CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

Vilnius University Hospital SANTAROS KLINIKOS

Branduolinės medicinos apšvita ir jos valdymas

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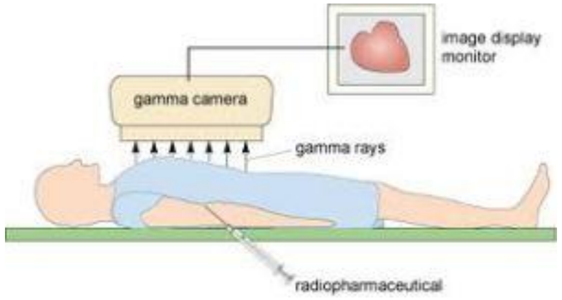
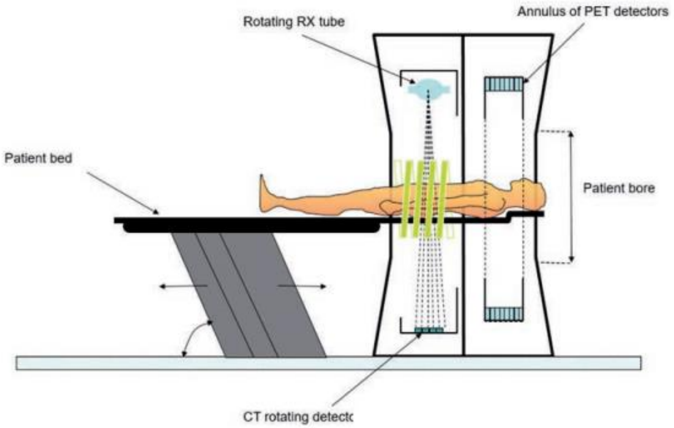
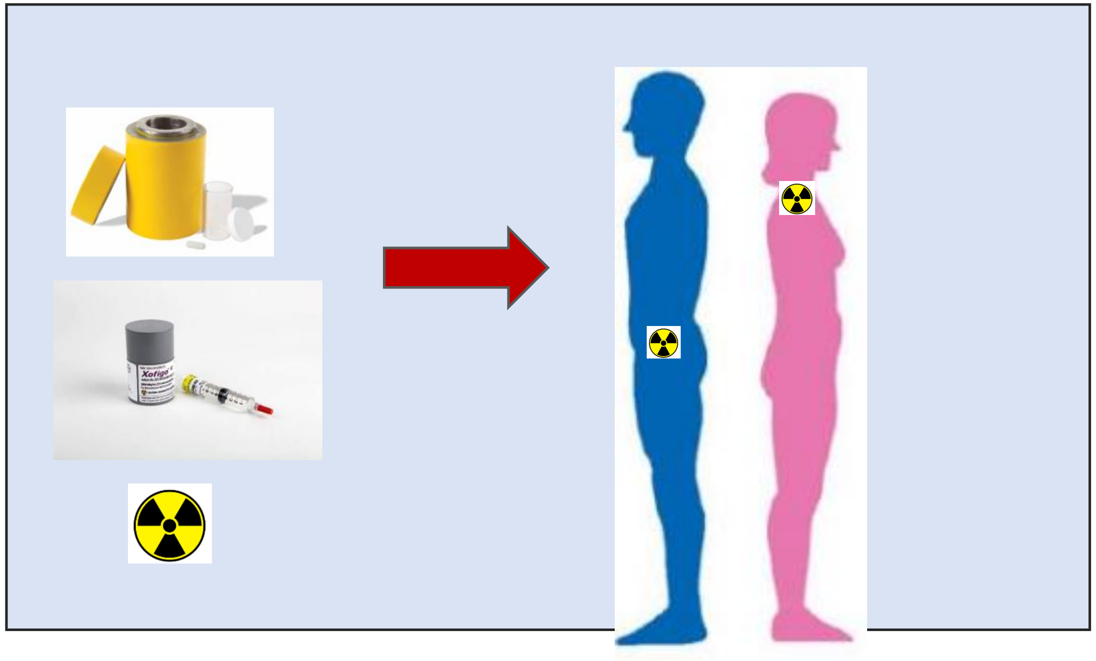
Branduolinė medicina

- Diagnostika
- Hibridinis vaizdinimas (diagnostika, diagnostika+terapija)
- Terapija (klasikinė)
- Molekulinė terapija/personalizuota terapija



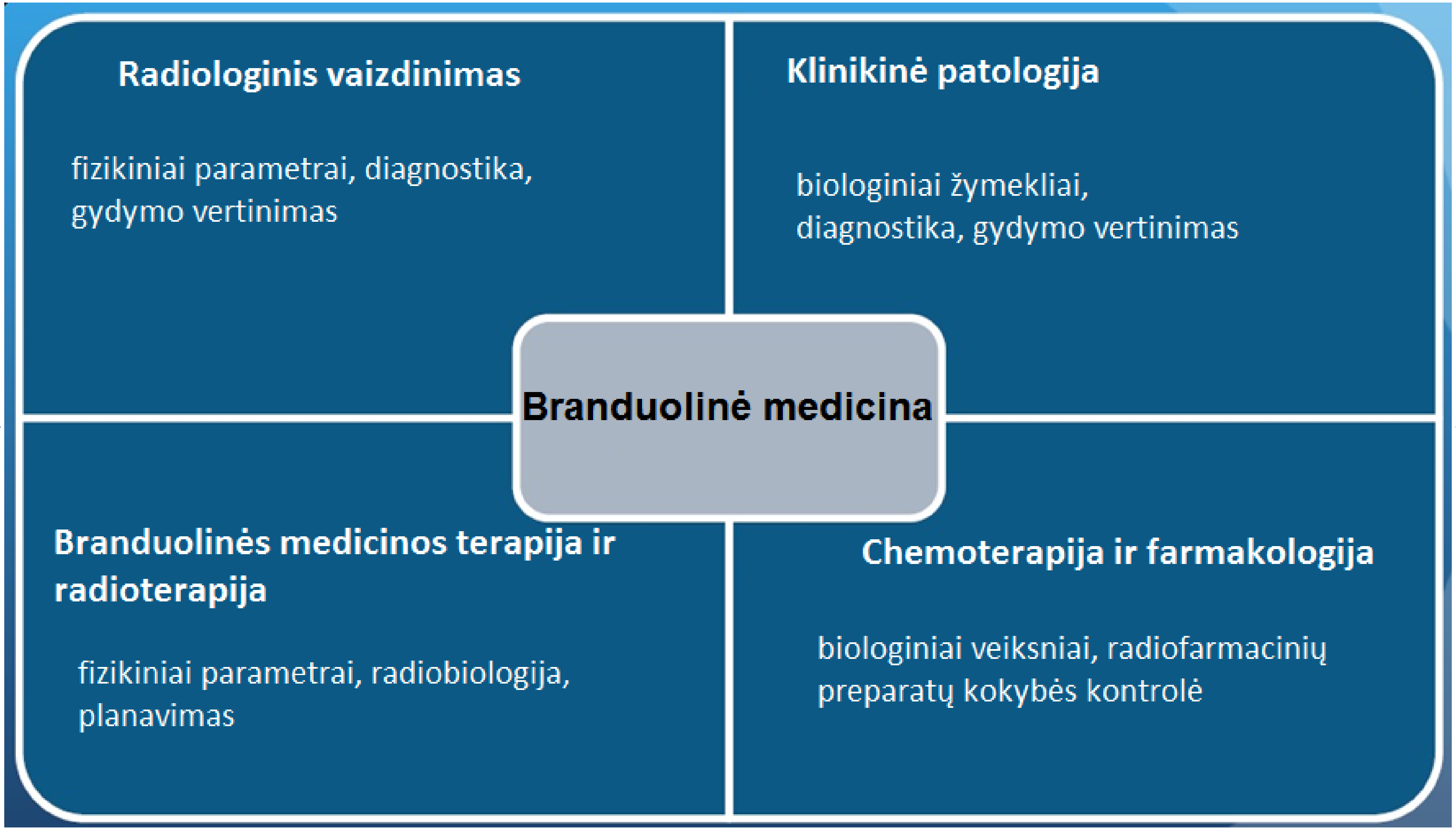


PET–CT scanner (courtesy of M. Marengo).



Šiuolaikinė branduolinė medicina

- Informacinės technologijos
- Metrologija
- Statistika

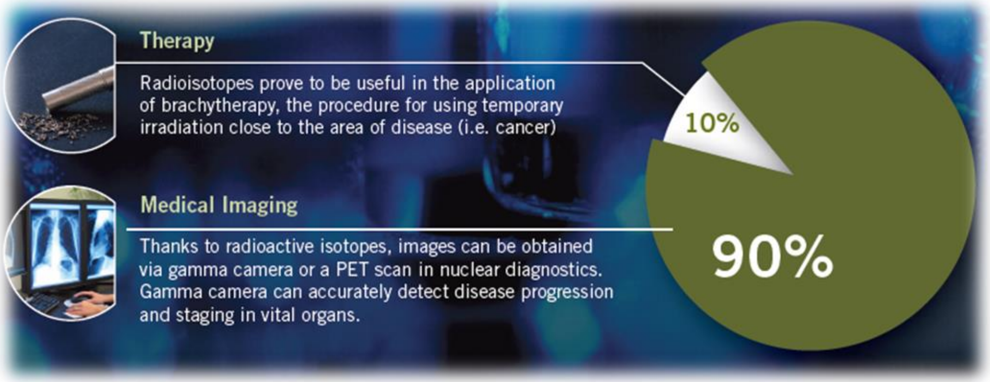


- Matematika
- Kokybės valdymo sistema
- Radiacinė sauga

Šiuolaikinė branduolinė medicina (BM)

- Pagal 2018 m. World Nuclear Association paskelbtus duomenis, kiekvienais metais pasaulyje atliekama virš 40 mln. branduolinės medicinos procedūrų ir šis skaičius auga 5 % kasmet.
- Pasaulyje yra daugiau nei 10 000 ligoninių, kuriose atliekamos BM procedūros.
- Terapija sudaro apie 10 %.
- Lietuvoje nuo 2017 iki 2020, dvylikai populiariausių procedūrų atlikimas padidėjo ~14 %.

Apie 10 % PET/KT procedūros su ^{18}F



American Nuclear Society

Lietuvoje medicinoje naudojami radionuklidai

(^{99m}Tc-MAA, ^{99m}Tc-MDP, ^{99m}Tc-DTPA, ^{99m}Tc-MAG$_3$, ^{99m}Tc-DMSA ir t..t

MDP – metilendifosfonatas skirtas kaulų scintigrafijai atlikti
MAA – makroagreguotas albuminas plaučių scintigrafijai

Diagnostikai:
^{99m}Tc
^{123}I
^{131}I
^{18}F

^{18}F-FDG
^{18}F-Florbetaben
^{18}F-Choline

Planuojama naudoti
Su 7,5 - 18 MeV ciklotronu
^{13}N
^{15}O
^{11}C
^{18}F

Su < 17 MeV ciklotronu
^{124}I; ^{123}I; ^{201}Ti
^{68}Ga
^{64}Cu ir t.t.

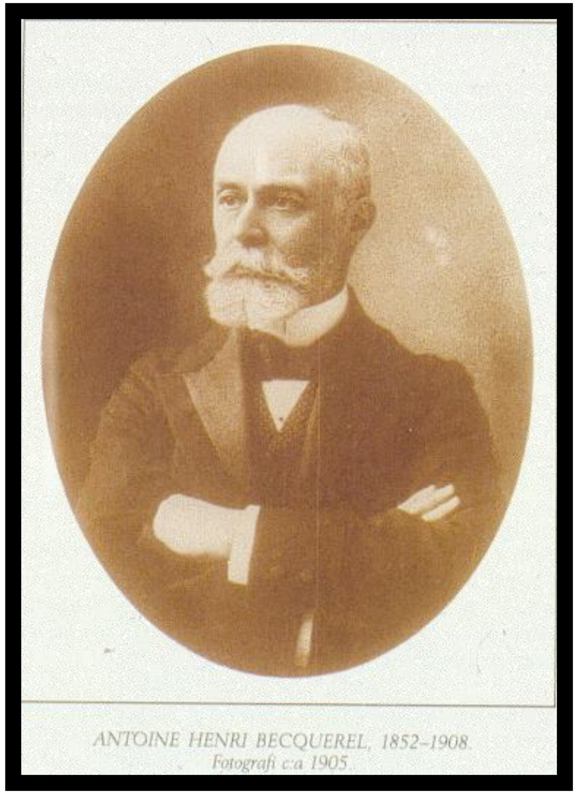
Terapijai:
^{131}I
^{223}Ra

Planuojama naudoti
^{90}Y
^{177}Lu
^{166}Ho

Su < 17 MeV ciklotronu
^{64}Cu
^{89}Zr ir t.t.

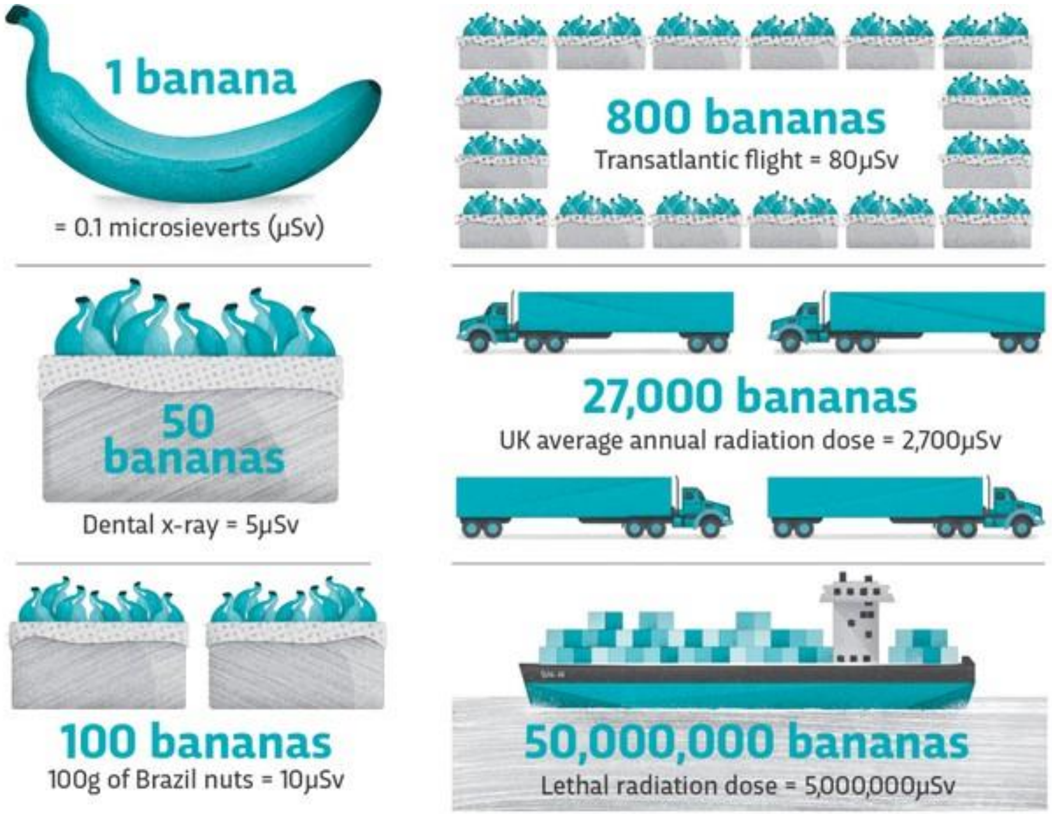
Bekerelis

- Bekerelis taip pavadintas fiziko Antuano Anri Bekerelio garbei.
- Bekerelis nusako, kiek nestabilių branduolių suskyla per vieną sekundę. Vienas bekerelis parodo, kad per vieną sekundę suskilo vienas nestabilus branduolys.
- 1 Ci = $3{,}7 \times 10^{10}$ Bq.
- Bekerelis yra labai mažas vienetas, apie 4000-5000 Bq yra žmogaus kūne (^{40}K).
- Branduolinėje medicinoje naudojamas ruožas nuo kBq iki GBq.



