VADE

20.5.2003

I N P S Q

Case study: VIII-3 Optimisation of doses to patients in nuclear medicine and radiotherapy

Introduction:

In nuclear medicine, unsealed radioactive sources are used in diagnosis and therapy. The risk involved in administration of radioactive material in nuclear medicine procedures is weighted against the advantages likely gained in terms of health and well being of patient. Keeping this factor in view, ICRP-73 has recommended diagnostic reference levels for patients in nuclear medicine procedures. These levels are nothing but the quantity of radionuclide administered in the patient for a particular test. The levels are arrived using generic optimisation of protection by choosing the initial values as percentile point on the observed distribution of doses to patients and optimising the nuclear medicine procedures. However, these levels are selected by professional medical bodies and reviewed at intervals that represent a compromise between the necessary stability and the long term changes in the observed dose distribution. These levels apply to medical exposure and not to occupation and public exposure. Therefore these levels are not used for regulatory or commercial purposes and have no link to dose limits or constraints. The selected values of levels are specified to a country or region.

The reference levels are not applicable for therapeutic procedures. Still, according to ICRP guidelines of radiation protection, any application of radionuclide in medicine is governed by the principles of Justification and Optimisation. There are various types of treatment procedures in nuclear medicine where beta and beta-gamma emitting radionuclides are used. Some of the nuclear medicine therapy procedures along with specific radionuclides and the route of administration are listed in the table - I.

$D_{(T \leftarrow S)} = A_0 \cdot S_{(T \leftarrow S)}$

$A = 1.44 \cdot A_0 \cdot f \cdot T_{eff}$

Table - I : Common therapeutic procures using radionuclides in nuclear medicine

Radio-nuclide	$T_{½}$ (days)	Energy (MeV)		Applications	Dose & mode of adm.
		Emax	Eavg		
^{131}I	8.0	0.60,..	0.162	• Thyrotoxicosis • Ca-thyroid • Malignancy	(1GBq, oral) (20GBq, oral) (10GBq, IV)
^{32}P	14	1.71	0.695	• Polycythemia vera	(200MBq,IV or oral)
^{89}Sr	50	1.46	0.58	• Bone metastasis	(150MBq,IV)
^{90}Y	2.7	2.27	0.935	• Malignant effusion • Radiosynoviorthesis	(5MBq,IC) (250 MBq, IA)
^{153}Sm	1.9	0.71,..	0.229	• Bone metastasis	
^{186}Re	3.8	1.07,..	0.362	• Bone metastasis • Radiosynoviorthesis	(150 MBq, IA)
^{169}Er	9.5	0.34		• Radiosynoviorthesis	(150 MBq, IA)

In general, attempts are made to determine whether the particular procedure has been adequately optimised and measures are aimed at not to exceed the clinically required radiation level. Practices are introduced to reduce the unwarranted exposures e.g. exposure to target organs due to source organ, exposure due to contamination etc., to the patient. Such exposures can be minimised by practicing the following procedures regularly -

The activity should be administered to the patient with empty stomach so that the activity is quick absorbed and distributed to reduce the probability of vomiting the radioactive material. This will avoid the chance of repeating the treatment.

Functional study of concerned organ(s) should be done before deciding the dose.

1. The radioactivity that is to be administered to the patient, should be calculated on the basis of prescribed radiation dose.
2. The activity should be measured before administration to the patient in order to ensure that required quantity of radionuclide is only administered.

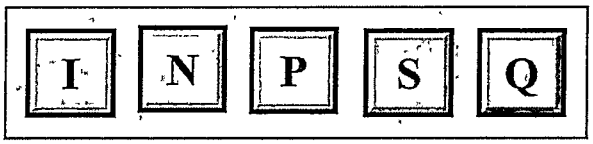
3. Radiation levels should be measured at 1 meter distance from the stomach in order to confirm the administration of correct activity to patient.
4. After the oral dose administration, action should be to promote excretion of saliva in order to reduce dose to salivary glands.
5. The patient should be asked to clear the bladder frequently in order to reduce the exposure to bladder and gonads.
6. The lactating mothers should be asked to pump out milk frequently in order to reduce the exposure to breast.
7. Personnel clothing and linen should be changed frequently in order to avoid unnecessary exposure from the contaminated clothing.

Extreme precautions are necessary in cases of treatment of thyroid diseases. Whereas the treatment with pure beta emitting radionuclides, the radiation exposure to patient is optimised by taking precautions referred above.

Aim:

In nuclear medicine the measures are aimed to keep the effective dose, resulting from the administration of radionuclides, to the lowest level consistent with obtaining the desired therapeutic effect. For this it is necessary to know the absorbed dose to be delivered and the correct equivalent dose to the organ(s) in a therapeutic application. It can precisely be evaluated if the size, shape and function of the organ and the bio-kinetic details of the radio-pharmaceutical are known. The radiation dose to patient is optimised from the risk involved due to the nuclear medicine procedure. The risk is evaluated from the dose to specific organ and the dose to gonads. In general, the exposure to patient can be is optimised to an extent if the following points are put in practice.

