EVALUATION OF THE DOSE RECEIVED IN THE TISSUES OF THE NECK DURING THE QUANTIFICATION OF IODINE IN THE THYROID BY X-RAY FLUORESCENCE SPECTROMETRY

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Table of Contents

- INTRODUCTION TO THE PROBLEM
- EVALUATION OF THE DOSE AND RISK TO THE TISSUES
  - ✓ Choice of Phantom
  - ✓ Choice of Dosimeters
- MEASURING CONDITIONS
- MEASUREMENT OF THE DOSE: EVALUATION OF REPEATABILITY
- INFLUENCE OF THE DISTANCE BETWEEN THE GENERATOR AND THE PHANTOM ON THE DOSE
- INFLUENCE OF IODINE CONCENTRATION ON THE DOSE
- “HEAD-NECK” PHANTOM
- CONCLUSIONS

Introduction to the Problem

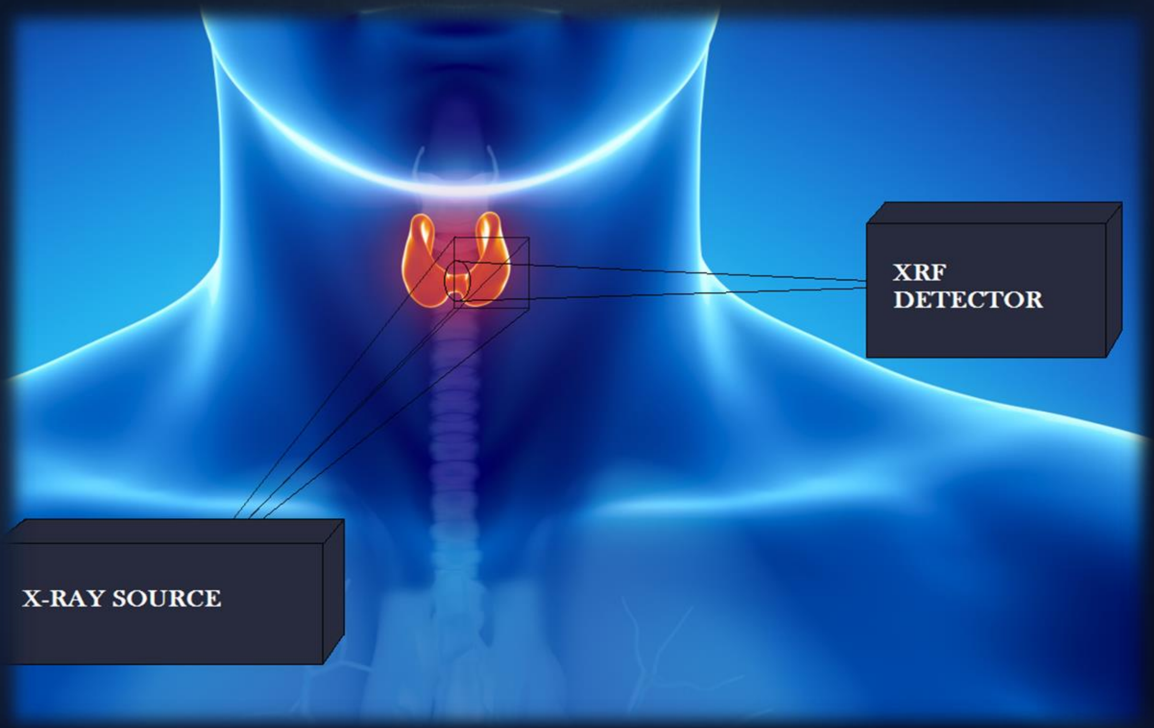
Knowledge of the amount of Iodine stored in the thyroid, considering that both deficient and excessive Iodine intake is known to cause thyroid dysfunction, may contribute to the understanding of thyroidal diseases.

Hence, there is a need for *non-invasive* methods for assessment of the Iodine pool *in vivo.*

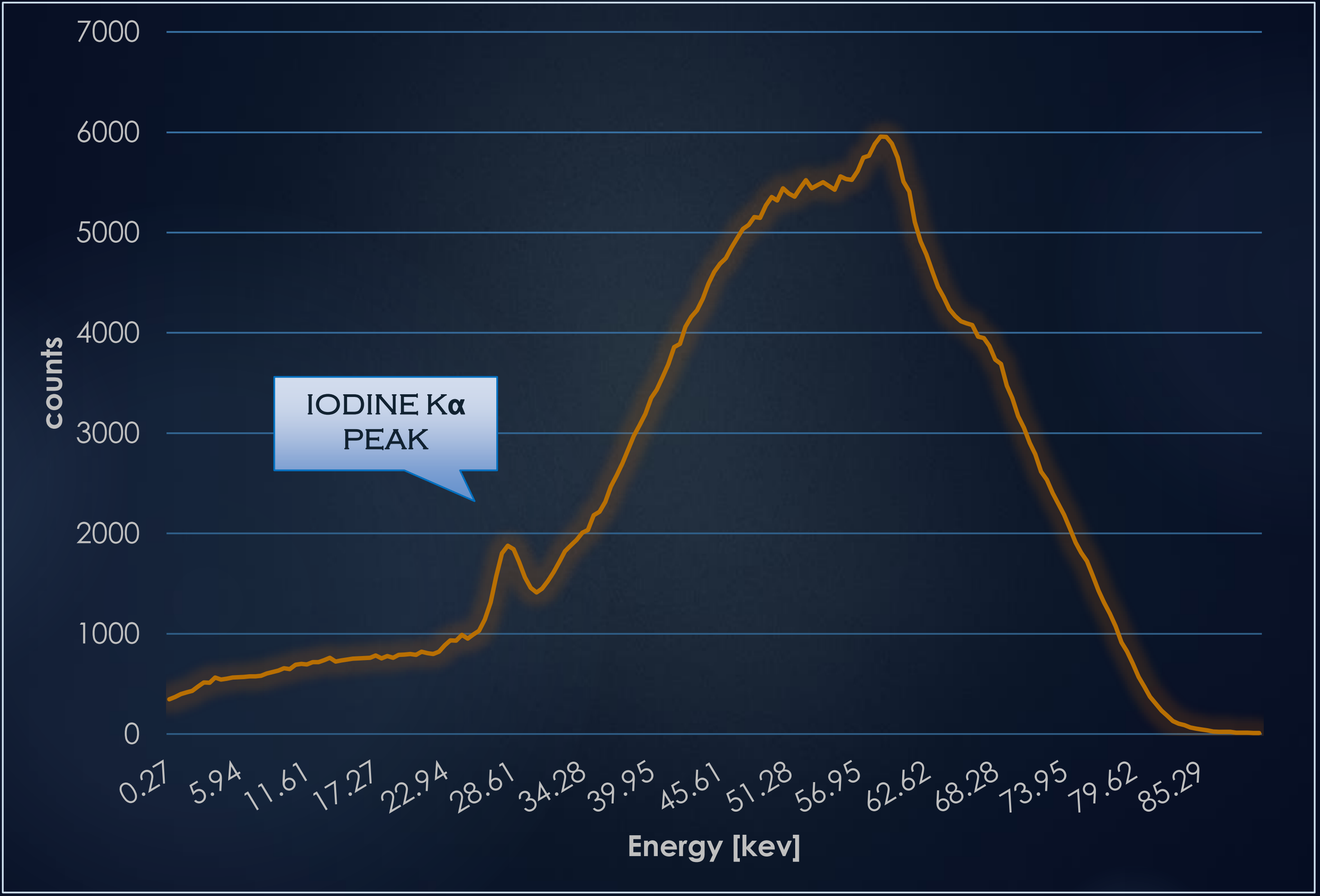
Previous works demonstrated that XRF spectrometry is an efficient tool for intrathyroidal iodine measurement.