130 Bq/kg

http://hps.org/publicinformation/ate/faqs/faqradbods.html



Main isotopes of potassium

Isotope	Abundance	Half-life ($t_{1/2}$)	Decay mode	Product
^{39}K	93.258%	stable		
^{40}K	0.012%	1.248×10^9 y	β^-	^{40}Ca
			ε	^{40}Ar
			β^+	^{40}Ar
^{41}K	6.730%	stable		

https://www.sciencefocus.com/science/how-many-bananas-would-i-need-to-eat-to-become-radioactive/

Fizinės radionuklidų charakteristikos

- Radioaktyviojo nuklido pusėjimo trukmė
- Spinduliuotės energija
- Aktyvumas (kBq, MBq, GBq)
- Skilimo rūšis
- Fizinės–cheminės savybės
- Gavimo metodas (reaktorius, ciklotronas)

Trumpas skilimas -> Diagnostikai

Ilgas skilimas -> Terapijai

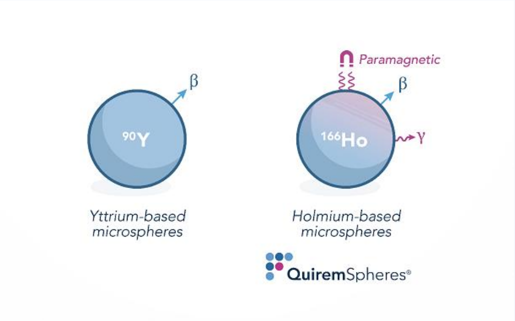
Maža dozė - diagnostikai

Isotope	$T_{1/2}$	E_{α} (MeV)	$E_{\beta,mean}$ (keV)	$E_{\beta,max}$ (keV)	E_{γ} (keV)	Γ @ 1m (μSv/h·GBq)
^{89}Sr	50.6 d		587	1501		
^{90}Y	64 h		934	2280		
^{131}I	8.02 d		182	334(7.2%) 606(90%) 807(0.4%)	284(6.1%) 364(81.5%) 637(7.2%)	57.3
^{153}Sm	46.5 h		224	635(31.3%) 704(49.4%) 808(18.4%)	103(29%)	12.2
^{177}Lu	6.65 d		134	498(79.4%)	113(6.2%) 208(10.4%)	4.7
^{186}Re	3.72 d		347	932(21.5%) 1069(71%)	137(9.5%)	2.7
^{223}Ra	11.43 d	5.6 5.7			81(5%) 84(24.7%) 269(13.9%)	20

IAEA Joint ICTP-IAEA Workshop on Internal Dosimetry, 21-25 November 2016, Trieste, Italy

Terapinių radionuklidų charakteristikos

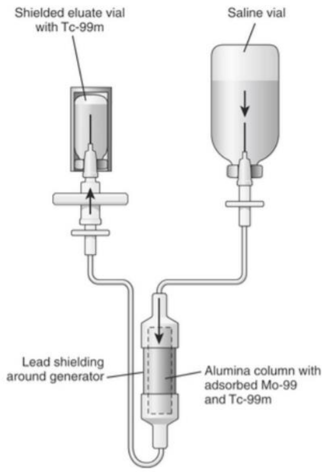
	QuiremSpheres®	
Isotope	Holmium-166	Yt-90
Beta-radiation (E_{max})	1.77 MeV (48.7%) 1.85 MeV (50.0%)	2.28 MeV
Gamma-radiation	81 keV (6.7%)	-
Visible on MRI	Yes	No
Half-life	26.8 hours	64.1 hours



Pagrindiniai jonizuojančiosios spinduliuotės šaltiniai, naudojami branduolinėje medicinoje

Atvirieji jonizuojančiosios spinduliuotės šaltiniai:

- Diagnostiniai: ^{99m}Tc, ^{131}I, ^{123}I, ^{18}F, ^{68}Ga ir t.t.
- Terapiniai: ^{131}I, ^{89}Sr, ^{90}Y, ^{177}Lu, ^{166}Ho, ^{223}Ra ir t.t.



Uždarieji jonizuojančiosios spinduliuotės šaltiniai:

- Kalibravimo: ^{22}Na, ^{137}Cs, ^{57}Co, ^{60}Co, ^{133}Ba, ^{68}Ge ir kt.

Branduolinė medicinos diagnostika

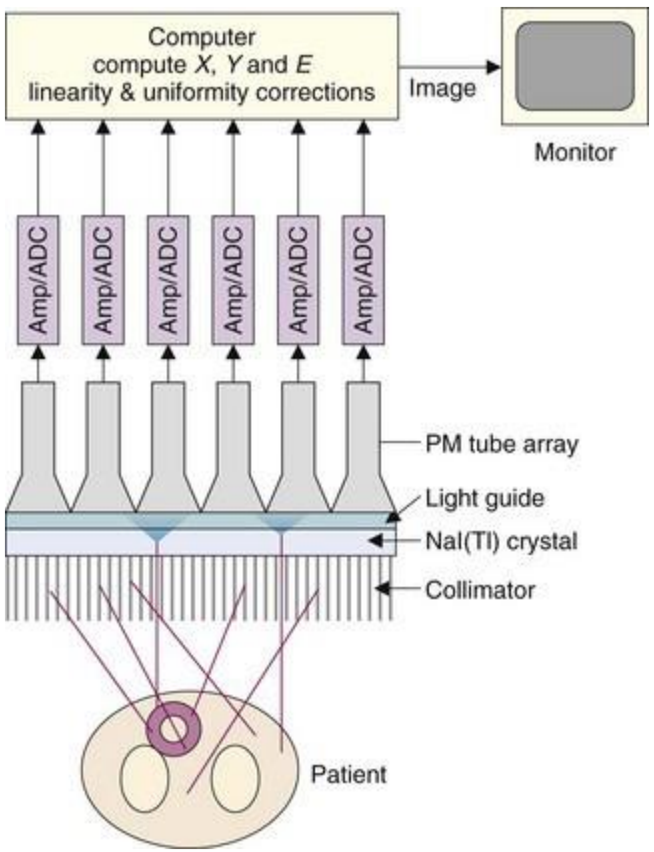
Gama kamera

Diagnostinė branduolinės medicinos įranga, kuri fiksuoja ir vaizduoja radiofarmacinių preparatų susikaupimą paciento organizme.

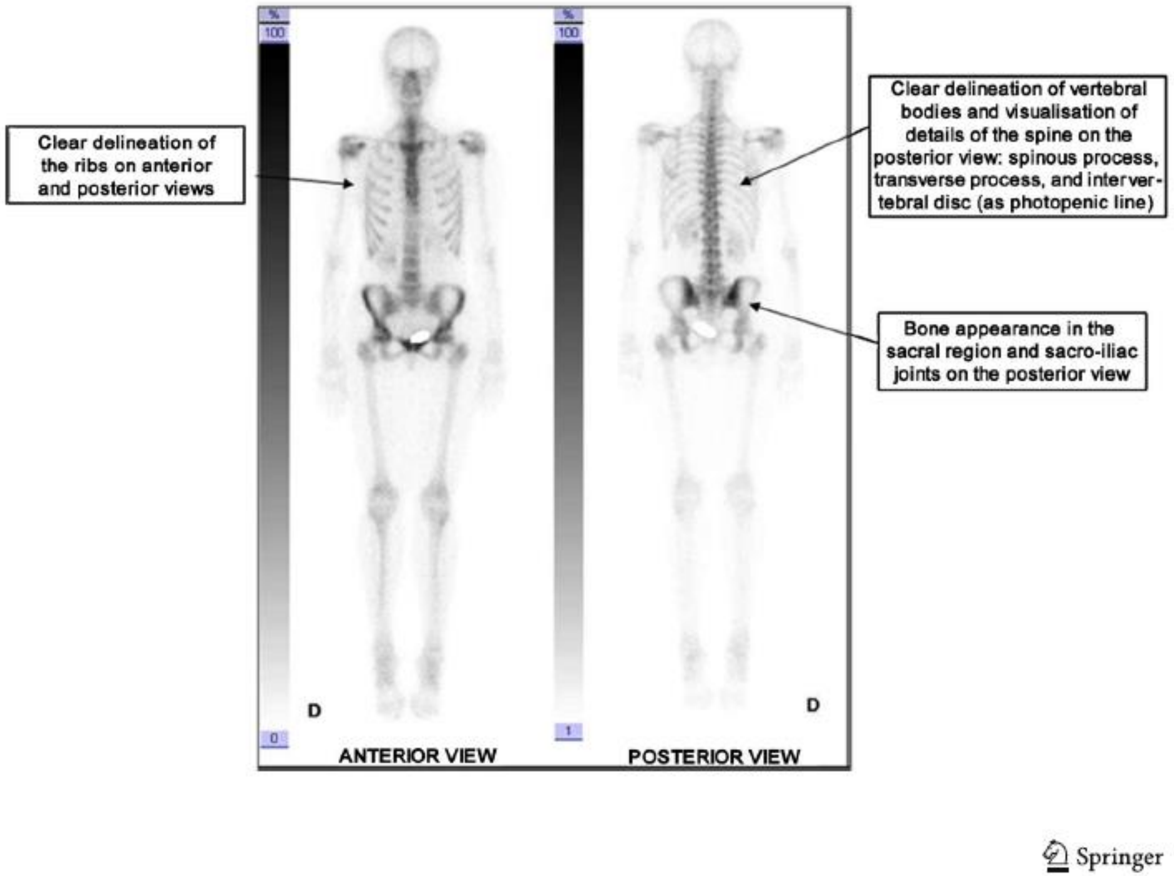
- Gaunamas 2D vaizdas (iš 3D vaizdo);
- Stačiakampis detektorius (NaI(Tl)) apie 40 x 54 cm;
- Sudaro 4 baziniai komponentai (kolimatorius, detektorius, kompiuteris, rėmas su stalu).

Hal Anger, 1953, https://tech.snmjournals.org/content/33/4/250

Gama kamera



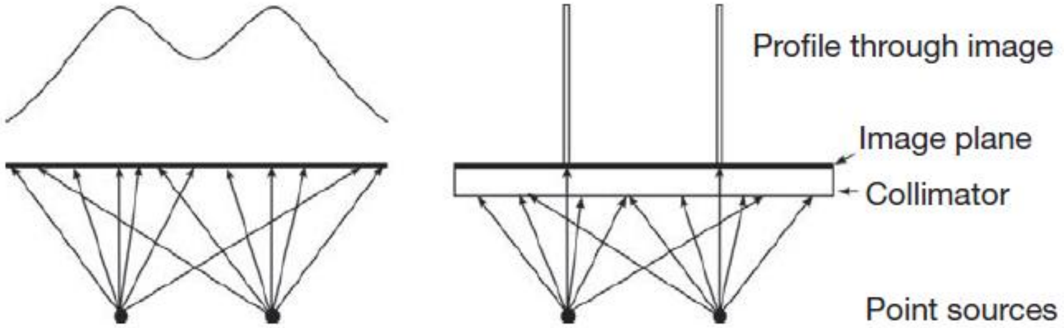
https://radiologykey.com/the-gamma-camera-basic-principles/

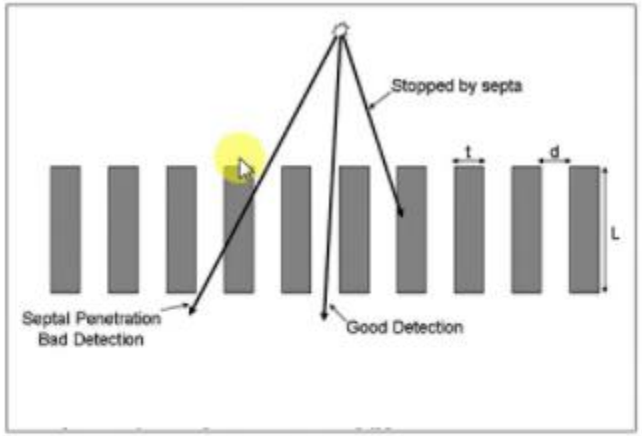


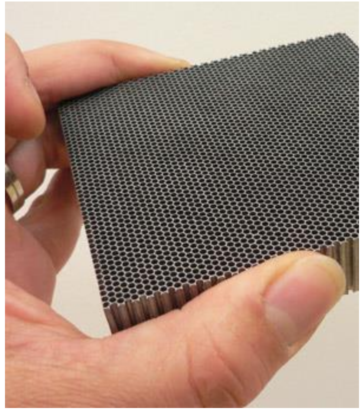
Eur J Nucl Med Mol Imaging (2016) 43:1723–1738
DOI 10.1007/s00259-016-3415-4

Kolimatoriai

Mažos energijos: Tl-201, Tc-99m, I-123
Vidutinės energijos: Ga-67, In-111, Lu-177
Didėles energijos I-131





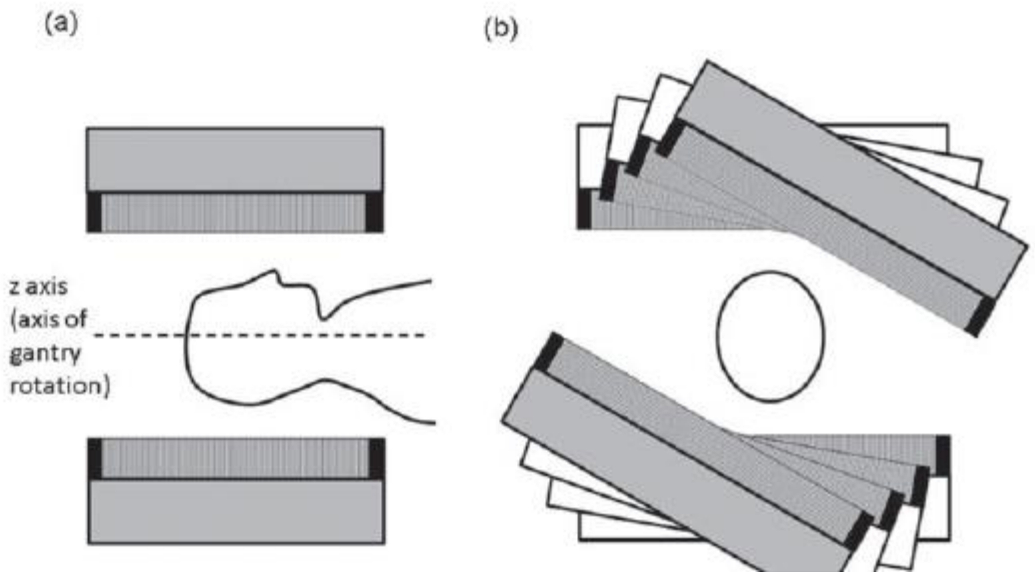


	Type of hole	Hole length (mm)	Hole diameter (mm)	Septal thickness (mm)	Number of holes
LEHR	Hexagonal	24.05	1.11	0.16	148000
WEHR	Square	45	2.26	0.2	33280

https://www.nuclearfields.com/collimators-nuclear-medicine.htm
T. Ito et al., Experimental evaluation of the GE NM/CT 870 CZT clinical SPECT system equipped with WEHR and MEHRS collimator, 2021

SPECT

Vieno (pavienių) fotono (-ų) emisijos tomografijos (SPECT) įranga – diagnostinė branduolinės medicinos įranga, kuri fiksuoja, registruoja ir kiekybiškai nustato radiofarmacinio preparato susikaupimą paciento organizme ir sukuria tomografinį radiofarmacinio preparato pasiskirstymo paciento organizme vaizdą.