1. take into account previous examination(s) to avoid unnecessary exposure or treatment with radio-pharmaceuticals.
2. select proper radio-pharmaceutical and treatment protocol
3. study functional behaviour of organ(s)
4. administer correct activity to obtain required benefit
5. reduce the chances of mis-administration of radio-pharmaceutical
6. carrying out Quality Assurance tests of equipment periodically, and
7. record and document the result of treatment in patient's file.



The practice of optimization of radiation dose to patient, in diagnostic and different therapeutic nuclear medicine procedures are discussed below one by one.

Case A : Optimisation of dose to patient in nuclear medicine diagnosis procedures

Apparatus:

Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Radiation Survey Meter : This instrument is used to measure radiation levels at 1 m from the patient to ensure the correct administration of radioactive dose to patient.

Procedure:

Following procedure to be followed.

a) Identify the patient
b) Take down previous history, whether the patient has under gone similar test elsewhere before.
c) Note down the medicines regularly being taken by the patient for example iodide based medicine in case of thyroid uptake test.
d) In case of female patient, ensure that the patient is not pregnant and clarify if the patient is lactating or not.
e) In case of child patient particularly, the nuclear medicine diagnostic test should be performed only if is absolutely necessary..
f) Take help of the physician to decide the radioactive dose to be administered to the patient. Ensure that the quantity of radioactivity is within the diagnostic reference level prescribed by the regulatory body.
g) Establish the route of administration of radioactivity in the patient.
h) Measure activity in the vial before administrating to the patient with the help of radioisotope dose calibrator.
i) Estimate the percent error in the measured activity with respect to the prescribed radioactivity to be administered to the patient. It should be within 50%.

j) After the activity administration, take precautions that the patient does not vomit the radioactive material.
k) Prepare instructions related to the patient's safety and ask the patient to follow them strictly.

Observations:

Name of the patient :

Age : Years

Sex : Male/Female

Female Patient :

Lactating : Yes/No

Pregnant : Yes/No

Precautions:

a) While injecting the radioactivity in the patient, it can happen that the radioapaharmaceutical may ooze out through the coupling of needle and the syringe consequently the radioactivity injected to the patient will not be correct. This situation may lead to result in poor image quality of scan and the test might have to be repeated. This situation may be avoided if care is taken in radioactivity administration.

b) When the radiopharmaceutical is administered orally, the patients some times vomit the activity. This situation can be avoided if the patient reports empty stomach and/or given control medicine.

c) One has to be very careful with child patient. The chances of wrong administration of dose are very high.

d) If the Q.A. test or functional study of the equipment is not done periodically, the dose administered to patient will not be correct and it will ultimately lead to unwarranted exposure to patient.

e) Mis-administration of radioactivity in patient has maximum probability in this case. This can be avoided by collective efforts and adopting a code of practice in a institution.

f) In case of mis-administration, consult physician to block the critical organ so that the radioactivity does not accumulate in the organ

Question:

Calculate mean dose to the liver, ovaries, testes and red bone marrow resulting from the intravenous administration of 5mCi of ^{99m}Tc labeled compound that localizes completely and uniformly in liver, assuming instant uptake of activity and infinite biological half life in liver.

Solution :

$D(T \leftarrow S) = \tilde{A}_S \times S(T \leftarrow S)$

$A_S = 1.44 \times 5 \times 10^3$ (μCi) x 6 (h)

$= 43.2 \times 10^3$ (μCi-h)

a. Dose to Liver

$D(Li \leftarrow Li) = 43.2 \times S(Li \leftarrow Li)$

$= 43.2 \times 4.6 \times 10^{-2}$ Rad

$= 198.72 \times 10^{-2}$ Rad

$= 198.72 \times 10^{-1}$ mSv $\cong$ 20mSv

b.. Dose to Ovaries

$D(Ov \leftarrow Li) = 43.2 \times S(Ov \leftarrow Li)$

$= 43.2 \times 4.5 \times 10^{-7}$ Rad

$= 194.4 \times 10^{-4}$ Rad

$= 194.4 \times 10^{-1}$ mSv $\cong$ 0.19 mSv

c.. Dose to Testies $\cdot 10^3$

$D(Ts \leftarrow Li) = 43.2 \times S(Ts \leftarrow Li)$

$\cdot 10^3$

$= 43.2 \times 6.2 \times 10^{-8}$ Rad

$= 267.84 \times 10^{-5}$ Rad

$= 267.84 \times 10^{-4}$ mSv $\equiv$ 0.027 mSv

4.. Dose to R.M $\times 10^3$

$D(RM \leftarrow Li) = 43.2 \times S(RM \leftarrow Li)$

$\times 10^3$

$= 43.2 \times 1.6 \times 10^{-6}$ Rad

$= 69.12 \times 10^{-3}$ Rad

$= 69.12 \times 10^{-2}$ mSv $=$ 0.69 mSv

Case B: Optimisation of dose to patient in treatment of thyroid disease in nuclear medicine

Apparatus:

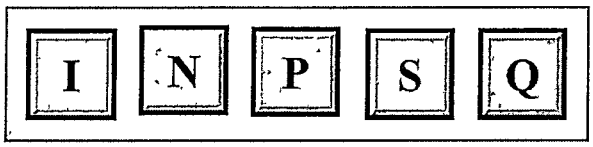
Thyroid Uptake measurement equipment : This unit is used to measure the uptake of radioiodine by thyroid. This unit should be tested and checked for Q.A.

Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Ionisation type radiation survey meter : This instrument is used for the measurement of radiation exposure at a particular distance from the patient administered with large dose of radioiodine.

Procedure:

Following procedure to be followed.



1. Identify the patient

2. Take down previous history, whether the patient has under gone similar test elsewhere before.

3. Note down the medicines regularly being taken by the patient, particularly iodide based medicine.

4. In case of female patient, ensure that the patient is not pregnant and clarify if the patient is lactating or not.

5. If thyroid uptake is not known, study the uptake. Determine the size, shape, mass and function of the thyroid.

6. Take help of physician to find out the radiation dose to be delivered to the patient.

7. Calculate the amount of radioactivity to be administered using MIRD.

8. Establish the route of administration of radioactivity in the patient.

9. Measure activity in the vial before administrating to the patient with the help of radioisotope dose calibrator.

10. Estimate the percent error in the measured activity with respect to the activity to be administered. It should be within 10%.

11. After the dose administration, measure the radiation level at 1 m from the surface of stomach to ensure that the intended dose is administered.

12. Record the mass of the gland, uptake of ^{131}I, dose to be delivered, activity administered, radiation level at 1 m from the surface of patient's stomach etc. in the patient's case file.

13. After the activity administration, take precautions that the patient does not vomit the radioactive material.

14. Prepare instructions related to the patient's safety and ask the patient to follow them strictly.

I N P S Q

Observation:

Name of the patient :

Age : Years

Sex : Male/Female

Female Patient :

Lactating : Yes/No

Pregnant : Yes/No

1. Thyroid Uptake measurement of patient

Sensitivity of the uptake unit : kBq/cpm

Amount of ^{131}I administered : kBq on ...

Effective half life of ^{131}I : days

Mass of the thyroid gland : kg

2. Calculation of dose

Radiation dose to be delivered : Sv

Activity to be administered (A) : MBq

(Refer Appendix-i)

3. Activity administered

Activity in vial before administration (A) : MBq

Activity in vial after administration (B) : MBq

% Error in the dispensed activity [(A-B)/A] x 100 : %

Rad. Exposure at 1 m from the surface of stomach : Gy/h

4. Instruction to patient, related to self safety (Appendix-ii)

Precautions:

Precautions to be taken in this case are also similar to that discussed in case A above.

Questions:

1. Calculate amount of ^{131}I to deliver a thyroid dose of 15 Gy in 3 days to a patient having thyroid uptake of 50% and effective half life 7.6 days.

Solution:

Refer appendix - i, dose to thyroid can be represented as

$$D(Th \neg Th) = A_{Th} \cdot S(Th \leftarrow Th)$$

$$A_{Th} = 1.44 \times A_o \times f \times T_{eff} \{ 1 - e^{-\mu t} \}$$

$f = 0.5$, $\{ 1 - e^{-\mu t} \} = 0.24$

$$S(Th \leftarrow Th) = 2.2 \times 10^{-2} \text{ .... [rad/mCi-h]}$$

$$= 142.7 \times 10^{-9} \text{ ... [Gy/Bq-d]}$$

$$A = D(Th \leftarrow Th) / S(Th \leftarrow Th)$$

$$= 15 / 142.56 \times 10^{-9} \text{ ..... [Bq-d]}$$

$$= 10.5 \times 10^{7} \text{ ..... [Bq-d]}$$

$$A_o \approx 81 \text{ MBq}$$

$$A_o = \frac{A}{1.44 \cdot 0.5 \cdot 7.6d \cdot 0.24}$$

2. What will be the exposure rate at 1 m from the surface of stomach containing 370 MBq of ^{131}I in stomach? Assuming no attenuation in body tissue.

Solution:

The Air Kerma Rate Constant for ^{131}I is 5.5 [mGy-m / 100MBq-h]

Exposure rate at 1 m from the stomach = 5.5 x 370 ... [mGy/h]

$\approx$ 20 m Gy/h

Case C. Optimisation of dose to patient from beta emitting radionuclides used in nuclear medicine therapy

Introduction:

In the treatment of polycythemia Vera, bone metastasis, malignant effusion etc., pure beta emitting radionuclides are used which are difficult to detect from outside. Therefore the optimisation of radiation dose to patient is taken care by :

a) evaluating correct activity to achieve required therapeutic benefit in patient

b) ensuring correct administration of radioactivity to the patient

c) selecting proper radionuclide and route of administration

d) avoiding repeat dose administration to the patient for the same nuclear medicine therapeutic procedure, and

e) instructing the patient to follow safety instructions strictly

Apparatus:

Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Procedure:

Following procedure to be followed.

a) Identify the patient

b) Take down previous history, whether the patient has under gone similar test elsewhere before.

c) Find out the medicines regularly being taken by the patient.

d) In case of female patient, ensure the patient is not pregnant and the patient is lactating or not.

e) Take help of physician to find out the radiation dose to be delivered to the patient.

f) Calculate the amount of radioactivity to be administered using MIRD.

g) Establish the route of administration of radioactivity in the patient.

h) Measure activity in the vial before administrating to the patient with the help of radioisotope dose calibrator.

i) Estimate the percent error in the measured activity with respect to the activity to be administered. It should be within 10%.

j) After the activity administration, measure the activity left over in the dose vial to ensure that the intended activity is administered.

k) Record the dose to be delivered and the activity administered in the patient's case file.

