



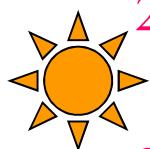
核子醫學治療(上)

邱宇莉醫師

2017-04-06

大鋼

1. 簡介



2. 甲狀腺癌&甲狀腺機能亢進 (Thyroid cancer & hyperthyroidism)

3. 骨轉移 (Bony metastasis)

4. 淋巴癌 (Lymphoma)

5. 肝癌&肝轉移 (Hepatoma & liver metastasis)

6. 神經內分泌瘤 (Neuroendocrine tumor)

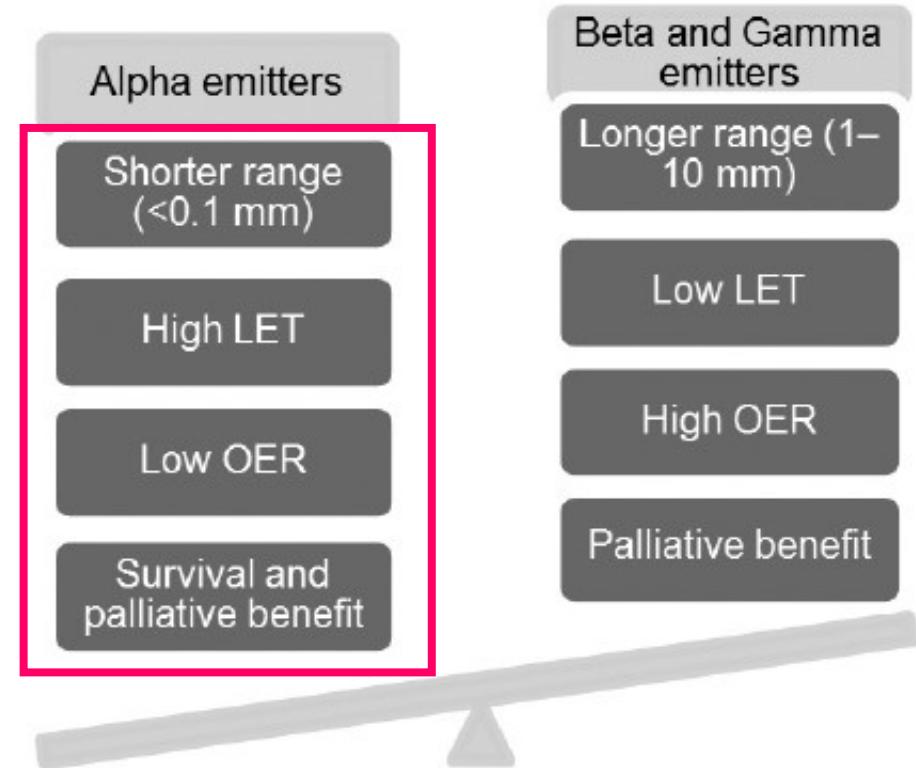


簡介

簡介

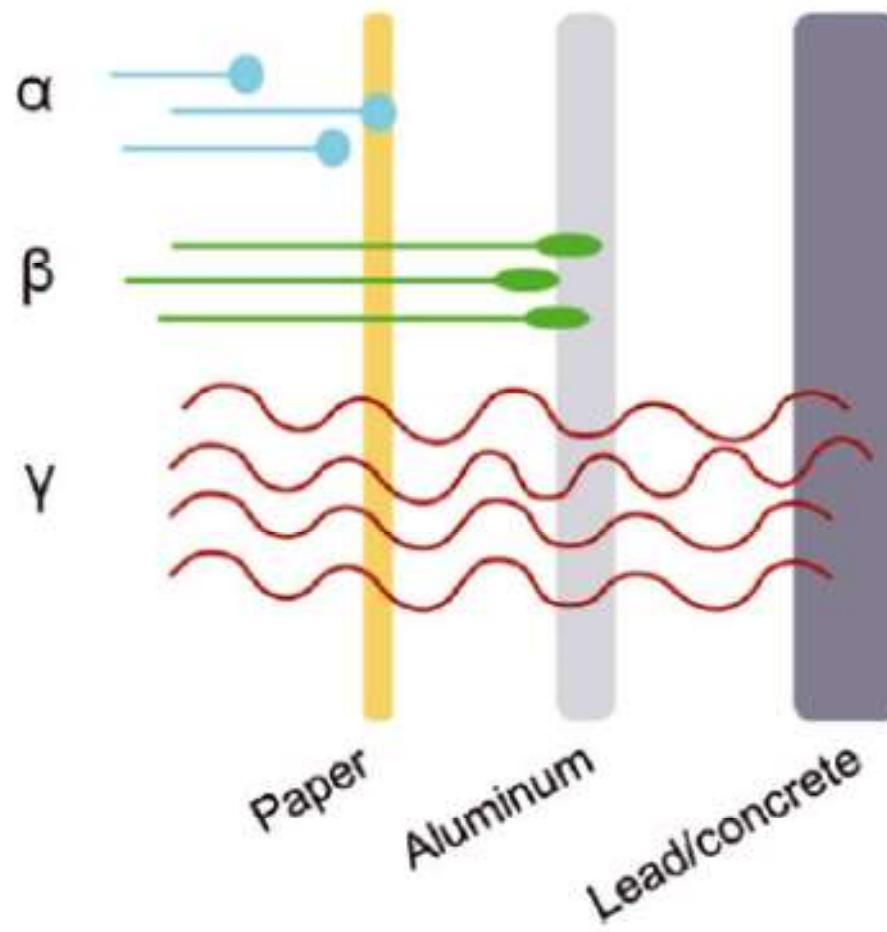
- 口服
- 靜脈注射
- 體腔注射 (如: 關節, 腹膜)

- α emitters: Ra-223
- β emitters: 最常見
- γ emitters: 造影定位, 輻射危害



1. 短射程 Range
2. 高直線能量轉移 LET (linear energy transfer)
3. 低氧增強比 OER (oxygen enhancement ratio)

