Nuklearna endokrinologija

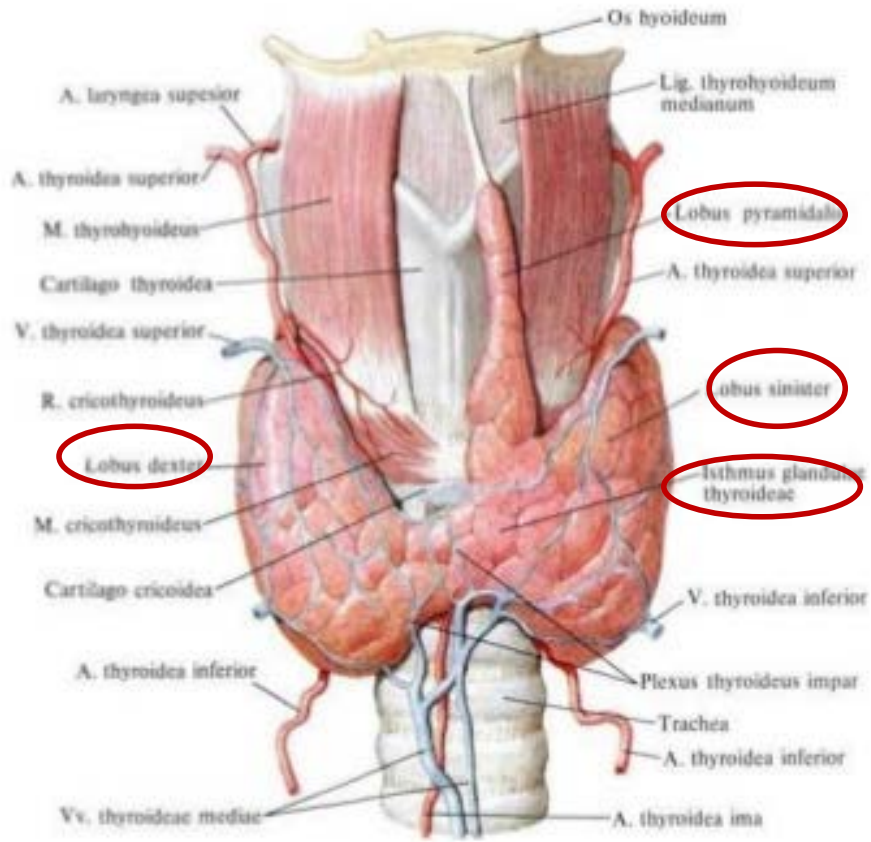
- scintigrafija štitaste žlezde
- test brzine akumulacije radiojodida u štitastoj žlezdi *(test „fiksacije“)*
- **terapija** bolesti štitaste žlezde radiojodidom
- scintigrafija kore nadbubrega
- scintigrafija srži nadbubrega
- **scintigrafija paraštitastih žlezda**

- najstarija grana nuklearne medicine
- prva klinički značajna primena radioaktivnog joda u proučavanju metabolizma joda u štitastoj žlezdi
- ***in vitro*** (određivanje hormona)
    - ***in vivo*** primena radionuklida (scintigrafija, terapija)

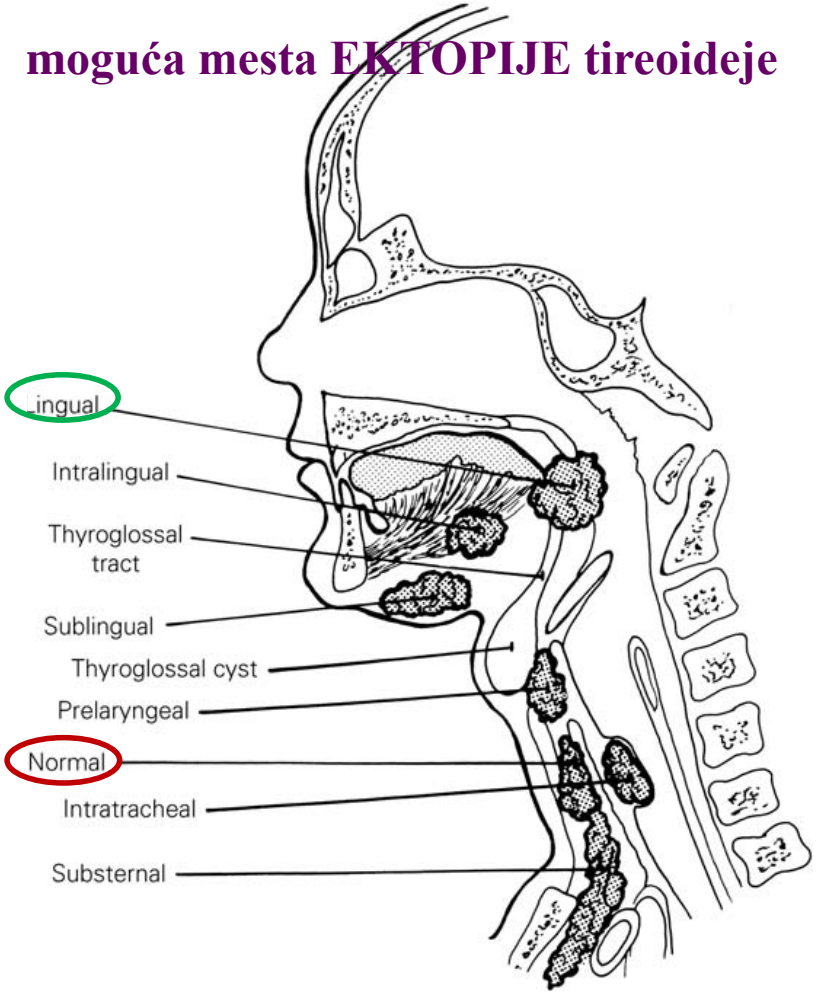
primena radiofarmaka u endokrinologiji

radiofarmak	distribucija: mehanizam nakupljanja	primena
$Na\ ^{99m}Tc\ O_4$	aktivan transport u tireocite	scintigrafija tireoideje
$Na\ ^{123}J$	aktivan transport u tireocite	scintigrafija u tireoideje
$Na^{131}\ J$	aktivan transport u tireocite	scintigrafija tireoideje
$^{125}\ J\ Ag\ (At)$		RIA; IRMA
$^{75}\ Se$ - metilholesterol	vezivanje za kortikalne ćelije nadbubrega	scintigrafija kore nadbubrega
MI ($^{131}/^{123}\ J$)BG	nakupljanje u kateholaminskim granulama	scintigrafija srži nadbubrega
$^{201}\ TlCl$	aktivan transport u tireocite	scintigrafija paraštitastih žlezda
$^{99m}\ Tc$ MIBI	Lipofilan; difuzija u ćelije i u lipoproteinske strukture (mitohondrije)	scintigrafija paraštitastih žlezda

Scintigrafija štitaste žlezde

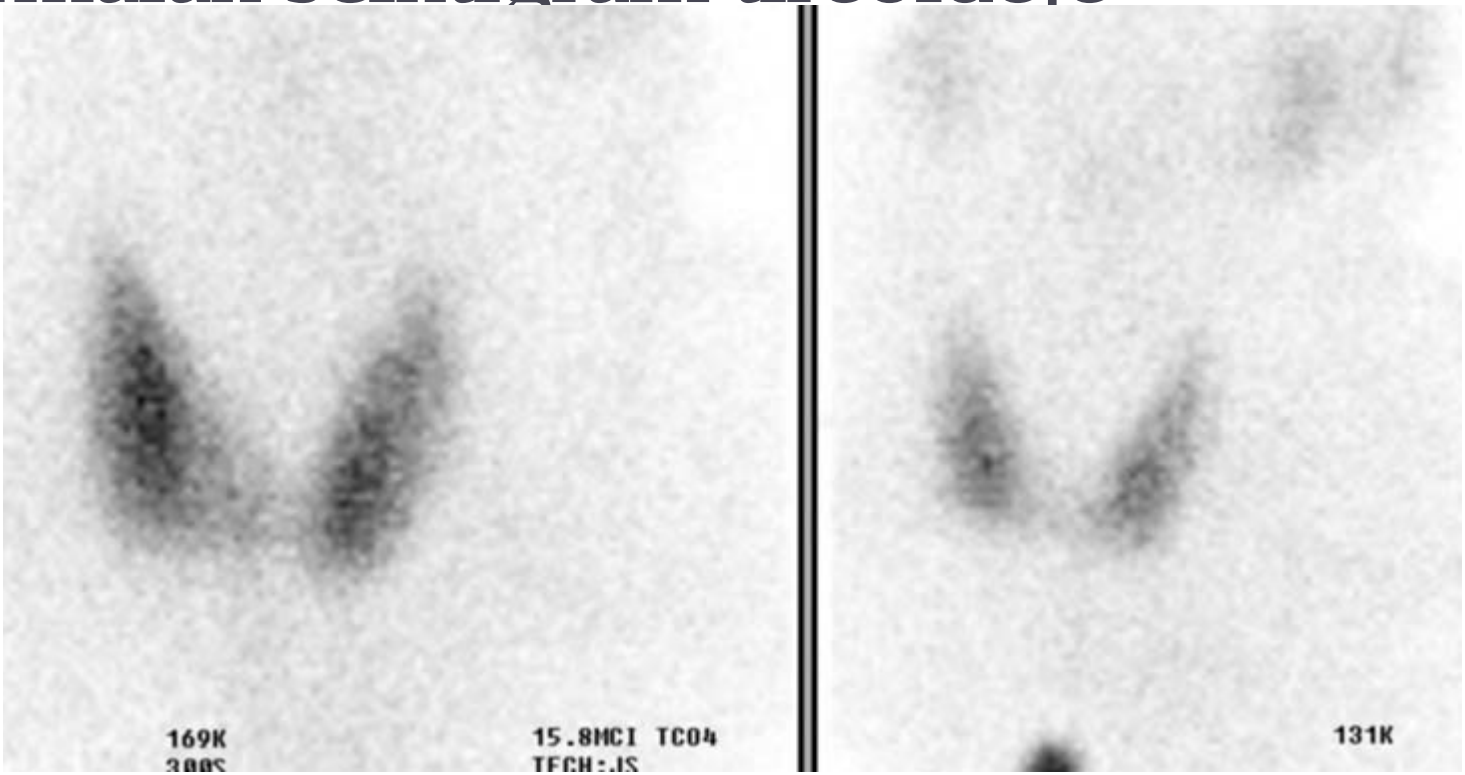


moguća mesta EKTOPIJE tireoideje



radiofarmak	$Na\ ^{99m}Tc\ O_4$	$Na\ ^{123}J$ $Na\ ^{131}J$
aplikovana aktivnost	80 -370 MBq (2-10 mCi) i.v.	20 MBq (500 μCi) 37 MBq (1mCi) per os ili i.v.
ekvivalentna doza	1-5 mSv (200-400 mrem)	4 mSv (400 mrem)
priprema pacijenta	ukidanje lekova za bolesti štitaste žlezde; bez „Minakve“, orahovače, zelenih oraščića u medu, morskih plodova, algi, povidon-joda, Ro kontrasta...	Ukidanje lekova za bolesti štitaste žlezde; bez „Minakve“, orahovače, zelenih oraščića u medu, morskih plodova, algi, povidon-joda, Ro kontrasta...
kolimator	„pinhol“ LEHR, LEGP, konvergentni	J^{131} MEGP „pinhol“ LEHR, LEGP, konvergentni
položaji snimanja	anteriorni; levi i desni anteriorni kosi položej; 600 s akvizicije ; 100 kilokaunta po slici	24h posle aplikacije; 100 000 impulsa po slici

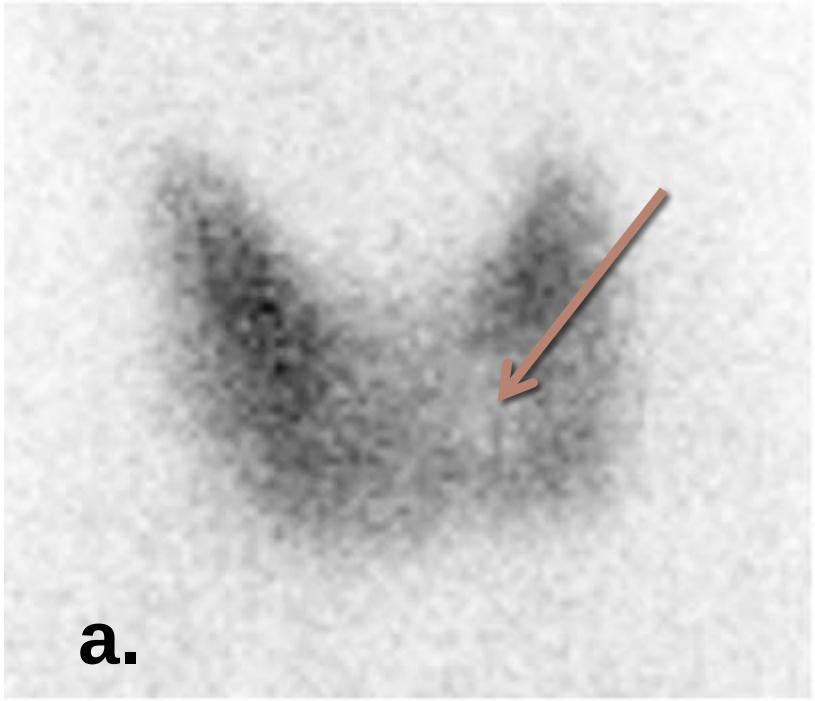
Normalan scintigram tireoideje

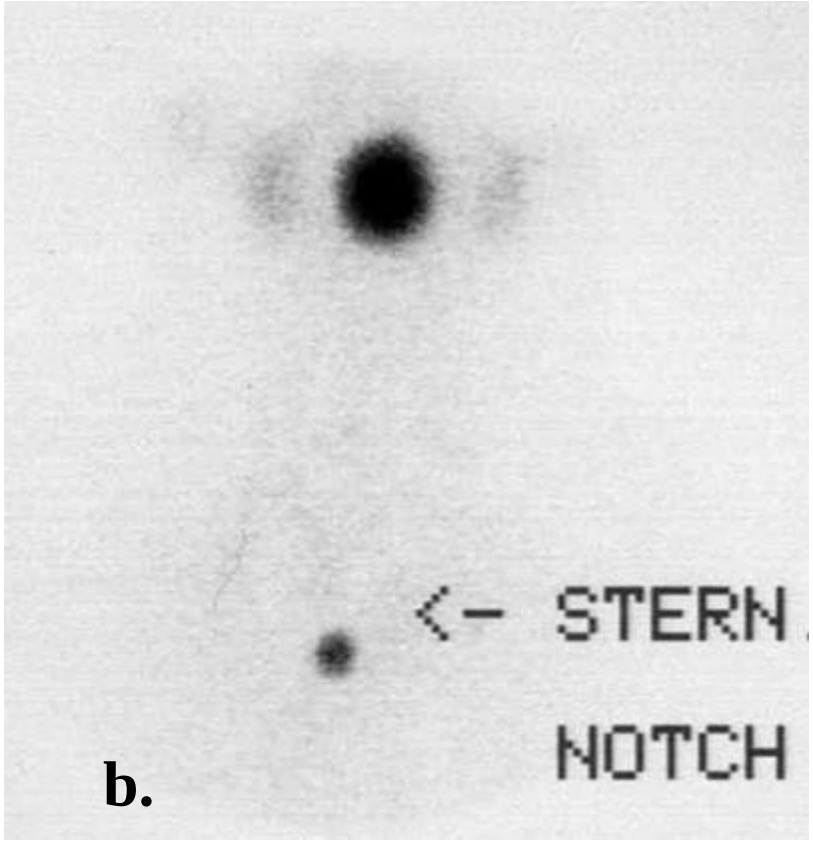


Simetrična, uobičajeno položena silueta štitaste žlezde koja ravnomerno i intenzivno nakuplja radiofarmak

a. hipofunkcijski (hladan) čvor u kaudalnom polu desnog režnja

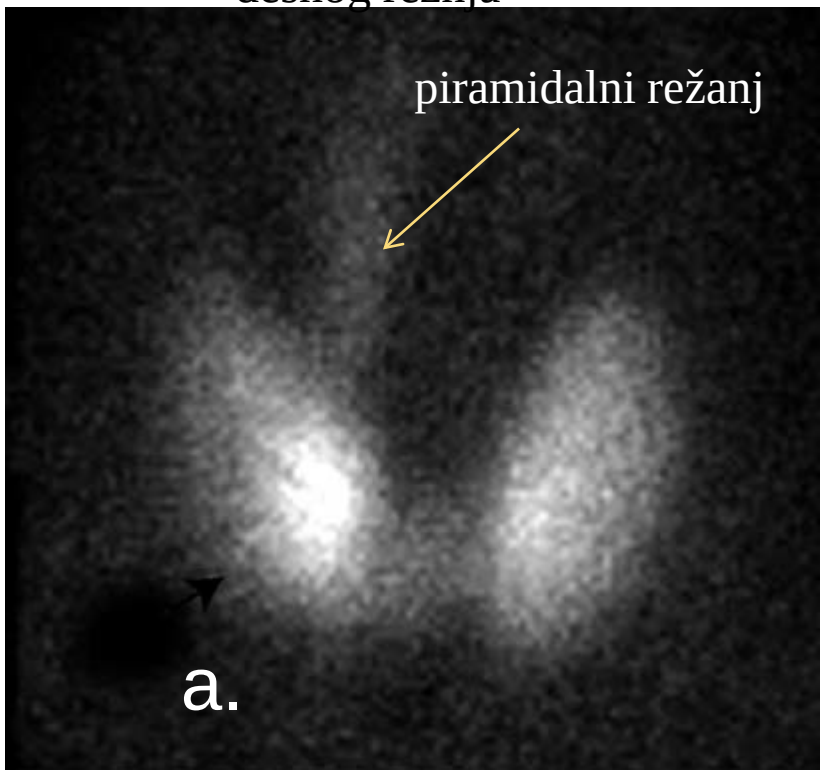
b. ektopičan, „lingvalni“ položaja tireoideje