We have to check, above all, that this technique results in a *low radiation dose to the patient*.

The purpose of our study is to determine the dose received by the thyroid and the tissues around, in the frame of this analysis.



CHARACTERISTIC XRF SPECTRUM OBTAINED



Evaluation of the Dose to the Tissues

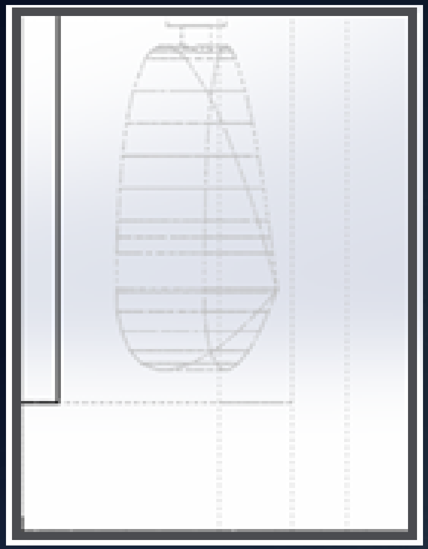
Choice of Phantom

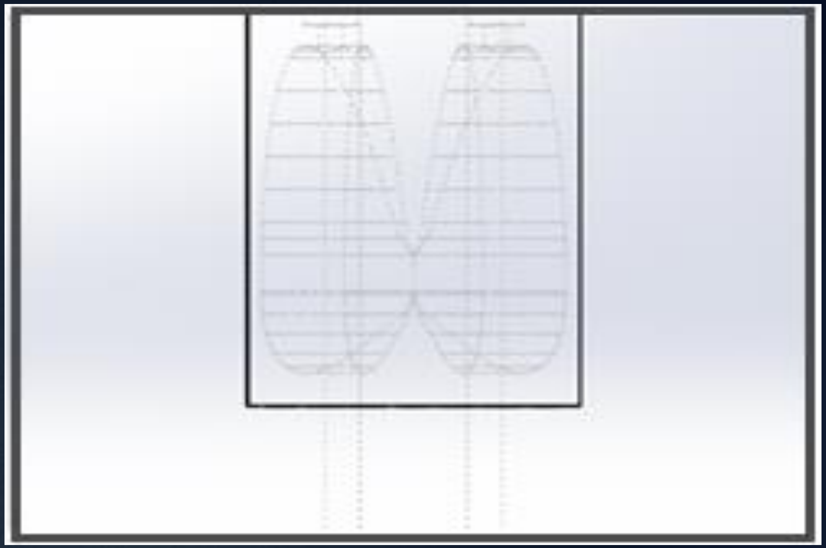
Our previous studies suggested to use a PLA (polylactic acid) phantom.

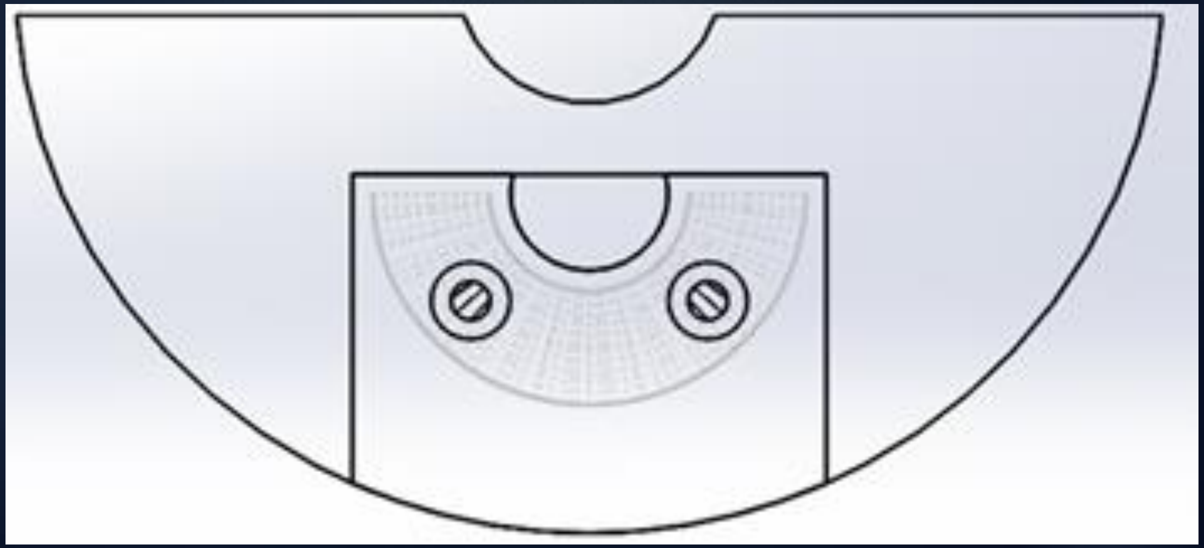
PLA is a suitble material for 3D printing and it has a mass attenuation coefficient (μ/ρ) comparable with the soft tissue one, in the range of energy characteristic of iodine peak. It can be considered as tissue equivalent.