Šiuolaikinės SPECT sistemos

Siemens Symbia Intevo Excel SPECT/CT

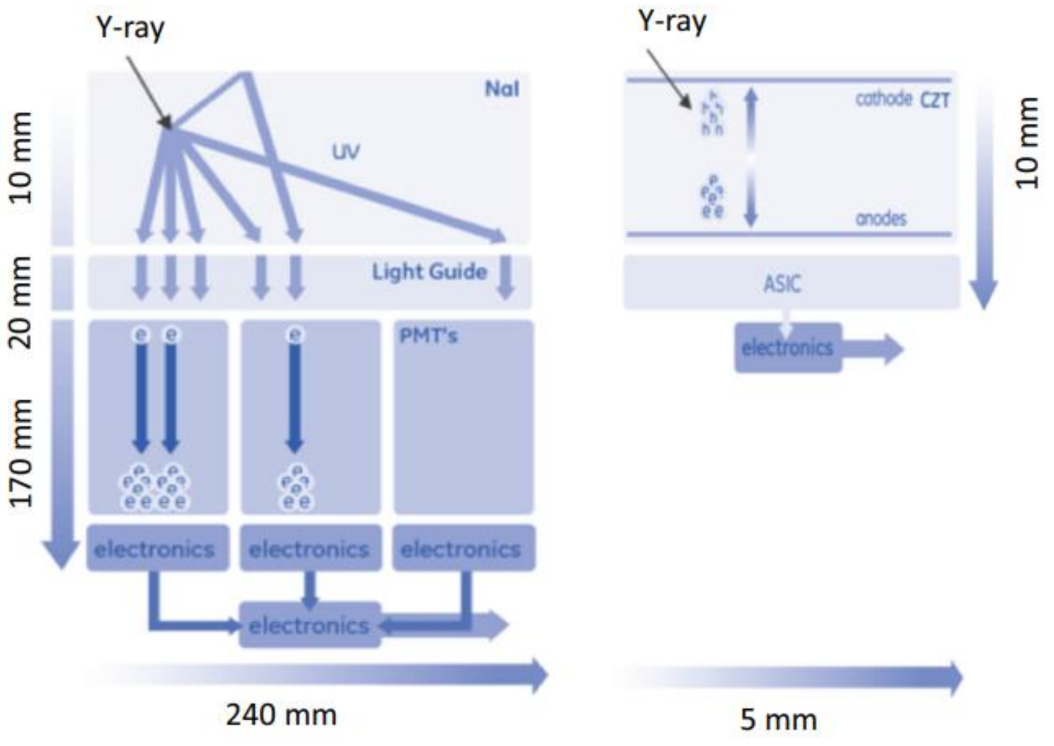
Mediso AnyScan SC SPECT/CT

GE NM/CT 870 CZT SPECT/CT

https://healthcare-in-europe.com/en/radbook/molecular/619-siemens-healthineers-symbia-intevo-excel.html
https://mediso.com/product/anyscanr-family/anyscanr-sc
https://www.gehealthcare.com/products/molecular-imaging/nuclear-medicine/nm-ct-870-czt

SPECT detektoriai ir fotonų registravimas

- NaI(Tl)
- CZT

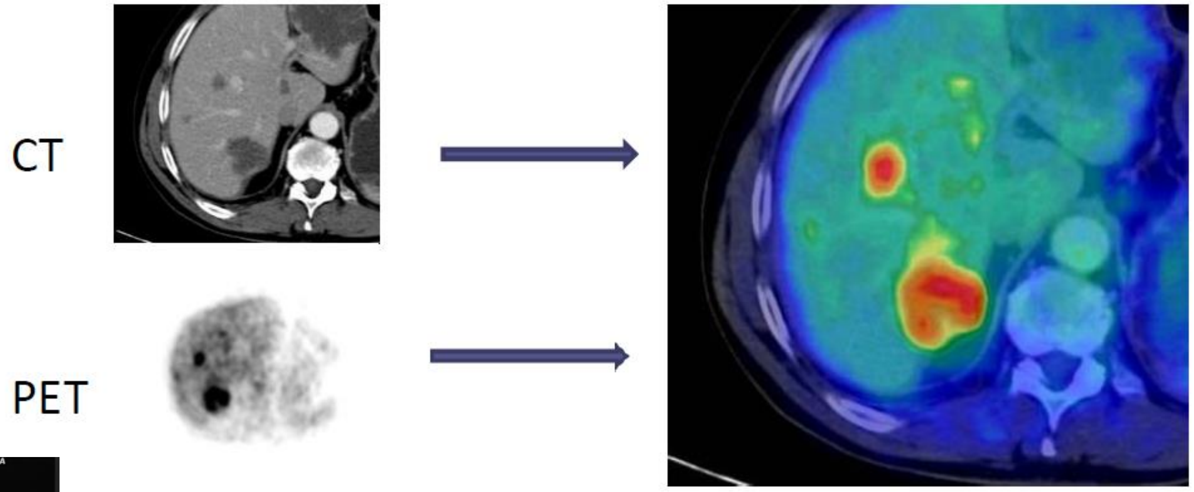


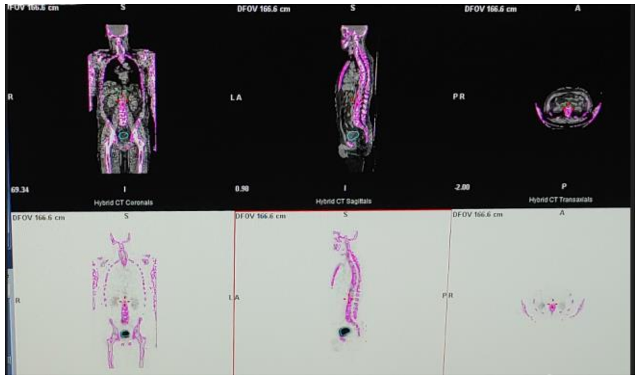
J.S.Lee, Advances in imaging instrumentation for nuclear cardiology, 2017

Hibridinis vaizdinimas

Hibridinė branduolinės medicinos įranga – diagnostinė branduolinės medicinos įranga, kurioje įdiegta kompiuterinės tomografijos ar magnetinio rezonanso tomografijos sistema.

- SPECT/KT
- PET/KT
- PET/MRT



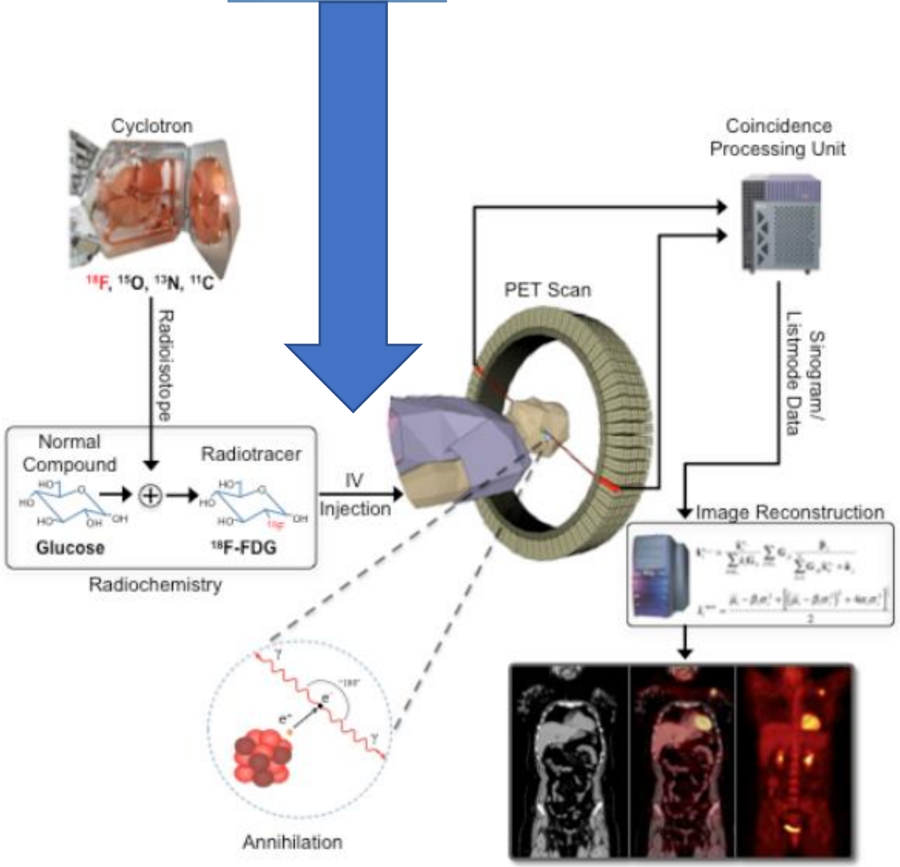


https://www.robots.ox.ac.uk/~jmb/lectures/InformaticsLecture7.pdf

Pozitronų emisijos tomografijos PET/CT procedūra



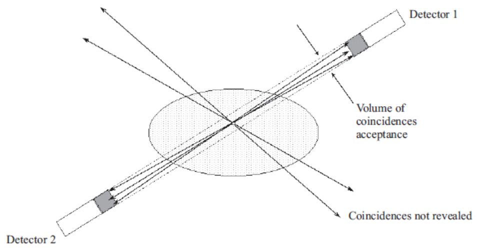


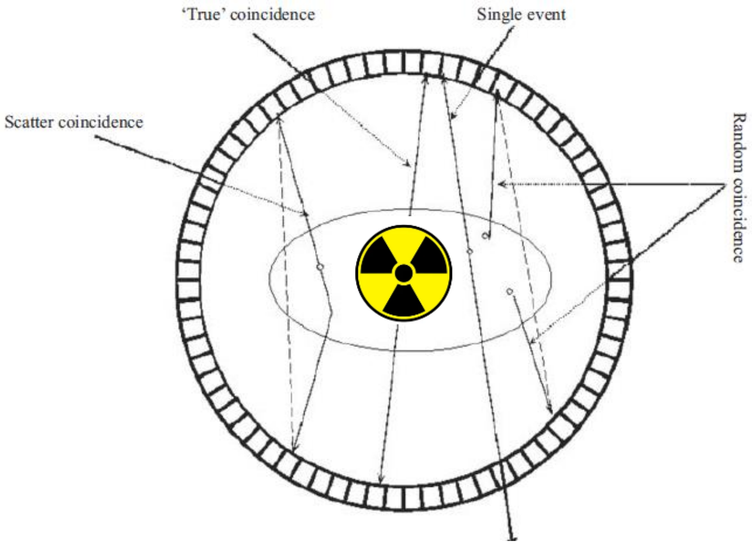


https://uofuhealth.utah.edu/huntsman/cqci/clinical-patient-imaging/information-for-patients.php

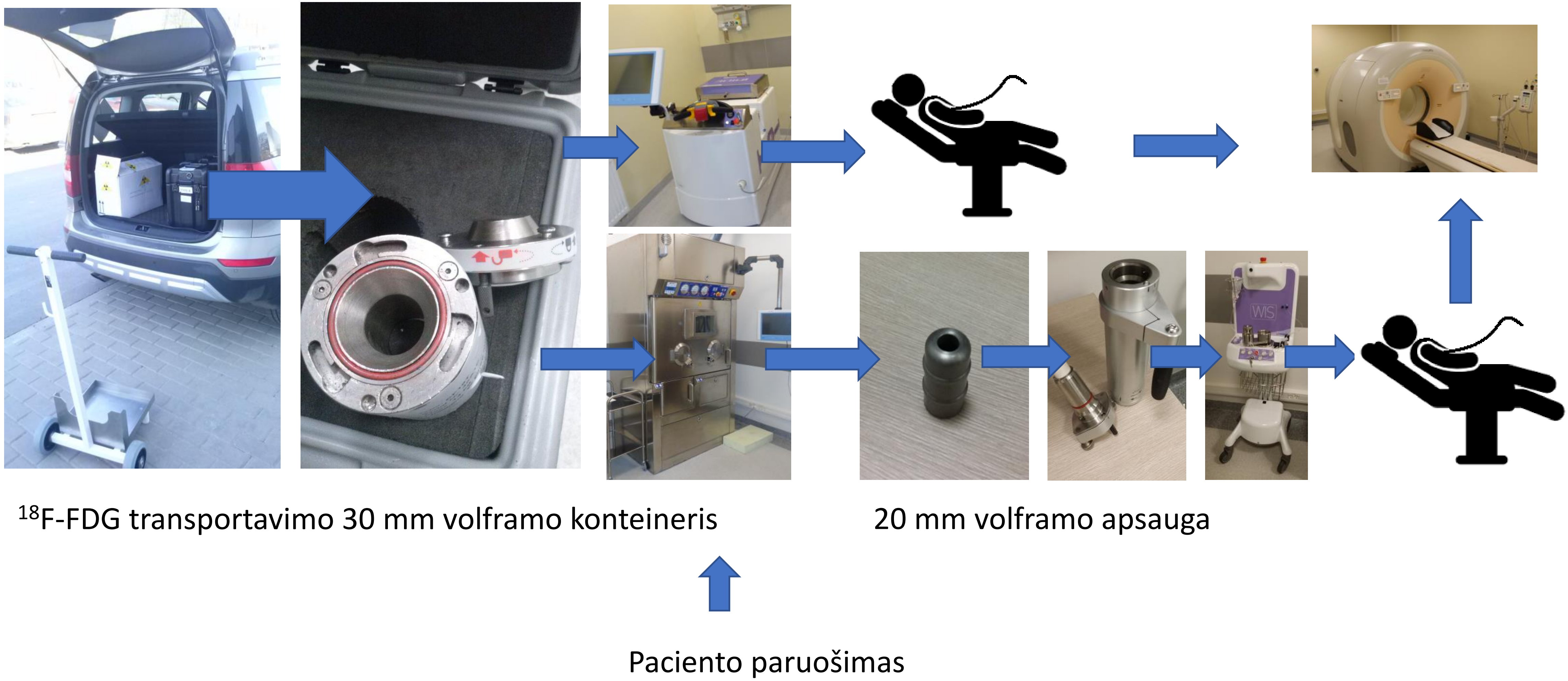
PET įranga

Pozitronų emisijos tomografijos (PET) įranga – diagnostinė branduolinės medicinos įranga, kuri pacientui paskyrus radiofarmacinio preparato, kurio sudėtyje yra pozitronus spinduliuojančių trumpaamžių radionuklidų, fiksuoja, registruoja, kiekybiškai nustato ir analizuoja fotonus, gaunamus anihiliuojant pozitronams ir elektronams, bei sukuria trimatį tomografinį vaizdą, kuriame vaizduojamas radiofarmacinio preparato susikaupimas paciento organizme.



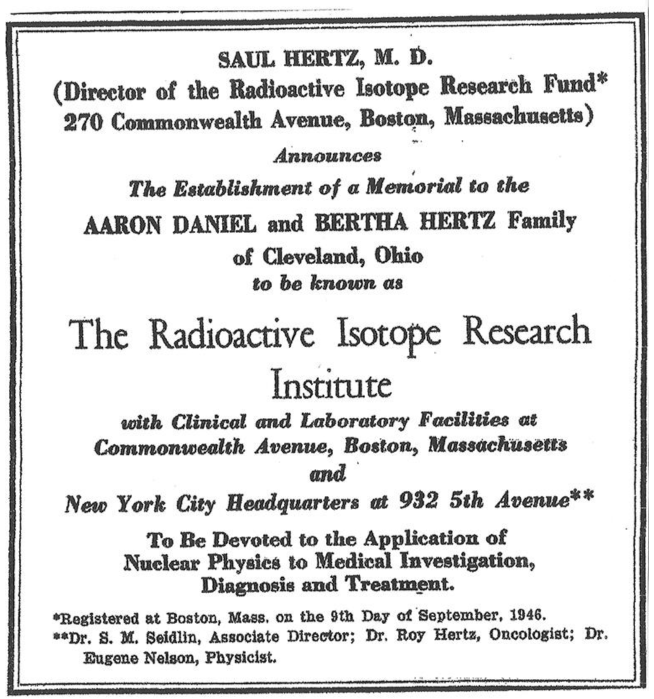


^{18}F-FDG procedūros seka



Branduolinė terapija

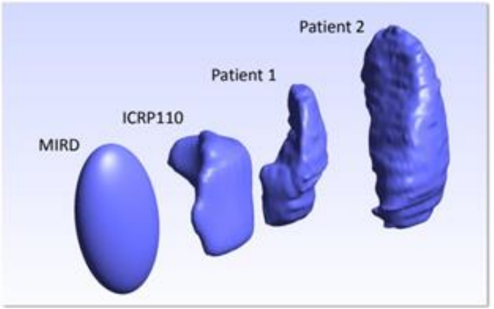
- Taikoma nuo 1946;
- Tikslinga radionuklidų terapija;
- Administruojama atsižvelgiant į paciento svorį, kūno paviršiaus plotą, naviko lokalizaciją ir t.t;
- Molekulinė terapija (personalus gydymas pagrįstas vaizdais). Panaši į spindulinę terapiją, individualiai administruojama;
- Privaloma dozimetrija.