VAJE

20.5.2003

I N P S Q

Case study: VIII-3 Optimisation of doses to patients in nuclear medicine and radiotherapy

Introduction:

In nuclear medicine, unsealed radioactive sources are used in diagnosis and therapy. The risk involved in administration of radioactive material in nuclear medicine procedures is weighted against the advantages likely gained in terms of health and well being of patient. Keeping this factor in view, ICRP-73 has recommended diagnostic reference levels for patients in nuclear medicine procedures. These levels are nothing but the quantity of radionuclide administered in the patient for a particular test. The levels are arrived using generic optimisation of protection by choosing the initial values as percentile point on the observed distribution of doses to patients and optimising the nuclear medicine procedures. However, these levels are selected by professional medical bodies and reviewed at intervals that represent a compromise between the necessary stability and the long term changes in the observed dose distribution. These levels apply to medical exposure and not to occupation and public exposure. Therefore these levels are not used for regulatory or commercial purposes and have no link to dose limits or constraints. The selected values of levels are specified to a country or region.

The reference levels are not applicable for therapeutic procedures. Still, according to ICRP guidelines of radiation protection, any application of radionuclide in medicine is governed by the principles of Justification and Optimisation. There are various types of treatment procedures in nuclear medicine where beta and beta-gamma emitting radionuclides are used. Some of the nuclear medicine therapy procedures along with specific radionuclides and the route of administration are listed in the table - I.

$$D_{(T\leftarrow S)} = A_0 \cdot S_{(T\leftarrow S)}$$

$$A = 1.44 \cdot A_0 \cdot f \cdot T_{eff}$$

Table - I : Common therapeutic procures using radionuclides in nuclear medicine

Radio-nuclide	$T_{½}$ (days)	Energy (MeV)		Applications	Dose & mode of adm.
		Emax	Eavg		
^{131}I	8.0	0.60,..	0.162	• Thyrotoxicosis • Ca-thyroid • Malignancy	(1GBq, oral) (20GBq, oral) (10GBq, IV)
^{32}P	14	1.71	0.695	• Polycythemia vera	(200MBq,IV or oral)
^{89}Sr	50	1.46	0.58	• Bone metastasis	(150MBq,IV)
^{90}Y	2.7	2.27	0.935	• Malignant effusion • Radiosynoviorthesis	(5MBq,IC) (250 MBq, IA)
^{153}Sm	1.9	0.71,..	0.229	• Bone metastasis	
^{186}Re	3.8	1.07,..	0.362	• Bone metastasis • Radiosynoviorthesis	(150 MBq, IA)
^{169}Er	9.5	0.34		• Radiosynoviorthesis	(150 MBq, IA)

In general, attempts are made to determine whether the particular procedure has been adequately optimised and measures are aimed at not to exceed the clinically required radiation level. Practices are introduced to reduce the unwarranted exposures e.g. exposure to target organs due to source organ, exposure due to contamination etc., to the patient. Such exposures can be minimised by practicing the following procedures regularly -

The activity should be administered to the patient with empty stomach so that the activity is quick absorbed and distributed to reduce the probability of vomiting the radioactive material. This will avoid the chance of repeating the treatment.

Functional study of concerned organ(s) should be done before deciding the dose.

1. The radioactivity that is to be administered to the patient, should be calculated on the basis of prescribed radiation dose.
2. The activity should be measured before administration to the patient in order to ensure that required quantity of radionuclide is only administered.

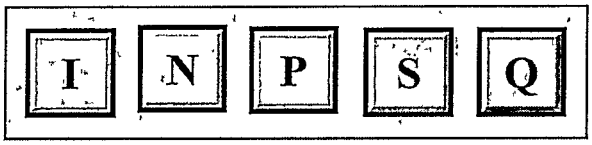
3. Radiation levels should be measured at 1 meter distance from the stomach in order to confirm the administration of correct activity to patient.
4. After the oral dose administration, action should be to promote excretion of saliva in order to reduce dose to salivary glands.
5. The patient should be asked to clear the bladder frequently in order to reduce the exposure to bladder and gonads.
6. The lactating mothers should be asked to pump out milk frequently in order to reduce the exposure to breast.
7. Personnel clothing and linen should be changed frequently in order to avoid unnecessary exposure from the contaminated clothing.

Extreme precautions are necessary in cases of treatment of thyroid diseases. Whereas the treatment with pure beta emitting radionuclides, the radiation exposure to patient is optimised by taking precautions referred above.

Aim:

In nuclear medicine the measures are aimed to keep the effective dose, resulting from the administration of radionuclides, to the lowest level consistent with obtaining the desired therapeutic effect. For this it is necessary to know the absorbed dose to be delivered and the correct equivalent dose to the organ(s) in a therapeutic application. It can precisely be evaluated if the size, shape and function of the organ and the bio-kinetic details of the radio-pharmaceutical are known. The radiation dose to patient is optimised from the risk involved due to the nuclear medicine procedure. The risk is evaluated from the dose to specific organ and the dose to gonads. In general, the exposure to patient can be is optimised to an extent if the following points are put in practice.