The phantom is made up of 2 parts:

- The first representing the thyroid and the trachea, in which the cavity may be filled with a saline solution containing varying concentrations of iodine.
- The latter representing the remaining part of the front of the neck







Choice of Dosimeters

We opted for LiF:Mg,Ti TLDs.

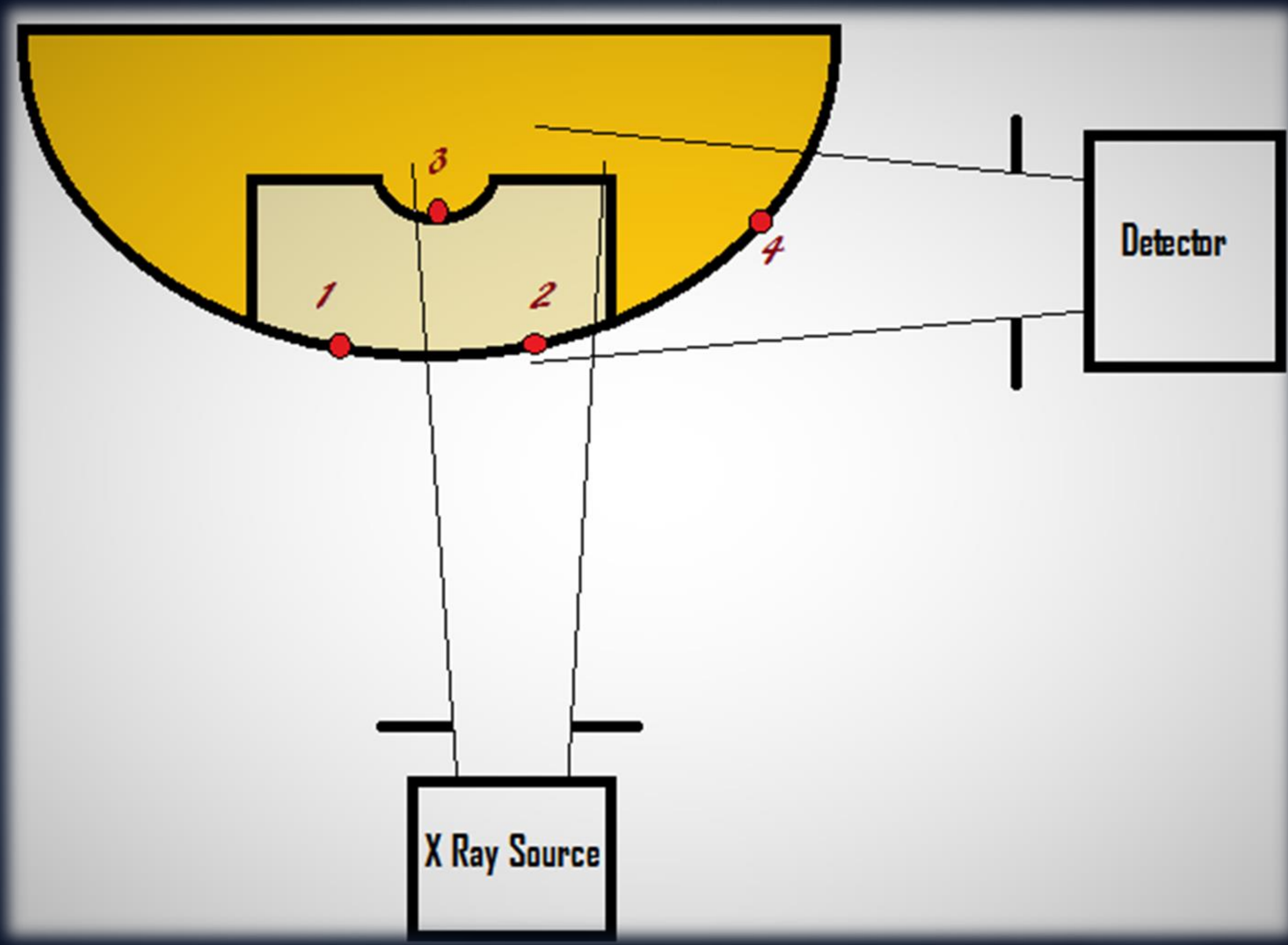
The choice is, firstly, due to the near tissue-equivalence of the material and to the small dimensions, moreover, they allow to measure doses down to 0,1 mGy with a moderate sensitivity.


A2
B5
A8

In agreement with previous work, the beam is aligned on the left lobe

4 dosimeters were positioned in different places on the phantom, one in the middle of the frame of the beam (n2), one in the trachea (n3) and two on each side of the beam (n1 and n4).

The dosimeters 1, 2 and 4 are giving dose at the skin.


3
1
2
4
Detector
X Ray Source

EVALUATION OF THE DOSE TO THE TISSUES

Measuring Conditions

The setup was finalised in previous studies:

- Distance between X-Ray source and phantom: 25cm
- Distance between phantom and detector: 6cm
- Angle between X-Ray primary beam and detector axes: 90°
- Tension and current of X-Ray source (w anode): 80kV and 0.5ma
- Size of X-Ray source squared collimator: 0.8x0.8cm
- Size of beam spot on phantom: 2.2x1.8cm
- Diameter of X-123CdTe detector circular collimator : 0.5mm
- Region of interest for iodine peak: from 26.5kev to 29.5kev
- Thickness of copper filter on primary x-ray beam: 0.5mm
- Irradiation time: 30s