SAUL HERTZ, M. D.
(Director of the Radioactive Isotope Research Fund*
270 Commonwealth Avenue, Boston, Massachusetts)
Announces
The Establishment of a Memorial to the
AARON DANIEL and BERTHA HERTZ Family
of Cleveland, Ohio
to be known as
The Radioactive Isotope Research Institute
with Clinical and Laboratory Facilities at
Commonwealth Avenue, Boston, Massachusetts
and
*New York City Headquarters at 932 5th Avenue***
To Be Devoted to the Application of
Nuclear Physics to Medical Investigation,
Diagnosis and Treatment.

*Registered at Boston, Mass. on the 9th Day of September, 1946.
**Dr. S. M. Seidlin, Associate Director; Dr. Roy Hertz, Oncologist; Dr. Eugene Nelson, Physicist.

$$\overline{D}_k = \sum_h \tilde{A}_h \times S_{(k \leftarrow h)}$$



Radionuklidų terapija (molekulinė terapija)

Sr-89: 150 MBq

Sm-153: 37 kBq/kg

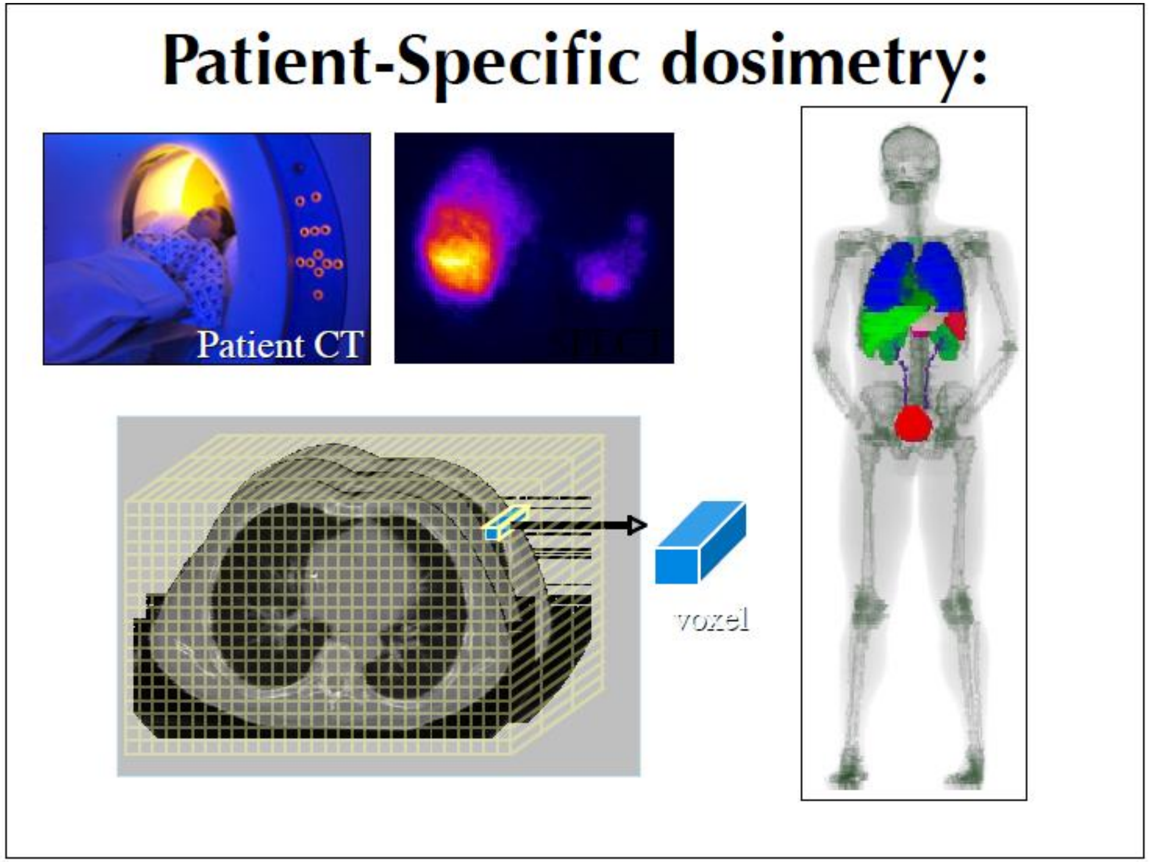
Ra-223: 55 kBq/kg (6 ciklai)

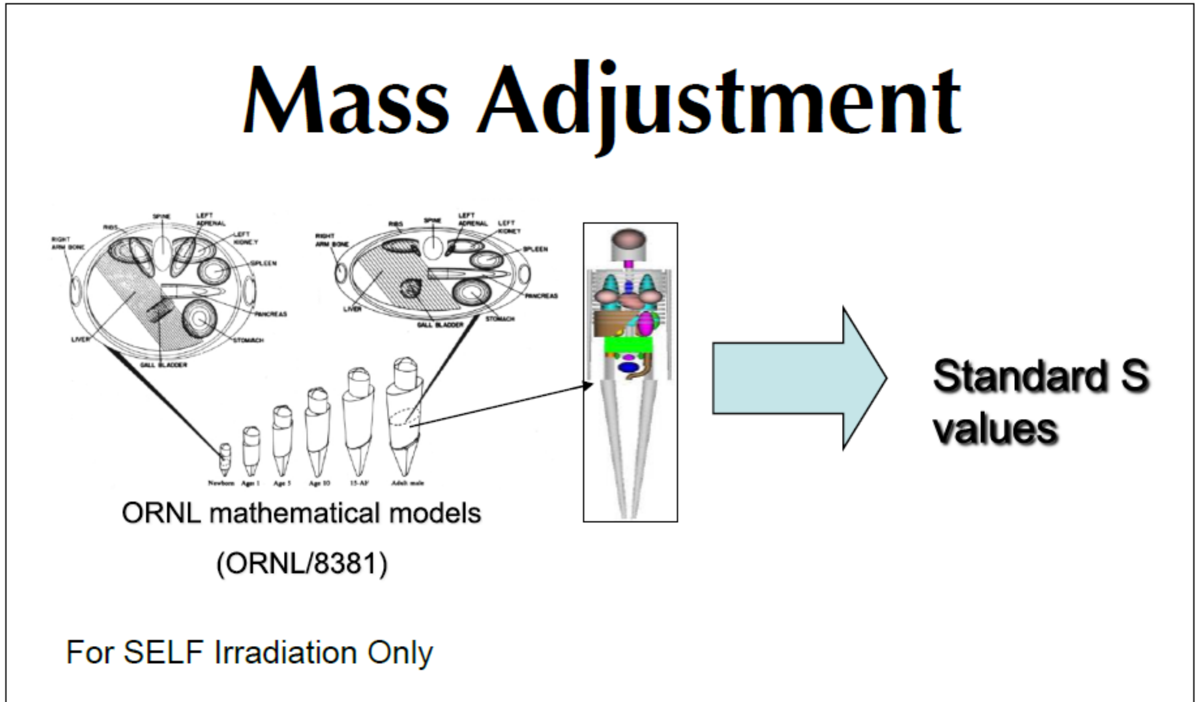
$$\text{Volume to be administered (mL)} = \frac{\text{Body weight (kg)} \times \text{activity (55 kBq/kg body weight)}}{\text{DK factor} \times 1100\ \text{kBq/mL}}$$

I-131: 1.85 GBq - 7.4 GBq (dažniausiai fiksuotos dozės)

Lu-177: 4-6 ciklai (~7 GBq × 4, intervalas apie 2 mėn)

Dozimetrija





$$S_{r\leftarrow r}(patient) = S_{r\leftarrow r}(standard) \cdot \frac{Mass_r(standard)}{Mass_r(specific)}$$

DosiIntro.key - 1 juillet 2016

Dozimetrija: I-131 pavyzdys

$$A_a[MBq] = \frac{0.714}{\overline{E}} \cdot \frac{M[g] \cdot D[Gy]}{RIU(t_e) \cdot 2^{t_e/T_{est}} \cdot T_{est}[d]}$$

$$\Downarrow$$

$$\frac{1}{\overline{E}} = \frac{7.2}{(M[g])^{0.25} + 18} \frac{MBq \cdot d}{Gy \cdot g}$$

RUI - suteikimas po 24 val.
M- skydliaukės masė

Eur J Nucl Med Mol Imaging (2008) 35:1405–1412
DOI 10.1007/s00259-008-0761-x

GUIDELINES

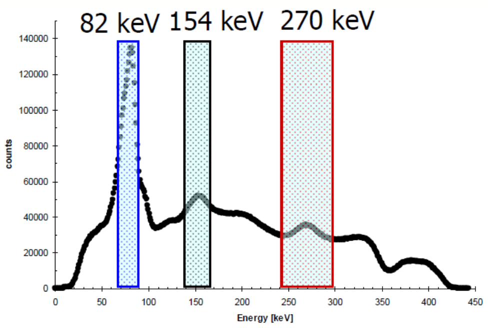
EANM Dosimetry Committee series on standard operational procedures for pre-therapeutic dosimetry I: blood and bone marrow dosimetry in differentiated thyroid cancer therapy

Michael Lassmann · Heribert Hänscheid · Carlo Chiesa · Cecilia Hindorf · Glenn Flux · Markus Luster

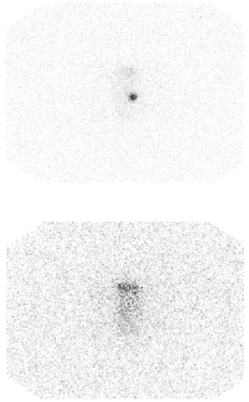
Table 1 Timelines of measurements

Time	Task	Details
0	Quality control, preparation of ^{131}I standard and tracer activity, micturition (just before administration) Administration of ^{131}I tracer activity Avoid micturition or defecation	"Preparation of ^{131}I standard and tracer activity" section
10 min (i.v. admin.); 2 h (oral admin)	Measurement of whole-body activity, blood sampling (2 ml)	"Pre-therapeutic quantification of whole-body retention" section "Blood sampling" section
6 h	Micturition (just before whole-body measurements), measurement of whole-body activity, blood sampling (2 ml)	"Pre-therapeutic quantification of whole-body retention" section "Blood sampling" section
24 h	Micturition (just before whole-body measurements), measurement of whole-body activity, blood sampling (2 ml)	"Pre-therapeutic quantification of whole-body retention" section "Blood sampling" section
96 h	Micturition (just before whole-body measurements), measurement of whole-body activity, blood sampling (2 ml)	"Pre-therapeutic quantification of whole-body retention" section "Blood sampling" section
144 h	Blood sampling (2 ml) optional: measurement of whole-body activity	"Pre-therapeutic quantification of whole-body retention" section "Blood sampling" section
	Evaluation of blood absorbed dose and therapeutic activity	"Absorbed dose calculation" section

Ra-223 kritinių ir kitų organų apšvitos vertinimas

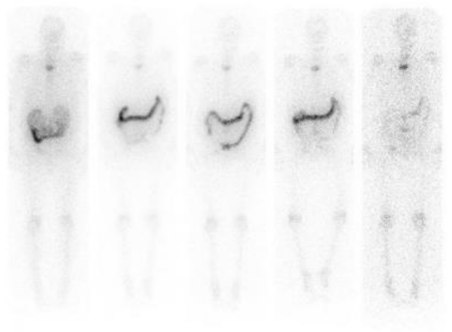


Energy window 1: 74 – 90 keV
Energy window 2: 142 – 166 keV
Energy window 3: 256 – 284 keV



Phantom scans

Figure 3. Anterior scans of radium-223 at days 0, 1, 2, 3 and 6 following administration of 55 kBq/kg.



Mother radioisotope	*Photon energy [keV]*	*Probability [fraction]*	*Type of photon*	*Imaging possibility*
^{223}Ra	122.3	0.0121	Gamma	Low probability of emission
^{223}Ra	144.2	0.0327	Gamma	Window 2
^{223}Ra	154.2	0.0570	Gamma	Window 2
^{223}Ra	269.5	0.139	Gamma	Window 3
^{223}Ra	323.9	0.0399	Gamma	Low probability of emission
^{223}Ra	338.3	0.0284	Gamma	Low probability of emission
^{223}Ra	83.78	0.251	X-ray, K	Window 1
^{223}Ra	81.07	0.152	X-ray, K	Window 1
^{223}Ra	94.90	0.115	X-ray, K	Partly included in Window 1
^{223}Ra	11.70	0.229	X-ray, L	Too low energy
^{219}Rn	271.2	0.108	Gamma	Window 3
^{219}Rn	401.8	0.0659	Gamma	Possible
^{219}Rn	11.10	0.0103	X-ray, L	Too low energy
^{211}Pb	404.9	0.0378	Gamma	Possible
^{211}Pb	427.1	0.0176	Gamma	Possible
^{211}Pb	832.0	0.0352	Gamma	Too high energy
^{211}Bi	351.0	0.129	Gamma	Possible
^{211}Bi	72.87	0.0126	X-ray, K	Partly included in Window 1

Cite this article as: Flux GD. Imaging and dosimetry for radium-223: the potential for personalized treatment. Br J Radiol 2017; 90: 20160748

Darbuotojų apšvitos ir darbo vietų stebėsena

Ribinės dozės pagal HN 73:2018

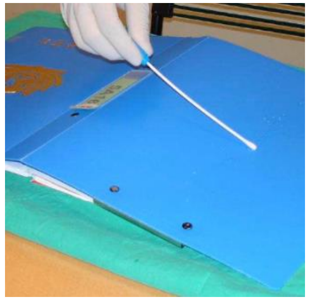
- Efektinė dozė 20 mSv per metus;
- Ribinė lygiavertė dozė akies lęšiukui – 20 mSv;
- Lygiavertė dozė odai, galūnėms (plaštakoms ir pėdoms) - 500 mSv.

Vidinė apšvita


Išorinė apšvita



Darbo vietų stebėsena

Vidinei apšvitai įvertinti naudojami

- SPECT
- Viso kūno HPGe detektorius;
- Skydliaukės aktyvumo matuoklis su natrio jodido Nal(TI) detektoriumi;
- Viso kūno (HPGe) ir skydliaukės (NaL(TI)) matavimai atliekami Radiacinės saugos centre;
- Biologinių medžiagų tyrimas.

Išorinės apšvitos individualiųjų dozių tyrimai

Profesinės apšvitos stebėsena vykdoma su pasyviais dozimetrais:

- Termoliuminescencinė dozimetrija (TLD)
- Filmai
- Optiškai stimuliuojamos liuminescencijos dozimetrai ir kt.

TLD minimali detektuojama dozė yra pakankami didelė ~ 50 mikroSv (kai dozimetro nešiojimo periodas 3 mėnesiai)

OSL užfiksuojama dozė ~ 20 mikroSv.

