Calculating, and analysis of the radiation protection and shielding of Nuclear Medicine Center including PET/CT center situated in University Hospital St. Marina in Varna, Bulgaria.

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Purpose

Positron Emission Tomography (PET) has been available in number of centers for more than 25 years, but its use was not wide spread until 10 years ago. In Bulgarian PET/CT was installed for the first time in 2009 in Nuclear Medicine Department in University Hospital St. Marina in Varna, Bulgaria.

Purpose: As a physicists the aim for us was to consider and calculate the shielding so that to protect the people and the stuff. The purpose is calculating and analysis of the radiation protection and shielding of Nuclear Medicine Center including PET/CT center situated in University Hospital St. Marina in Varna, Bulgaria.

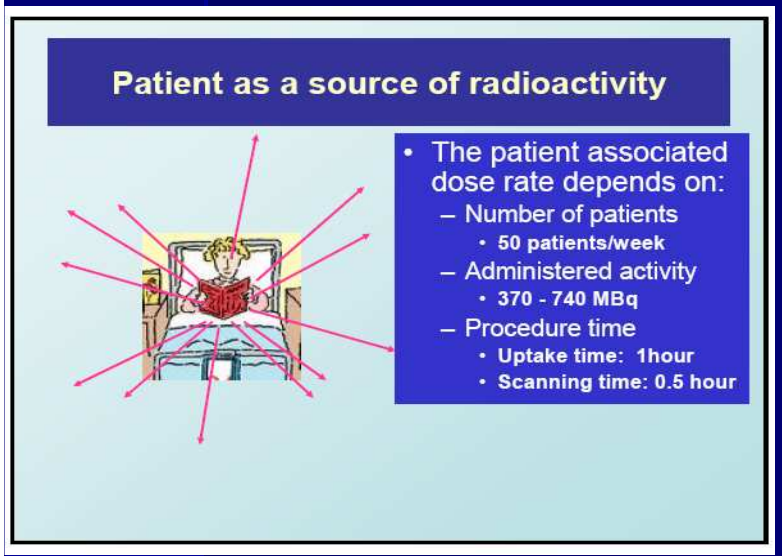
Principles in radiation protection

- **ALARA**, *"As Low As Reasonably Achievable"*,
- 3 major ways to reduce radiation exposure to workers or to population:

  - Shielding. Use proper barriers to block or reduce ionizing radiation.
  - Time. Spend less time in radiation fields.
  - Distance. Increase distance between radioactive sources and workers or population

Method:

Calculating the shielding of PET/CT Center using the experien
of American Assosiation of Physicists in Medicine (AAPM) Tas
Group 108



Needed Information for calculation:

Radionuclide:	18FDG
Administrated activity:	15mCi (555MBq)
Number of patients a day:	10
Number of patients a week:	50
Uptake time:	60min
Imaging time:	30min

UPTAKE ROOM CALCULATION

- Patients undergoing PET scan need to be kept in a quite resting state prior to imaging to reduce uptake in the skeletal muscles. This uptake time varies from 30 to 90 min but for our clinic it is 60 min. The total dose at a point "*d*" meter from the patient during the uptake time is:

- $D(tU) = 0.092\ (Sv.m^2/MBq.h) * A_0\ (MBq)*t_U(h)*Rt_U) / d^2(m^2)$

A0 **–**administrated activity (*MBq*)
tU **–** uptake time (*h*)
RtU – dose reduction factor under the uptake time *tU*:

  - $Rt_U = D(t)/[D(0).t] = 1{,}443.(T_{1/2}/t).[1-\exp(-0{,}693.t/T_{1/2})]$

- Thus the transmission factor (***B***) required is:

- $B = 10{,}9*P*d^2/[T*Nw*A_0*t_U(h)*Rt_U]$

P – weekly dose limit (*μSv)* different for every country
P=400 *μSv for* controlled area and ***P***=20 *μSv for* uncontrolled area
T – occupancy factor
Nw is the number per patients per week,

- For uncontrolled area
- $B_U = 218*d^2(m^2) / (T*Nw*A_0(MBq)*t_U(h)*Rt_U)$

- For controlled area
- $B_U = 4360*d^2(m^2) / (T*Nw*A_0(MBq)*t_U(h)*Rt_U)$

- ***B*** represents the factor that the dose rate has to be reduced by:
- ***B*** is equal to regulatory dose limit divided by actual (estimated) dose
- If ***B<1*** then shielding is required
- If ***B>1*** no shielding is necessary
- The appropriate thickness of shielding material can be found from the shielding tables or graph as soon as ***B*** is determined.