1. take into account previous examination(s) to avoid unnecessary exposure or treatment with radio-pharmaceuticals.
2. select proper radio-pharmaceutical and treatment protocol
3. study functional behaviour of organ(s)
4. administer correct activity to obtain required benefit
5. reduce the chances of mis-administration of radio-pharmaceutical
6. carrying out Quality Assurance tests of equipment periodically, and
7. record and document the result of treatment in patient's file.



The practice of optimization of radiation dose to patient, in diagnostic and different therapeutic nuclear medicine procedures are discussed below one by one.

Case A : Optimisation of dose to patient in nuclear medicine diagnosis procedures

Apparatus:

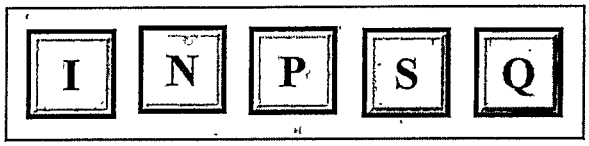
Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Radiation Survey Meter : This instrument is used to measure radiation levels at 1 m from the patient to ensure the correct administration of radioactive dose to patient.

Procedure:

Following procedure to be followed.

a) Identify the patient
b) Take down previous history, whether the patient has under gone similar test elsewhere before.
c) Note down the medicines regularly being taken by the patient for example iodide based medicine in case of thyroid uptake test.
d) In case of female patient, ensure that the patient is not pregnant and clarify if the patient is lactating or not.
e) In case of child patient particularly, the nuclear medicine diagnostic test should be performed only if is absolutely necessary..
f) Take help of the physician to decide the radioactive dose to be administered to the patient. Ensure that the quantity of radioactivity is within the diagnostic reference level prescribed by the regulatory body.
g) Establish the route of administration of radioactivity in the patient.
h) Measure activity in the vial before administrating to the patient with the help of radioisotope dose calibrator.
i) Estimate the percent error in the measured activity with respect to the prescribed radioactivity to be administered to the patient. It should be within 50%.



j) After the activity administration, take precautions that the patient does not vomit the radioactive material.
k) Prepare instructions related to the patient's safety and ask the patient to follow them strictly.

Observations:

Name of the patient :

Age : Years

Sex : Male/Female

Female Patient :

Lactating : Yes/No

Pregnant : Yes/No

Precautions:

a) While injecting the radioactivity in the patient, it can happen that the radioapaharmaceutical may ooze out through the coupling of needle and the syringe consequently the radioactivity injected to the patient will not be correct. This situation may lead to result in poor image quality of scan and the test might have to be repeated. This situation may be avoided if care is taken in radioactivity administration.

b) When the radiopharmaceutical is administered orally, the patients some times vomit the activity. This situation can be avoided if the patient reports empty stomach and/or given control medicine.

c) One has to be very careful with child patient. The chances of wrong administration of dose are very high.

d) If the Q.A. test or functional study of the equipment is not done periodically, the dose administered to patient will not be correct and it will ultimately lead to unwarranted exposure to patient.

e) Mis-administration of radioactivity in patient has maximum probability in this case. This can be avoided by collective efforts and adopting a code of practice in a institution.

f) In case of mis-administration, consult physician to block the critical organ so that the radioactivity does not accumulate in the organ

Question:

Calculate mean dose to the liver, ovaries, testes and red bone marrow resulting from the intravenous administration of 5mCi of ^{99m}Tc labeled compound that localizes completely and uniformly in liver, assuming instant uptake of activity and infinite biological half life in liver.

Solution :

$D(T \leftarrow S) = \tilde{A}_S \times S(T \leftarrow S)$

$A_S = 1.44 \times 5 \times 10^3$ (μCi) x 6 (h)

$= 43.2 \times 10^3$ (μCi-h)

a. Dose to Liver

$D(Li \leftarrow Li) = 43.2 \times S(Li \leftarrow Li)$

$= 43.2 \times 4.6 \times 10^{-2}$ Rad

$= 198.72 \times 10^{-2}$ Rad

$= 198.72 \times 10^{-1}$ mSv $\cong$ 20mSv

b.. Dose to Ovaries

$D(Ov \leftarrow Li) = 43.2 \times S(Ov \leftarrow Li)$

$= 43.2 \times 4.5 \times 10^{-7}$ Rad

$= 194.4 \times 10^{-4}$ Rad

$= 194.4 \times 10^{-1}$ mSv $\cong$ 0.19 mSv

c.. Dose to Testies $\cdot 10^3$

$D(Ts \leftarrow Li) = 43.2 \times S(Ts \leftarrow Li)$

$\cdot 10^3$

$= 43.2 \times 6.2 \times 10^{-8}$ Rad

$= 267.84 \times 10^{-5}$ Rad

$= 267.84 \times 10^{-4}$ mSv $=$ 0.027 mSv

4.. Dose to R.M $\times 10^3$

$D(RM \leftarrow Li) = 43.2 \times S(RM \leftarrow Li)$

$\times 10^3$

$= 43.2 \times 1.6 \times 10^{-6}$ Rad

$= 69.12 \times 10^{-3}$ Rad

$= 69.12 \times 10^{-2}$ mSv $=$ 0.69 mSv

Case B: Optimisation of dose to patient in treatment of thyroid disease in nuclear medicine

Apparatus:

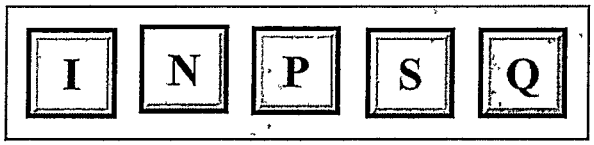
Thyroid Uptake measurement equipment : This unit is used to measure the uptake of radioiodine by thyroid. This unit should be tested and checked for Q.A.

Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Ionisation type radiation survey meter : This instrument is used for the measurement of radiation exposure at a particular distance from the patient administered with large dose of radioiodine.

Procedure:

Following procedure to be followed.



1. Identify the patient

2. Take down previous history, whether the patient has under gone similar test elsewhere before.

3. Note down the medicines regularly being taken by the patient, particularly iodide based medicine.

4. In case of female patient, ensure that the patient is not pregnant and clarify if the patient is lactating or not.

5. If thyroid uptake is not known, study the uptake. Determine the size, shape, mass and function of the thyroid.

6. Take help of physician to find out the radiation dose to be delivered to the patient.

7. Calculate the amount of radioactivity to be administered using MIRD.

8. Establish the route of administration of radioactivity in the patient.

9. Measure activity in the vial before administrating to the patient with the help of radioisotope dose calibrator.

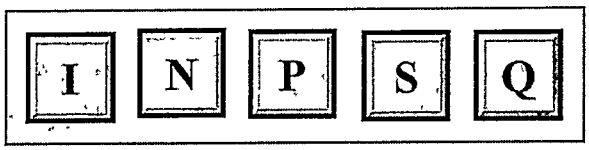
10. Estimate the percent error in the measured activity with respect to the activity to be administered. It should be within 10%.

11. After the dose administration, measure the radiation level at 1 m from the surface of stomach to ensure that the intended dose is administered.

12. Record the mass of the gland, uptake of ^{131}I, dose to be delivered, activity administered, radiation level at 1 m from the surface of patient's stomach etc. in the patient's case file.

13. After the activity administration, take precautions that the patient does not vomit the radioactive material.

14. Prepare instructions related to the patient's safety and ask the patient to follow them strictly.



Observation:

Name of the patient :

Age : Years

Sex : Male/Female

Female Patient :

Lactating : Yes/No

Pregnant : Yes/No

1. Thyroid Uptake measurement of patient

Sensitivity of the uptake unit : kBq/cpm

Amount of ^{131}I administered : kBq on ...

Effective half life of ^{131}I : days

Mass of the thyroid gland : kg

2. Calculation of dose

Radiation dose to be delivered : Sv

Activity to be administered (A) : MBq

(Refer Appendix-i)

3. Activity administered

Activity in vial before administration (A) : MBq

Activity in vial after administration (B) : MBq

% Error in the dispensed activity [(A-B)/A] x 100 : %

Rad. Exposure at 1 m from the surface of stomach : Gy/h

4. Instruction to patient, related to self safety (Appendix-ii)

Precautions:

Precautions to be taken in this case are also similar to that discussed in case A above.

Questions:

1. Calculate amount of ^{131}I to deliver a thyroid dose of 15 Gy in 3 days to a patient having thyroid uptake of 50% and effective half life 7.6 days.

Solution:

Refer appendix - i, dose to thyroid can be represented as

$$D(Th \neg Th) = A_{Th} \cdot S(Th \leftarrow Th)$$

$$A_{Th} = 1.44 \times A_o \times f \times T_{eff} \{ 1 - e^{-\mu t} \}$$

($f \approx 0.5$, $\{ 1 - e^{-\mu t} \} \approx 0.24$)

$$S(Th \leftarrow Th) = 2.2 \times 10^{-2} \text{ .... [rad/mCi-h]}$$

$$= 142.7 \times 10^{-9} \text{ ... [Gy/Bq-d]}$$

$$A = D(Th \leftarrow Th) / S(Th \leftarrow Th)$$

$$= 15 / 142.56 \times 10^{-9} \text{ ..... [Bq-d]}$$

$$= 10.5 \times 10^{7} \text{ ..... [Bq-d]}$$

$$A_o \approx 81 \text{ MBq}$$

$$A_o = \frac{A}{1.44 \cdot 0.5 \cdot 7.6d \cdot 0.24}$$

2. What will be the exposure rate at 1 m from the surface of stomach containing 370 MBq of ^{131}I in stomach? Assuming no attenuation in body tissue.