Elektroniniai personaliniai dozimetrai

Darbuotojų apšvitos ilgalaikiam vertinimui ir stebėsenai naudojami personaliniai elektroniniai dozimetrai POLIMASTER PM1610B-01.
Dabar naudojame The Thermo Scientific™ EPD TruDose

APD POLIMASTER PM1610B-01 (Geiger-Muller tube detector).
APDs were calibrated and verified once per year by the Vilnius Metrology Centre.
APD provides measurement of personal dose equivalent Hp(10) between 0.001 μSv - 24.0 Sv.
The energy range 48 keV - 3 MeV (±30%) and 0.05 μSv to 20.0 Sv for continuous and pulsed photon radiation

On-axis Energy Response
Photon Hp(10) (Ref. ^{137}Cs)
±15% 16keV to 1.5MeV -15% to +50% 1.5MeV to 10MeV

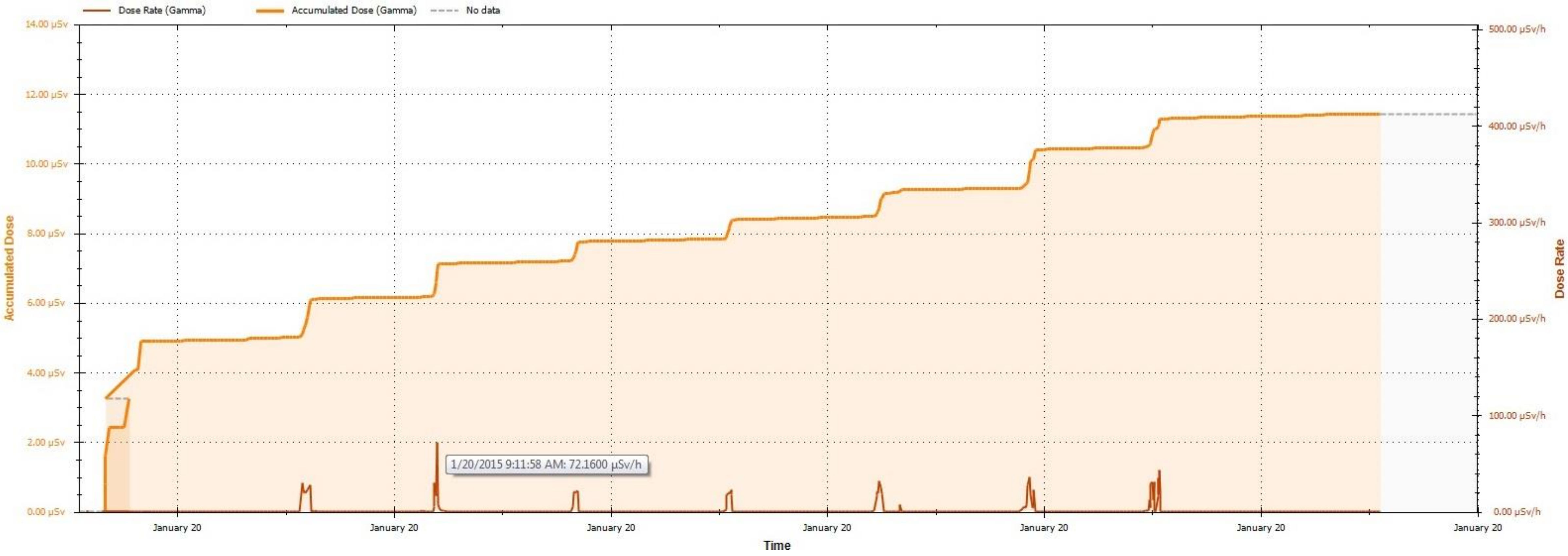
Combined Energy and Angular Response
Photon Hp(10) (Ref. ^{137}Cs)
-29% to +67% for 17keV to 6MeV, 0° to 60°

Accuracy
Photon Hp(10) (Ref. ^{137}Cs)
±5%

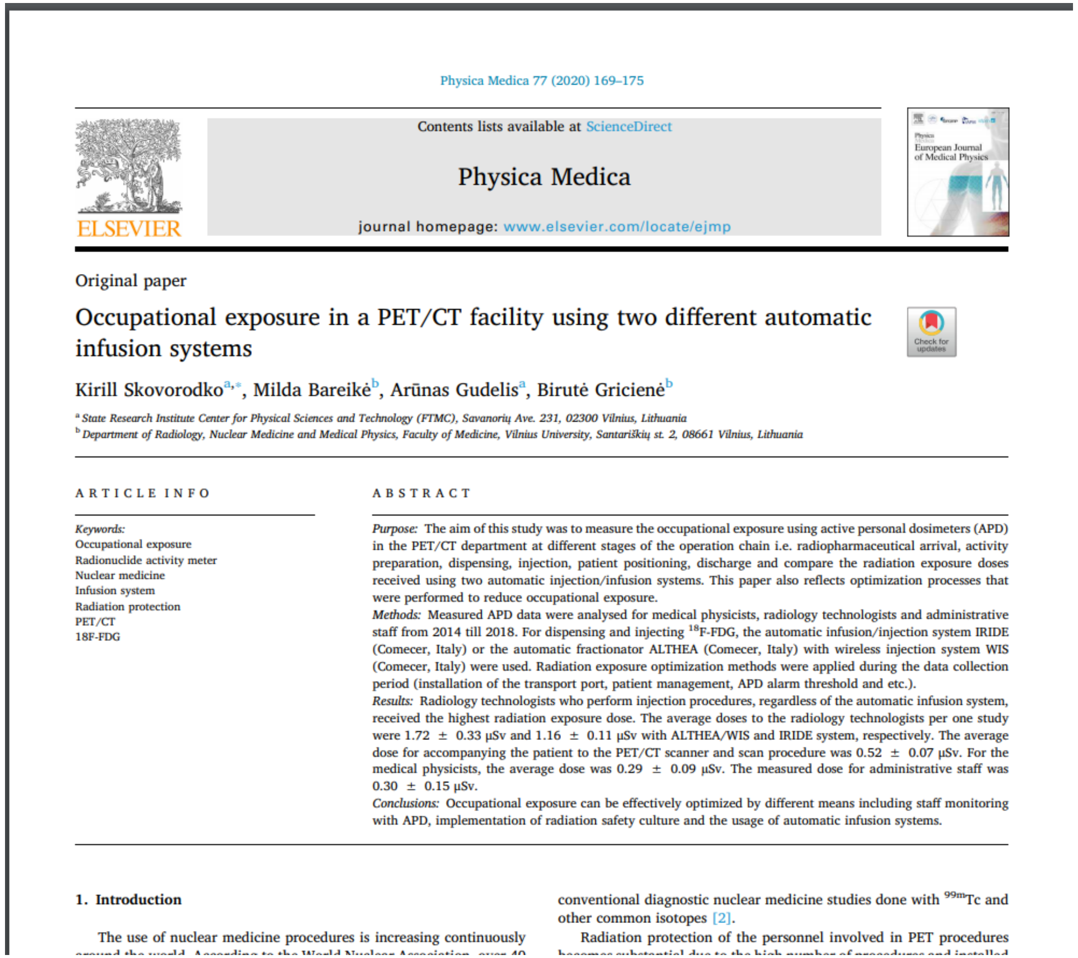
Dose Range, IEC61526 Ed. 3 (Display & Measurement)
Hp(10)
• **Effective Range of Dose:** 1.0 μSv to ≥ 10 Sv (0.1 mrem to ≥ 1000 rem) • **Overload Indication:** 10 Sv/h to >50 Sv/h (1000 rem/h to >5000 rem/h) • **Display Resolution**: 0.1 μSv to 10.00 Sv (0.01 mrem to 1000 rem), up to four decimal places

Dose Rate Range (Display & Measurement)
Hp(10)
• **Effective Range of Dose Rate (IEC60846-1):** 1 μSv/h to 10 Sv/h (0.1 mrem/h to 1000 rem/h) • **Dose Rate Range of Dose (IEC61526 Ed.3):** 0.05 μSv/h to 10 Sv/h (0.005 mrem/h to 1000 rem/h) • **Display Resolution:** 0.1 μSv/h to 10.0 Sv/h (0.01 mrem/h to 1000 rem/h), up to three decimal places • **Overload Indication:** 10 Sv/h to >50 Sv/h (1000 rem/h to >5000 rem/h

Personalinio dozimetro grafikas



PET/KT tyrimų metu personalo gaunamos dozės



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Original paper

Occupational exposure in a PET/CT facility using two different automatic infusion systems

Check for updates

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ARTICLE INFO

Keywords:
Occupational exposure
Radionuclide activity meter
Nuclear medicine
Infusion system
Radiation protection
PET/CT
18F-FDG

ABSTRACT

Purpose: The aim of this study was to measure the occupational exposure using active personal dosimeters (APD) in the PET/CT department at different stages of the operation chain i.e. radiopharmaceutical arrival, activity preparation, dispensing, injection, patient positioning, discharge and compare the radiation exposure doses received using two automatic injection/infusion systems. This paper also reflects optimization processes that were performed to reduce occupational exposure.

Methods: Measured APD data were analysed for medical physicists, radiology technologists and administrative staff from 2014 till 2018. For dispensing and injecting ^{18}F-FDG, the automatic infusion/injection system IRIDE (Comecer, Italy) or the automatic fractionator ALTHEA (Comecer, Italy) with wireless injection system WIS (Comecer, Italy) were used. Radiation exposure optimization methods were applied during the data collection period (installation of the transport port, patient management, APD alarm threshold and etc.).

Results: Radiology technologists who perform injection procedures, regardless of the automatic infusion system, received the highest radiation exposure dose. The average doses to the radiology technologists per one study were 1.72 ± 0.33 μSv and 1.16 ± 0.11 μSv with ALTHEA/WIS and IRIDE system, respectively. The average dose for accompanying the patient to the PET/CT scanner and scan procedure was 0.52 ± 0.07 μSv. For the medical physicists, the average dose was 0.29 ± 0.09 μSv. The measured dose for administrative staff was 0.30 ± 0.15 μSv.

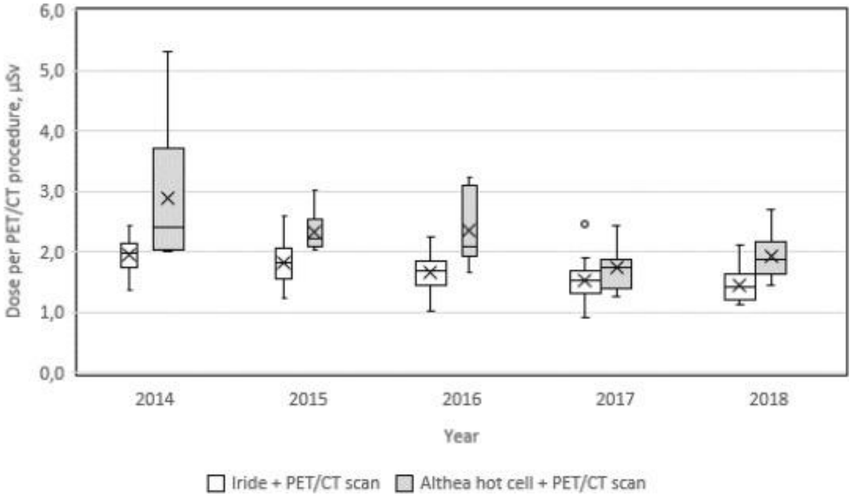
Conclusions: Occupational exposure can be effectively optimized by different means including staff monitoring with APD, implementation of radiation safety culture and the usage of automatic infusion systems.

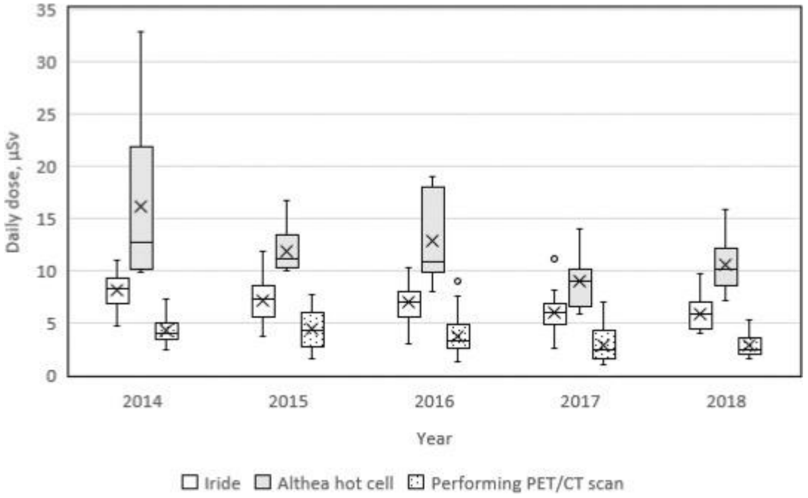
1. Introduction

The use of nuclear medicine procedures is increasing continuously

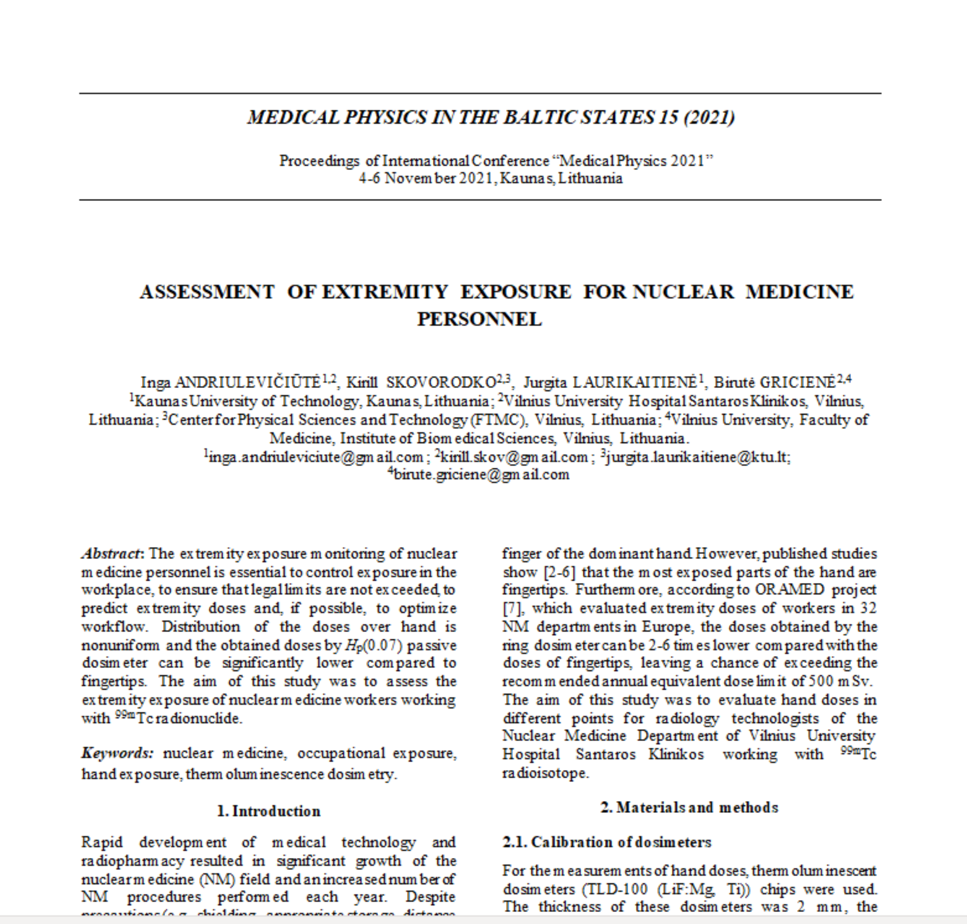
conventional diagnostic nuclear medicine studies done with ^{99m}Tc and other common isotopes [2].

Radiation protection of the personnel involved in PET procedures





Rankų apšvitos kontrolė



MEDICAL PHYSICS IN THE BALTIC STATES 15 (2021)

Proceedings of International Conference "Medical Physics 2021"
4-6 November 2021, Kaunas, Lithuania

ASSESSMENT OF EXTREMITY EXPOSURE FOR NUCLEAR MEDICINE PERSONNEL

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Abstract: The extremity exposure monitoring of nuclear medicine personnel is essential to control exposure in the workplace, to ensure that legal limits are not exceeded, to predict extremity doses and, if possible, to optimize workflow. Distribution of the doses over hand is nonuniform and the obtained doses by $H_p(0.07)$ passive dosimeter can be significantly lower compared to fingertips. The aim of this study was to assess the extremity exposure of nuclear medicine workers working with ^{99m}Tc radionuclide.