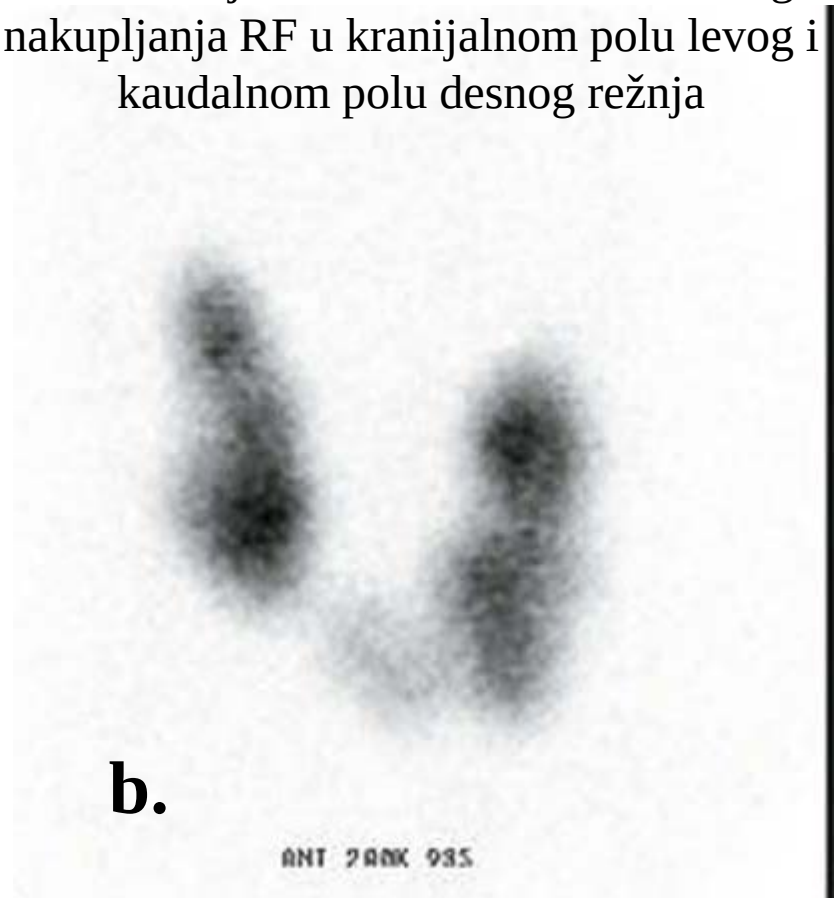


a. tireoideja u Grejvsovoj bolesi (piramidalni lobus)
b. polinodozna tireoideja

simetrična i uvećana tireoideja neravnomerne u celini intenzivne akumualcije RF, zona intenzivne akumulacije RF u kaudalnom polu desnog režnja

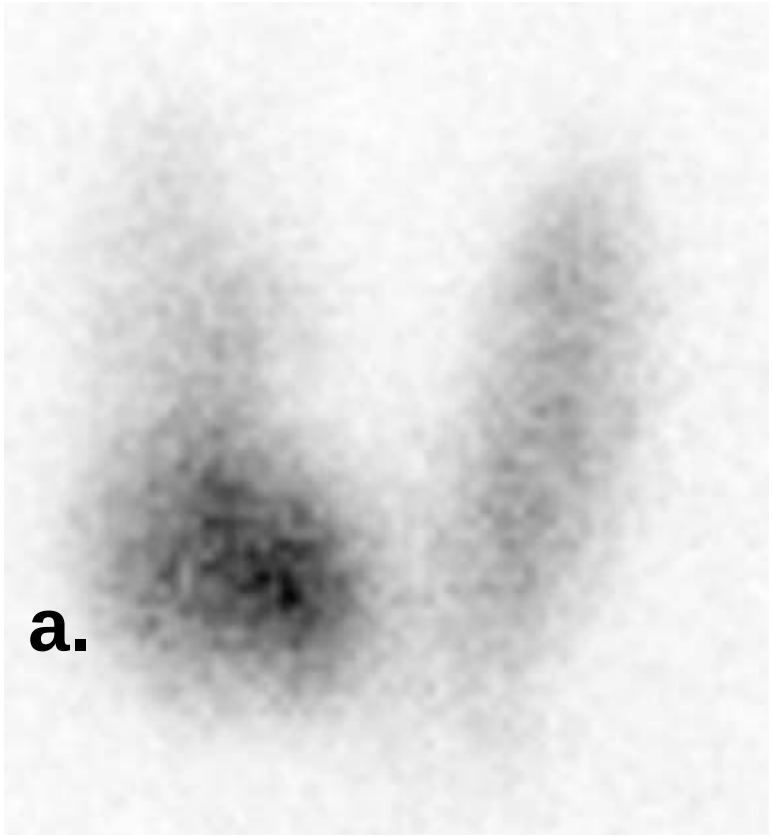


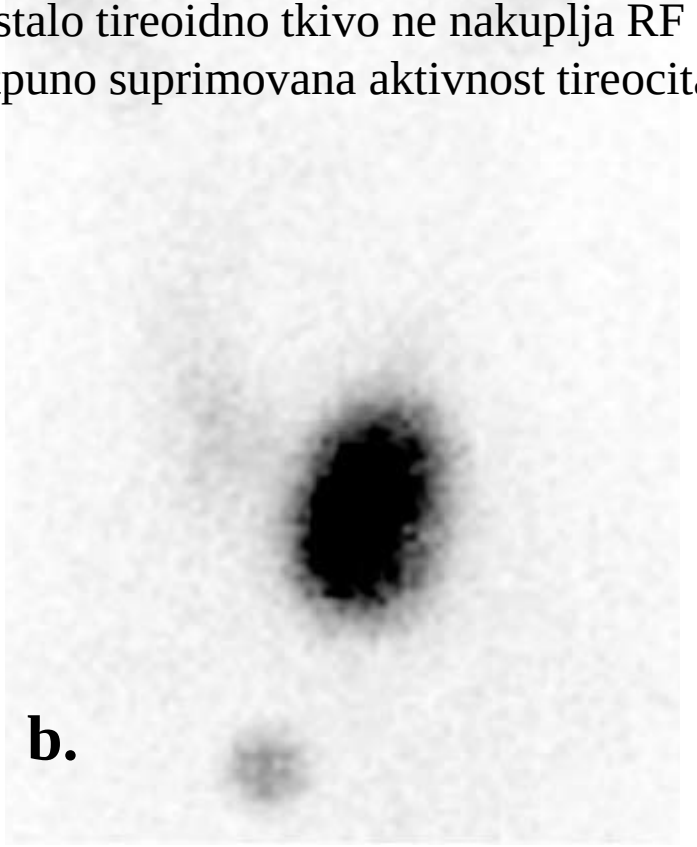
Nesimetrična tireoideja neravnomerne akumualcije RF, sa zonama intenzivnog nakupljanja RF u kranijalnom polu levog i kaudalnom polu desnog režnja



a. „subtilan“ hiperfunkcijski čvor
b. jasno ocrtan autonomni nodus (toksični adenom)

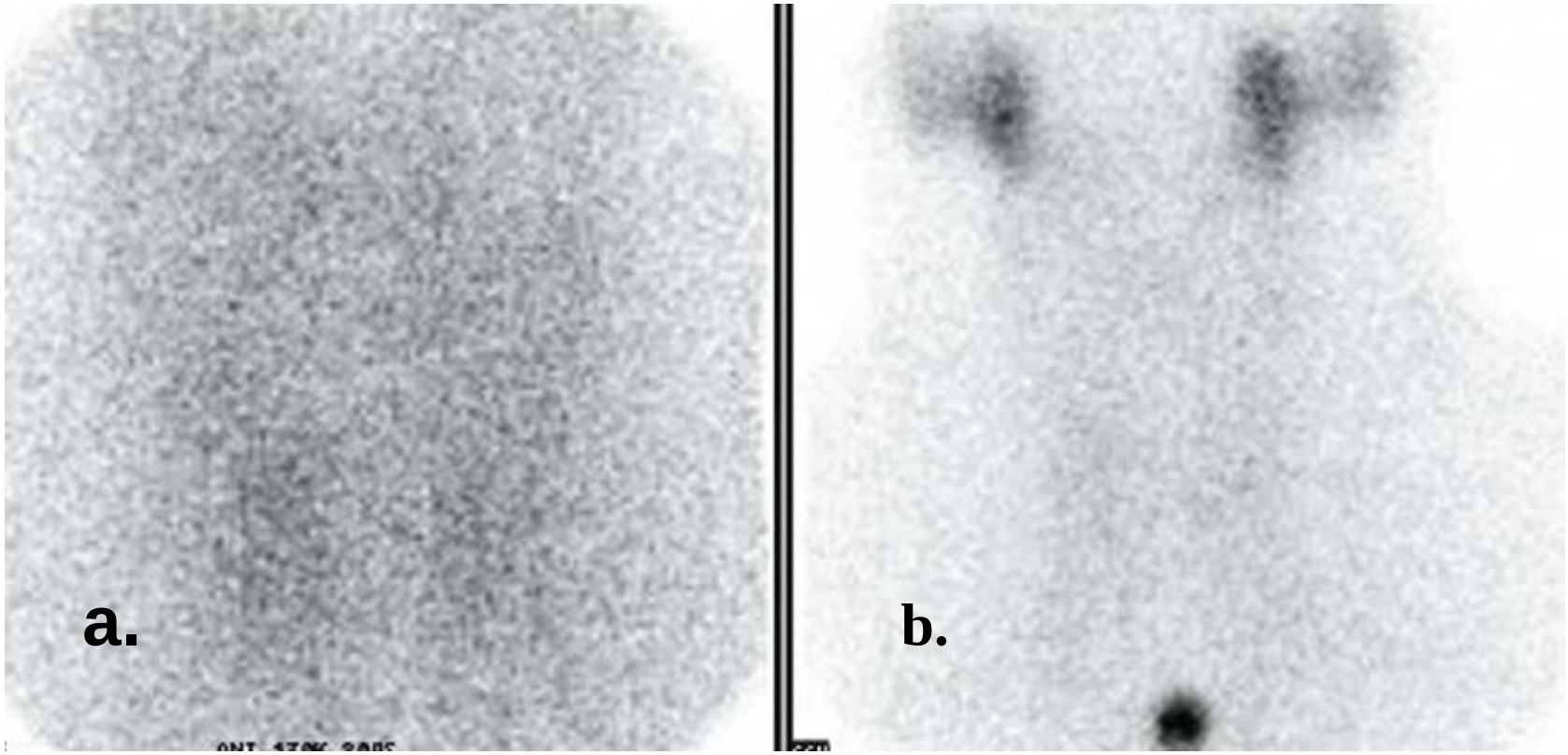
u kaudalnom polu levog režnja se prikazuje ovalna zona intenzivne akumulacie RF; ostalo tireoidno tkivo ne nakuplja RF (potpuno suprimovana aktivnost tireocita)





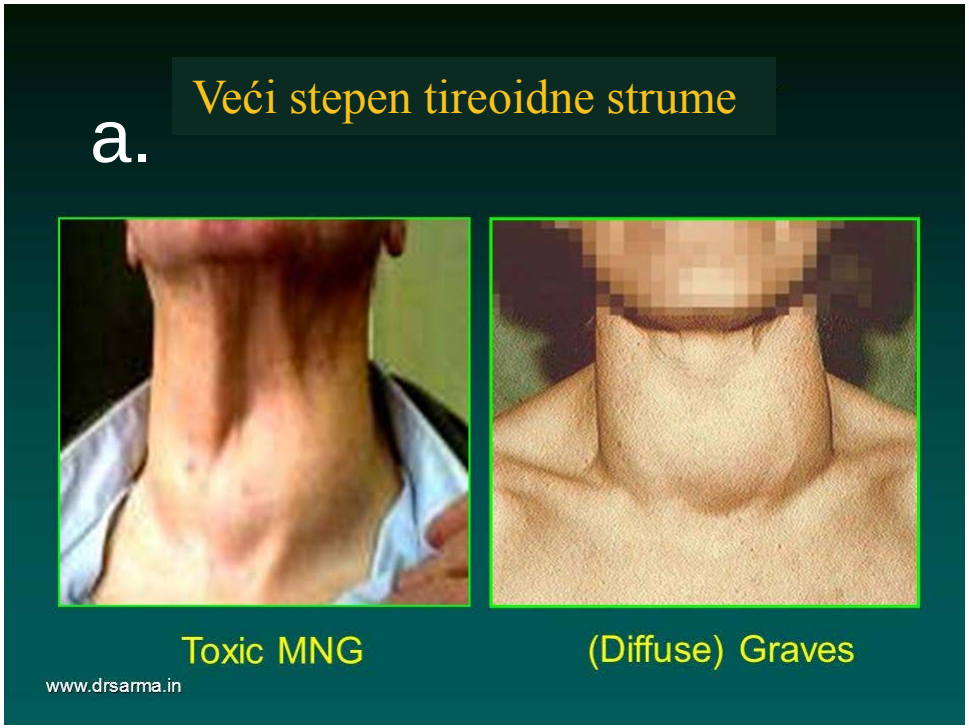
a. subakutni tireoiditis

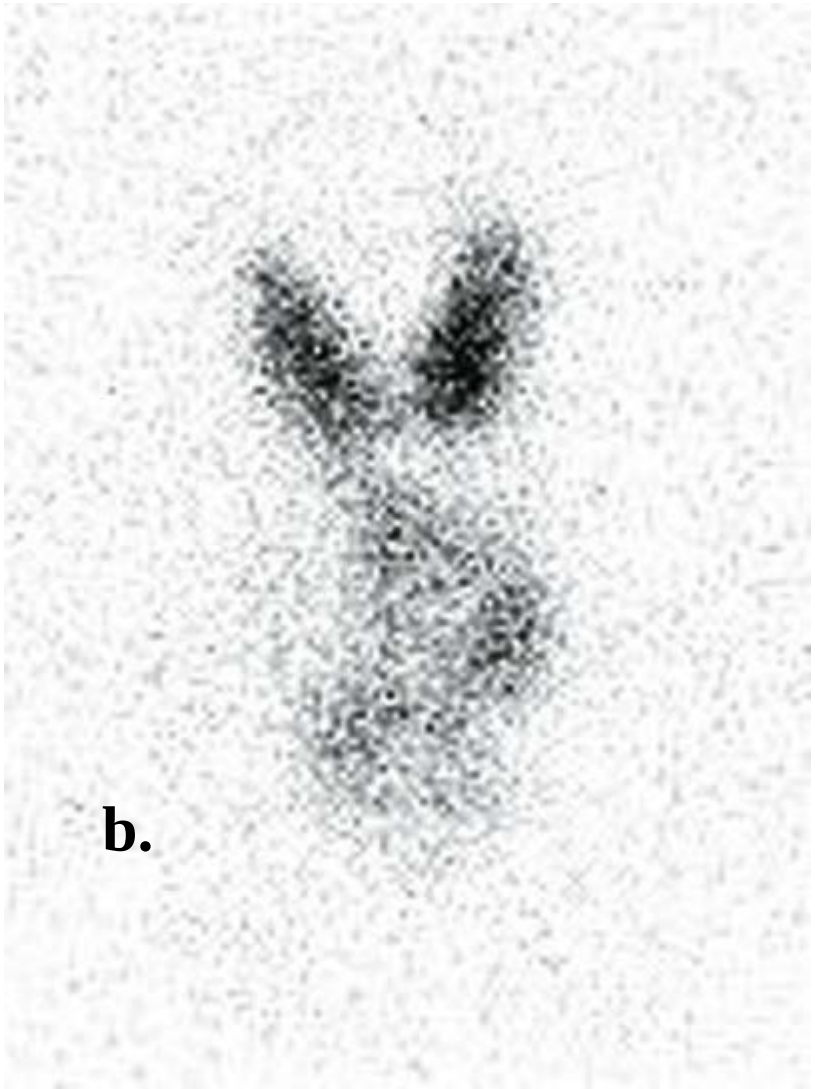
b. subakutni tireoiditis : ne prikazuje se akumulacija RF u tireoidnom krevetu (marker od ^{57}Co u sternumu)