1. 短射程 Range

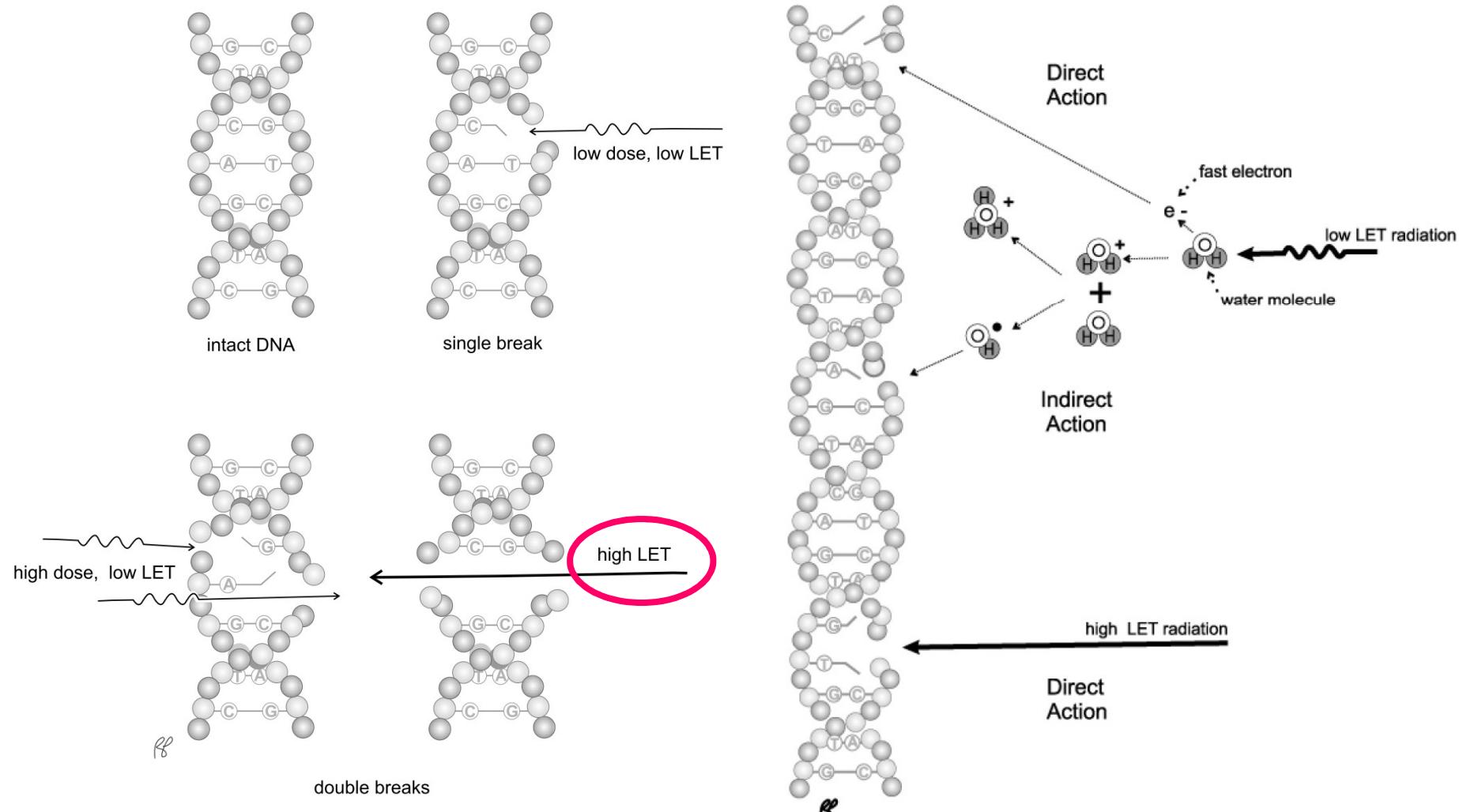


Treatment of castration-resistant prostate cancer and bone metastases with radium-223 dichloride.
Int J of Urol Nurs. 2015;9(1):3-13

2. 高直線能量轉移 LET (linear energy transfer)

單股與雙股斷裂

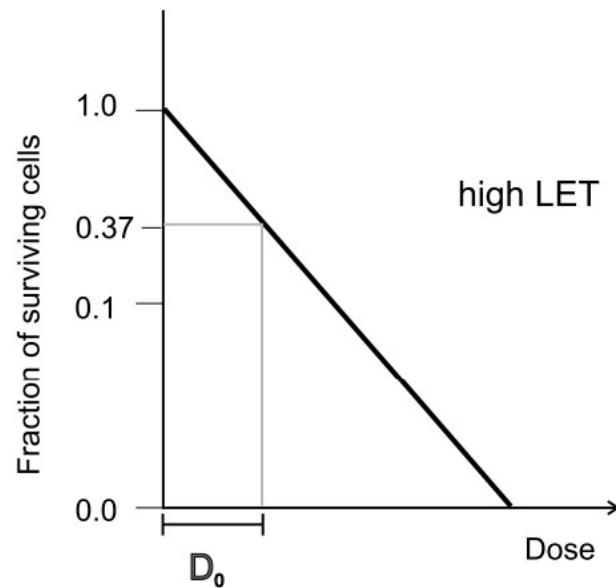
直接與間接作用



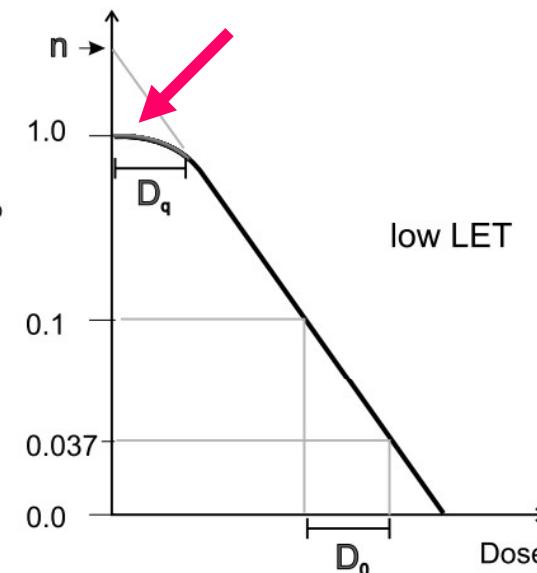
2. 高直線能量轉移 LET (linear energy transfer)