IMAGING ROOM CALCULATION

- Using the same formula, but now we take into account that the administrated activity is decreased during the uptake phase by:
- $D(t_U) = 0.092\ (Sv.m^2/MBq.h)*N_W*A_0\ (MBq)*0.85*F_U*t_I(h)*Rt_I) / d^2(m^2)$
- Thus the transmission factor (B) required is:

FU – uptake time decay factor (μSv) :
$FU = exp(-0{,}693.t/T1/2)$

- $B = 12.8*P*d^2/[T*Nw*A_0*F_U*t_I(h)*Rt_I]$
- For uncontrolled area
- $B = 256*d^2(m^2) / (T*Nw*A_0(MBq)*F_U*t_U(h)*Rt_U)$
- For controlled area
- $B = 5129*d^2(m^2) / (T*Nw*A_0(MBq)*F_U*t_U(h)*Rt_U)$

CALCULATION FOR ROOMS ABOVE AND BELOW PET FACILITY

- It is assumed that the patient (source of 511keV annihilation photons) is situated 1m above the floor. So the dose rate is calculated at 0,5m above the floor for rooms above the scanner and 1,7m above the floor for rooms below the scanner room.

	T	N_w	A_0 MBq	t_U h	R_{tI}	F_U	R m	k	B_{public}	$B_{personal}$	Pb mm	Бетон cm	available shielding from concrete	Extra shielding from concrete
Outside yard	0,2	40	740	0,75	0,87	0,68	3,3	5	0,211		11,1	14		20 cm
corridor (4)	1	40	740	0,75	0,87	0,68	5,2	2,5		4,192				
corridor (19)	0,1	40	740	0,75	0,87	0,68	3,3	2,5		16,882				
Injection room	0,1	40	740	0,75	0,87	0,68	4,6	2,5		32,804				
upper floor	1	40	740	0,75	0,87	0,68	2,7	5	0,028		24,1	28	16 cm	2 mm Pb
lower floor	0,1	40	740	0,75	0,87	0,68	2,5	5	0,242		10,2	13	16 cm	

Results:

Uptake room walls

	T	N_w	A_0 MBq	t_U h	R_{tU}	R m	k	B_{public}	$B_{personal}$	Pb mm	Бетон см	available shielding from concrete	Extra shielding from concrete
Outside yard	0,2	40	740	1	0,83	3	5	0,0796		17,4	21		21 cm
Injection room	1	40	740	1	0,83	2	2,5		0,2831	9,1	12		12 cm
Controlled corridor	0,1	40	740	1	0,83	3,5	2,5		8,67023				
Injecting room	1	40	740	1	0,83	2	5	0,0071		33,1	36		36 cm
upper floor	0,1	40	740	1	0,83	2,7	5	0,1290		14,3	18	16 cm	2 cm
lower floor	0,1	40	740	1	0,83	2,5	5	0,1106		15,3	19	16 cm	3 cm

Waiting room walls

	T	N_w	A_0 MBq	t_U h	R_{tI}	F_U	R m	k	B_{public}	$B_{personal}$	Pb mm	Бетон см	available shielding from concrete	Extra shielding from concrete
Outside yard	0,2	40	740	0,75	0,87	0,68	3,3	5	0,211		11,1	14		20 cm
Imaging room	1	40	740	0,75	0,87	0,68	5,2	2,5		4,192				
Clear corridor	0,1	40	740	0,75	0,87	0,68	3,3	2,5		16,882				
Injection room	0,1	40	740	0,75	0,87	0,68	4,6	2,5		32,804				
upper floor	1	40	740	0,75	0,87	0,68	2,7	5	0,028		24,1	28	16 cm	2 mm Pb
lower floor	0,1	40	740	0,75	0,87	0,68	2,5	5	0,242		10,2	13	16 cm	

Results:

- The inner and outer walls was covered with lead sheets of 2mm, 5mm, 10mm and 20mm thickness depends on the calculations. The walls between patients are made with 30cm Pb. The top of the scanner room is covered with 2mm Pb.

- The aim was achieved. The Department was opened. It is working now with about 10 patients every day. The administrated activity is lower than this using for calculations. It is 0.14 mCi per kilo (about 10mCi average activity per patient). FDG comes from Debrecen, Hungary by plane every day at noon. The work is organized in 2 shifts.

- The dose rates measured with personal TLD's for the last year for the stuff are under 3mSv. As the doses over 1mSv are only for nurses who injected the FDG and the rest personal doses are around (under) 1mSv.

Future plans:

- To protect the technicians we have audio and video connection with the patient, and patients are instructed to enter the scanner room and to position their selves alone except immobilized patients.
- In the future we plan to install injecting system separate or combined with dispensing system so that to decrease the doses of nurses.
- Our future plans also include installation of cyclotron and working not only with FDG, but also with other short lived PET radionuclides.

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