Ne prikazuje se nakupljanje RF u štitastoj žlezdi

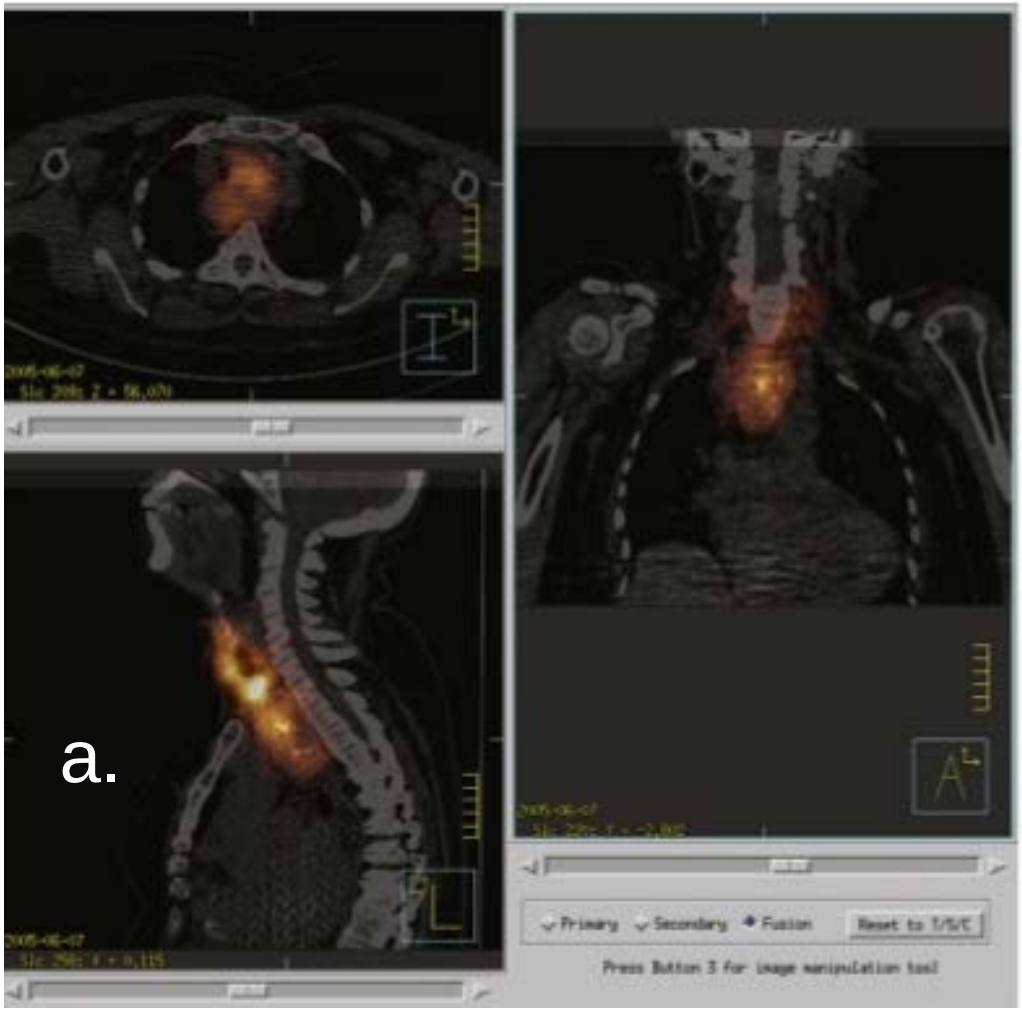
a. velika polinodozna struma
b. retrosternalna struma (Na^{123} J)

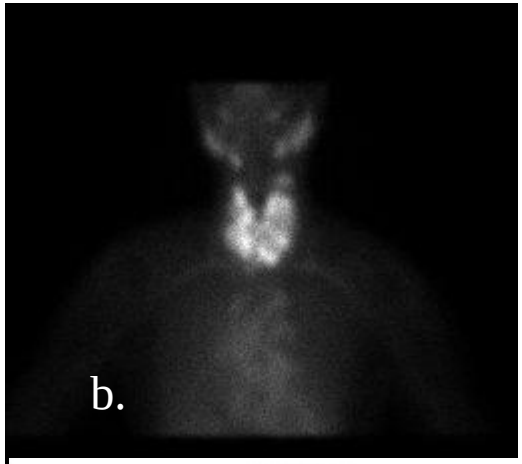


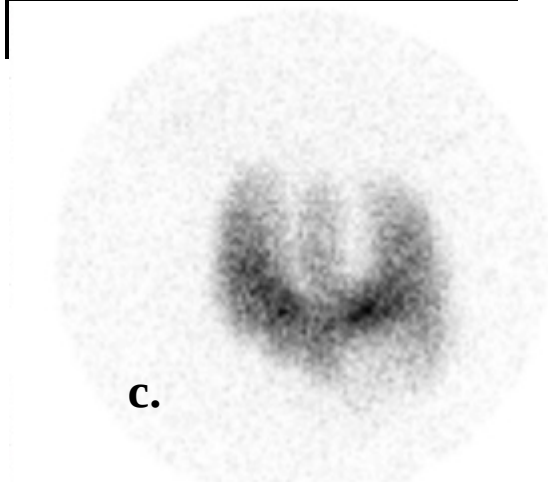


a. SPECT/CT velike retrosternalne strume

b; c. polinodozna i retrosternalna struma; polinodozna ŠŽ







a. WBdS whole body diagnostic scintigram (dijagnostički scintigram celog tela pomoću J^{131})

b. negativan J^{123} sken postterapijski kod folikulskog Ca

c. metastaze u plućima papilarni Ca

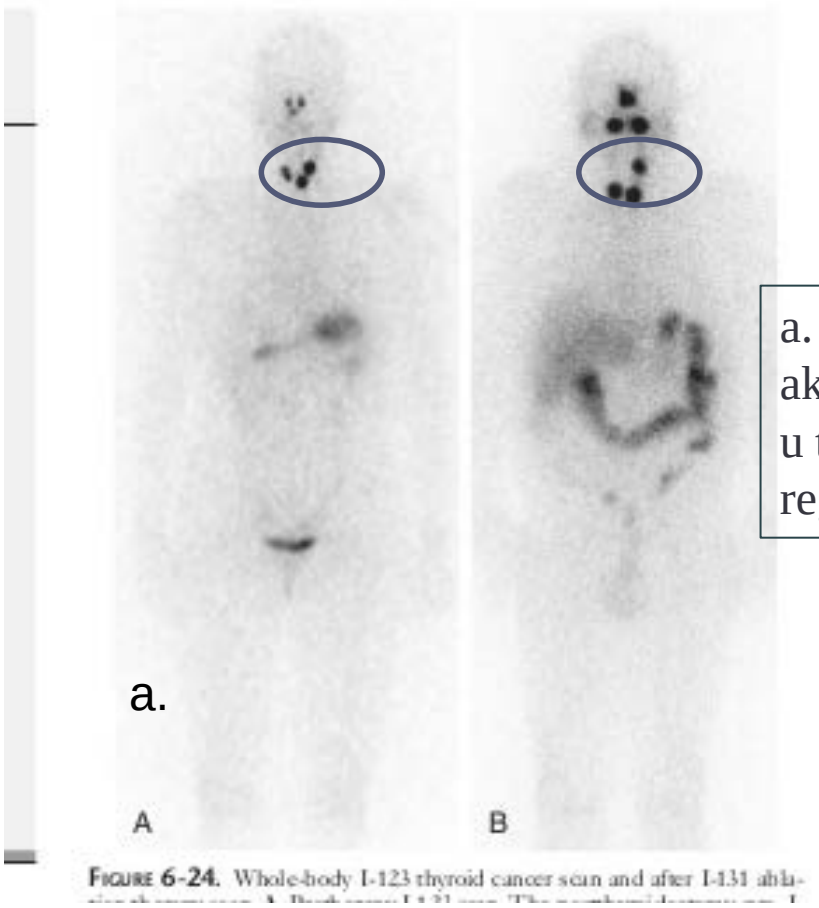
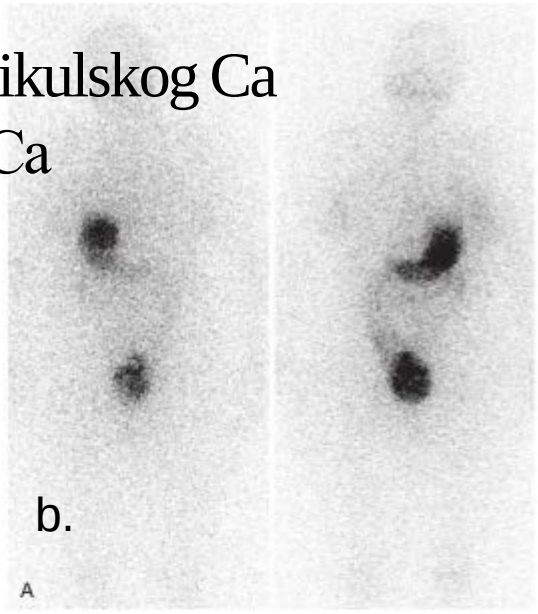
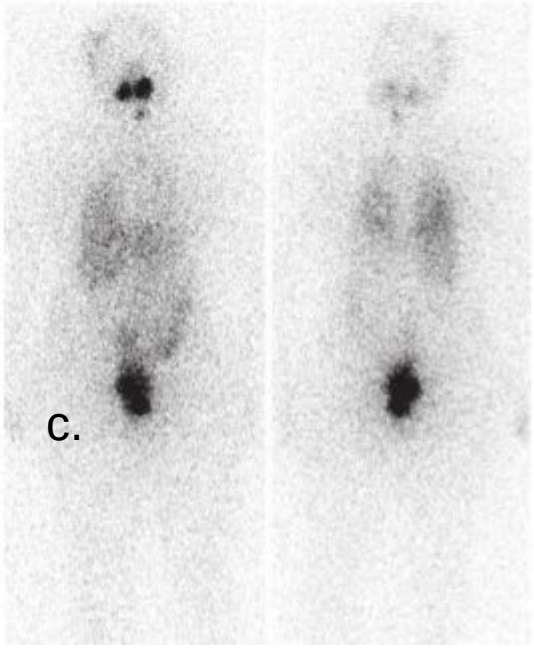


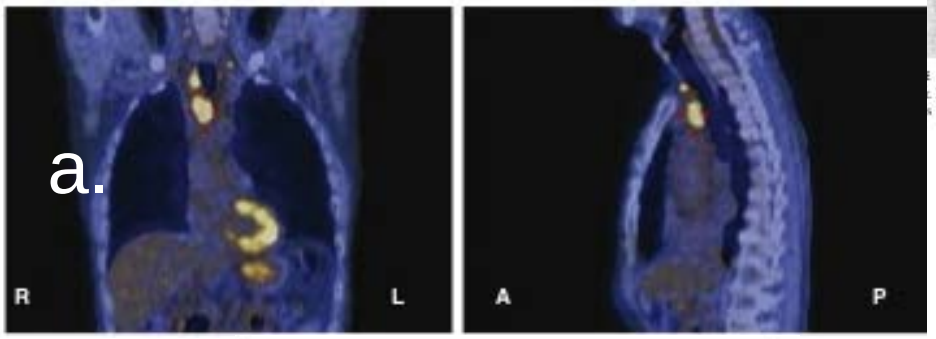
FIGURE 6-24. Whole-body I-123 thyroid cancer scan and after I-131 abla-

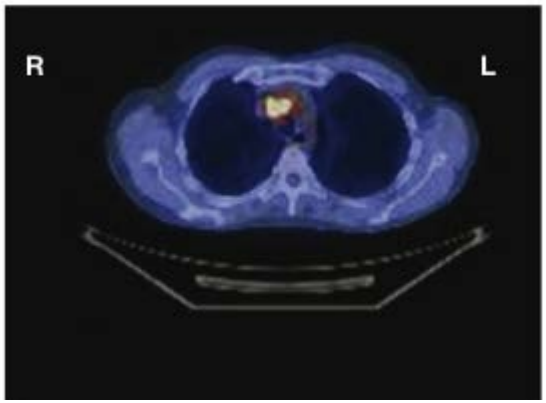
a. patološka akumulacija RF u tireoidnom regionu vrata

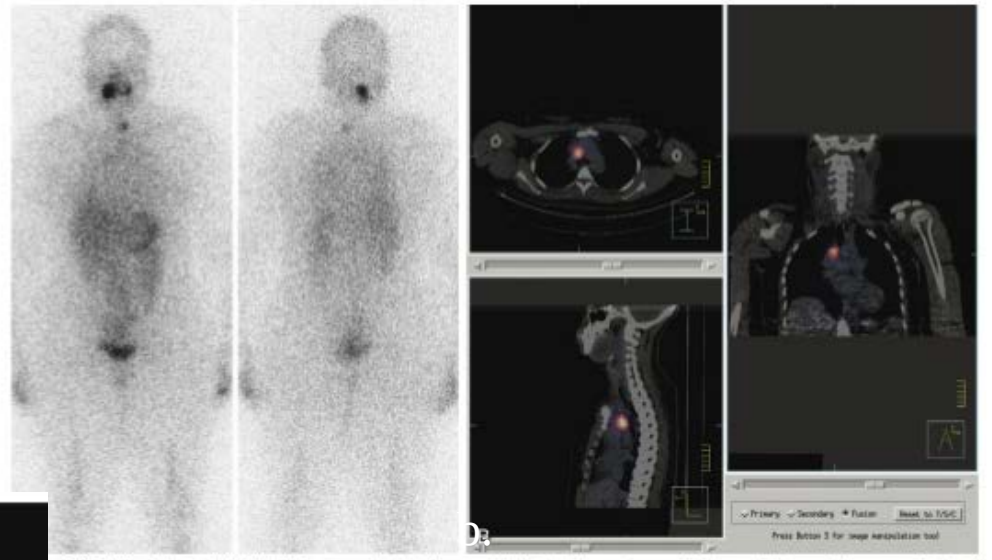




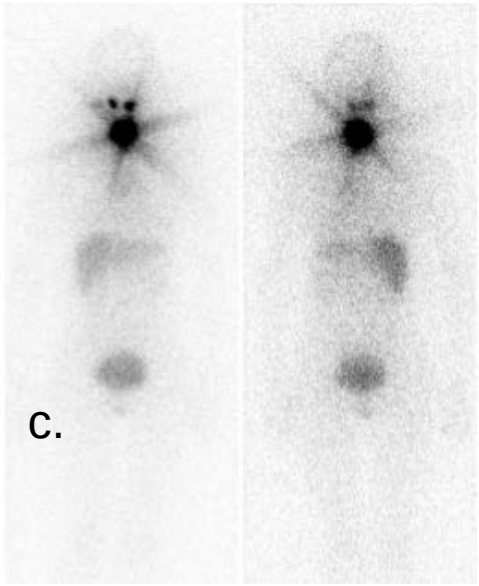
a. FDG-PET/CT Ca tireoideje
b. SPECT/CT kod TC
c. „star efekat“ u postterapijskom WBS
(velika doza...velika energija J^{131})