Measurement of the dose: Evaluation of Repeatability

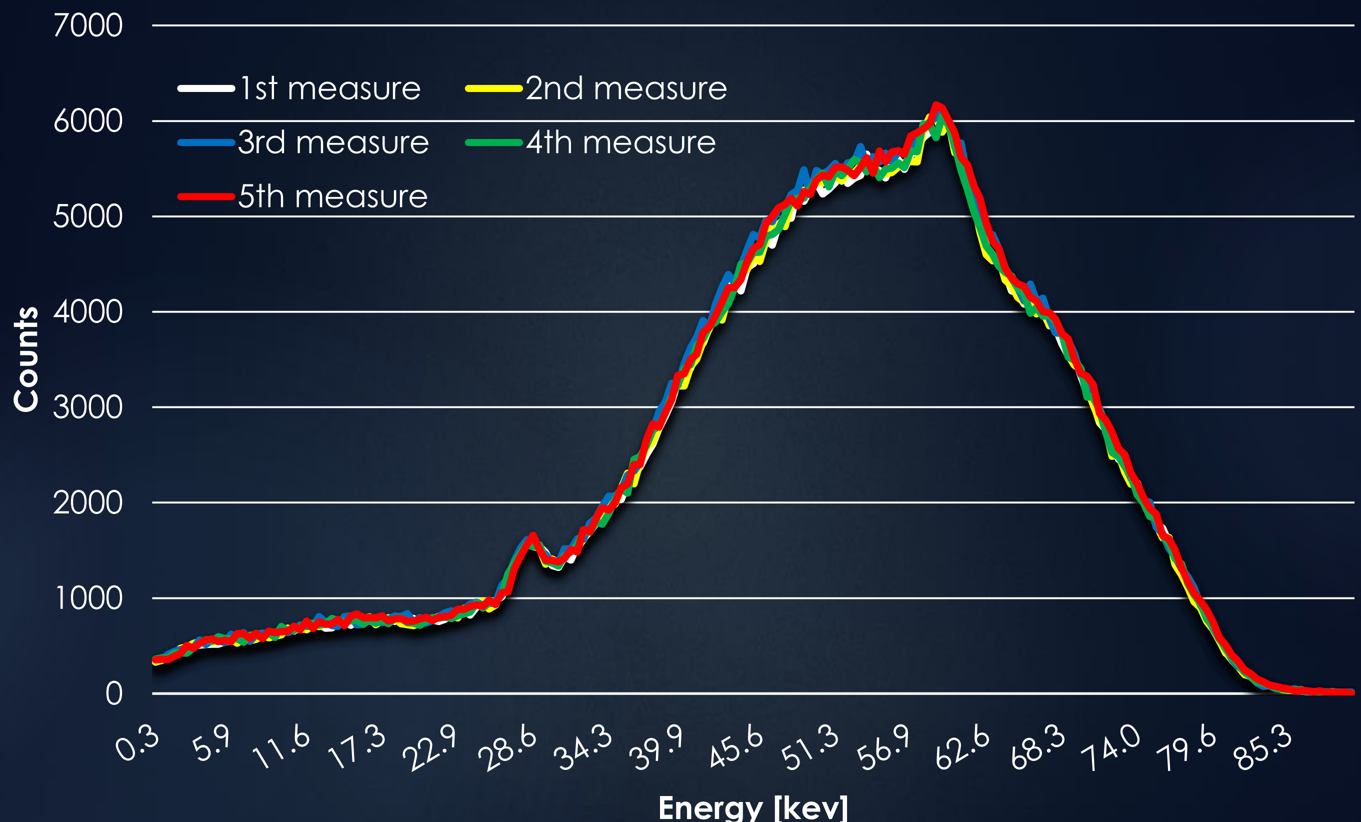
The XRF acquisition is repeated 5 times (conditions of measurement strictly the same), using 4 dosimeters for each acquisition.