Keywords: nuclear medicine, occupational exposure, hand exposure, thermoluminescence dosimetry.

1. Introduction

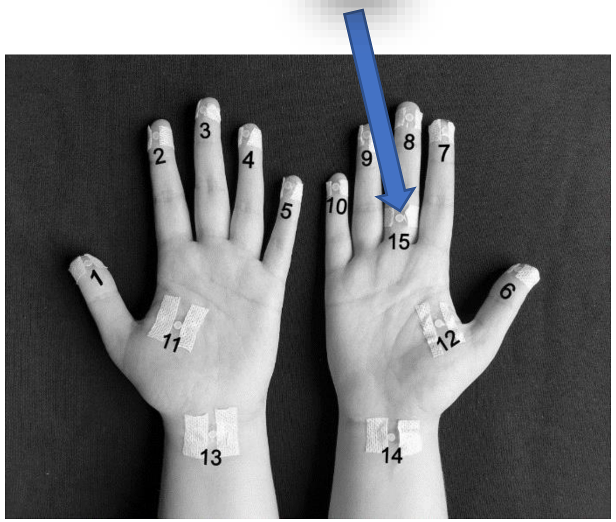
Rapid development of medical technology and radiopharmacy resulted in significant growth of the nuclear medicine (NM) field and an increased number of NM procedures performed each year. Despite

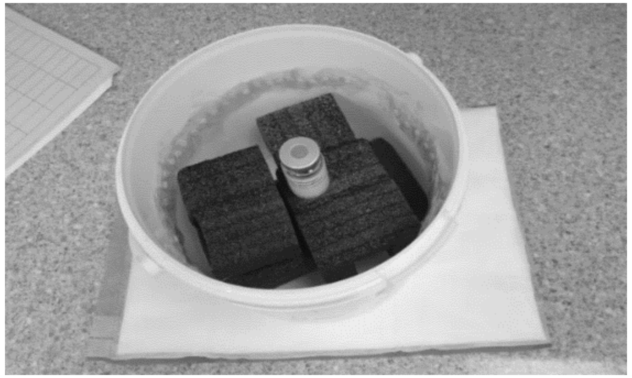
finger of the dominant hand. However, published studies show [2-6] that the most exposed parts of the hand are fingertips. Furthermore, according to ORAMED project [7], which evaluated extremity doses of workers in 32 NM departments in Europe, the doses obtained by the ring dosimeter can be 2-6 times lower compared with the doses of fingertips, leaving a chance of exceeding the recommended annual equivalent dose limit of 500 mSv. The aim of this study was to evaluate hand doses in different points for radiology technologists of the Nuclear Medicine Department of Vilnius University Hospital Santaros Klinikos working with ^{99m}Tc radioisotope.

2. Materials and methods

2.1. Calibration of dosimeters

For the measurements of hand doses, thermoluminescent dosimeters (TLD-100 (LiF:Mg, Ti)) chips were used. The thickness of these dosimeters was 2 mm, the





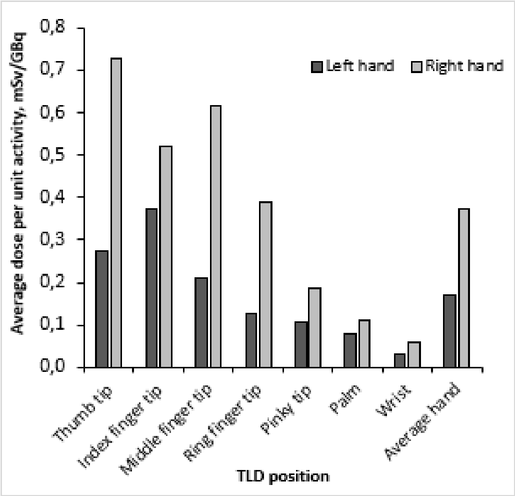


Fig. 4. Hand dose distribution of different TLD positions while working in a hot lab with ^{99m}Tc.

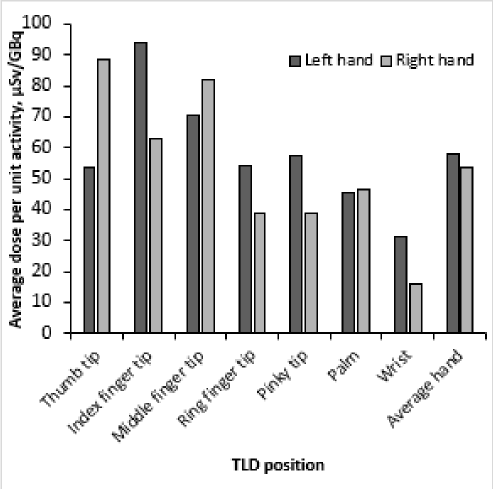


Fig. 5. Hand dose distribution of different TLD positions while administering ^{99m}Tc- labelled radiopharmaceuticals

3.2. Doses obtained from typical monitoring position

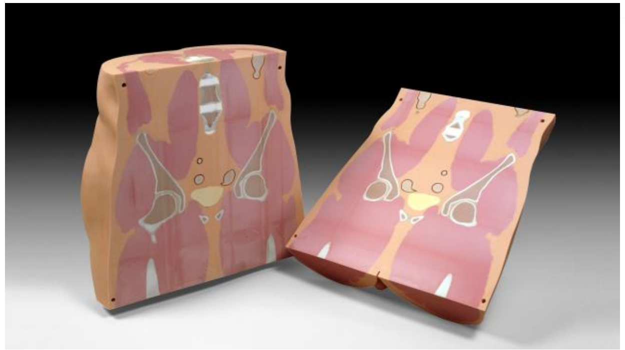
Pacientų apšvitos kontrolė branduolinėje medicinoje

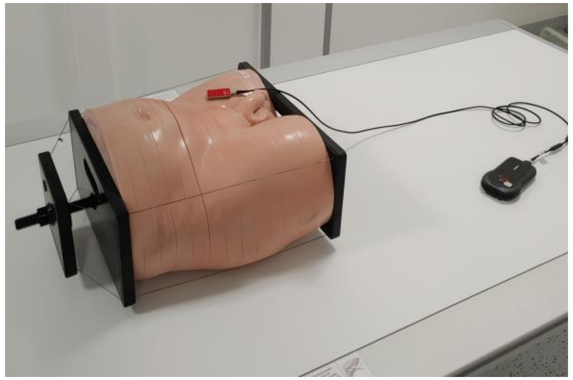
- Diagnostiniai atskaitos lygiai
- Matavimai su fantomais
- Kalibraciniai bandymai

Table 1. Number of procedures selected for the survey, used radiopharmaceuticals, number of hospitals performing procedures, data of analyzed administered activities and DRLs in Lithuania during the survey (until 2022) period.

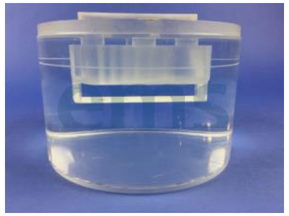
Procedure	Radiophar-maceuticals	Number of hospitals performing procedures	Number of procedur es	Min	Max	75th percen tile	Median	Mean ± SD	DRLs in Lithuania during the survey
Bone scintigraphy	99mTc-MDP	4	2293	317	691	575,5	533	528,36±59	700
Renal imaging	99mTc-DTPA Renal	3	440	134	256	203	165	177,62±29	250
Renal imaging	99mTc-MAG3, 99mTc-EC renal	3	539	35	141	109,25	96,2	99,78±15	100
Parathyroid scintigraphy	99mTc-MIBI	2	365	300	563	519	504	474,18±78	740
Lung perfusion	99mTc-MAA	2	453	105	213	179	161	161±21	185
Thyroid scintigraphy	99mTc Thyroid	4	604	39	135	120	111	107,66±18	150
Myocardial perfusion scintigraphy, stress	99mTc-MIBI	2	651	145	490	316	250	270,87±77	550
Myocardial perfusion scintigraphy, rest	99mTc-MIBI	2	651	251	775	646	570	571±96	750
Neuroendocrine imaging	99m-TC octreotide	3	362	340	840	633	575,5	549,27±109	800
Hepatobiliary scintigraphy	99m-Tc BRIDA	1	68	160	238	215	205	206,9±11	200
Lymphangioscintigra phy	99m-TC Nanocolloid	3	955	10,1	168	86,4	69	69,62±26	200
Tumor examination	18F-FDG	2	598	150	396	320	301	301±32	500

Antropomorfinis fantomas (VIRTUAL HUMAN MALE PELVIS PHANTOM MODEL 801-P)



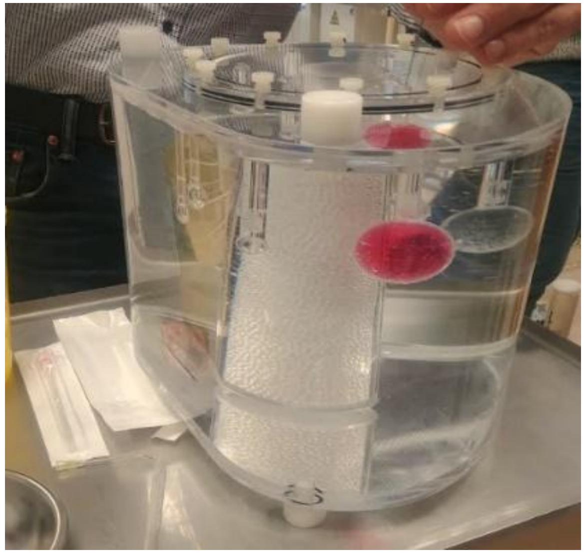






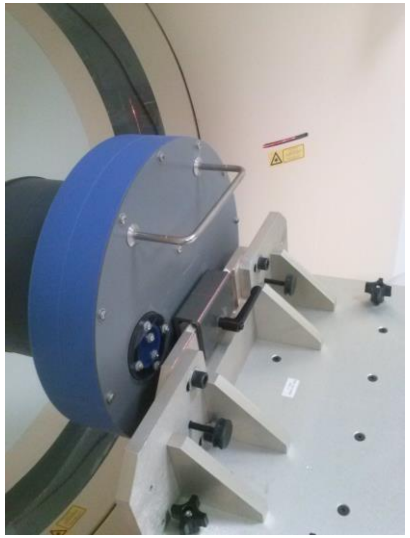
CIRS has combined this anatomical detail with our advanced tissue mimicking technology. The phantom is made from proprietary epoxy materials that mimic the density and radiation attenuation properties of human tissue within 1% from 50 keV to 25 MeV. It contains anatomically precise bone, cartilage, spinal cord, vertebral disks, muscle, intestines, bladder, prostate, rectum and interstitial fat.

Fantomai



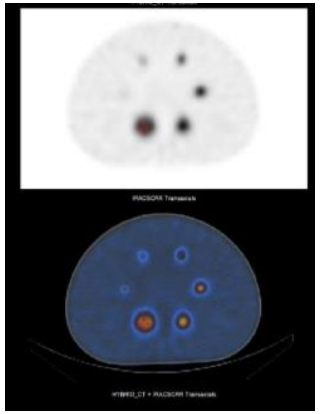
NEMA-IEC

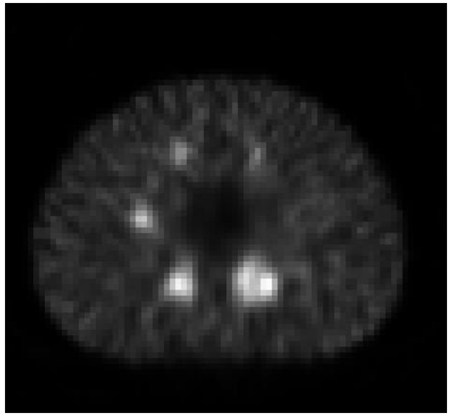
SUV verčių

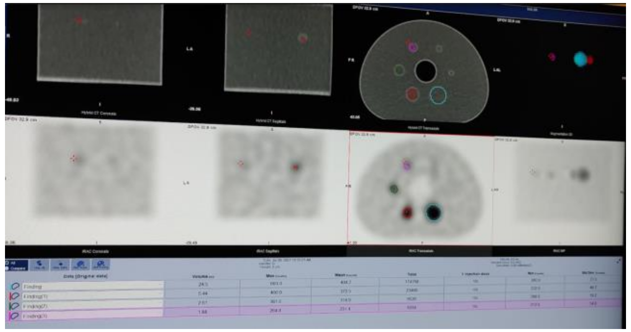


KT dalies

Jaszczak





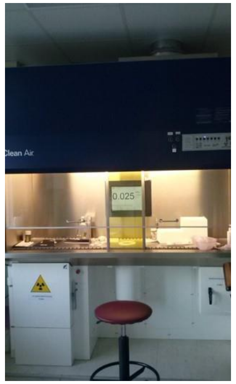


Kita branduolinės medicinos įranga

- Radiofarmacinio preparato aktyvumo matuokliai;
- Automatiniai injekavimo prietaisai;
- Laminarinės traukos švinuotos spintos;
- Fantomai;
- Taršos matavimo įranga ir kt.







Metrologija branduolinėje medicinoje

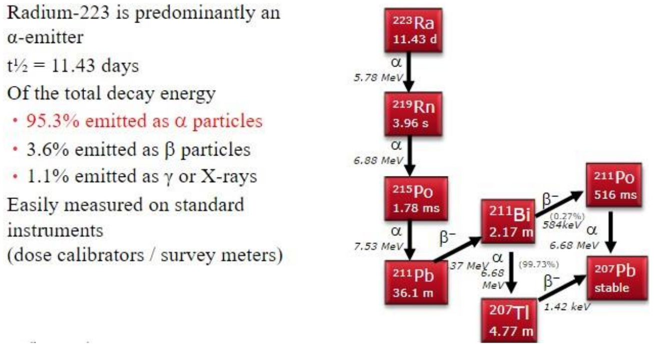
Pirminių metodų pagalba sukuriami radionuklidų šaltiniai, kurie naudojami kalibravimui;

Antriniai radionuklidų standartizavimo metodai taikomi BM.

Aktyvumas turi būti ne mažesnis kaip 100 kBq ir iki 200 GBq;

Įvairių kintamųjų, turinčių įtakos matavimo rezultatui sąlygos:

- Radioaktyviojo nuklido pusėjimo trukmė;
- Spinduliuotės energija;
- Aktyvumas (kBq, MBq, GBq);
- Skilimo rūšis;
- Fizinės–cheminės savybės;
- Matavimo geometrijos poveikis.