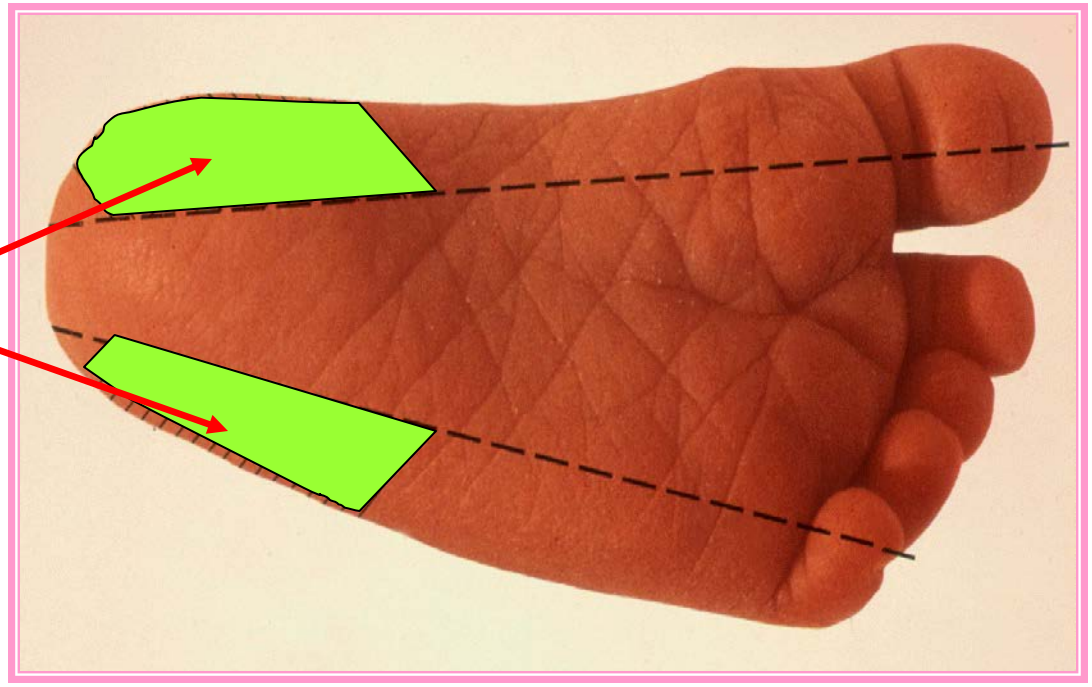


6-26. Added value of SPECT/CT for metastatic thyroid cancer. **A,** Whole-body posttherapy I-131 scan for 48-year-old woman with thyroid Lymph node dissection of the neck revealed positive nodes. The scan shows uptake in the upper mediastinum. **B,** SPECT/CT three-view fused precisely localize the uptake to pretracheal nodes.



ODREĐIVANJE NIVOA TSH iz kapi krvi „screening“ na kongenitalnu hipotireozu

mesta za uzimanje kapi krvi



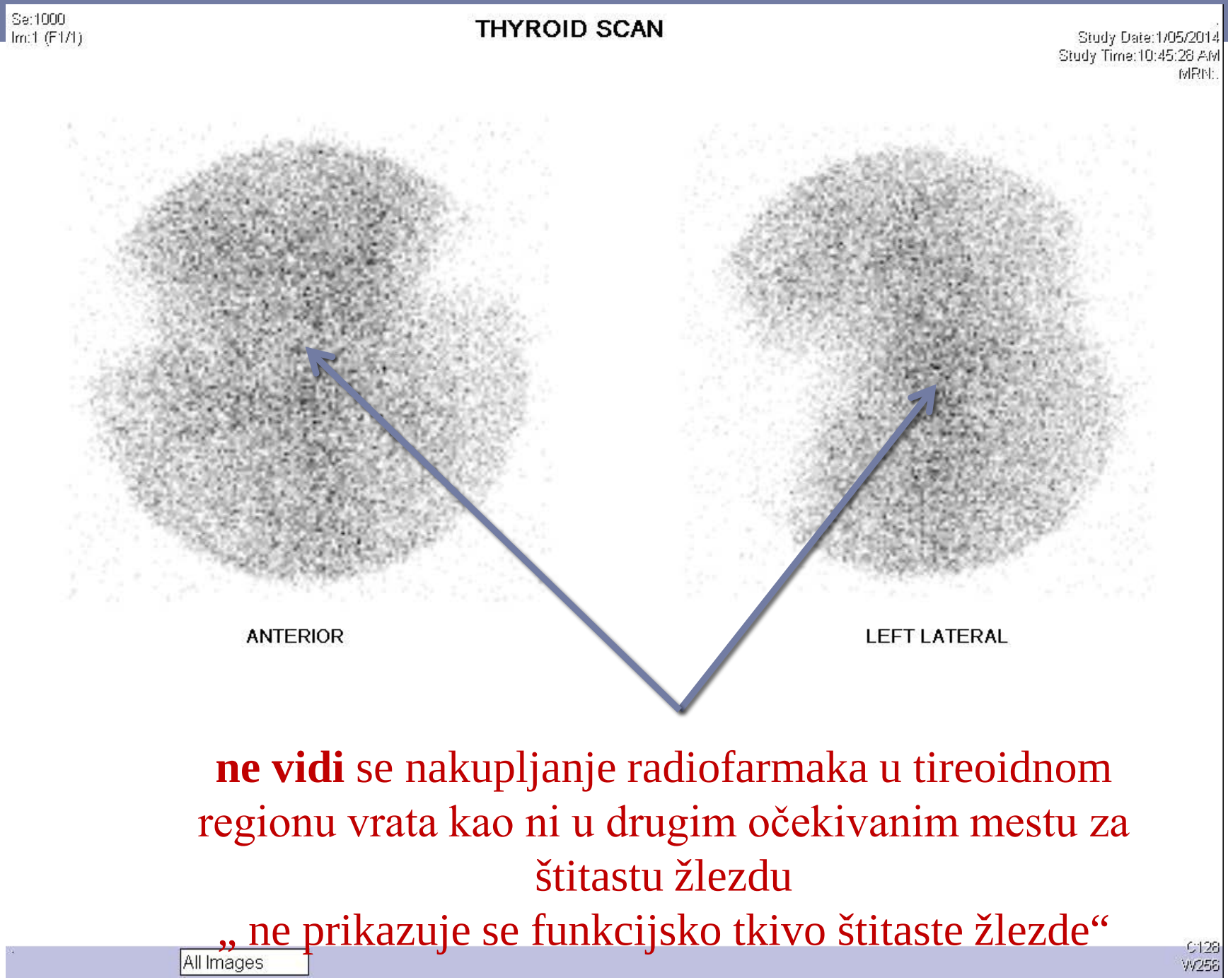
stopalo novorođenčeta

- ako novorođenče ima povećane vrednosti TSH u testiranoj kapi krvi (preko 4 mIJ/l.... (80...200....1000))

→ **scintigrafija štitaste žlezde**

- **otkriva vrstu anomalije u razvoju tireoideje**

  - **agenezija (atireoza: odsustvo štitaste žlezde)**
  - **hemiagenezija (nedostatak jednog režnja)**
  - **ektopija (štitasta žlezda nije na svom mestu)**
  - **akcesorna tireoideja (dodatna št. žl.)**



ne vidi se nakupljanje radiofarmaka u tireoidnom regionu vrata kao ni u drugim očekivanim mestu za štitastu žlezdu

„ ne prikazuje se funkcijsko tkivo štitaste žlezde“

test brzine akumulacije RAJ u š.ž.









- priprema pacijenta kao i kod scintigrafije š.ž.
- I merenje posle 3h normalno 8-20%
- II merenje posle 24 h normalno 20 - 45%

Standard Capsule Method

Uptake calculation

3) Calculate the % radioiodine uptake using the following formula:

$$\%\ \text{uptake} = \frac{\text{neck cpm} - \text{thigh cpm}}{\text{standard cpm} - \text{room bkg cpm}} \times 100$$

$$= \frac{\text{Net neck cpm}}{\text{Net capsule cpm}} \times 100$$

cpm - counts per minute (broj impulsa u minuti)

bkg – „background“ (broj impulsa u minutu u sobi u kojoj se izvodi test)

radionuklid	123 J	131 J	99mTc pertehnetat
vrsta RA raspada	elektronski zahvat	ß- raspad	izomerna tranzicija
T ½	13h	8 dana	6h
energija keV	159	364	140
vrsta radijacije	Čist γ emiter	γ Fotoni i β čestica	Čist γ emiter
mehanizam nakupljanja	Aktivni transport: preuzimanje i organifikacija	Aktivni transport: preuzimanje i organifikacija	Aktivni transport: smo preuzimanje bez organifikacije
aplikacija	per os	per os	i.v.
doza	100-400 μCi	50-100 μCi	2 mCi
uslovi snimanja	3-4h ili 24h	24h	20 min
prednost	oslikava i preuzimanje i organifikaciju; nema β čestično zračenje; čist γ emiter	oslikava i preuzimanje i organifikaciju; retrosternalna struma	oslikava i preuzimanje; čist γ emiter; kratko vreme snimanja; niska E (malo ozračivanje)
nedostatak	Ciklotronski proizvod	β čestično zračenje; visoka E gama zraka	oslikava samo preuzimanje vijabilnim tireoicitima

Scintigrafija paraštitastih žlezda

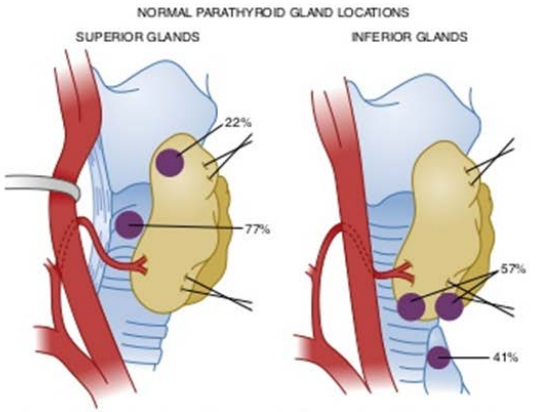


FIGURE 6-29. Normal parathyroid gland locations. The superior pair of glands *(closed circles)* usually lie within the fascial covering of the posterior aspect of the thyroid gland outside the capsule. Intrathyroidal locations are rare. Most are adjacent to the thyroid or cricothyroid cartilage. Superior glands are located just posterior to the superior pole or midpole of the thyroid *(left)*. Inferior glands *(closed circles)* are located immediately posterior or lateral to the inferior pole of the thyroid or in the thyrothymic ligament *(right)*.

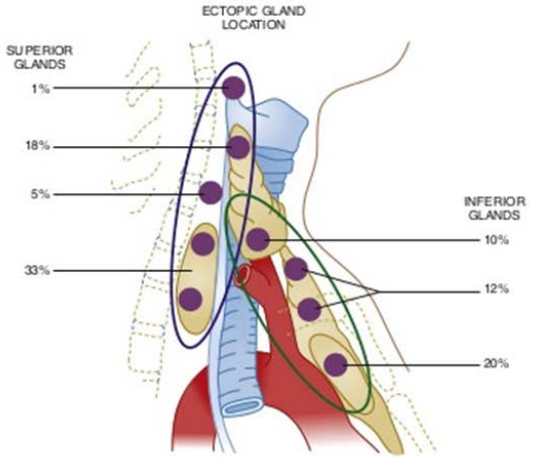


FIGURE 6-30. Ectopic gland locations. Because of abnormal embryological descent, ectopic glands can be found as cephalad as the carotid bifurcation, as inferior as the region of the pericardium, anterior to the thyroid, posterior in the tracheoesophageal groove, and in the superior mediastinum. In the anterior-posterior plane, inferior glands descend anteriorly and superior glands descend more posteriorly.

protokol scintigrafije paraštitastih žlezda

radiofarmak	**pertehnetat i ^{201}TlCl**	**Tc^{99m} MIBI (Sestamibi®)**
aplikovana radioaktivnost	80 MBq (2 mCi) ^{201}Tl; 370 MBq (10 mCi) ^{99m}Tc	925 MBq (25 mCi)
ekvivalentna doza	4.6 mSv (460 mrem)	5 mSv (500 mrem)
priprema pacijenta	kao kod sc. tireoideje	nema
kolimator	konvergentni ili LEHR, paralelnih otvora	LEHR (low energy high resolution)
položaji i uslovi snimanja	Prvo se ubrizga Tl pa se snimi slika posle 15 minuta od 100 000 impulsa: tireoidni region vrata i mediastinum.. Bez pomeranja pacijenta uradi se sc. ŠŽ. Izvrši se subtrakcija sc. ŠŽ od talijumske slike.	anterioriorni (kosi položaji ako je potrebno); 20, 60 i 120 minuta posle i.v. aplikacije RF (and oblique); SPECT se doda ako je potrebno

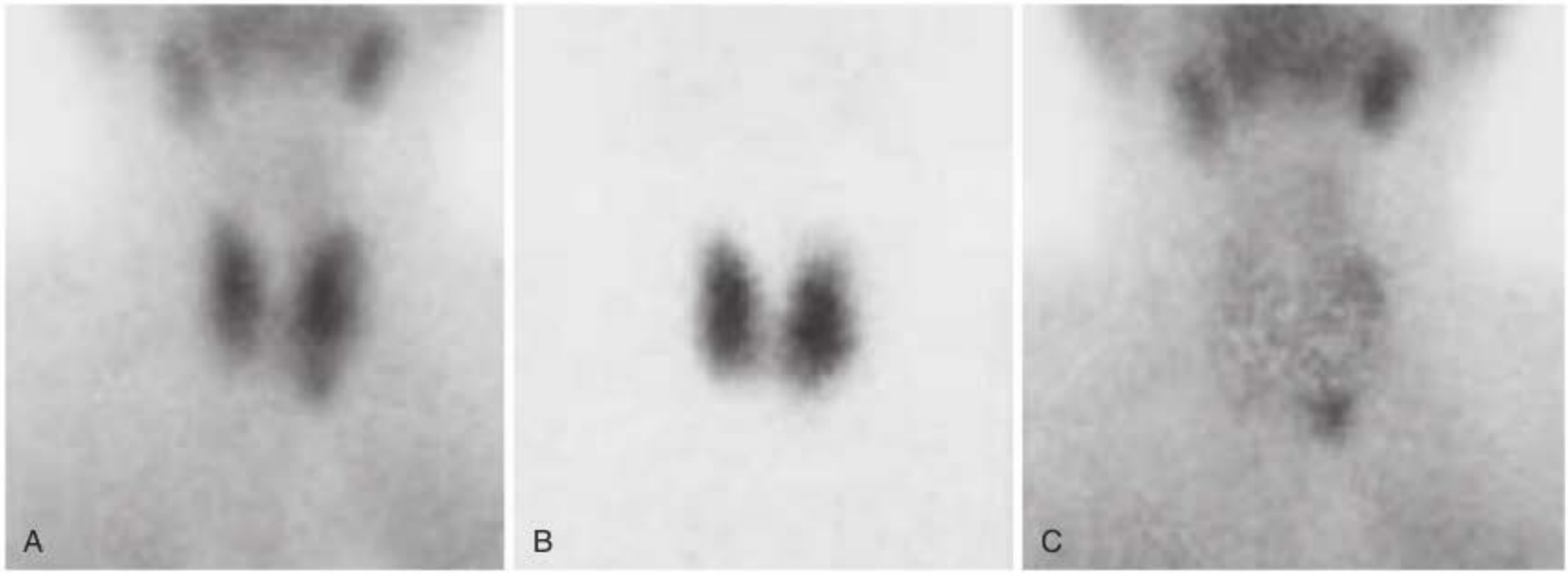
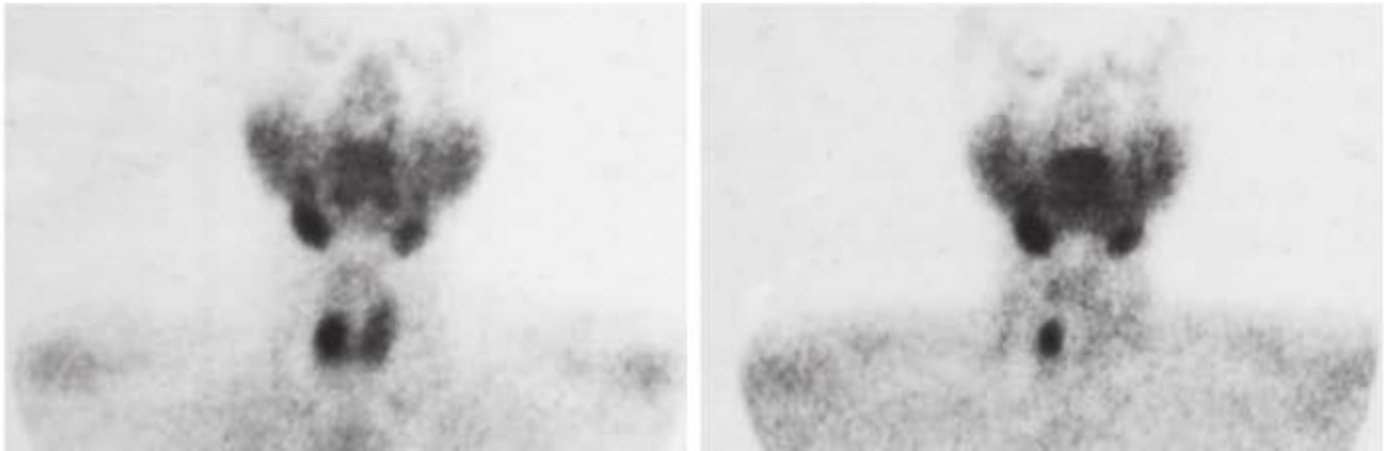