Phantom filled with 0.9mg/ml iodine solution

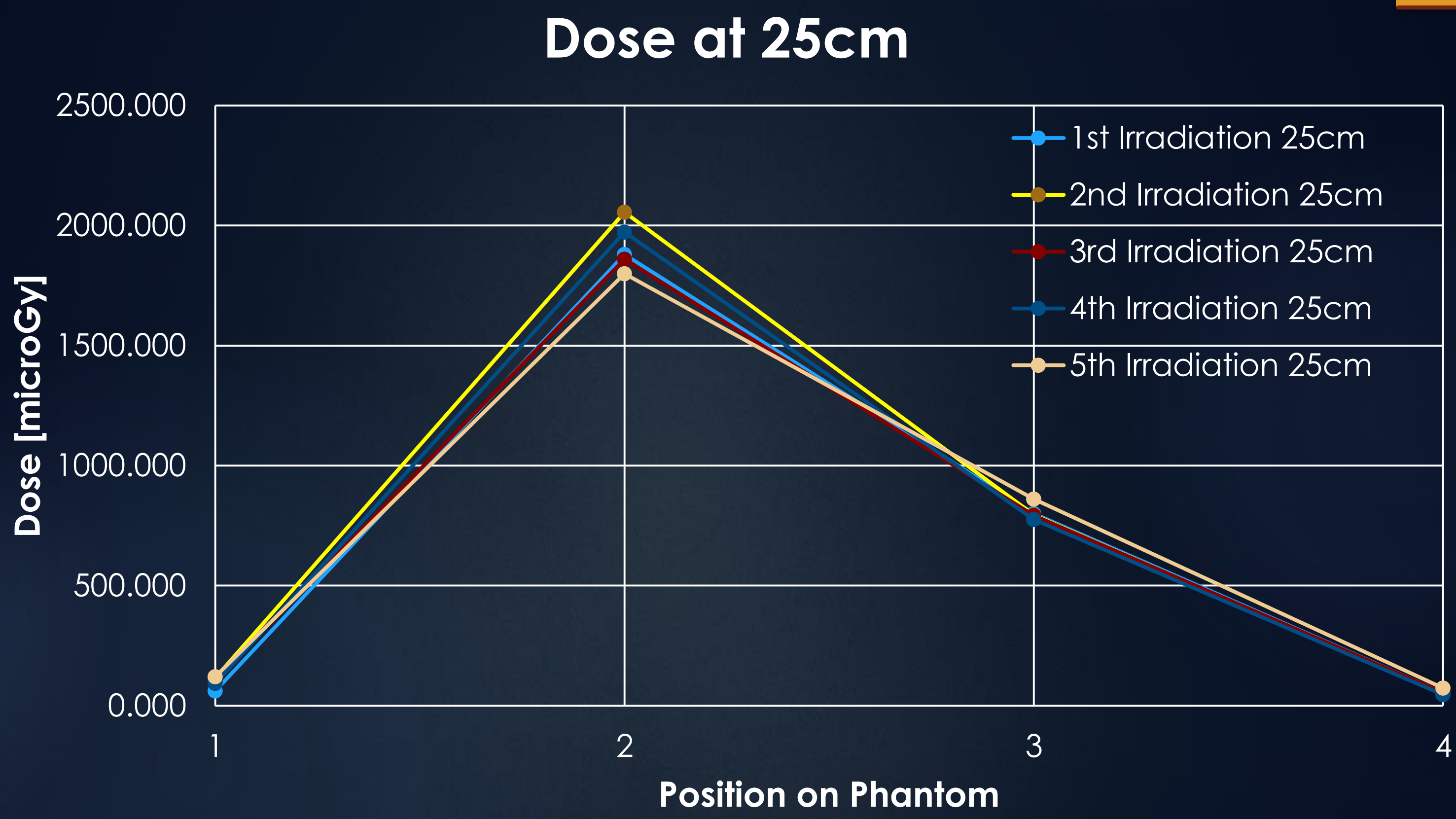
-Acquisition of the spectrum

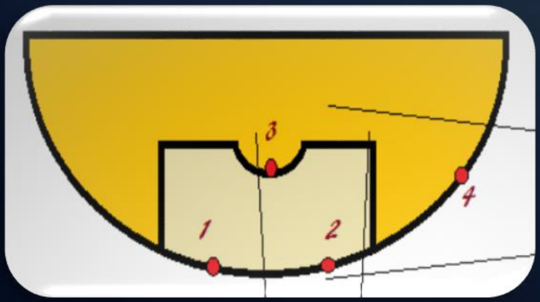
-Measurement of the dose

XRF Spectrometry with 0,9mg/ml IODINE



	Mean Value	St. Dev.	RSD
Background counts in the peak area	7119	80,9	1,14%
Net peak Ka counts	1577	106,1	6,73%
Ratio Ka peak/background	18,14%	1,05%	5,79%





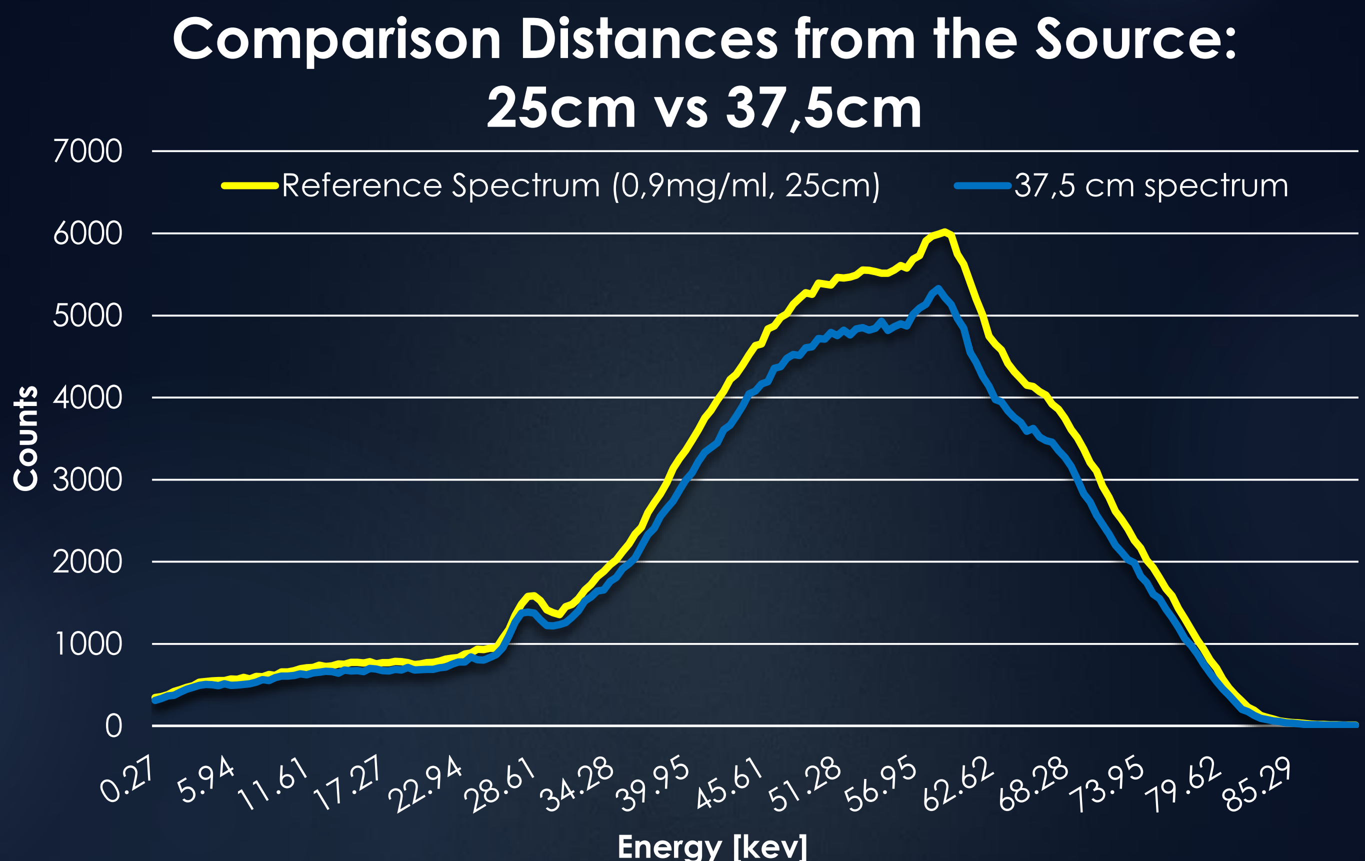
Position	Mean Value	St. Dev.	Relative St. Dev.
1	99,74	23,3	23%
2	1913,37	100,8	5%
3	804,68	32,6	4%
4	54,87	10,9	20%