低和高LET輻射的細胞存活曲線

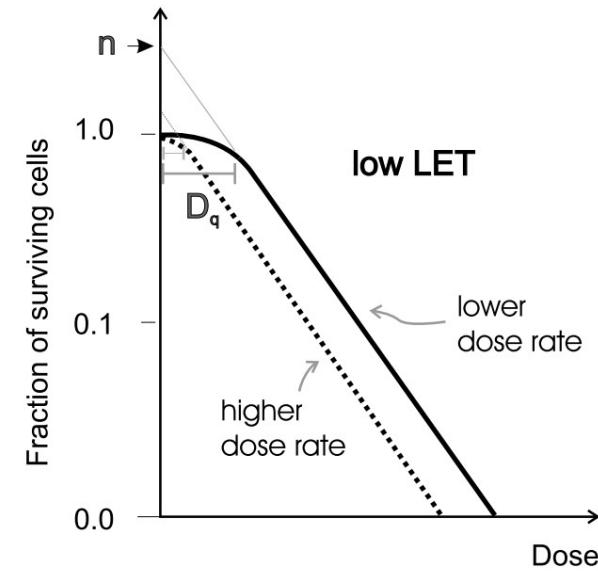
劑量率對細胞存活的影響



high LET



low LET

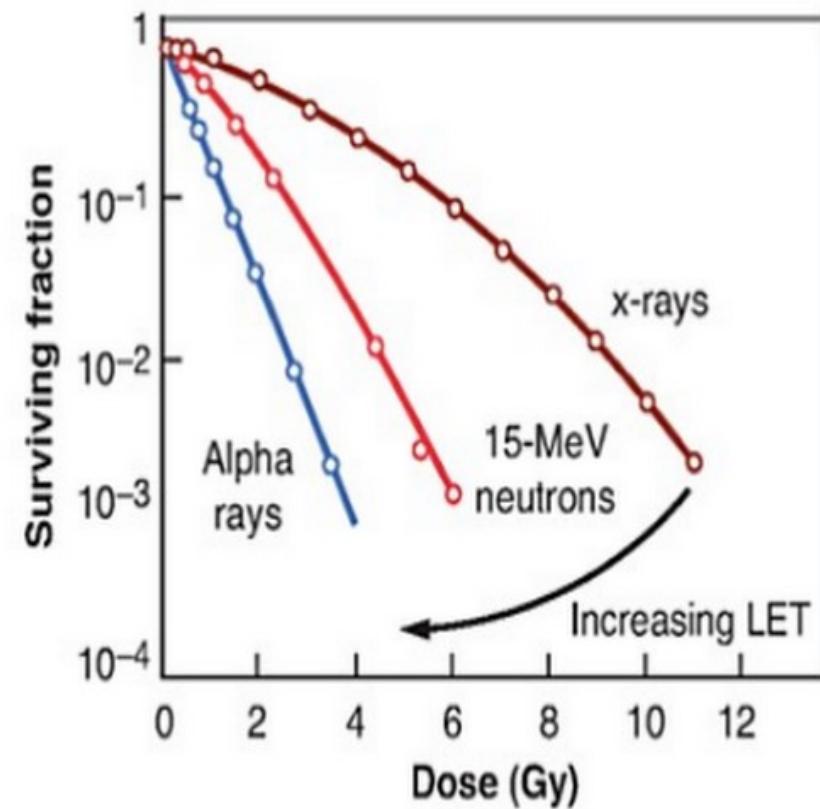
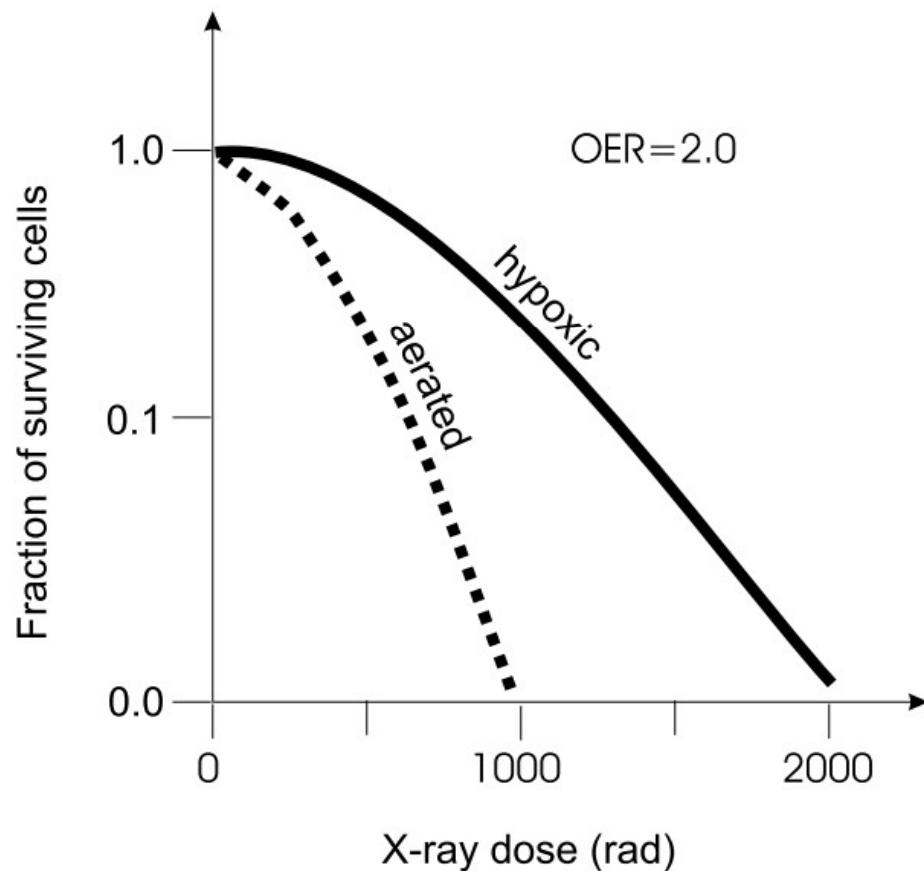


low LET

higher dose rate
lower dose rate

3. 低氧增強比 OER (oxygen enhancement ratio)

低LET輻射氧對細胞存活曲線的影響





甲狀腺癌&甲狀腺機能亢進

Thyroid cancer & hyperthyroidism

■碘 I-131

131I

週期表

說明

原子序
元素符號
元素名稱
原子量

金屬

惰性氣體

1 IA 18 VIIA

2 II A

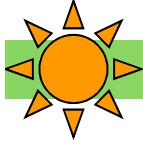
過 渡 元 素

3 III B 4 IVB 5 VB 6 VI B 7 VII B 8 VII B 9 VII B 10 VII B 11 I B 12 II B

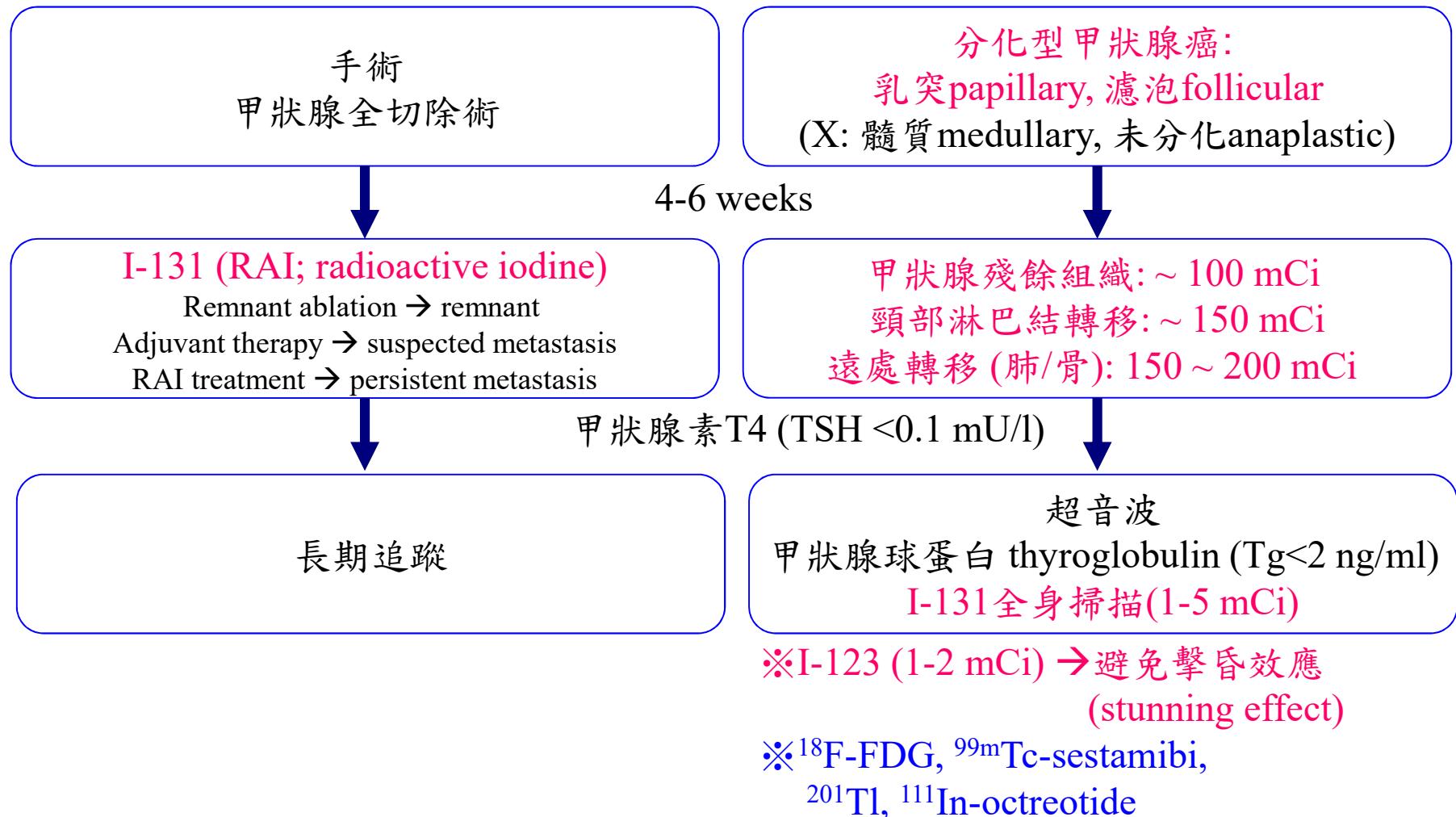
1 H 氢 1008	2 He 氦 4003
3 Li 錳 6941	4 Be 鋹 9012
5 B 硼 1081	6 C 碳 12.01
7 N 氮 14.01	8 O 氧 16.00
9 F 氟 19.00	10 Ne 氖 20.18
11 Na 鈉 22.99	12 Mg 長 24.31
13 Al 鋁 26.98	14 Si 砂 28.09
15 P 磷 30.97	16 S 硫 32.07
17 Cl 氯 35.45	18 Ar 氪 39.95
19 K 鉀 39.10	20 Ca 鈣 40.08
21 Sc 鈦 44.96	22 Ti 鈸 47.88
23 V 鈮 50.94	24 Cr 鈮 52.00
25 Mn 鈮 54.94	26 Fe 鐵 55.85
27 Co 鐵 58.93	28 Ni 鎳 63.55
29 Cu 銅 65.39	30 Zn 鋅 69.72
31 Ga 鋅 72.59	32 Ge 鋆 74.92
33 As 砷 78.96	34 Se 砒 79.90
35 Br 溴 83.8	36 Kr 氪 83.8
37 Rb 鈾 85.47	38 Sr 鈏 87.62
39 Y 鈦 88.91	40 Zr 鈮 91.22
41 Nb 鈮 92.91	42 Mo 鈮 95.94
43 Tc 鈮 98.91	44 Ru 鈮 101.1
45 Rh 鈮 102.9	46 Pd 鈮 106.4
47 Ag 銀 107.9	48 Cd 鋨 112.4
49 In 鋨 114.8	50 Sn 鋸 118.7
51 Sb 鋸 121.8	52 Te 碲 127.6
53 I 碲 126.9	54 Xe 氪 131.3
55 Cs 銀 132.9	56 Ba 銀 137.3
57-71 鋰系元素	72 Hf 鈮 178.5
73 Ta 鈮 180.9	74 W 鋨 183.9
75 Re 鋸 186.2	76 Os 鋸 190.2
77 Ir 鋸 192.2	78 Pt 鋸 195.1
79 Au 鋸 197.0	80 Hg 鋸 200.6
81 Tl 鋸 204.4	82 Pb 鋸 207.2
83 Bi 鋸 209.0	84 Po 鋸 210.0
85 At 鋸 210.0	86 Rn 氪 222.0
87 Fr 鋸 223.0	88 Ra 鋸 226.0
89-103 鋰系元素	104 Unq 鋸 261.0
105 Unp 鋸 262.0	106 Unh 鋸 263.0
107 Uns 鋸 262.0	108 Uno 鋸 265.0
109 Une 鋸 266.0	
鑱系元素	57 La 鋰 138.9
58 Ce 鋰 140.1	
59 Pr 鋰 140.9	
60 Nd 鋰 144.2	
61 Pm 鋰 144.9	
62 Sm 鋰 150.4	
63 Eu 鋰 152.0	
64 Gd 鋰 157.3	
65 Tb 鋰 158.9	
66 Dy 鋰 162.5	
67 Ho 鋰 164.9	
68 Er 鋰 167.3	
69 Tm 鋰 168.9	
70 Yb 鋰 173.0	
71 Lu 鋰 175.0	
銅系元素	89 Ac 銅 227.0
90 Th 銅 232.0	
91 Pa 銅 231.0	
92 U 銅 238.0	
93 Np 銅 237.0	
94 Pu 銅 239.1	
95 Am 銅 243.1	
96 Cm 銅 247.1	
97 Bk 銅 247.1	
98 Cf 銅 252.1	
99 Es 銅 252.1	
100 Fm 銅 257.1	
101 Md 銅 256.1	
102 No 銅 259.1	
103 Lr 銅 260.1	