Solution:

The Air Kerma Rate Constant for ^{131}I is 5.5 [mGy-m / 100MBq-h]

Exposure rate at 1 m from the stomach = 5.5 x 370 ... [mGy/h]

$\approx$ 20 m Gy/h

Case C. Optimisation of dose to patient from beta emitting radionuclides used in nuclear medicine therapy

Introduction:

In the treatment of polycythemia Vera, bone metastasis, malignant effusion etc., pure beta emitting radionuclides are used which are difficult to detect from outside. Therefore the optimisation of radiation dose to patient is taken care by :

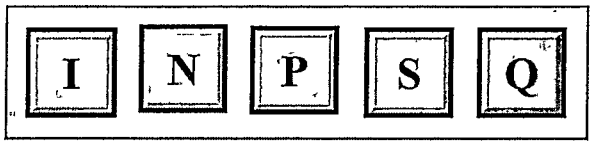
a) evaluating correct activity to achieve required therapeutic benefit in patient

b) ensuring correct administration of radioactivity to the patient

c) selecting proper radionuclide and route of administration

d) avoiding repeat dose administration to the patient for the same nuclear medicine therapeutic procedure, and

e) instructing the patient to follow safety instructions strictly



Apparatus:

Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Procedure:

Following procedure to be followed.

a) Identify the patient

b) Take down previous history, whether the patient has under gone similar test elsewhere before.

c) Find out the medicines regularly being taken by the patient.

d) In case of female patient, ensure the patient is not pregnant and the patient is lactating or not.

e) Take help of physician to find out the radiation dose to be delivered to the patient.

f) Calculate the amount of radioactivity to be administered using MIRD.

g) Establish the route of administration of radioactivity in the patient.

h) Measure activity in the vial before administrating to the patient with the help of radioisotope dose calibrator.

i) Estimate the percent error in the measured activity with respect to the activity to be administered. It should be within 10%.

j) After the activity administration, measure the activity left over in the dose vial to ensure that the intended activity is administered.

k) Record the dose to be delivered and the activity administered in the patient's case file.

l) After the dose administration, take precautions that the patient does not vomit the dose.

m) Prepare instructions related to the patient's safety and ask the patient to follow them strictly.

Observation:

Name of the patient :

Age : Years

Sex : Male/Female

Female Patient :

Lactating : Yes/No

Pregnant : Yes/No

1. Effective half life of the radionuclide : days

Mass of the body : kg

2. Calculation of dose

Radiation dose to be delivered : Sv

Activity to be administered (A) (Refer Appendix-i) : MBq

3. Activity administered

Activity in vial before administration (A) : MBq

Activity in vial after administration (B) : MBq

% Error in the dispensed activity [(A-B)/B] x 100 : %

4. Instruction to patient, related to self safety (Appendix-ii)

Precautions:

The problems faced in this case are also similar to that discussed in case A above.

Question:

1. Calculate the amount of 32P to delivered a committed dose of 22 Gy to bone marrow of a patient having 70% uptake in bones and 1155 days effective half life.

Solution:

$$D(BM \leftarrow B) = A_B \,.\, S(BM \leftarrow B)$$

$$A_B = 1.44 \times A_o \times f \times T_{eff}$$

$$S(BM \leftarrow B) = 8.7 \times 10^{-5} \text{ .... [rad/mCi-h]}$$

$$= 5.64 \times 10^{-10} \text{ ... [Gy/Bq-d]}$$

$$A = D(Th \leftarrow Th) / S(Th \leftarrow Th)$$

$$= 22 / 5.64 \times 10^{-10} \text{ ..... [Bq-d]}$$

$$= 3.9 \times 10^{10} \text{ ..... [Bq-d]}$$

$$Ao \approx 33 \text{ MBq}$$

I N P S Q

Case D: Optimisation of dose to patient in the treatment of radiosynoviorthesis in nuclear medicine

Introduction:

In the treatment of radiosynoviorthesis, beta emitting radionuclides are injected locally. In this case the optimisation of radiation dose to patient is taken care by :

a) evaluating correct radiation dose to achieve required therapeutic benefit in patient

b) ensuring correct radioactive dose administration to the patient

c) selecting proper radionuclide

d) avoiding repeat dose administration to the patient for the same therapeutic procedure, and

e) immobilising the joint where activity is injected so that the radioactivity does not migrate to other place or organ.

f) ensuring proper intra-articular administration of radioactivity.

Apparatus:

Isotope dose calibrator : This instrument is used to measure every radioactive dose before administration to patient. The Q.A. test of the equipment should necessarily be done periodically and its performance be tested every day with a check source.

Procedure:

Following procedure to be followed.

1. Identify the patient

2. Take down previous history, whether the patient has under gone similar test elsewhere before.

3. In case of female patient, ensure that the patient is not pregnant and the patient is lactating or not.

4. Take help of physician to find out the radiation dose to be delivered to the patient.

5. Calculate the amount of radioactivity to be administered using MIRD.

6. Measure activity in the syringe before the administration to the patient

7. Estimate the percent error in the measured activity with respect to the activity to be administered. It should be within 10%.

8. After the activity administration, measure the activity left over in the syringe to ensure that the intended activity is administered.