Influence of the Distance Between the Generator and the Phantom on the Dose

We measured dose at 2 different distances between source and phantom:

25cm and 37.5cm

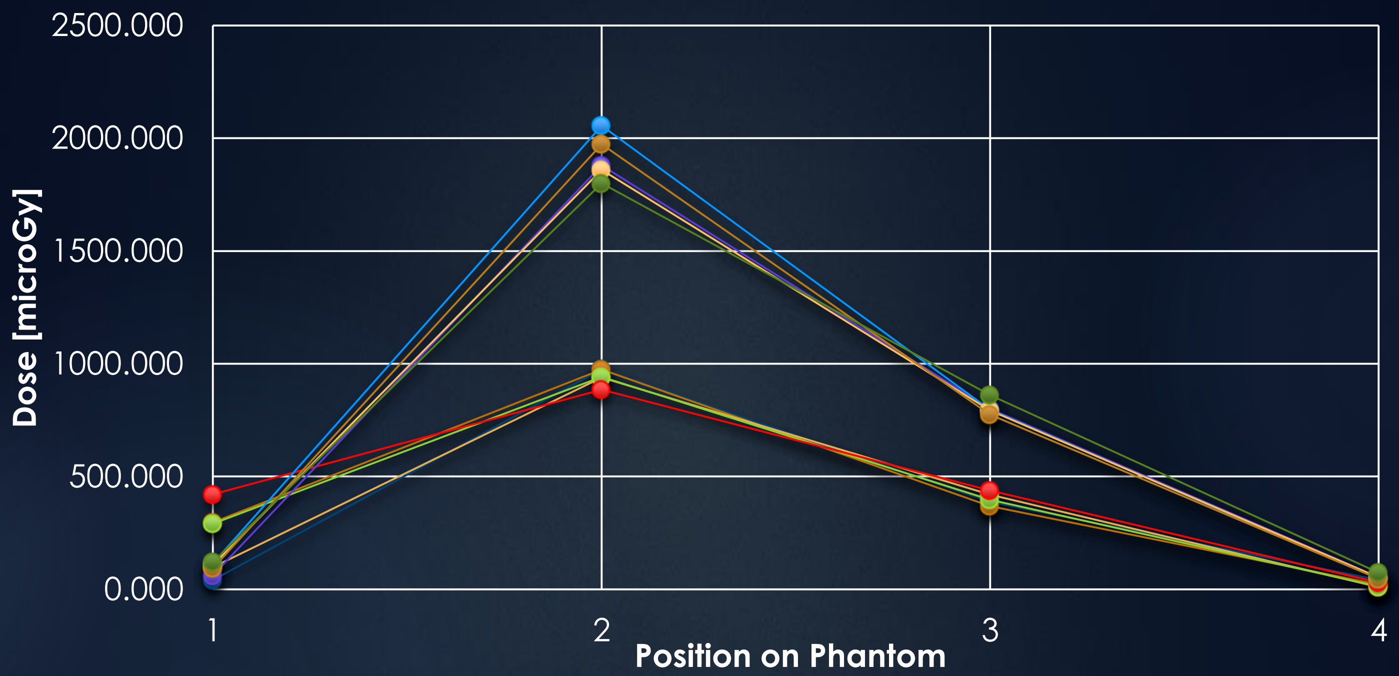
Phantom filled with 0.9mg I/ml



	Mean Value		St. Dev.		RSD	
	37,5cm	**25cm**	37,5cm	**25cm**	37,5cm	**25cm**
Background counts in the peak area	6289	**7119**	169,9	**80,9**	2,7%	**1,14%**
Net peak Ka counts	1498	**1577**	200,4	**106,1**	13,38%	**6,73%**
Ratio Ka peak/background	19,23%	**18,14%**	2,36%	**1,05%**	12,27%	**5,79%**

INFLUENCE OF THE DISTANCE BETWEEN THE GENERATOR AND THE PHANTOM ON THE DOSE

Dose at 37,5cm vs Dose at 25cm



Results for 37,5cm

Position	Mean Value	St. Dev.	Relative St. Dev.
1	229,17	156,2	68%
2	943,59	37,2	4%
3	402,48	27,1	7%
4	22,76	12,9	56%

