RADIATION PROTECTION IN THE INTRA- AND POST-OPERATIVE DIAGNOSIS OF THE SENTINEL LYMPH NODE (SLN)

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1. INTRODUCTION:

Radioactive marked colloids have gained wide acceptance in the diagnosis of sentinel lymph nodes (SLN) compared to dyes. Therefore various aspects of radiation protection have to be taken into account. Application and preoperative diagnosis usually takes place in a nuclear medicine ward where the personnel is highly trained in the use of radioactive material. Intra- and postoperative diagnosis involves personnel in the operating cabinet and the pathology that is not necessarily radiation protected and trained and therefore should not exceed a yearly dose of 1mSv [1]. Organizational problems would arise if all those people have to be included into a full radiation protection program and supervision. The expected exposure has to considered to decide about the necessary actions that have to be taken.
Additionally the exposure of the patient has to be estimated to assess the corresponding radiation risk. The reason for a wide resulting variation of organ dose are the uncertainties of the various methods of dose calculation, the individual differences of the patients (e.g. size of mamma) and the differences in surgical removal of radioactivity contaminated tissue.

Radiation Exposure of the Personnel
The estimation of exposure was done under conservative assessments of times and distances to the patient or the specimen. It was assumed that sentinel lymph node ectomy (SLNE) was performed immediately after tumor resection.

Surgeon		**OP-Personnel**		**Pathologist**	
Tumor-resection	0.5m / 20min	Tumor-resection / SLNE	0.5m / 30min	Tumor	0.5m / 30min
	1.0m / 20min				1.0m / 10min
	2.0m / 20min		1.0m / 1h		2.0m / 10 min
SLNE	0.5m / 20min			SLN	0.5m / 30min
	1.0m / 20min		2.0m / 2h		1.0m / 10min
	2.0m / 20min				2.0m / 10 min

Table 1a: Parameters of residence (distance/time) for the assessment of the exposure of the personnel from SLNE and tumor-resection in malignant melanoma or mamma-carcinoma

Surgeon		**OP-Personnel**		**Pathologist**	
Prostate-ectomy	0.5m / 2h	Prostate-ectomy / SLNE	0.5m / 30min	Prostate-diagnostic	0.5m / 30min
	1.0m / 30min				1.0m / 10min
	2.0m / 30min		1.0m / 1h		2.0m / 10 min
SLNE	0.5m / 30 min			SLN-diagnostic	0.5m / 30min
			2.0m / 2h		1.0m / 10min
					2.0m / 10 min

Table 1b: Parameters of residence (distance/time) for the assessment of the exposure of the personnel from SLNE and prostate-ectomy in prostate-carcinoma

Table 1 lists the residence parameters that where used for the dose assessments of the personnel. The parameters for the pathologist contain the examinations of the SLN and the tumor immediately after surgery (rapid section).
For surgeon and OP-personnel the activity distribution by the special type of application and the residual activities from the resulting biodistribution of the tracer are considered in the various applications of the SLNE[8]. These parameters considerably differ in case of prostate-carcinoma because of excretion via urine from those resulting from a subcutaneous injection. Surgery was always assumed to be performed 24h after application (two day protocol).
Dose calculations were based on the following typical activities:
Malignant Melanoma 80 MBq ^{99m}Tc
Mamma-Carcinoma 160 MBq ^{99m}Tc
Prostate-Carcinoma 200 MBq ^{99m}Tc
The resulting whole body doses per applied activity resulted for surgeon, additional OP-personnel (e.g. nurse, anesthesiologist) and the pathologist are shown in table 2:

	Malignant Melanoma and Mamma-Carcinoma	**Prostate-Carcinoma**
Surgeon	2,5 nSv/MBq	6 nSv/MBq
OP-Personnel	5,5 nSv/MBq	2,5 nSv/MBq
Pathologist	3,8 nSv/MBq	0,5 nSv/MBq

Table 2: Radiation exposure (nSv/MBq) of personnel per patient and per applied activity from SLNE in various applications

Even if a colleague is involved in 200 operations with SLNE within one year a radiation exposure between 0.02 und 0.2mSv would result which is well below the 1mSv limit to become a radiation worker.

Contamination

Taking the specified applied activities, the tracer biokinetics and the radioactive decay into account the residual activities in the patient 24h post injection are approximately:

	Total activity	**Tumor-specimen**	**SLN**
Malignant Melanoma:	≈ 5 MBq	≈ 5 MBq	≈ 20 kBq
Mamma-carcinoma:	≈ 10 MBq	≈ 10 MBq	≈ 20 kBq
Prostate-carcinoma:	≈ 9,5 MBq	≈ 1 MBq	≈ 20 kBq

Those activities being relatively fixed to the tissue do not produce contaminations that exceed the allowed levels for areas of the public. The usual measures in the operation cabinet or pathology to prevent from infections are also sufficient to avoid any kind of incorporation. Nevertheless this problem has to be addressed during installation of the method and if higher activities or shorter time intervals between application and surgery are choosen.

