of right-handed persons, index finger, thumb and middle finger of the left hand are most exposed, resulting from holding of the vials or syringes. The doses at the right hand are often lower by one order of magnitude. In the ‘Assistance’ the doses at both hands are comparable.

The staff at institution “A” wore photon finger ring dosimeters. These dosimeters showed *annual* doses at the same level as the *daily* doses caused by beta radiation which were determined in our investigations.

Due to the high specific activities (up to 222 MBq in ≤ 1 ml liquid volume) and the way of handling, contamination occurs in all three areas at a considerable level. Up to 160 kBq were measured on the palm of a nurse (‘Assistance’). Under realistic conditions estimated exposures of the hands due to contamination are in the same order of magnitude as those caused by direct radiation in some institutions.

In some cases it was detected that the used Latex^{TM}-gloves were not tight enough to prevent the skin against contamination with beta radionuclides.

Consequently, the personnel can receive daily skin doses at the hands due to direct radiation and contamination in the range of the annual limits (500 mSv/a). With 40 therapy days per year on average, it must be assumed that the legal limit for skin dose could be considerably exceeded.

6. CONCLUSIONS

Use of radionuclides in RSO causes partial body exposures in particular of the skin of the hands due to direct radiation and contamination that

- can exceed dose limits
- are not reflected adequately with the currently used dosimetry (official whole body personal dosimeter, finger ring dosimeter, area dosimeter) and that
- are not foreseen due to the lack of suitable precautions (calculations, contamination measurements).

The ignorance of the high exposures due to beta radiation leads to inadequate radiation protection measures in use of beta nuclides during RSO.

On the other hand drastic dose reduction can be achieved by an increased awareness of the problem and by using a manipulator and syringe protector (see Table 2, ‘Application’, e.g. F1 to F2). The specific dose decreased from

135 µSv/MBq to <1 µSv/MBq). Unfortunately the risk of contamination increased due to use of a pair of forceps to hold the cannula during application. More proper manipulators are in development.

The following measures to reduce radiation exposure from beta emitters are proposed:

- Application of radiation protection measures (use of manipulators, protectors, solvent resistant gloves)
- Implementation of a strict regime for the monitoring and removal of contamination
- Wearing of authorized finger ring dosimeters optimised for the measurement of beta radiation
- Provision of information, exchange of experience and feedback between the institutions
- Special training measures (both in radiation protection as well as in proper handling the radioactive substance).

7. REFERENCES

[1] G. Mödder, *Radiosynoviorthesis,Warlich Druck und Verlagsgesellschaft mbH, Meckenheim, 2001*

[2] *Radionuclide and Radiation Protection Data Handbook, 2002,* Rad. Prot. Dosim. Vol. 98 No. 1 2002