FIGURE 6-31. Parathyroid subtraction scintigraphy. Tc-99 sestamibi and I-123. **A,** Tc-99m sestamibi scan. **B,** I-123 scan. **C,** Computer subtraction of the I-123 scan from the Tc-99m sestamibi scan reveals uptake only in the parathyroid, consistent with an adenoma.



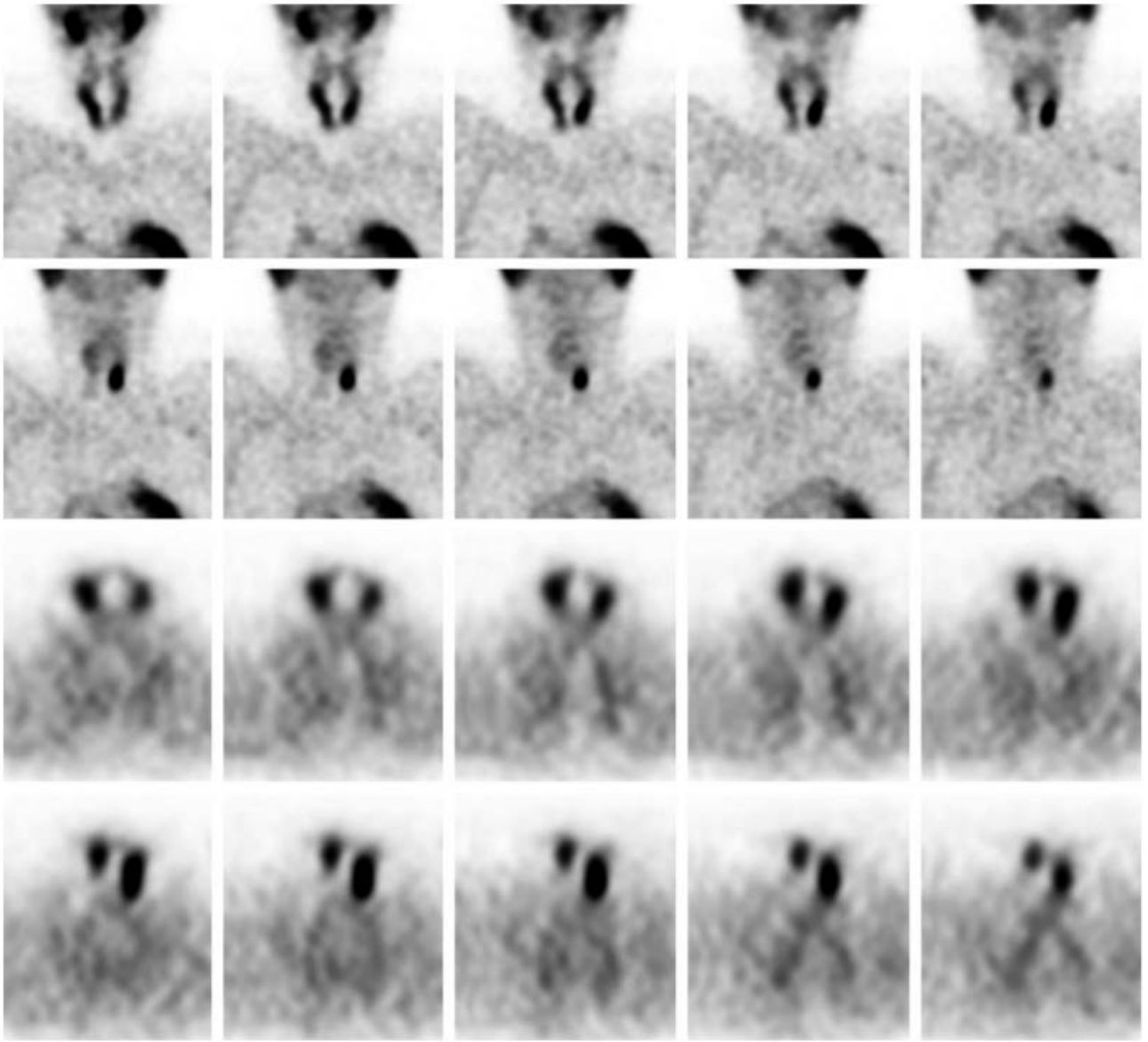


FIGURE 6-33. Tc-99m sestamibi single-photon emission computed tomography parathyroid scan. Clinical diagnosis of hyperparathyroidism. Scan ordered for localization. Sequential coronal *(top two)* and transverse *(bottom two)*, each with early images above and delayed images below. The coronal images show that the adenoma is inferior to the thyroid on the left side. The transverse images show that the parathyroid is rather posterior on the left side, suggesting a superior parathyroid adenoma.



FIGURE 6-37. Tertiary hyperparathyroidism with four hyperfunctioning glands detected. Tc-99m parathyroid sestamibi scan in a patient with renal failure with elevated calcium. SPECT/CT sequential coronals show four abnormal foci, the left superior parathyroid gland being the largest, but also the left inferior, right superior, and right inferior glands detected.

hiperaktivna paratireoideja

fiziološka akumulacija
MIBI u miokardu

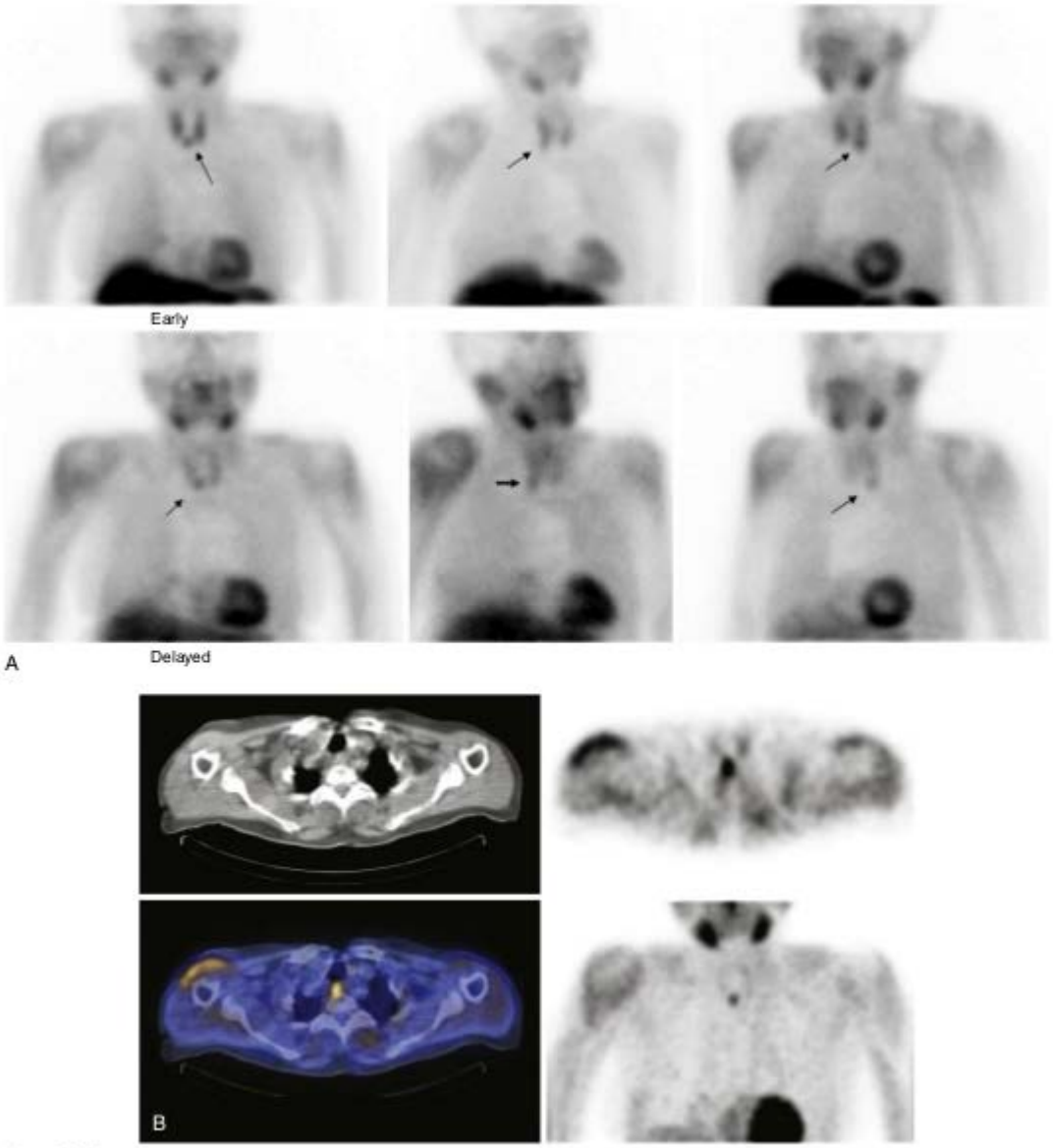
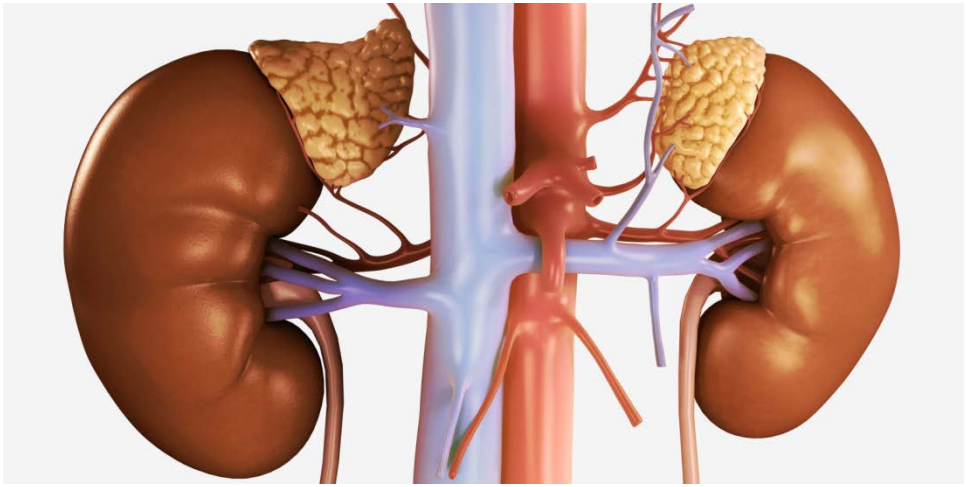
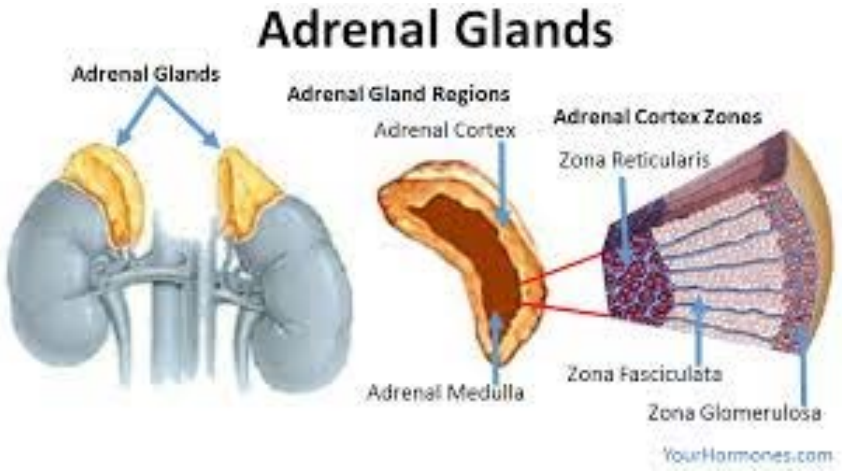


FIGURE 6-34. Retrosternal localization with SPECT/CT. **A.** Early and delayed images. Anterior *(left)*, right anterior oblique (RAO) *(middle)*, left anterior oblique (LAO) *(right)*. In the anterior view, a suspicious adenoma is noted midline just below the two thyroid lobes. On the RAO and LAO views the adenoma appears to be in the lower right lobe and lower left lobe, respectively. **B.** The fused SPECT/CT images *(left lower)* show that the parathyroid adenoma is retrotracheal.