9. Record the dose to be delivered and activity administered in the patient's case file.

10. After injecting the activity, ensure that the activity remains localised in the area of interest

11. Prepare instructions related to the patient's safety and ask the patient to follow them strictly.

Observation:

Name of the patient :

Age : Years

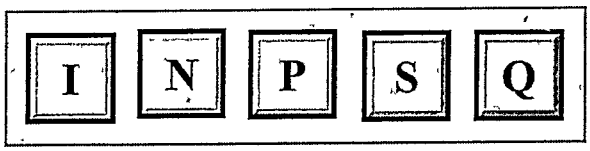
Sex : Male/Female

Female Patient :

Lactating : Yes/No

Pregnant : Yes/No

1. Calculation of dose



Radiation dose to be delivered : .... Sv

Activity to be administered : MBq

2. Activity administered

Activity in syringe before administration (A) : MBq

Activity in the syringe after administration (B): MBq

% Error in the dispensed activity (A/B) x 100 : %

3. Instruction to patient, related to self safety (Appendix-ii)

References:

1. ICRP-73, Radiological protection & safety in medicine (1996).
2. ICRP-52, Protection of patient in nuclear medicine (1987)
3. Instrumentation in Nuclear medicine - H.J.Hine and G.J.Brownell.
4. Textbook of Nuclear Medicine : Basic Science - A.F.G.Rocha & J.C.Harbert. Second Edition

Appendix - i

To deliver correct dose in a therapeutic application or to evaluated the risk due to a nuclear medicine examination, it is necessary to determine the absorbed dose to different organs and the effective dose to patient. But it is difficult to assess asses dose due to the uncertainty in metabolic behaviour of radiopharmaceutical in the body. However, to arrive at the optimum quantity of radiopharmaceutical, it is necessary to have knowledge of the types of radiations emitted from the radionuclide to be administered and have the data about the size, shape and the accumulation of activity in organ(s).

Dose to an organ from all types of radiation emitted is expressed as

$$D(T \leftarrow S) = A_S \,.\, \Sigma_i \Delta_i \,.\, \Phi_i(T \leftarrow S) \ldots [Gy]$$

Where A_S - Cumulated activity in the source organ in [MBq-h]

Δ_i - is the equilibrium dose constant for i type of radiation in [Gy-Kg/MBq-h]

$\Phi_i(T \leftarrow S)$ - is Specific Absorbed Fraction for i type of radiation in an organ

$$\Phi_i(T \leftarrow S) = \phi_i(T \leftarrow S)/M$$

Where

$\phi_i(T \leftarrow S)$ - Absorbed Fraction for i type of radiation

M - Mass of the source organ in Kg

$$D(T \leftarrow S) = \text{`} A_S \,.\, S(T \leftarrow S)$$

$$S(T \leftarrow S) = S_i \Delta_i \,.\, \Phi_i(T \leftarrow S)$$

$S(T \leftarrow S)$ - is known as Absorbed Dose per unit Cumulated Activity

MIRD has published S-values for different organs and radionuclides in old units (rad/mCi-h). These are to be converted in SI units.

For example S(Th ← Th) for ^{131}I is 2.2×10^{-2} rad/mCi-h

In SI unit $S(Th \leftarrow Th) = 142.56 \times 10^{-9}$ [Gy/Bq-d]

Similarly the equilibrium dose constant for i types of radiation emitted per disintegration is expressed as

$\Delta_i = k_i \cdot n_i \cdot E_i$ ..... [Gy-Kg/MBq-h]

Where k_i - is a constant, the numeric value of which depends on the unit chosen

n_i - is the number of particles per disintegration

E_i - is the mean energy of the particles per disintergration

The values of Δ_i can be found in MIRD pamphlet. The MIRD pamphlet deals in old units [rad-g/mCi-h]. Therefore, the figures are to be calculated in SI units.

For example Δ_i for 0.365 MeV photons of ^{131}I is

$\Delta_i = 0.833 \times 0.365 = 0.304$ ... [MeV/disintegration]

$\Delta_i = 0.304 \times 106 \times 1.602 \times 10^{-19}$ .. [J/disintegration]

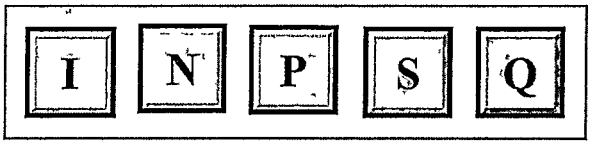
$\Delta_i = 0.487 \times 10^{-13}$ ..... [J/disintegration]

If we assume an activity of 1 MBq, then

$\Delta_i = 0.487 \times 10^{-13} \times 10^{6}$ ..... [J/MBq-s]

$= 0.487 \times 10^{-7} \times 3600$ .... [J/MBq-h]

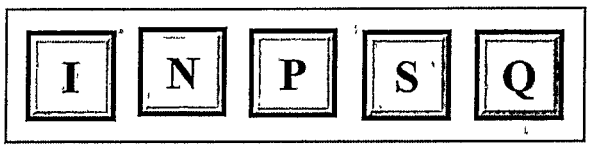
$= 1.753 \times 10^{-4}$ ..... [J/MBq-h]



$= 1.753 \times 10^{-4}$ ..... [Gy-Kg/MBq-h]

Cumulative activity

Using equation-1, one can also calculated the required amount of activity to deliver specified exposure to the patient or organ.



Appendix - ii

Instruction to the patient

1. Patient should consume more and more fluid in order to enhance the urination.

2. Patient should clear the bladder frequently and wash the organs after urination.

3. Patient should change personal clothes frequently

4. The lactating mother should pump out breast milk frequently

5. Patient should wash body thoroughly regularly