	I-131	I-123	I-124	I-125	Tc-99m
Mode of decay (%)	β^- (100)	Electron capture (100)	Electron capture, β^+ (77/23)	Electron capture (100)	Isometric transition (100)
Half-life	8 days ✎	13.2 hr	4.2 days	60 days	6 hr
γ -ray energy (keV)	284, 364, 637	159	511 (annihilation)	35 X-ray (27-32)	140
Abundance	6, 81, 7%	83%	46%	7%	90%
Common production method	$^{130}\text{Te}(n,\gamma)^{131}\text{Te}$ $^{235}\text{U}(n,f)^{131}\text{Te}$ $^{131}\text{Te} \rightarrow ^{131}\text{I}$	$^{121}\text{Sb}(\alpha,2n)^{123}\text{I}$	$^{124}\text{Te}(p,n)^{124}\text{I}$	$^{124}\text{Xe}(n,\gamma)^{125}\text{Xe}$ $^{125}\text{Xe} \rightarrow ^{125}\text{I}$	$^{99}\text{Mo} \rightarrow ^{99\text{m}}\text{Tc}$

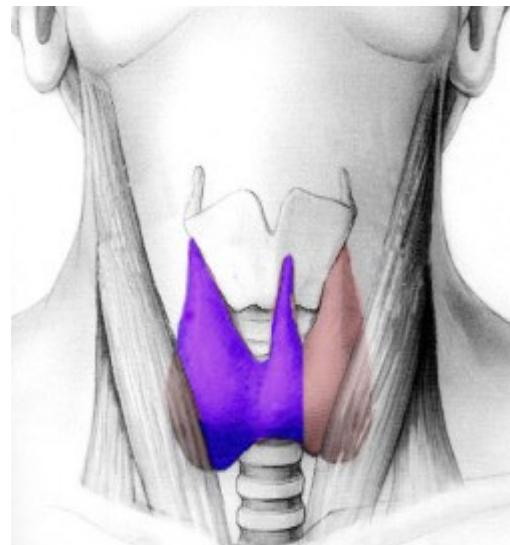
- 排泄: 尿液 (predominant route), 粪便 (some)



碘 Iodine-131 ($^{131}\text{I-NaI}$) <甲狀腺癌>

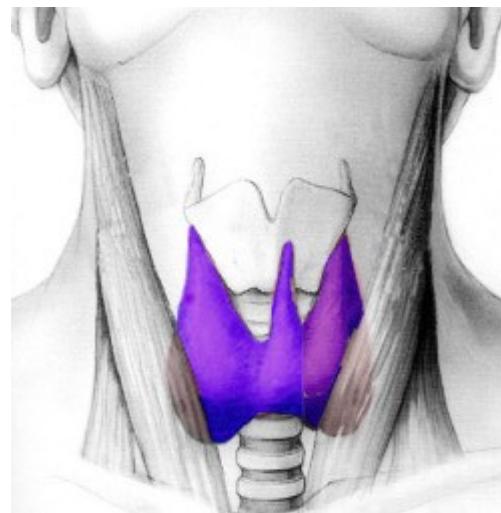


Hemithyroidectomy
(Lobectomy)