Scintigrafija nadbubrega





Scintigrafija kore nadbubrega

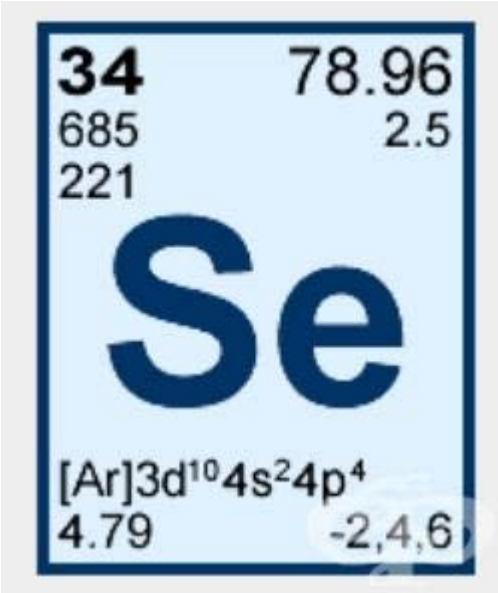
- **Radiofarmak** izbora **^{131}I-6β-jodometil-19-norholesterol** (poznat i kao jodoholesterol ili NP-59)
- visok aviditet za **koru nadbubrega**
- glavni nedostatak je ***visoka energija J^{131}***
- **mehanizam nakupljanja**:
  - holesterol je prekursor hormona NB žlezde:
  - zavisi od nivoa LDL holesterola (što je veći nivo holesterola u krvi, vezivanje RF je manje);
  - povećan nivo cirkulišućeg ACTH povećava nakupljanje RF u kori nadbubrega
- radioholesterol se skladišti u kortikalnim ćelijama ali se ne esterifikuje i zato se ne ugrađuje u hormone
- posle i. v. injekcije radioholesterol se progresivno nakuplja danima pa i nedeljama
- nakupljanje RF po žlezdi je manje od 0,02% (znatna ekspozicija zračenju)

PROTOKOL SCINTIGRAFIJE

radiofarmak	**^{131}I-6β-jodometil-19-norholesterol** **^{75} Se-selenometil-norholesterol (Scintadren ®)**
aplikovana radioaktivnost	**35 MBq (1 mCi)**
ekvivalentna doza	**105 mSv (10 ram)**
priprema pacijenta	**„blokada“ tireoideje**
kolimator	**HEGP, paraleni otvori**
polažaji snimanja (akvizicije)	**posteriorna, anteriorna, lateralne i kosi položaji abdomena; 20 minuta po položaju**
vreme snimanja	**4 do 7 dana posle aplikacije RF**

^{75}Se-selenometil-norholesterol

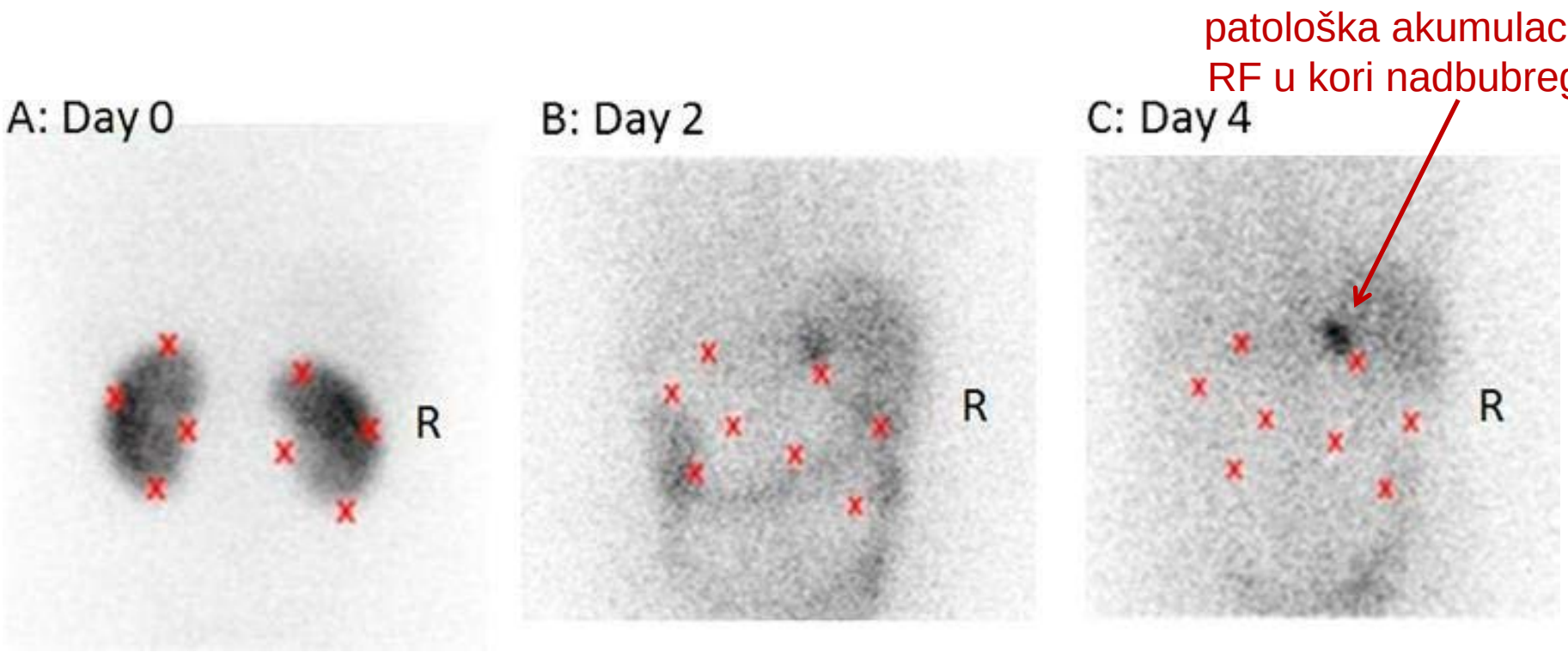
(Scintadren ®)



$T_{1/2}$ ..... 120 dana

E ..... 97 do 410 keV

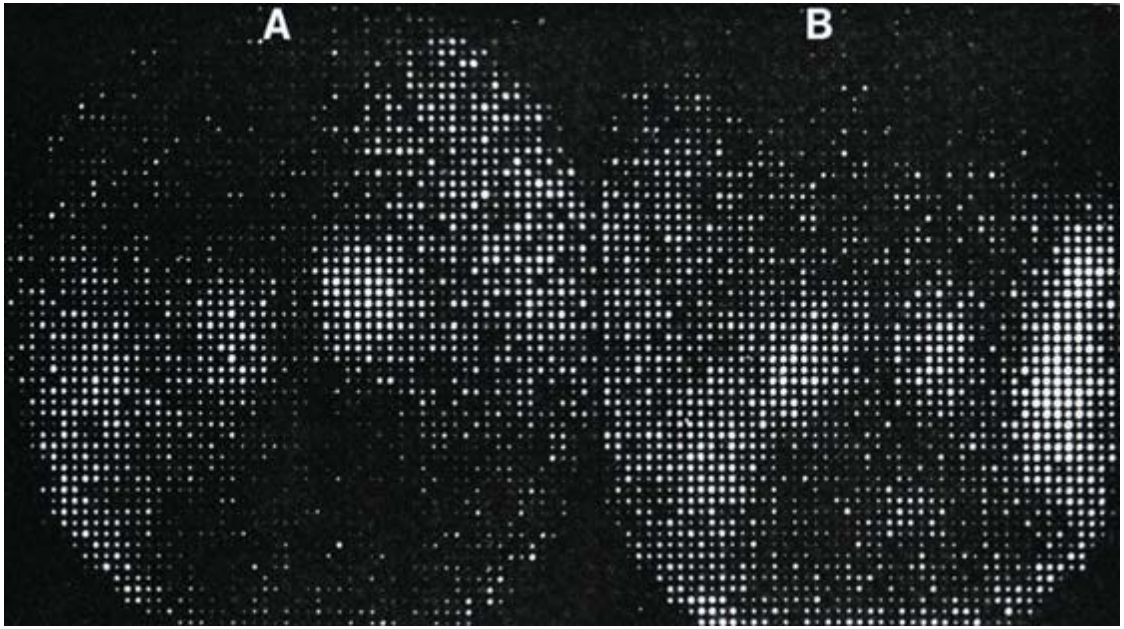
nakupljanje RF tokom vremena



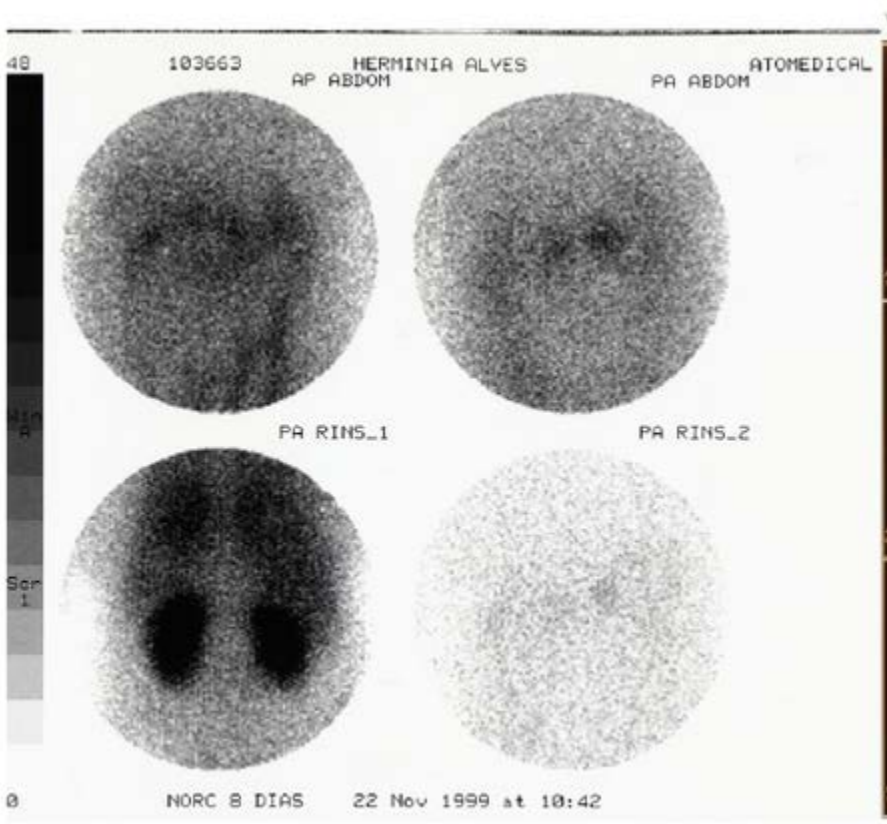
C:posle 4 dana od aplikacije RF se uočava njegovo nakupljanje u hiperaktivnoj kori nadbubrežne žlezde

A: scintigram bubrega da bi se „lokalizovala“ nad**bubrežna** žlezda

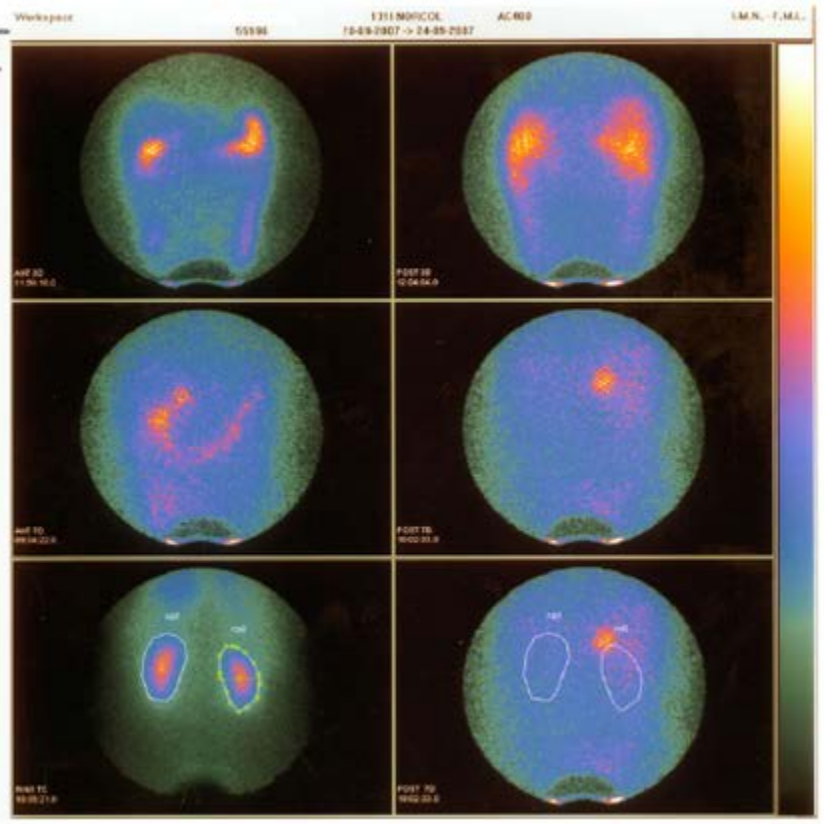
Normalan scintigram kore nadbubrega pomoću NP 59