BIPM

⬇

National Metrology Institutes
(National Physical Laboratory and Czech Metrology Institute)

⬇

Secondary Standards Laboratory
(Center for Physical Sciences and Technology, Metrology Department, Ionizing Radiation Metrology Laboratory)

⬇

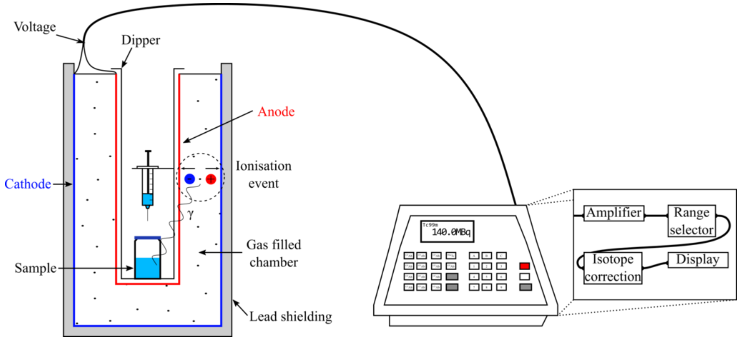
Reference Instrument (Capintec CRC-15R and Fidelis)

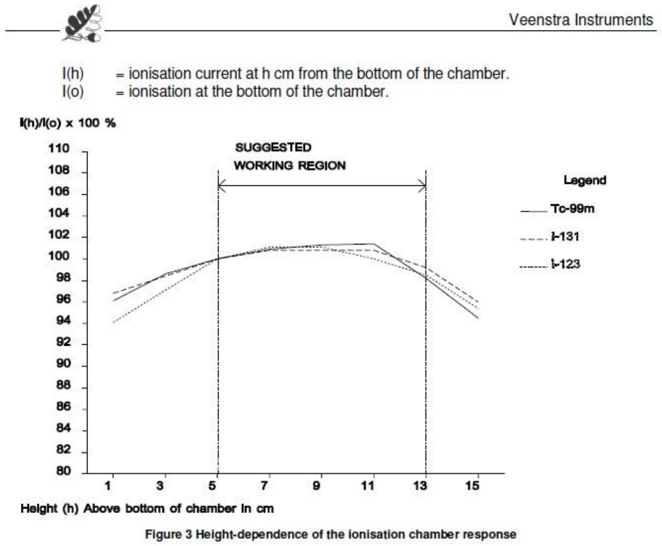
⬇

Field Instrument

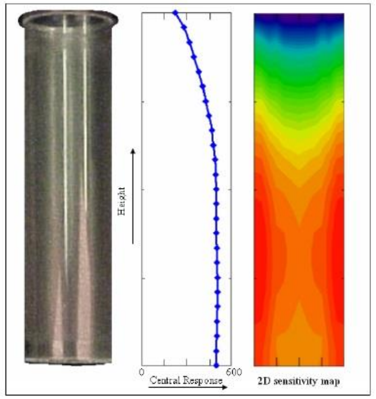
(Veenstra VDC-404, Veenstra VDC-405, Veenstra VIK-202, COMECER PITAGORA, Capintec CRC-15R, PTW – CURIEMENTOR 2, LEMER PAX ScintiDose, ATOMLAB 100)

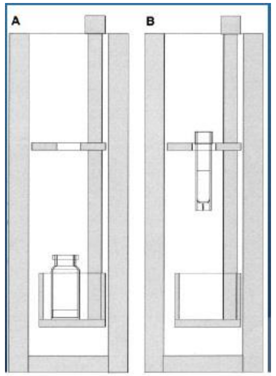
Jonizacinės kameros atsako priklausomybė nuo aukščio ir nuo šaltinio geometrijos

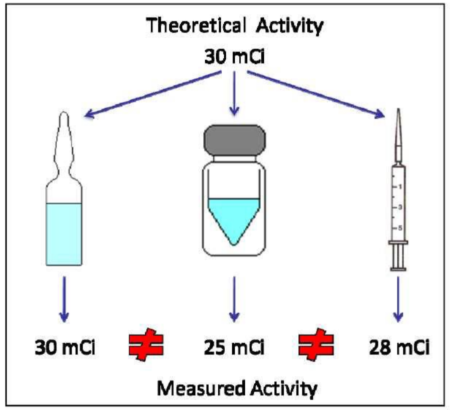


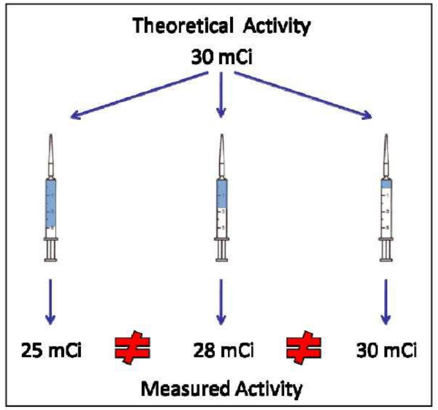


Jonizacinės kameros erdvinis jautris









National Physical Laboratory Good Practice Guide No. 93. Protocol for establishing and maintaining the calibration of medicine radionuclide calibrators and their quality control, 2006, NPL

Įrangos parametrai ir kiti veiksniai, priklausantys nuo aktyvumo matuoklio

Branduolinės medicinos įrangos kokybės kontrolė

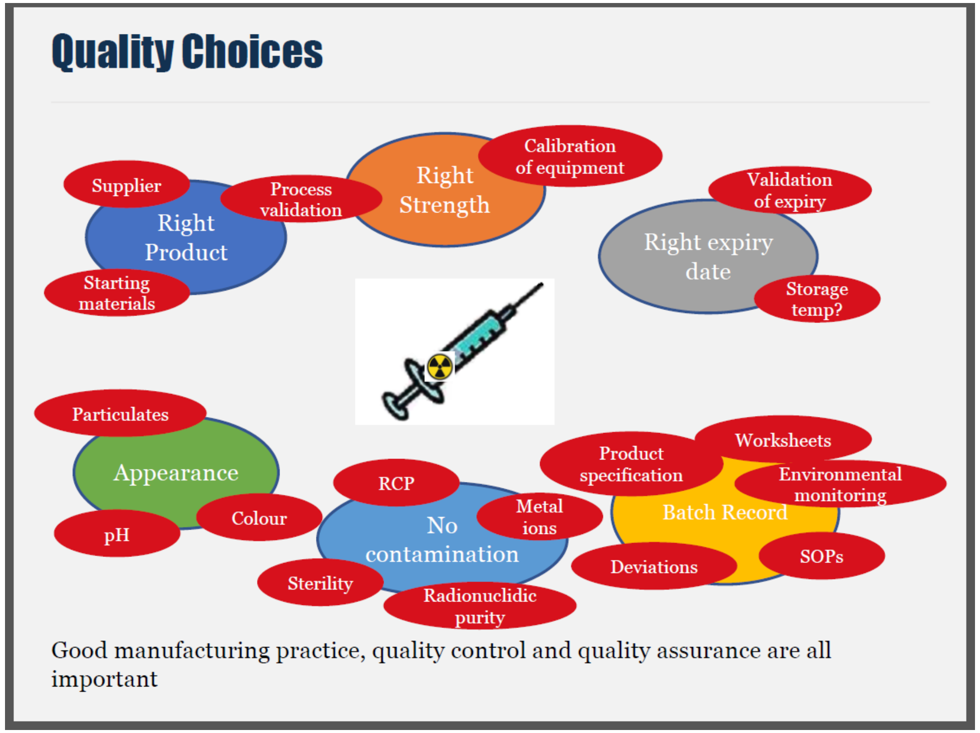
Radiofarmacinių preparatų kokybės kontrolė

Pacientų radiacinė sauga

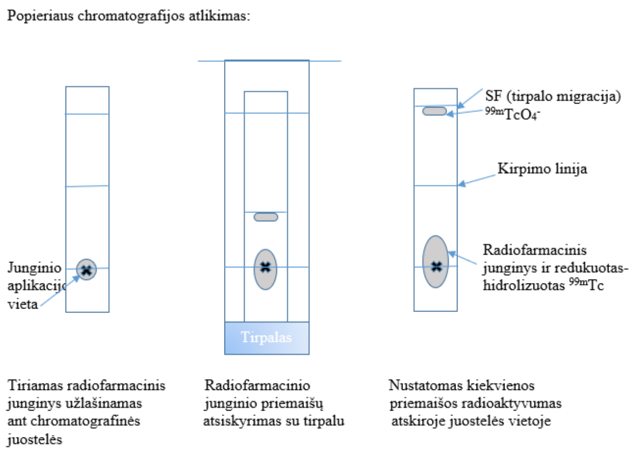
Kvantifikacija

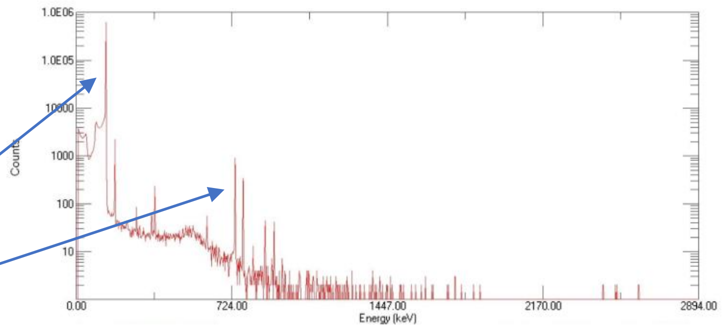
Darbuotojų radiacinė sauga

Radiofarmacinių preparatų kokybės kontrolė

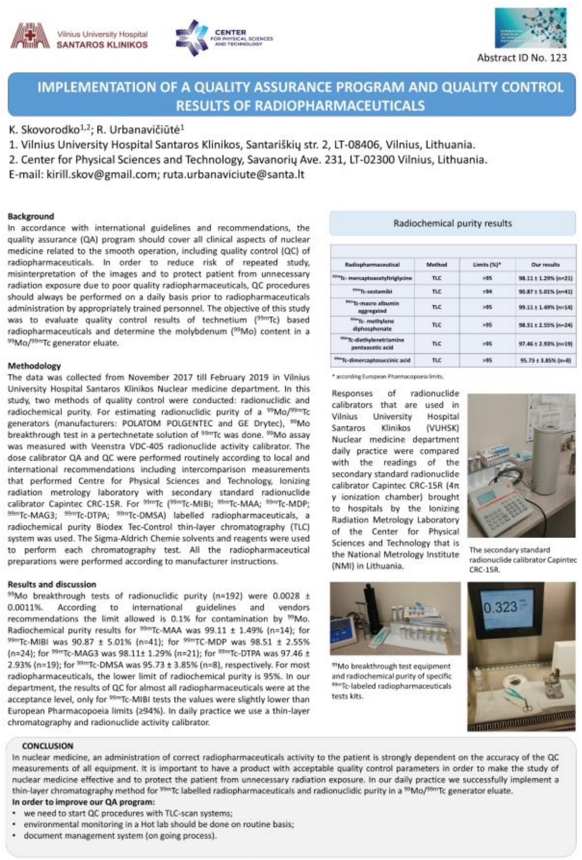


Dr. Maggie Cooper, RADIOPHARMACEUTICAL CHEMISTRY OF TECHNETIUM





^{99m}Tc ir ^{99}Mo



Abstract ID No. 123

IMPLEMENTATION OF A QUALITY ASSURANCE PROGRAM AND QUALITY CONTROL RESULTS OF RADIOPHARMACEUTICALS

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E-mail: kirill.skov@gmail.com; ruta.urbanaviciute@santa.lt

Background

In accordance with international guidelines and recommendations, the quality assurance (QA) program should cover all clinical aspects of nuclear medicine related to the smooth operation, including quality control (QC) of radiopharmaceuticals. In order to reduce risk of repeated study, misinterpretation of the images and to protect patient from unnecessary radiation exposure due to poor quality radiopharmaceuticals, QC procedures should always be performed on a daily basis prior to radiopharmaceuticals administration by appropriately trained personnel. The objective of this study was to evaluate quality control results of technetium (^{99m}Tc) based radiopharmaceuticals and determine the molybdenum (^{99}Mo) content in a $^{99}Mo/^{99m}Tc$ generator eluate.

Methodology

The data was collected from November 2017 till February 2019 in Vilnius University Hospital Santaros Klinikos Nuclear medicine department. In this study, two methods of quality control were conducted: radionuclidic and radiochemical purity. For estimating radionuclidic purity of a $^{99}Mo/^{99m}Tc$ generators (manufacturers: POLATOM POLGENTEC and GE Drytec), ^{99}Mo breakthrough test in a pertechnetate solution of ^{99m}Tc was done. ^{99}Mo assay was measured with Veenstra VDC-405 radionuclide activity calibrator. The dose calibrator QA and QC were performed routinely according to local and international recommendations including intercomparison measurements that performed Centre for Physical Sciences and Technology, Ionizing radiation metrology laboratory with secondary standard radionuclide calibrator Capintec CRC-15R. For ^{99m}Tc (^{99m}Tc-MIBI; ^{99m}Tc-MAA; ^{99m}Tc-MDP; ^{99m}Tc-MAG3; ^{99m}Tc-DTPA; ^{99m}Tc-DMSA) labelled radiopharmaceuticals, a radiochemical purity Biodex Tec-Control thin-layer chromatography (TLC) system was used. The Sigma-Aldrich Chemie solvents and reagents were used to perform each chromatography test. All the radiopharmaceutical preparations were performed according to manufacturer instructions.

Results and discussion

^{99}Mo breakthrough tests of radionuclidic purity (n=192) were 0.0028 ± 0.0011%. According to international guidelines and vendors recommendations the limit allowed is 0.1% for contamination by ^{99}Mo. Radiochemical purity results for ^{99m}Tc-MAA was 99.11 ± 1.49% (n=14); for ^{99m}Tc-MIBI was 90.87 ± 5.01% (n=41); for ^{99m}TC-MDP was 98.51 ± 2.55% (n=24); for ^{99m}Tc-MAG3 was 98.11± 1.29% (n=21); for ^{99m}Tc-DTPA was 97.46 ± 2.93% (n=19); for ^{99m}Tc-DMSA was 95.73 ± 3.85% (n=8), respectively. For most radiopharmaceuticals, the lower limit of radiochemical purity is 95%. In our department, the results of QC for almost all radiopharmaceuticals were at the acceptance level, only for ^{99m}Tc-MIBI tests the values were slightly lower than European Pharmacopoeia limits (≥94%). In daily practice we use a thin-layer chromatography and radionuclide activity calibrator.

Radiochemical purity results

Radiopharmaceutical	Method	Limits (%)*	Our results
^{99m}Tc- mercaptoacetyltriglycine	TLC	>95	98.11 ± 1.29% (n=21)
^{99m}Tc-sestamibi	TLC	>94	90.87 ± 5.01% (n=41)
^{99m}Tc-macro albumin aggregated	TLC	>95	99.11 ± 1.49% (n=14)
^{99m}Tc- methylene diphosphonate	TLC	>95	98.51 ± 2.55% (n=24)
^{99m}Tc-diethylenetriamine pentaacetic acid	TLC	>95	97.46 ± 2.93% (n=19)
^{99m}Tc-dimercaptosuccinic acid	TLC	>95	95.73 ± 3.85% (n=8)

* according European Pharmacopoeia limits.

Responses of radionuclide calibrators that are used in Vilnius University Hospital Santaros Klinikos (VUHSK) Nuclear medicine department daily practice were compared with the readings of the secondary standard radionuclide calibrator Capintec CRC-15R (4π γ ionization chamber) brought to hospitals by the Ionizing Radiation Metrology Laboratory of the Center for Physical Sciences and Technology that is the National Metrology Institute (NMI) in Lithuania.

The secondary standard radionuclide calibrator Capintec CRC-15R.

^{99}Mo breakthrough test equipment and radiochemical purity of specific ^{99m}Tc-labeled radiopharmaceuticals tests kits.