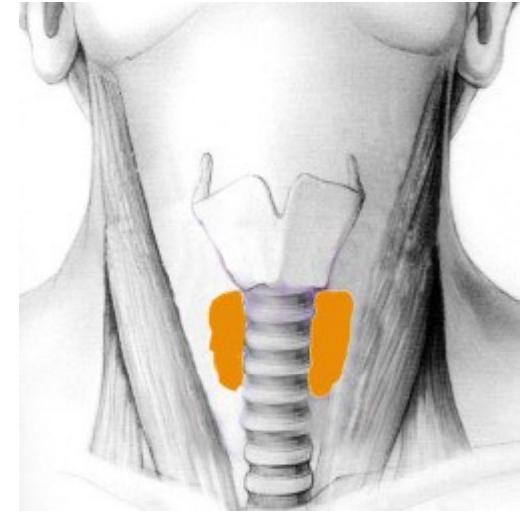


Near-total
lobectomy
 <1 g

Total
thyroidectomy



Subtotal
thyroidectomy



Near-total
thyroidectomy

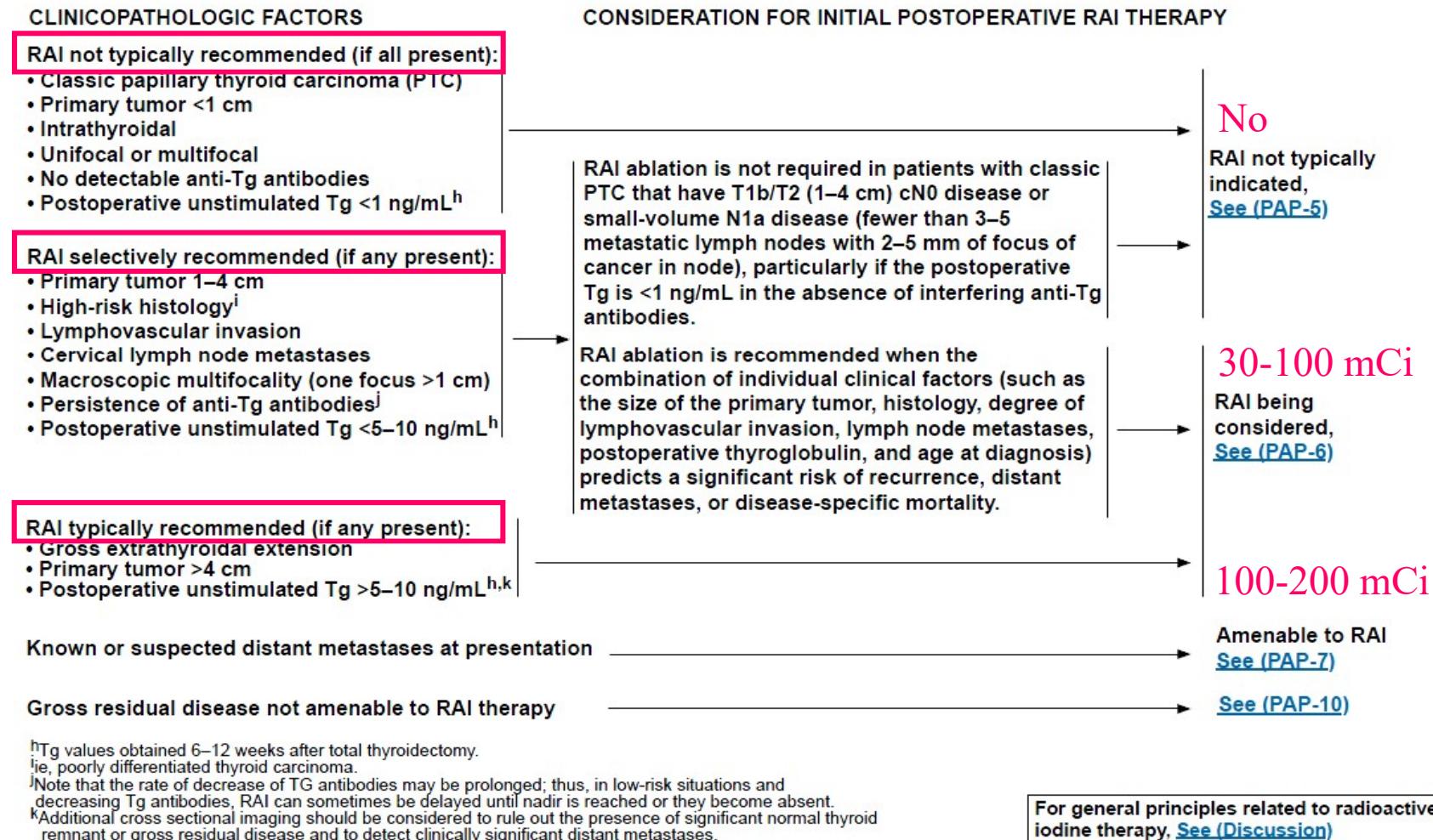
1. Hemithyroidectomy (Lobectomy)
+ Near-total lobectomy
2. Bilateral near-total lobectomy

2015 ATA guideline. Thyroid. 2016;26(1):1-133

- High risk: **100-200 mCi**
 - 1. ETE/ Size 1-4cm
 - 2. LN: No. 5, Size 0.2-3 cm
 - 3. Vascular invasion: 4 foci
 - 4. Histology
 - 5. Incomplete resection
 - 6. Distant metastasis
- Intermittent risk: **30-150 mCi**
- Low risk: **X**

(ETE: extrathyroid extension)

NCCN guidelines Version 2.2015





治療前

- Low iodine diet for 1-2 weeks
- Thyroid hormone withdrawal (THW) for 3-4 weeks
- Recombinant human TSH (rhTSH; Thyrogen) 0.9 mg IM QD *2 days

- 治療釋放：

- a survey instrument at one meter: ≤ 7 mrem/h (0.07 mSv/h)
- oral I-131 dose: ≤ 33 mCi (1.2 GBq)
- effective doses to other persons: ≤ 500 mrem (5 mSv)

- 治療後

- 何時照相? 4 to 10 days
- 何時補充甲狀腺賀爾蒙? 3 to 5 days
- 何時可懷孕? 6-12months
- 何時可再次治療? 6 to 12 months
 - 肺纖維化 (pulmonary fibrosis): 600 mCi
 - 骨髓抑制 (bone marrow suppression): 800 mCi
 - 繼發性腫瘤 (secondary tumor: leukemia, bladder & breast): 800 mCi



TSH >30 µIU/mL

- 低碘飲食 1-2 weeks
- 停用含碘食物/藥物 3-4 weeks
- 施打甲狀腺促進素 rhTSH (Thyrogen, 0.9 mg IM) 2 days

食物或藥物	建議停用時間
甲狀腺賀爾蒙(天然or合成)	3-4wk for T4, 10-14d for T3
海帶,石花菜,carrageenan, Lugol solution	2-3wk (根據碘含量)
綜合維他命(含碘)	7-10d
Thionamide medications (propythiouracil, methimazole, carbimazole)	3d
Amiodarone	3-6mo or longer
飽和的碘化鉀溶液(SSKI)	2-3wk
外用碘酒(手術皮膚準備)	2-3wk
顯影劑(水溶性)	6-8wk (假設正常腎功能)
顯影劑(親油性)	1-6mo



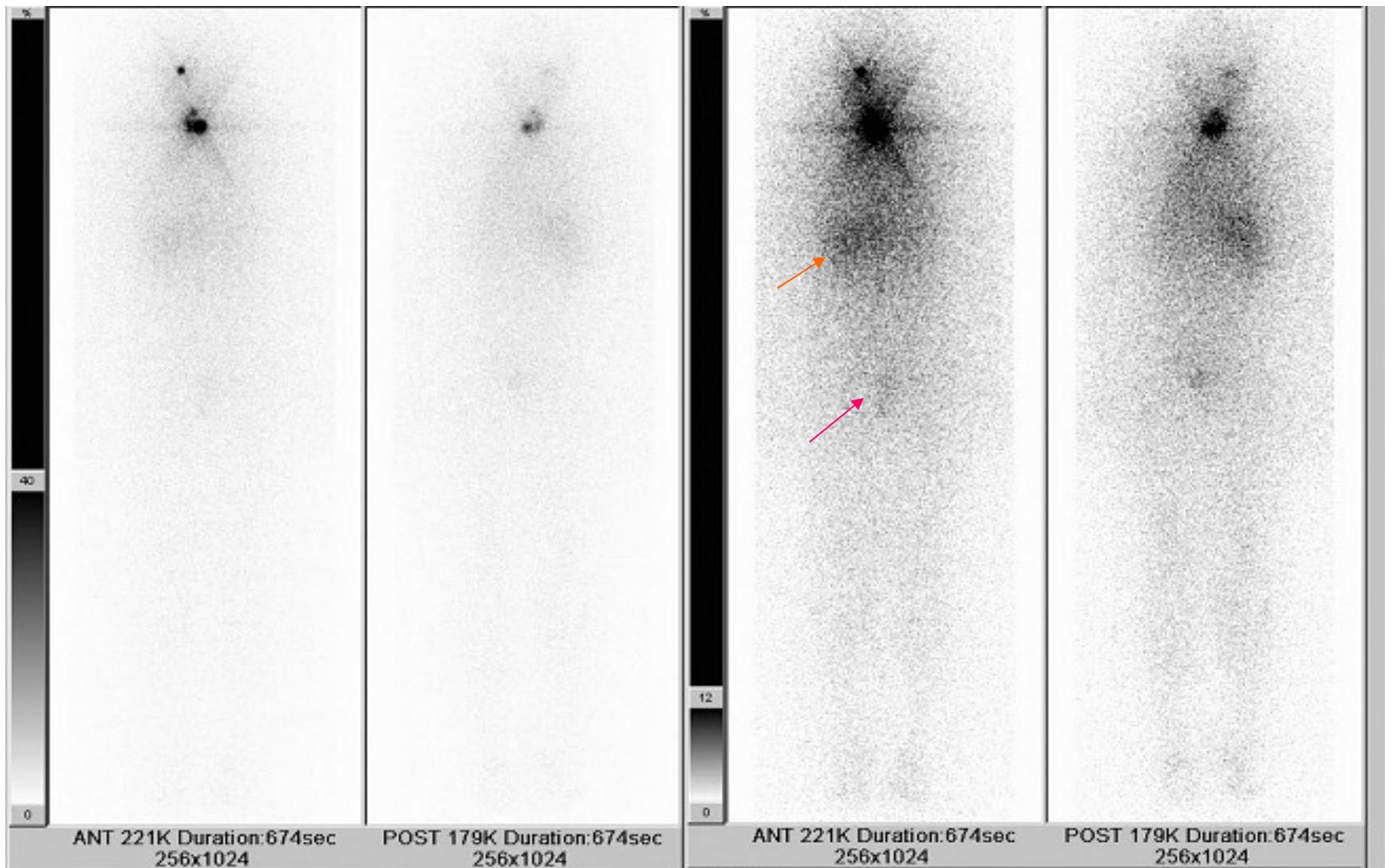
※早期副作用(短暫,輕微)