primarni hiperaldosteronizam

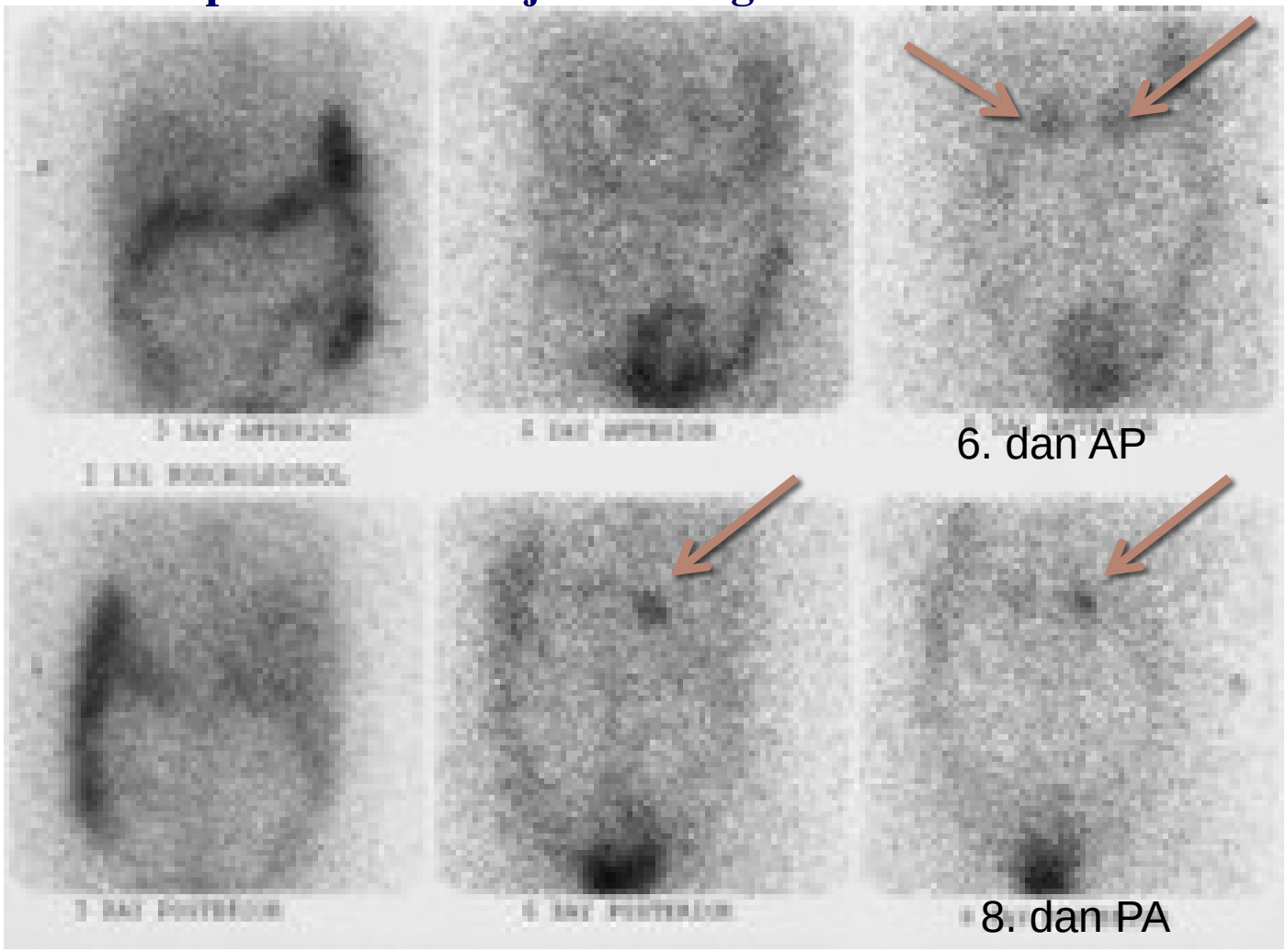


a



b

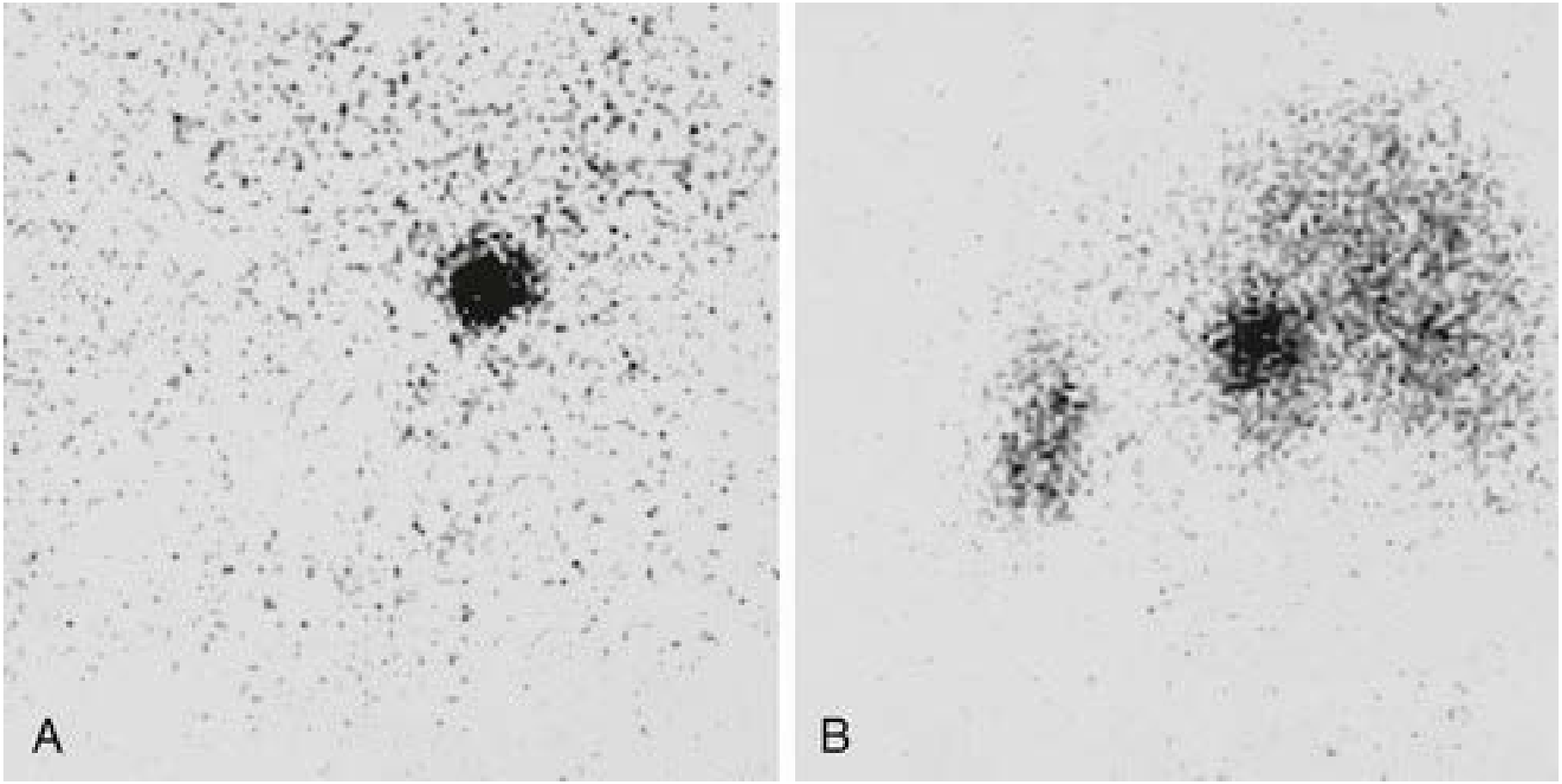
Konov sindrom (Conn)
primarni hiperaldosteronizam
povećano lučenje iz zone glomeruloze NB žlezde

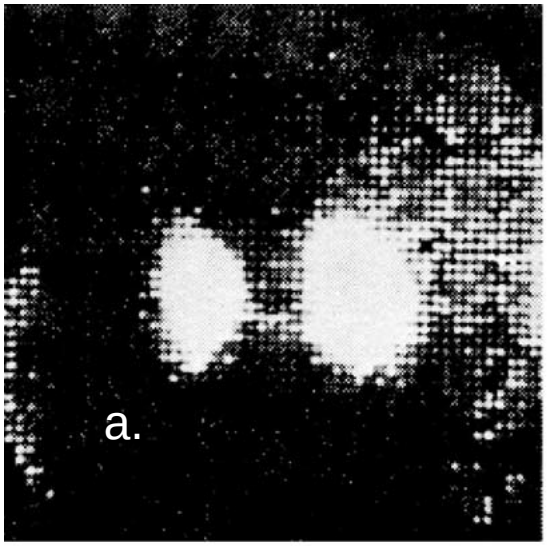


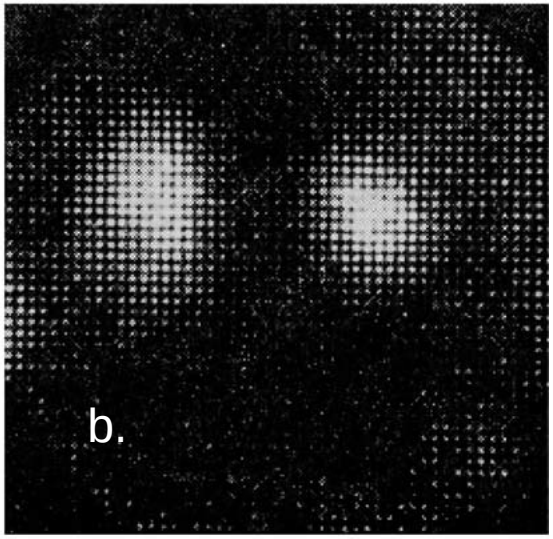
Kušing-ov sindrom („hiperkorticizam“; povećan nivo ACTH:

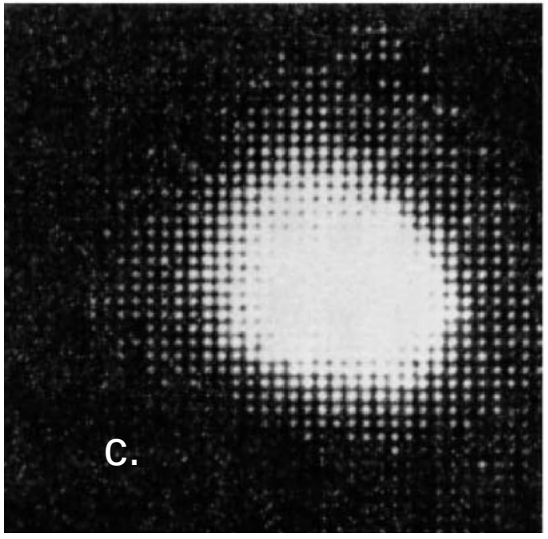
A. posteriorna projekcija „hiperkorticizma“ 7 dana posle i.v. aplikacije RF

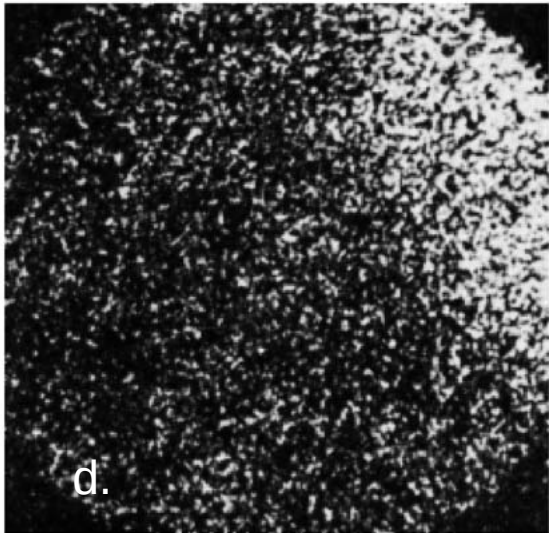
B. asimetrično vezivanje RF kod pacijenta sa makronodularnom hiperplazijom nadbubrega











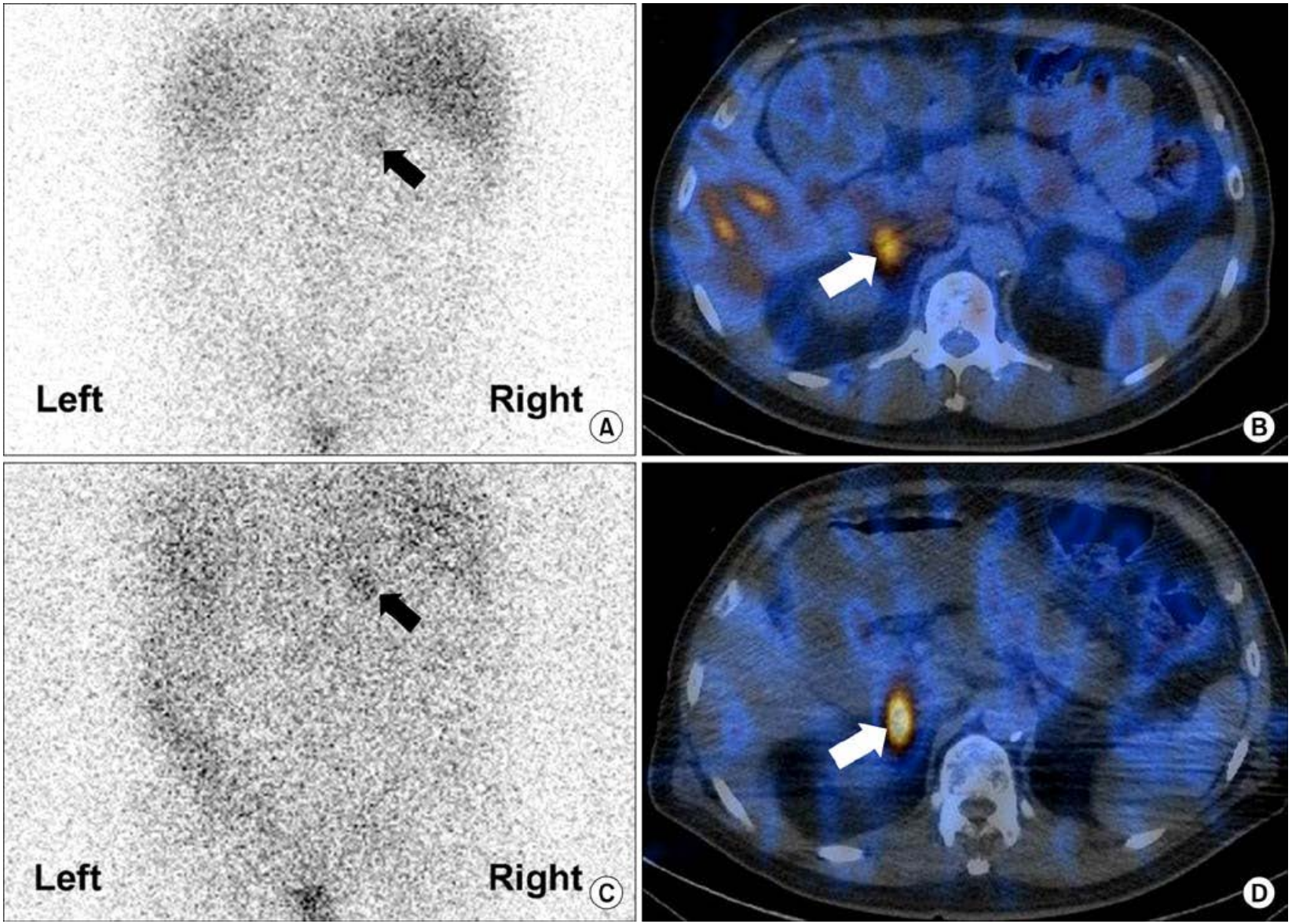
a. **ACTH-zavisna, bilateralna hiperplazija**

b. ACTH nezavisna bilateralna nodularna hiperplazija

c. Adrenokortikalni adenom

d. Adrenokorticalni karcinom (karcinomi NE vezuju RF)

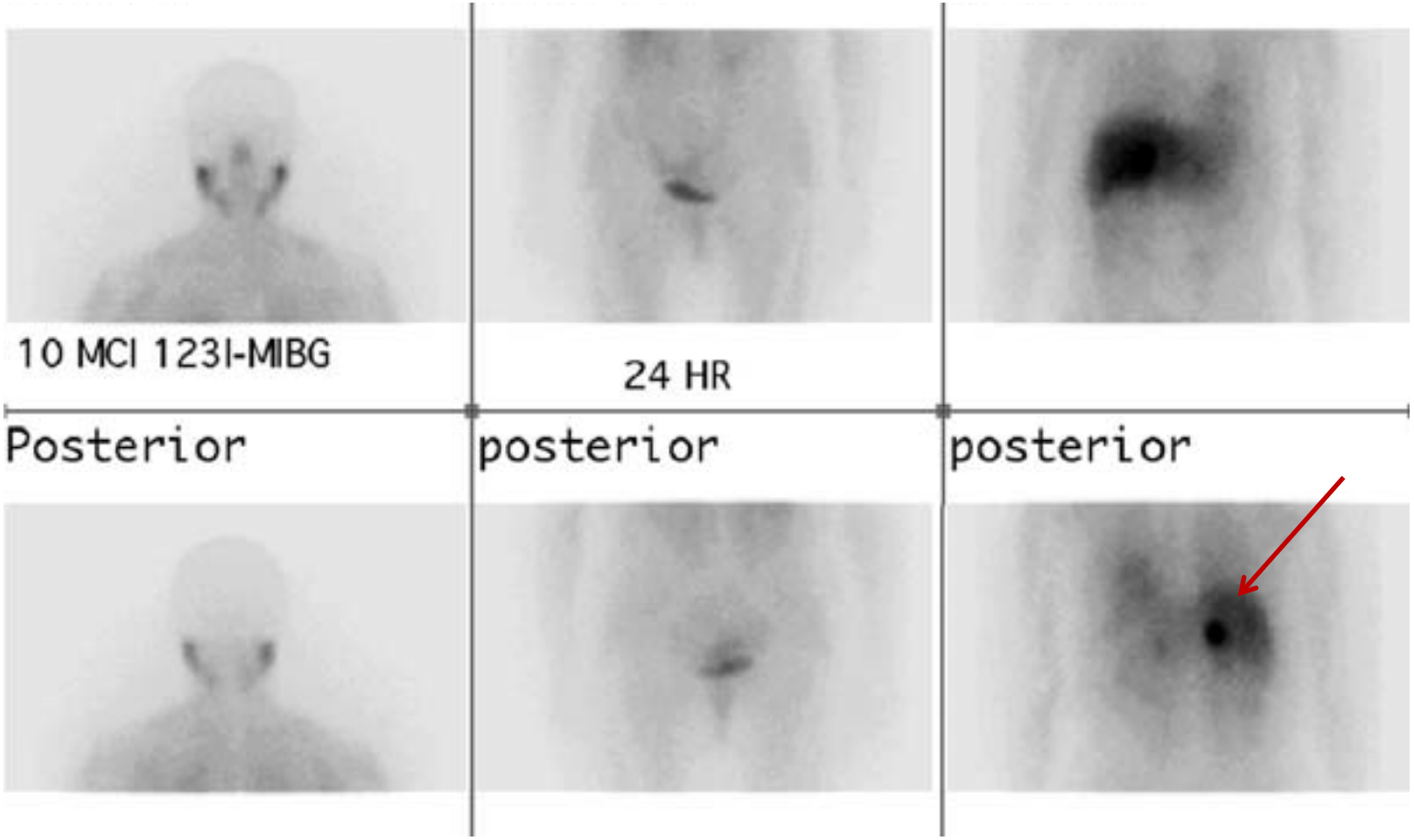
SPECT/CT bilateralne adrenalne nodularne hiperplazije