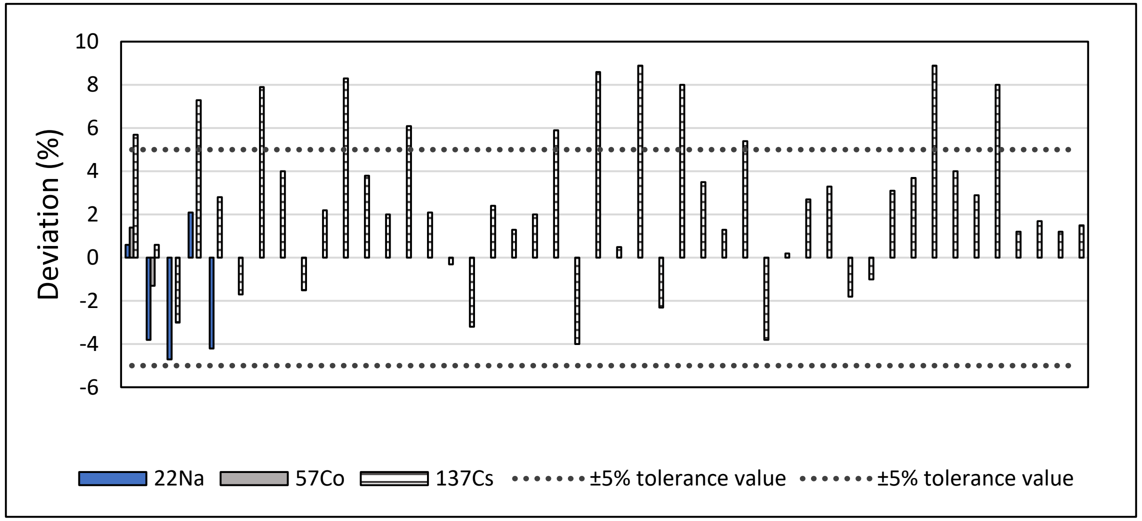
CONCLUSION

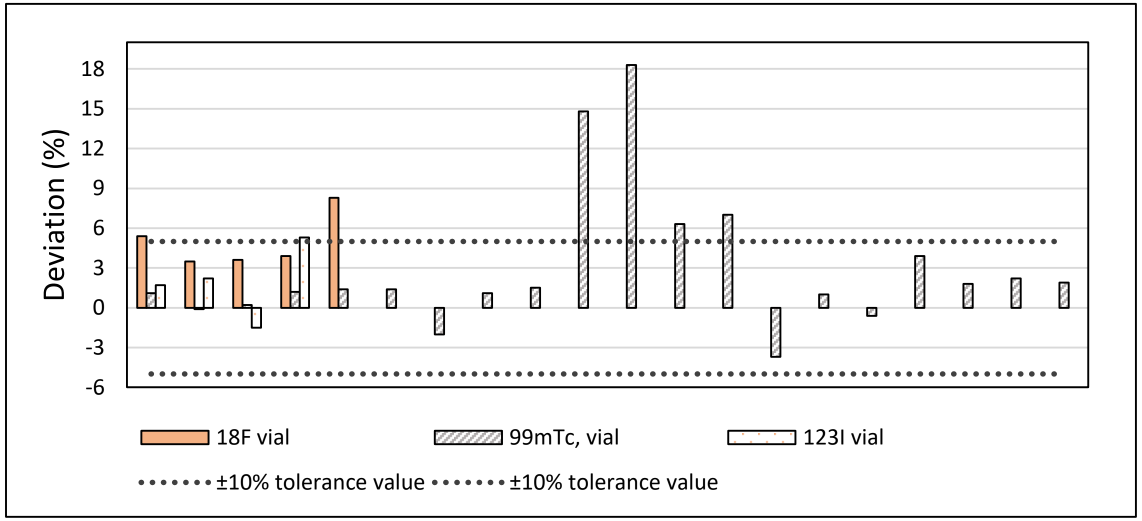
In nuclear medicine, an administration of correct radiopharmaceuticals activity to the patient is strongly dependent on the accuracy of the QC measurements of all equipment. It is important to have a product with acceptable quality control parameters in order to make the study of nuclear medicine effective and to protect the patient from unnecessary radiation exposure. In our daily practice we successfully implement a thin-layer chromatography method for ^{99m}Tc labelled radiopharmaceuticals and radionuclidic purity in a $^{99}Mo/^{99m}Tc$ generator eluate.

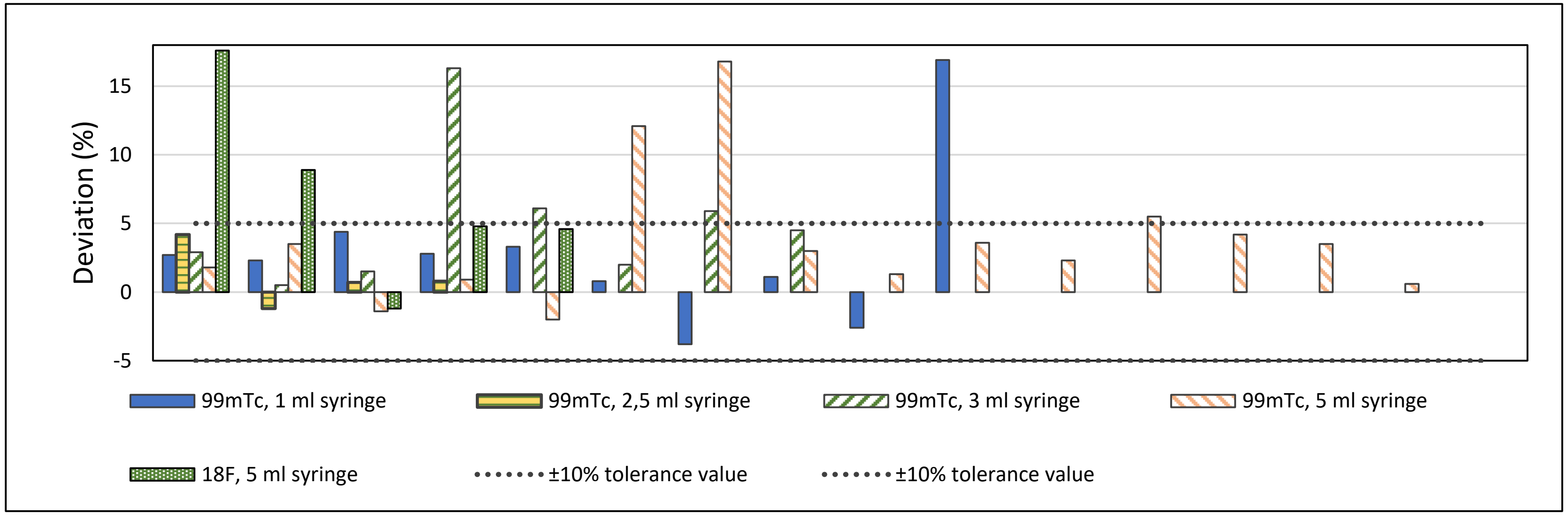
In order to improve our QA program:

- we need to start QC procedures with TLC-scan systems;
- environmental monitoring in a Hot lab should be done on routine basis;
- document management system (on going process).

Lietuvos ligoninių branduolinės medicinos skyriuose naudojamų radionuklidų kalibratorių palyginamųjų matavimų su antriniu etalonu rezultatai





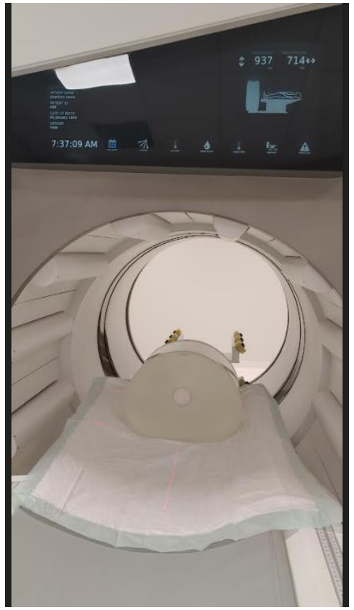


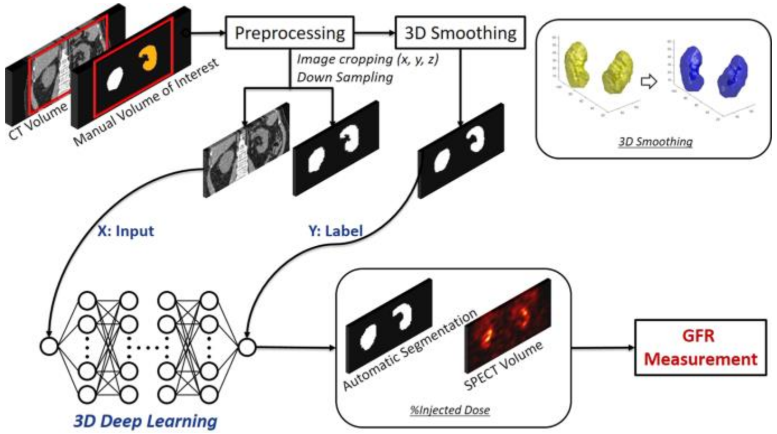
Ateitis

SPECT

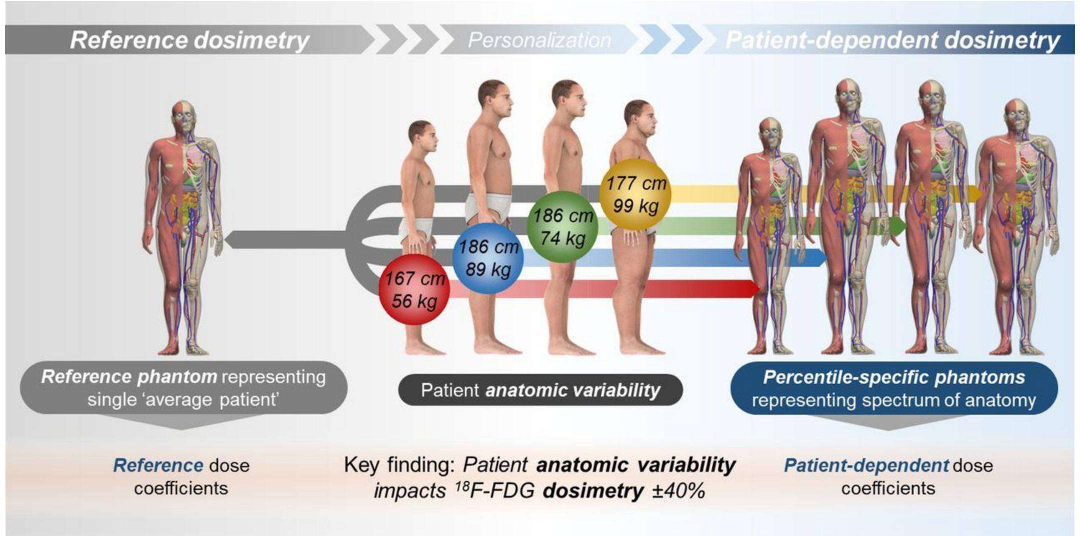
Nauji detektoriai

Medicininių rentgeno ir branduolinės diagnostikos procedūrų optimizavimas naudojant antropomorfinius fantomus ir pasitelkiant dirbtinį intelektą





https://doi.org/10.1038/s41598-019-40710-7



https://jnm.snmjournals.org/content/62/12/1805.abstract

PET/MRT SPECT/MRT personalo dozimetrijai tinkami prietaisai

SIGNA™ PET/MR Technical Data

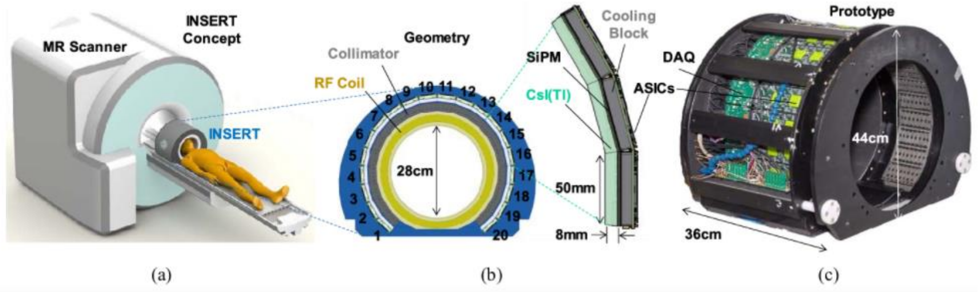


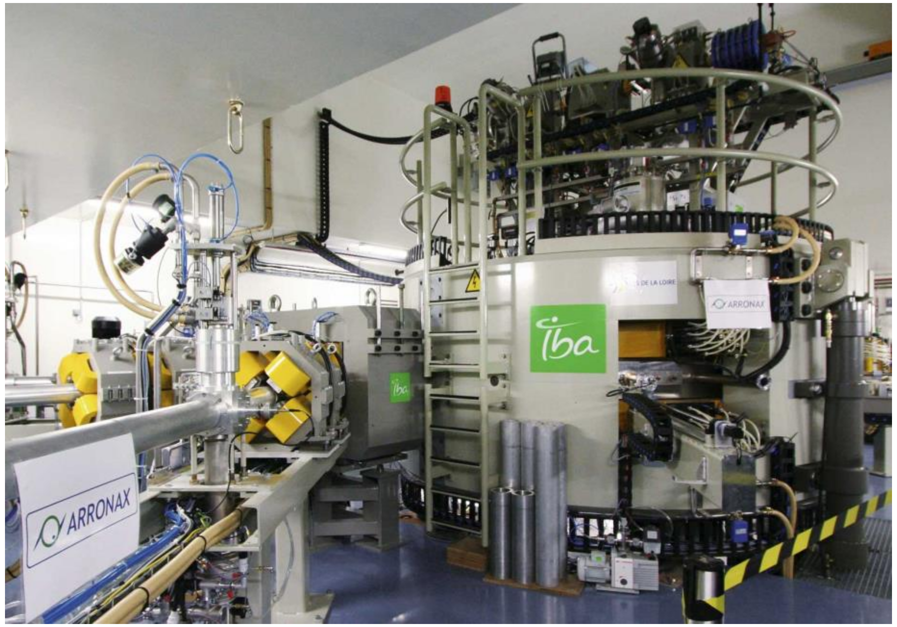
Fig. 1. Human brain clinical SPECT insert. (a) Simultaneous operation inside unmodified MRI scanners. (b) Layout of the ring of 20 detectors and zoom on the module cross section showing the thin sandwich of scintillator... Expand

Published in IEEE Transactions on Radiation and Plasma Medical Sciences 2020

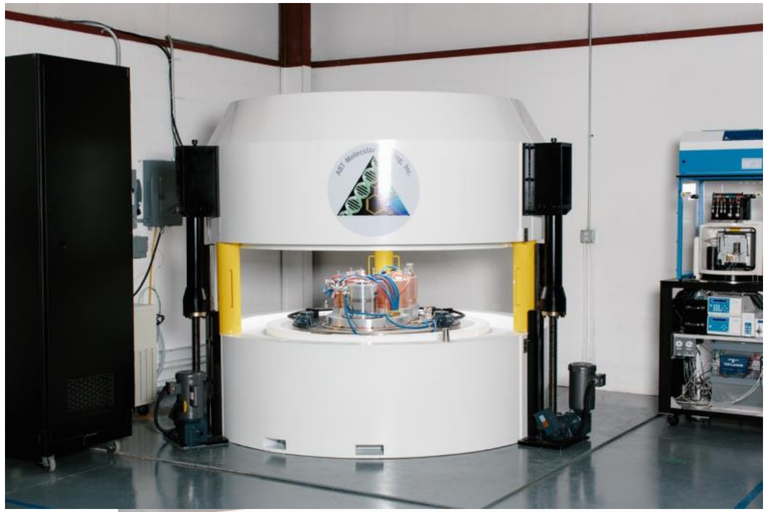
Clinical SiPM-Based MRI-Compatible SPECT: Preliminary Characterization

M. Carminati, I. D'Adda, +9 authors C. Fiorini

Kompaktinių ciklotronų gamyba



https://www.espace-sciences.org/sciences-ouest/260/actualite/un-cyclotron-contre-le-cancer



https://www.oncomed-solutions.com/solutions_cyclotron_abt_molecular_imagining_inc.php

Radiofarmacija

- Ciklotronas Lietuvoje (radionuklidų gamybai)
- Nauji junginiai

Ateities perspektyvos TAT terapija: (Targeted-Alpha-Therapy)

Eur J Nucl Med Mol Imaging. 2014; 41(11): 2106–2119. PMCID: PMC4525192
Published online 2014 Jul 29. doi: 10.1007/s00259-014-2857-9 PMID: 25070685

^{213}Bi-DOTATOC receptor-targeted alpha-radionuclide therapy induces remission in neuroendocrine tumours refractory to beta radiation: a first-in-human experience

C. Kratochwil, F. L. Giesel, F. Bruchertseifer, W. Mier, C. Apostolidis, R. Boll, K. Murphy, U. Haberkorn, and A. Morgenstern

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Review

Targeted α Therapies for the Treatment of Bone Metastases

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https://www.mdpi.com/1420-3049/22/8/1282/htm