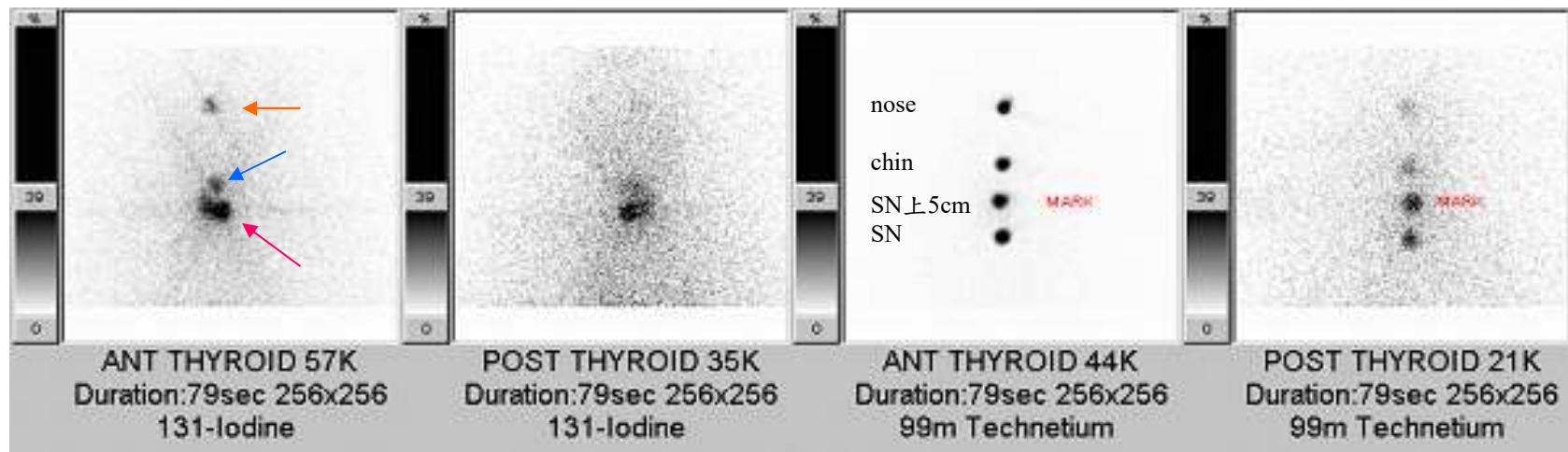
1. 口腔黏膜炎
2. 嘔心(rare)
3. 嘔吐 (occasional)
4. 唾液腺炎
5. 喪失味覺
6. 味覺改變(金屬味)(unusual)
7. 甲狀腺炎(脖子疼痛&腫脹)
8. 白血球/血小板↓→↑感染or出血

※晚期副作用

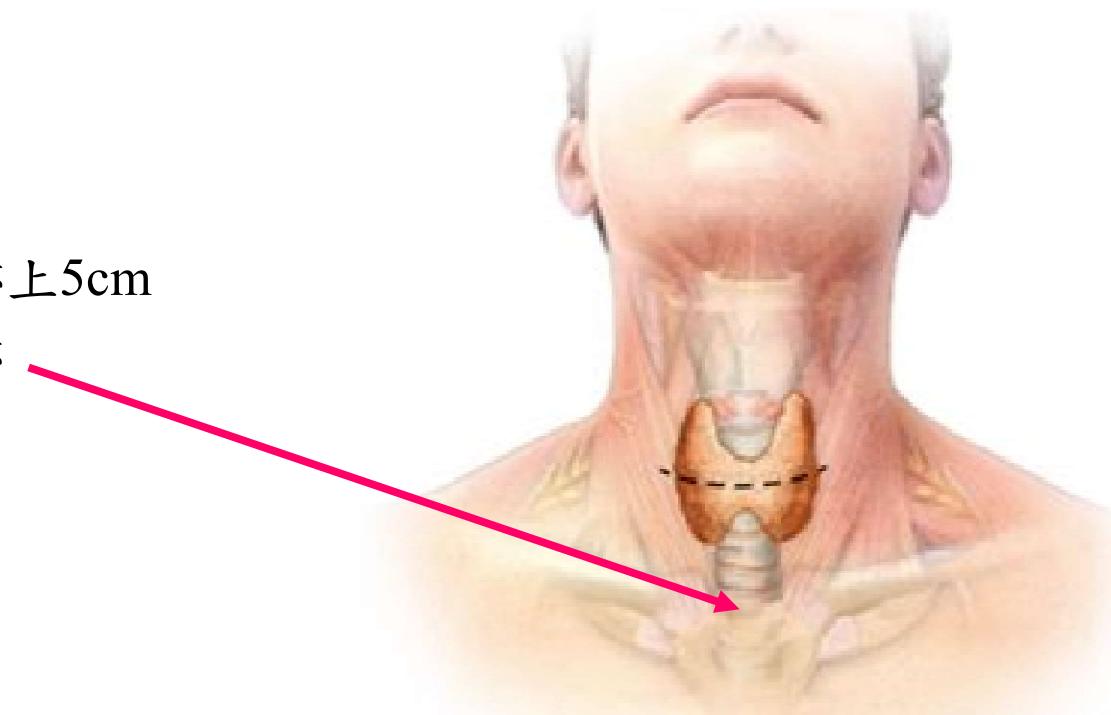
1. 不孕
2. 永久性唾液腺損傷:口乾/唾液腺
結石/過度齲齒/味覺障礙/結膜
乾燥/溢淚
3. 癌症:胃癌/膀胱癌/大腸癌/唾液
腺癌/黑色素瘤/白血病
(uncommon)

52歲♀,乳突癌, near-total thyroidectomy (2006-09-11), 100 mCi I-131 ablation
I-131 WBS 7 days after ablation (2006-11-07):