HIGH RSD DUE TO THE DIFFICULTIES IN POSITIONING OF THE PHANTOM

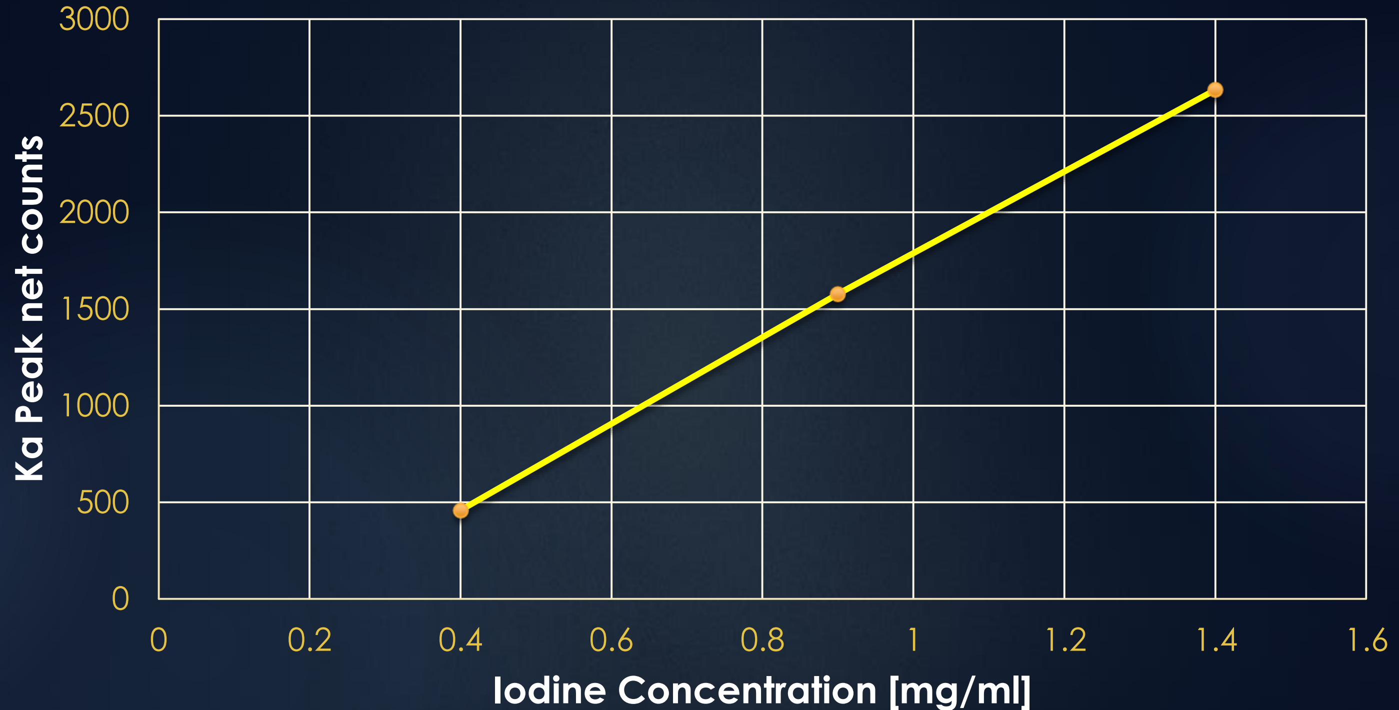
HIGH RSD LINKED TO THE LOW VALUE OF THE MEASUREMENT

Influence of Iodine Concentration on the Dose

In a previous study, we observed a linearity between the counting rate in the peak of Iodine and the concentration of Iodine.

We want to check that the dose is not influenced by this concentration.

Calibration Ka Peak counts vs Iodine Concentration



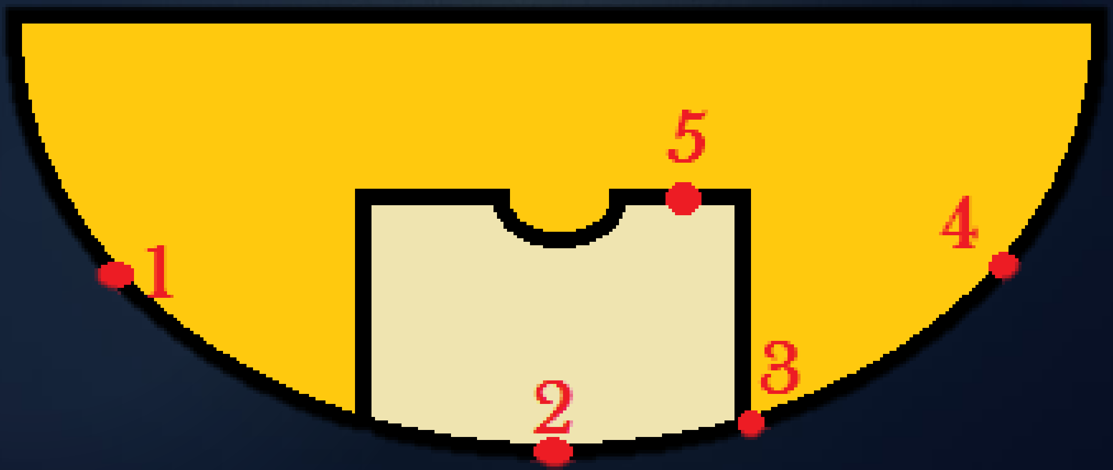
Iodine Concentration [mg/ml]	Ka Peak net counts	St. Dev.
0,4	459	2,46%
0,9	1577	1,05%
1,4	2634	1,87%

