Safety of knee radiosynovectomy with yttrium - 90

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Abstract. Radioisotope knee synovectomy is based on an Yttrium - 90 citrate injection (185 - 222 MBq) into the knee joint cavity. The performance of procedure needs participation of a nuclear medicine specialist as well as an orthopedist or a rheumatologist and a technologist, who prepares radiopharmaceuticals. The ionization doses for patients and personnel depend not only on the injected activity, but also on the method and process of injection and the radioactivity measurement procedure used. The aim of this study is the evaluation of the degree of radiation exposure of patients and medical personnel during the performance of therapy with ⁹⁰Y.

1. Introduction
According to ICRP classification, there are three types of radiation exposure risks, i.e. medical exposure, occupational exposure of medical personnel and finally general public exposure [1]. In case of radiation exposure it is necessary to define the emission properties of the isotope used. ⁹⁰Y is a β-emitter, so it induces secondary radiation called Bremsstrahlung also during the radiopharmaceutical’s preparation.

Pure β-ray emitters are used as therapeutic radionuclides, because of the short range of radiation (typically less than 1 cm) in the tissue. It has been implicitly assumed that there is no significant external radiation hazard from internally emitted β-rays. With the relatively low energy (of the order of 100 keV or less) of β-rays typically encountered in nuclear medicine and the low effective atomic number (∼7.9 [2, 3]) of soft tissue, there is virtually no bremsstrahlung produced in vivo, and the assumption of no external radiation hazard from β-rays is altogether reasonable. With increasing therapeutic use of relatively high-energy emitted β-rays (of the order of 1 MeV or more, for example ⁹⁰Y with maximum energy of 2.27 MeV [4]) particularly in materials with high atomic numbers such as bone with an effective atomic number of ∼ 20, equivalent to that of calcium, production in vivo of bremsstrahlung is sufficient for external detection and imaging [5].

The most frequently used method of measurement is the thermoluminescence dosimetry. This method may give contradictory results due to the high level of uncertainty (read error). In some cases (Bremsstrahlung or β/γ - emitters), gamma camera measurements seem to be useful and precise tool in dosimetry.
2. Materials and methods
Dosimetry measurements were performed in the Central Clinical Hospital of the Ministry of Internal Affairs and Administration in Warsaw. Patients were suffering from diseases like rheumatoid arthritis, psoriatic arthropathy, serosynovitis and haemophilic arthropathy.

2.1. Thermoluminescence dosimeters
For the quantification of the exposure to ionizing radiation thermoluminescence dosimeters were used. The personal dose, equivalent at 0.07 mm and 10 mm depth in the body of 70 persons and 30 medical personnel, and the kinetic energy released per unit air mass were calculated.

The thermoluminescence dosimeters that were used to determine the:
- personal dose equivalent at 0.07 mm depth in the body Hp(0.07), in mSv, are dosimeter type PI-01,
- personal dose equivalent at 10 mm depth in the body Hp(10), in mSv, are dosimeter type DI-02,
- kinetic energy released per unit air mass (air KERMA) Ka, in mGy, are dosimeter type DS-04.

Measurements of dosimeters PI-01, DI-02 and DS-04 were performed at the Laboratory of Individual and Environmental Dosimetry of the Institute of Nuclear Physics in Kraków, Poland.

Each patient taking part in this study was equipped with a dosimeter type: PI-01 (attached immediately after injection close to the place of injection), DI-02 (placed under clothing on the patient’s chest) and DS-04 (0.5 m to 1 m over the patient’s bed). Exposure of the activity was measured for a minimum of 48 h. Special instructions had been prepared for patients to explain how to deal with dosimeters and a questionnaire helped to understand the process of dosimetry exposure (patient’s compliance). Additionally, all medical records were collected for each patient.

2.2. Scintigraphy
For proper assessment of radiation emitted by a radionuclide, its energy spectrum and reduction of radiation were established using gamma camera analysers. Static studies (10 min) of patient’s knee joint (20 knee joint) were performed. Imaging studies were done using the dual head gamma camera Ecam (Siemens, Erlangen, Germany). Whole body study after injection was performed in 6 patients for the purpose of assessment of the extra-articular location of the tracer.

3. Results
The average number of radiosynovectomy procedures performed per month in each Polish Nuclear Medicine department is six. Limit dose equivalent values are defined by the Atomic Law and the safety of RS experiments is met [6]. Individual dosimetry of the medical personnel proved that the small number of conducted procedures is safe for the medical staff (table 1).

Similarly the absorbed dose to the patients was within the acceptable limits, if good radiation protection practice is implemented (table 2).
Yttrium-90 citrate colloid is a radiopharmaceutical that usually does not remain stable in the target organ. Qualitative analysis had shown an absence of the radiopharmaceutical flow outside the joint cavity (figure 1).

Dosimetric procedures proved that its local concentration is changing in time, so that compartmental analysis can be implemented to check the influence of the disease pathophysiology on the kinetics of the radiopharmaceutical (figure 2).

| TLDs     | Medical personnel (μSv) |
|----------|-------------------------|
|          | Physician (15 persons)  | Technologist (15 persons) |
| PI-01-Hp(0.07) | 1                        | 3                        |
| DI-02-Hp(10)   | 0.8                      | 1                        |
| DS-04-Ka       | 0.7                      | 0.9                      |
Table 2. Mean values of the dosimeter readouts (TLDs) for patients; values have been normalized to 1 MBq of injected radiopharmaceutical activity.

| TLDs      | Dose (μSv) |
|-----------|------------|
| PI-01 – Hp(0.07) | 68         |
| DI-02 – Hp(10)   | 0.7        |
| DS-04 – Ka       | 0.8        |

**Figure 1.** Whole-body scans after (a) 1 h, (b) 24 h, (c) 96 h after injection of the radiopharmaceutical.

**Figure 2.** Static scans of the joint after (a) 1 h, (b) 24 h, (c) 96 h after injection of the radiopharmaceutical.

4. Conclusion
Scintigraphy of the knee joint at a given moment during the therapy provides a useful means of monitoring the accumulation process of radiopharmaceutical. It gives very useful information for a physician. Using this information, the physician can foresee the results of the undertaken therapy. The analysis of the whole body scintigraphy images proved that no more than 10% of the original radiopharmaceutical activity injected to the joint escaped outside the joint cavity. The biodistribution of radiopharmaceuticals in the patient’s body requires more dosimetric experiments.

References
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