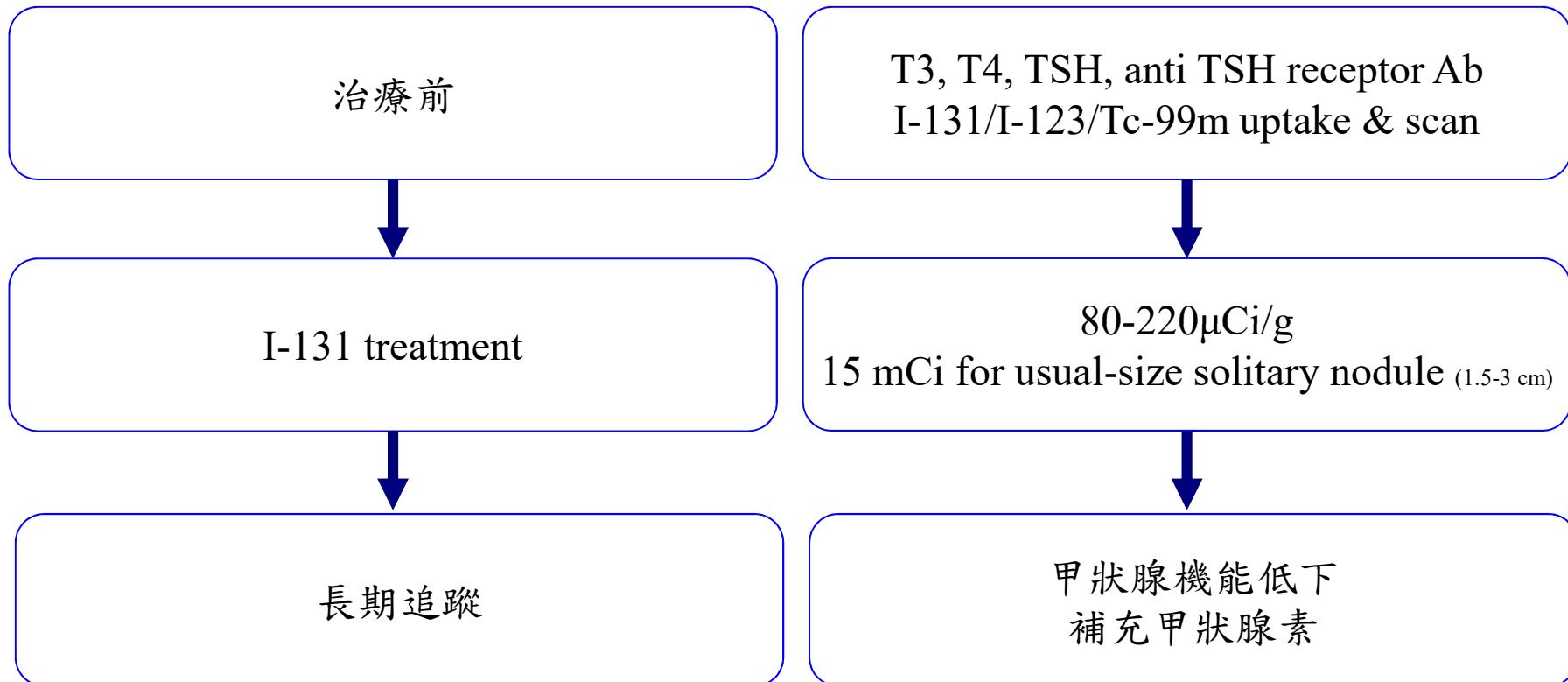


1. 鼻子
2. 下巴
3. 胸骨切跡上5cm
4. 胸骨切跡

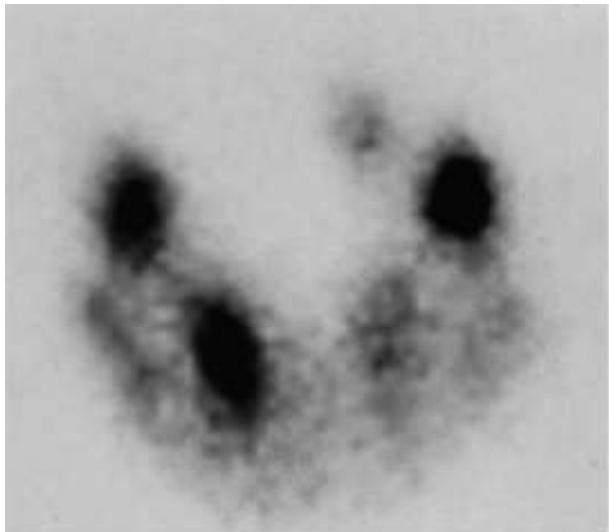


碘Iodine-131 ($^{131}\text{I-NaI}$)

<甲狀腺功能亢進: Graves' disease,
toxic nodules, nontoxic nodular goiter>

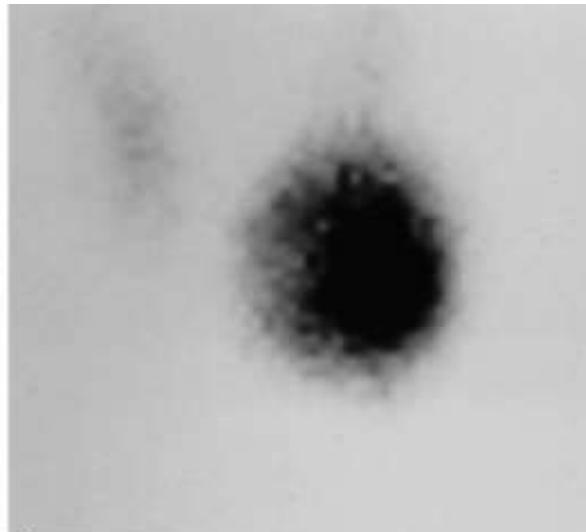


結節性甲狀腺腫
Multinodular goiter

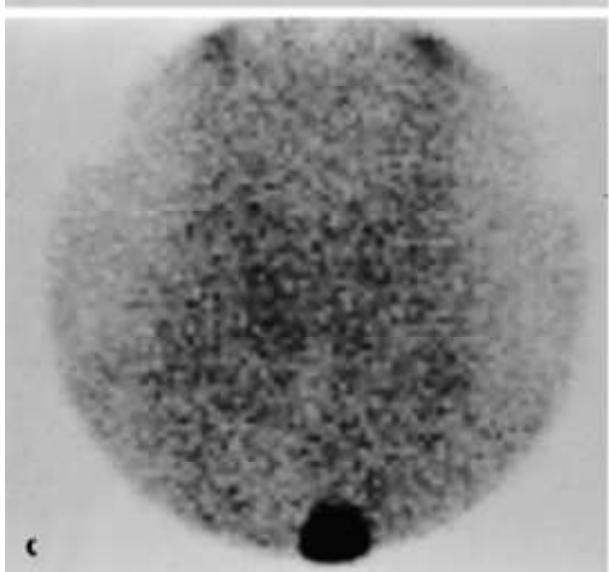


a

孤立性高功能甲狀現結節
Solitary hyperfunctioning thyroid nodule

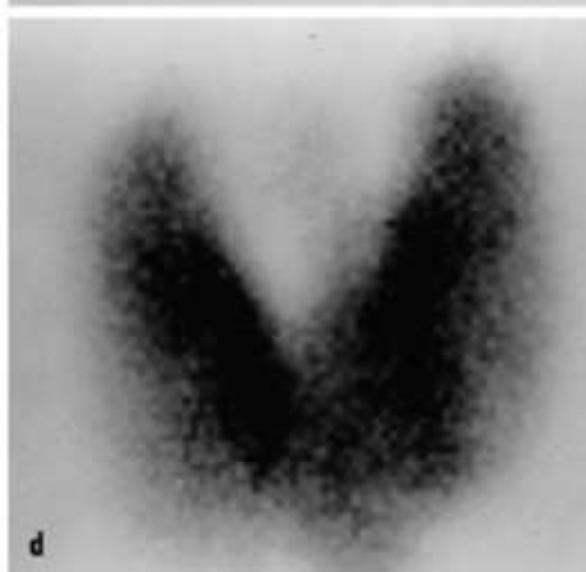


b



c

甲狀腺炎 Thyroiditis



d

葛瑞夫茲氏病 Graves' disease

- 劑量
 - 1. 甲狀腺大小
 - 2. 腺體是否有結節
 - 3. 甲狀腺碘吸收能力
- 副作用
 - 1. 甲狀腺功能低下
 - 2. 甲狀腺炎(脖子疼痛&腫脹)(1-5%)
 - 3. 喉返神經麻痺(very common)
 - 4. 味覺障礙(very common)
 - 5. Graves' disease 眼病加劇
- There is no evidence:
 - 1. an increased risk of thyroid carcinoma or other malignancy
 - 2. an increased risk of infertility
 - 3. an increased incidence of birth defects