Radiation Exposure of the Patient

Biodistribution of ^{99m}Tc-Nanocolloid
Distribution and kinetic of the tracer highly depends on the type and spot of injection that is defined by the tumor. After a intradermal injection of ^{99m}Tc-nanocolloid a minimal transport of the tracer can be observed that is nearly totally restricted to the lymphatic vessels guiding the radioactivity the regional lymph nodes. The tracer is trapped by the reticular cells of intact lymph nodes. The uptake is usually between 0.1% and 1% of the applied activity [5]. The retention of ^{99m}Tc-naocolloid is therefore larger than 95% in case of mamma-carcinoma or malignant melanoma [7]. A small amount can reach the blood and is deposited in the RES of liver, spleen and red bone marrow. Only a trace is excreted by the kidneys [4].
After an intraparenchymal injection the transport of the tracer differs significantly from a subdermal injection. For example the retention of ^{99m}Tc-nanocolloid following an intraprostatic application is only around 10%. 25% of the activity goes immediately retrourethral into the bladder. More than 60% of the radiotracer reaches the RES via blood. The lymphatic flow produces an uptake in the regional lymph nodes between 0.005% and 0.5%.

2. RESULTS:

Tables 3 and 4 show the calculated doses for intradermal and intramammary injection from measured biokinetic distributions.
In case of mamma-carcinoma we calculated a specific effective dose of 0.021 mSv/MBq [3,7] or an effective dose of 3.4mSv if 160MBq are applied. If the variation in size of the breast and the exact localization of the tumor or injection spot are considered the individual effective dose varies from 1mSv to more than 10mSv. Many dose calculations do not take into account that the injection spot, that contains more than 95% of the activity, is nearly total surgically removed. If this is included into the dose assessment the effective dose is reduced by a quotient of 3.
In case of malignant melanoma the variation of effective dose is even higher than in mamma-carcinoma because of the wide variation of possible localizations. The removal of the injection spot has also to be considered. The resulting effective dose from an applied activity of 80MBq is around 0.5mSv if the parameters of table 3 are taken into consideration.
Taking the above biokinetic data for prostate-carcinoma and an applied activity of 200MBq the effective dose is calculated to be around 1.5mSv.

Organ	**Specific Dose [mGy/MBq]**	**Dose for 80 MBq [mGy]**
Injection spot	12.0	960
Lymph-nodes	0.59	47
Liver	0.016	1.3
Spleen	0.0041	0.33
Bladder-wall	0.0097	0.78
Red Marrow	0.0057	0.46
Ovaries	0.0059	0.47
Testes	0.0035	0.28
Whole Body	0.0046	0.37

Table 3: Organ-doses after intradermal injection of ^{99m}Tc-nanocolloid [4]

Organ	Specific Dose [mGy/MBq]	Dosis for 160 MBq [mGy]
Injected breast	0.72	115
Lung	0.0078	1.25
Stomach, Pancreas, Liver, Bone-surface	< 0.003	< 0.5
Spleen, Gallbladder-wall, Thyroid, Red Marrow, Muscle	< 0.002	< 0.3
Uterus, Ovaries	0.0001	0.02

Table 4: Organ-doses after intramammary (peritumoral) injection of ^{99m}Tc-nanocolloid [7]

3. CONCLUSION:

The radiation exposure of the personnel in the operating room and the pathology is well beyond 1mSv per year. The usual dosimeters can not register those small dose values and are therefore obsolete. From the radiation safety point of view there is also no limitation for pregnant women. Although the personnel is therefore not be considered as radiation workers an instruction with regular actualization is highly recommended. The instructions should cover the method, the principles of radiation protection, the possible doses and their consequences and the necessity to avoid any kind of incorporation. The measurement of radioactivity in the operation ward should only be performed by well trained personnel under radiation safety supervision. The means to minimize radiation dose during the course of an SLNE can be put into an instruction sheet. National and international guidelines and recommendations can be helpful [1, 2, 7, 9].

An exact value of the effective dose to the patient can only be given on an individual basis as far as subdermal and intramammary application is concerned. This is mainly due to the variation of tumor localization and breast size. All together the radiation exposure is in all kinds of SLN diagnostics is in the low range of medical doses about a yearly natural exposure. Taking the disease of the patient into account the radiation risk of the patient is justified by the benefit from minimization of surgery and improved diagnostic of lymph node metastases.

4. REFERENCES:

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