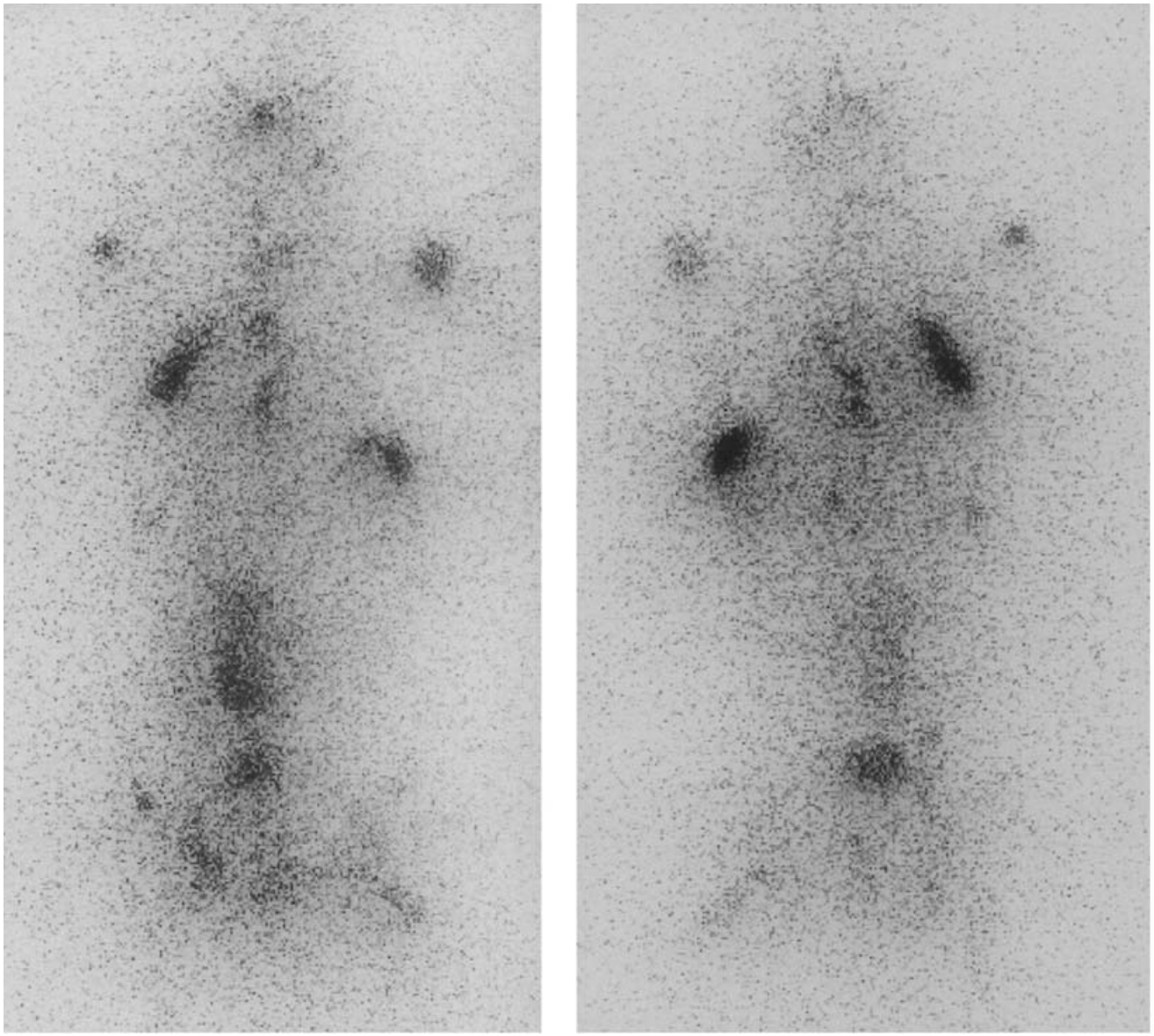
Scintigrafija **srži nadbubrega**

radiofarmak	^{123} I-MIBG (Adreview®)	^{131} I-MIBG
aplikovana radioaktivnost	400 MBq (10 mci)	20 MBq (0,5 mCi)
ekvivalentna doza	6 mSv (600 mrem)	3 msv (300 mrem)
priprema pacijenta	„blokada“ tireoideje (Lugolov rastvor ili kalijum perhlorat)	„blokada“ tireoideje (Lugolov rastvor ili kalijum perhlorat)
kolimator	LEHR	HEGP(high energy general purpose)
polažaji snimanja (akvizicije)	celo telo (whole body) anteriorni i posteriorni, 10 minuta po slici, 24 h posle i.v. aplikacije.SPECT ciljanog dela tela	celo telo, anteriorna i posteriorna projekcija, 20 minuta po slici, 48 h (i 72 h ako je potrebno) posle i.v. injekcije

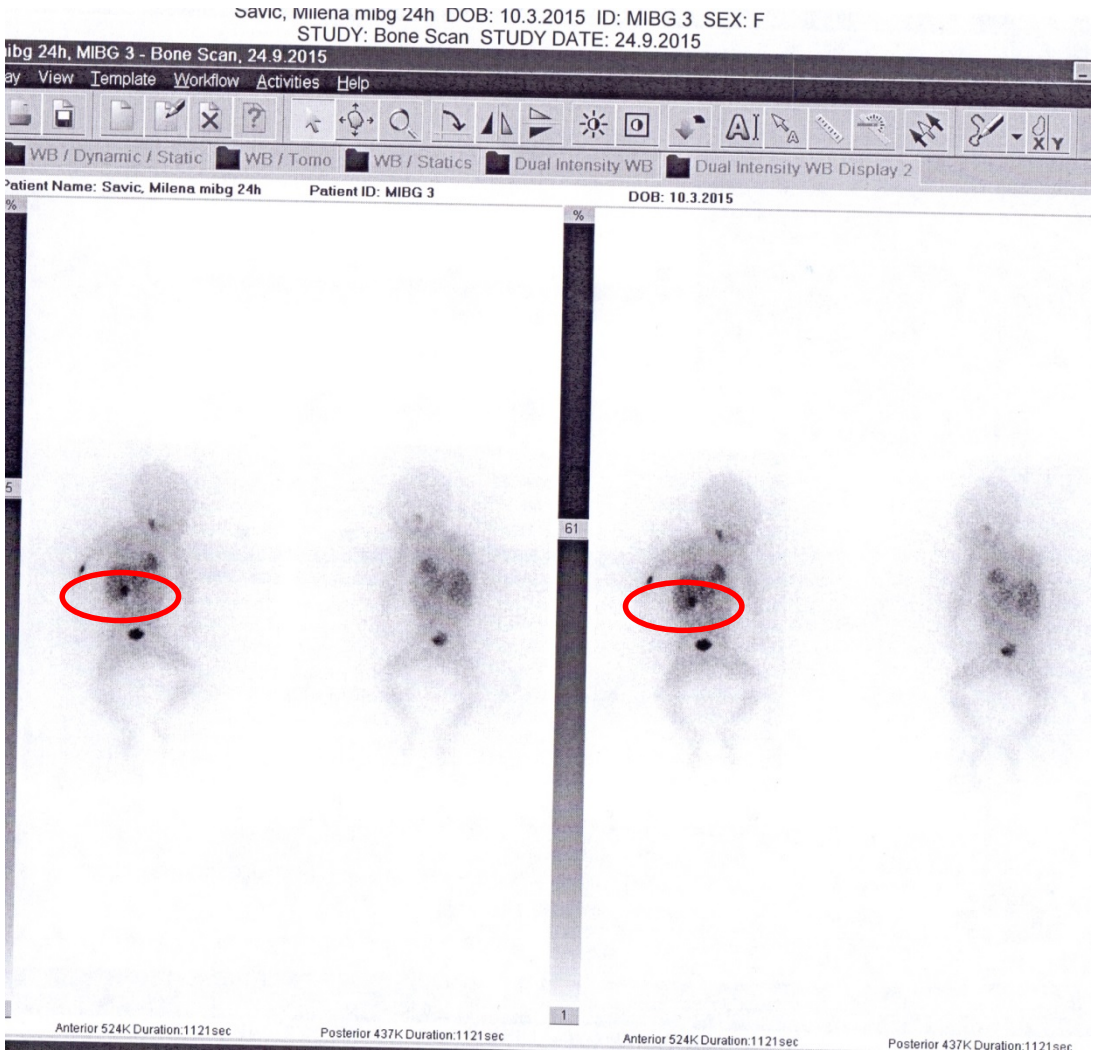
unilateralni feohromocitom



metastaze feohromocitoma

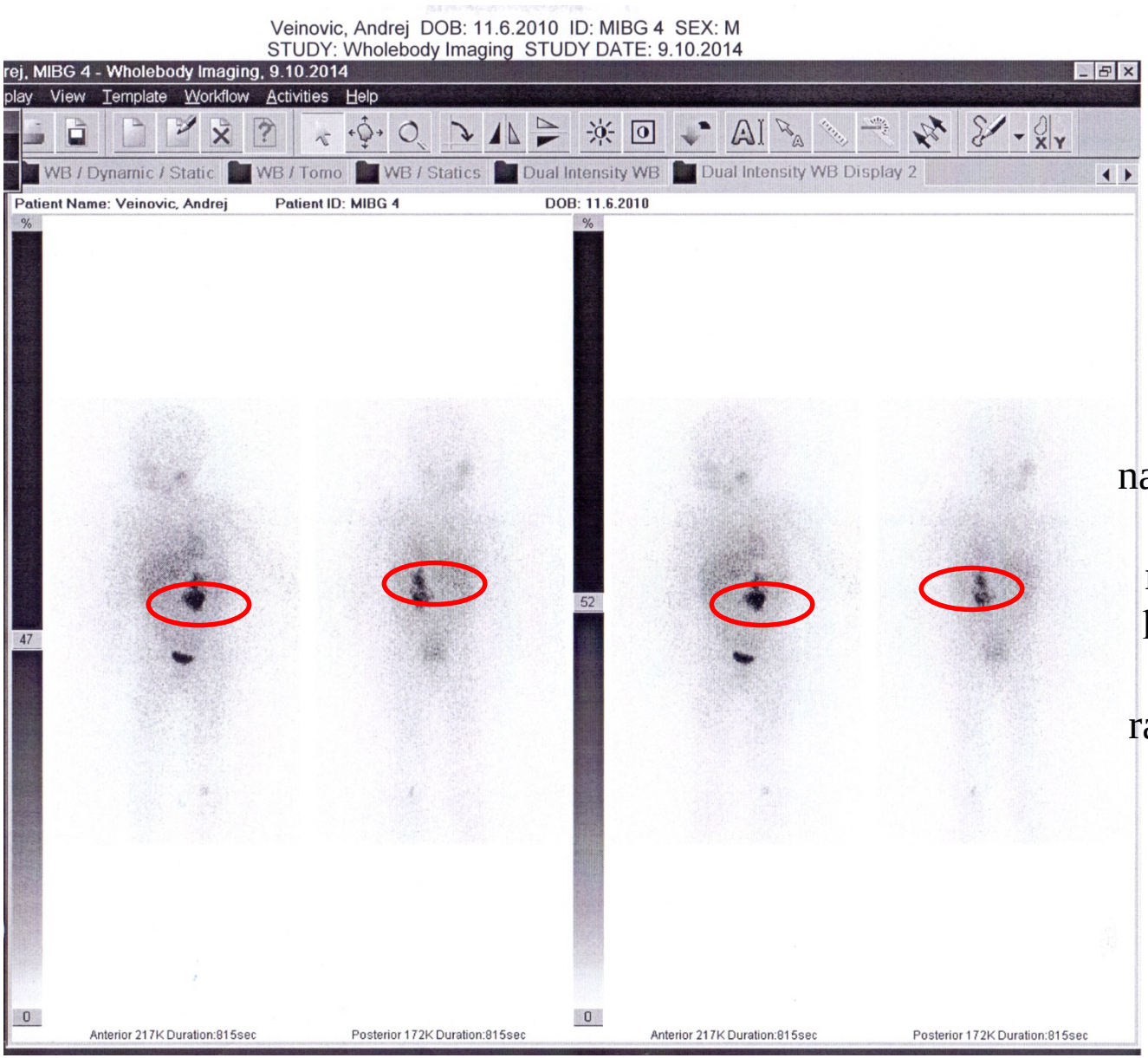


Scintigrafija dece obolele od **neuroblastoma** pomoću mI (^{123}J)BG



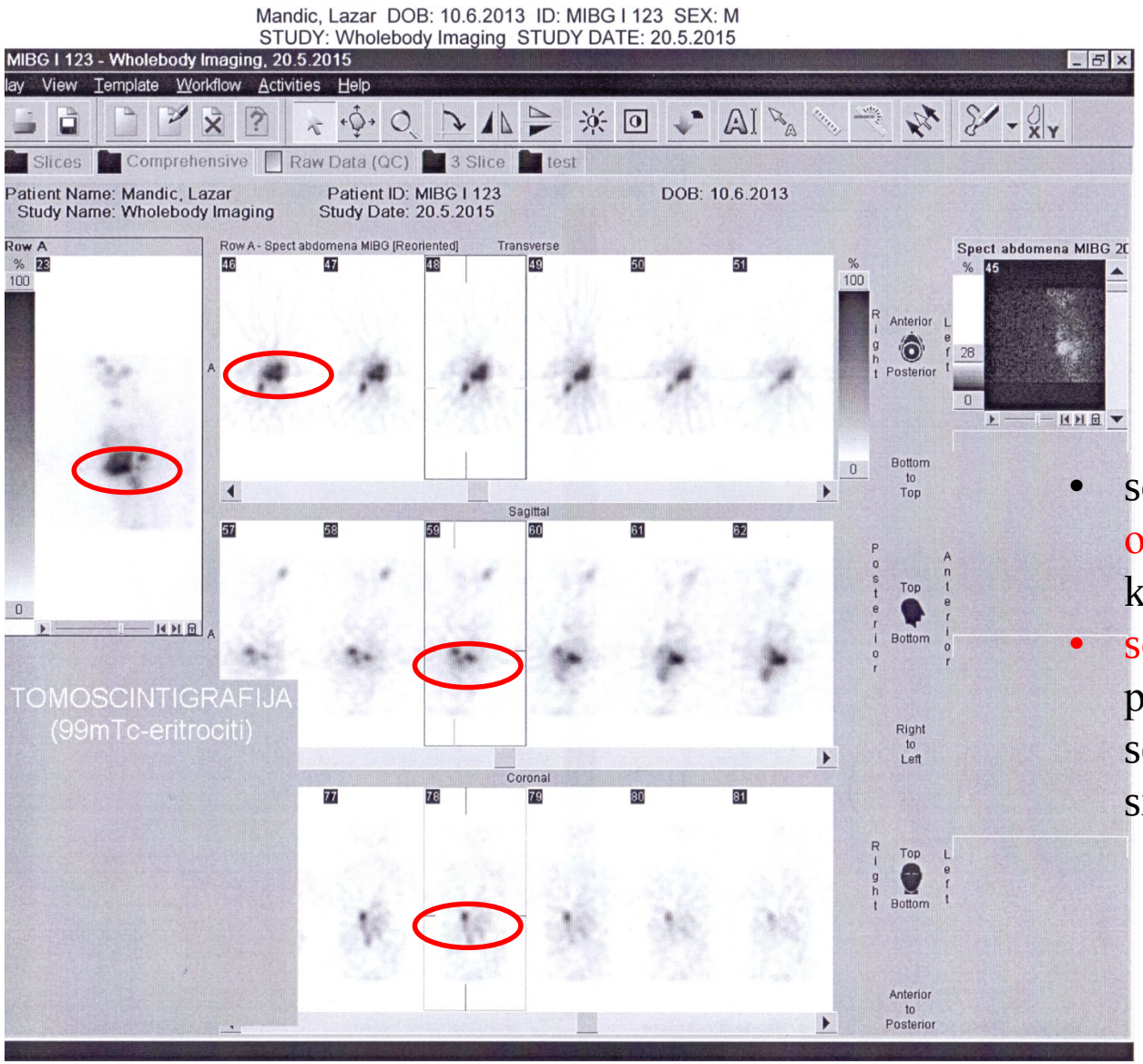
- neuroblastom je najčešći ekstrakranijalni tumor dečjeg uzrasta
- potiče od **neuroblasta**, ćelija iz neuralnog grebena
- klinički se klasifikuje u 5 kliničkih stadijuma - **INSS** sistem (International Neuroblastoma Staging Sistem)
  - I (prvi)
  - II (drugi)
  - III (treći)
  - IV (četvrti)
  - IVs („četvrti es“) „specijalni“ stadijum: spontano regresivni stadijum
- prognoza kod obolelih se kreće od spontane regresije tumora do smrti uprkos opsežnom lečenju koje obuhvata operaciju, hemioterapiju i transplantaciju koštane srži

opis planarnog mI (^{123}J)BG scintigrama kod neuroblastoma



na planarnom scintigramu dobijenog pomoću mI(^{123}J)BG se u levom hemiabdomenu uočava zona intenzivne i ravnomerne akumulacije radiofarmaka

SPECT mI(^{123}J)BG kod deteta obolelog od neuroblastoma



- scintigrafija pomoću mIBG je obavezan dijagnostički test kod obolele dece
- semikvantifikacija se izvodi pomoću SIOPEN semikvantitativnog bodovnog sistema