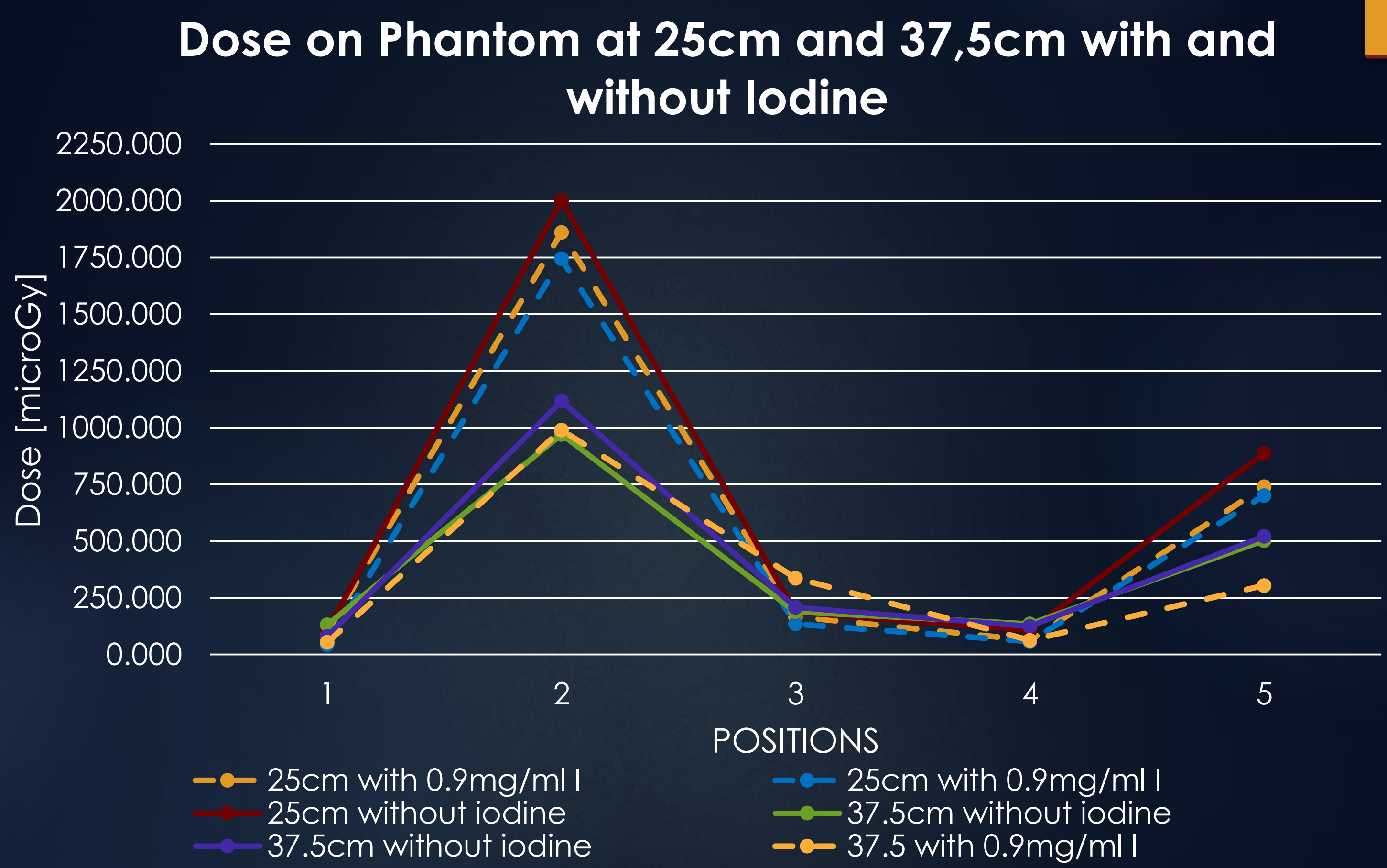
INFLUENCE OF IODINE CONCENTRATION ON THE DOSE

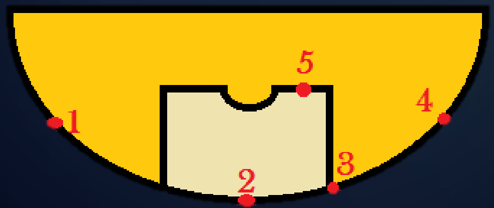
We evaluated dose on phantom in the same conditions as before, using 3 times a 0,9mg/ml iodine solution and 3 times a saline solution without iodine to fill the phantom.

In this case, we utilized more dosimeters for each irradiation, in order to perform a more complete dose map.

The dosimeters n2 and n5 are directly on the beam spot







Iodine concentration does not affect the dose on neck tissues

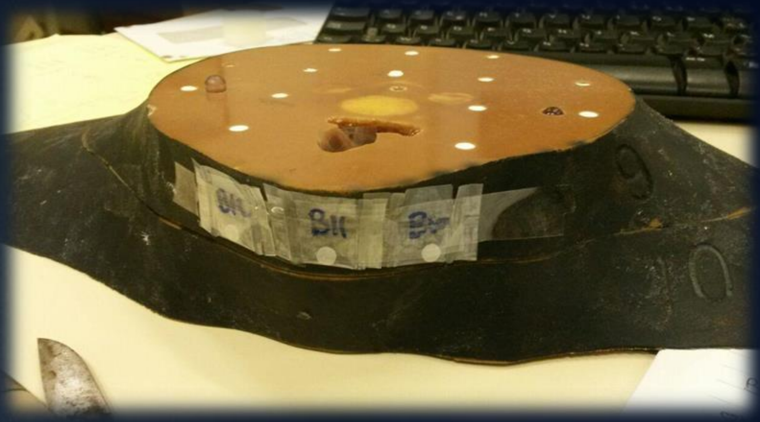
"Head-neck" Phantom

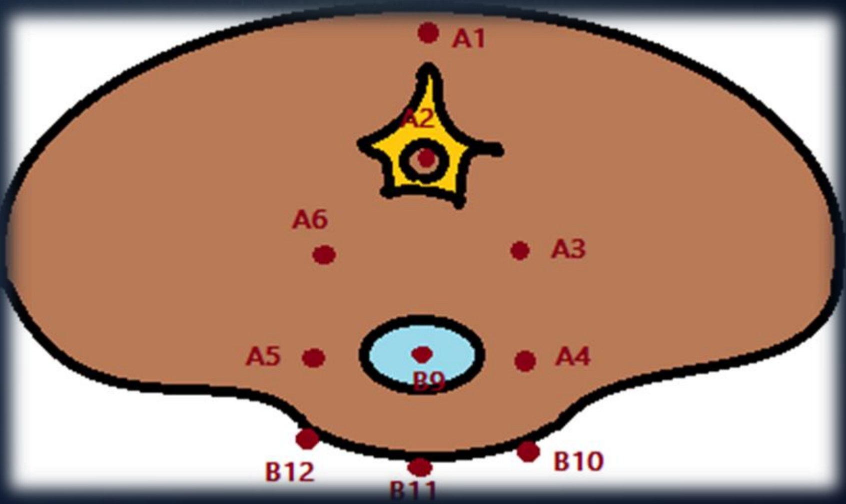
Phantom "head-neck" composed of soft tissue equivalent material and real bone for the spine.

Measurement of the dose at important organs spine (spinal cord), eye(lens), trachea.

Beam focused on the center of the neck.

Dose measured with the same procedure.




A1
A2
A6
A3
A5
A4
B9
B12
B11
B10

A2, ON THE SPINE	303µGy
A1, BEHIND THE SPINE	139µGy
ON THE RIGHT EYE	17µGy
ON THE LEFT EYE	19µGy
B9, TRACHEA	990µGy
B11, FRONT SKIN	1005µGy
B12 LEFT SIDE OF BEAM	38µGy

Less conservative conditions, XR beam focused on the middle of the neck.

Doses similar (same order of magnitude) to the one obtained with the PLA phantom.

Results for very sensitive organs (eye, spinal cord).

Highlight the necessity to focus the XR beam slightly shifted from the axis trachea-spine.

Conclusions

The aim of this study was to evaluate the dose received by the patient in the frame of XRF measurement of Iodine in the thyroid.

We selected LiF dosimeters, because of their good sensitivity in the range of dose measured, and because of their size appropriate to our phantom.

The dose is varying with the position of the dosimeter on and in the neck.

Using our measurement conditions, the dose is varying from 2mGy to several µGy.

It is possible to keep the dose at the skin at the point of impact with the beam lower than 1 mGy, keeping adequate conditions to have an accurate measurement of Iodine.

The dose at the organs, other than the thyroid, is much lower and in the range of several µGy.

The dose measurement has to be continued in different situations: varying thickness of tissue between the skin and the thyroid, for example.