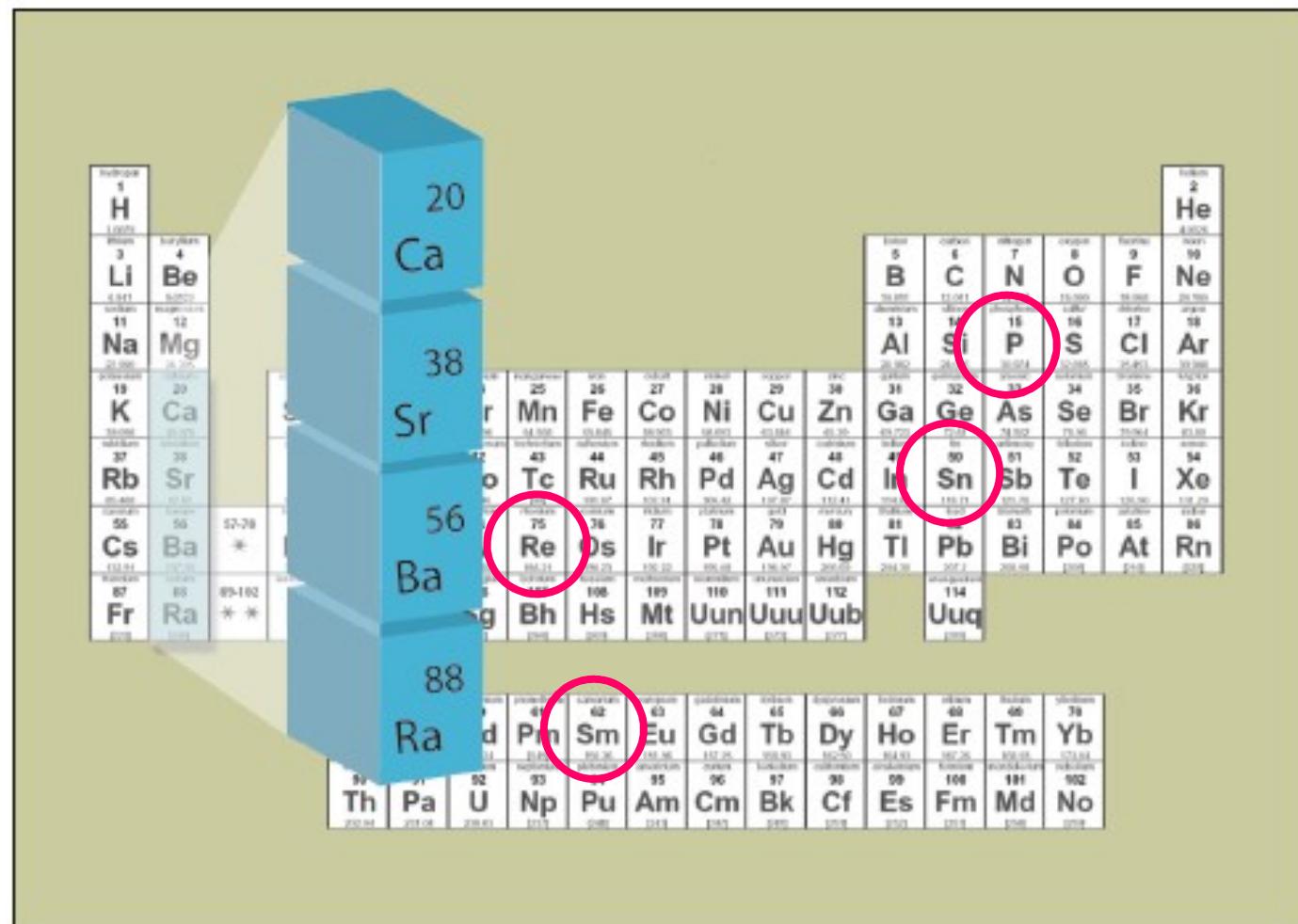
骨轉移

Bony metastasis

- 磷 P-32
- 銷 Sr-89
- 錸 Re-186/Re-188
- 鈦 Sm-153
- 錫 Sn-117m
- 鐳 Ra-223

- 止痛藥(口服/注射/貼片)
- 放射線治療(外部)
- 放射性核種治療(內部)

1. 磷 P-32
2. 錫 Sr-89
3. 錳 Re-186
Re-188
4. 鈦 Sm-153
5. 錫 Sn-117m
6. 鐳 Ra-223



Alpha particles as radiopharmaceuticals in the treatment of bone metastases: mechanism of action of radium-223 chloride (Alpharadin) and radiation protection. Oncology (Williston Park). 2012;26(4):330-7, 341.



Bone-Seeking Radionuclides for Therapy. J Nucl Med 2005; 46:38S–47S

TABLE 1
Physical Characteristics of Therapeutic Radionuclides for Bone Pain Palliation

Radionuclide	Half-life	Maximum energy (MeV)	Mean energy (MeV)	Maximum range	γ -Emission (keV)
³² P	14.3 d	1.7 (β)	0.695 (β)	8.5 mm	None
⁸⁹ Sr	50.5 d	1.4 (β)	0.583 (β)	7 mm	None
¹⁸⁶ Re	3.7 d	1.07 (β)	0.362 (β)	5 mm	137
¹⁸⁸ Re	16.9 h	2.1 (β)	0.764 (β)	10 mm	155
¹⁵³ Sm	1.9 d	0.81 (β)	0.229 (β)	4 mm	103
^{117m} Sn	13.6 d	0.13 and 0.16 conversion electrons		<1 μ m	159
²²³ Ra	11.4 d	5.78 (α) (average)		<10 μ m	154

TABLE 2
Administered Activities, Typical Response Times and Duration, and Retreatment Intervals
for Bone-Seeking Radionuclides

Radiopharmaceutical	Usual administered activity	Typical response time	Typical response duration	Retreatment interval
³² P	444 MBq [fractionated]	14 d	10 wk	>3 mo
⁸⁹ SrCl ₂	148 MBq	14–28 d	12–26 wk	>3 mo
¹⁸⁶ Re-HEDP	1.3 GBq	2–7 d	8–10 wk	>2 mo
¹⁸⁸ Re-HEDP	1.3–4.4 GBq	2–7 d	8 wk	NE
¹⁵³ Sm-EDTMP	37 MBq/kg	2–7 d	8 wk	>2 mo
^{117m} Sn-DTPA	2–10 MBq/kg	5–19 d	12–16 wk	>2 mo
²²³ RaCl ₂	50–200 kBq/kg	<10 d	NE	NE

NE = not established.

1. 磷 Phosphorus-32 (^{32}P -sodium orthophosphate)

- Half-life: 14.3 d
- ※ No γ emission
- β emission
- Maximum energy: 1.7 MeV; Mean energy: 0.695 MeV
- Maximum range: 8.5 mm

- Usual administered activity: 444 MBq (fractionated)
- Typical response time: 14 d
- Typical response duration: 10 wk
- Retreatment interval: >3 mo

- ※ The main disadvantage of ^{32}P therapy is dose-limiting myelosuppression with reversible pancytopenia (血球減少) maximal at 5-6 wk after administration.
- ※ 可治療真性紅血球增多症 (polycythemia vera) (74-111 MBq/m²; 2-3 mCi/m²)

2. 錫 Strontium-89 ($^{89}\text{SrCl}_2$)

※ Half-life: 50.5 d (最長)

※ No γ emission

- β emission
- Maximum energy: 1.4 MeV; Mean energy: 0.583 MeV
- Maximum range: 7 mm

- Usual administered activity: 148 MBq
- Typical response time: 14-28 d (最長)
- Typical response duration: 12-26 wk (最長)
- Retreatment interval: >3 mo

※ 在正常骨骼與癌症轉移病灶的代謝(turnover)速率比值約10:1

- Excretion is predominantly renal.
- The toxicity of treatment is limited to temporary myelosuppression, which typically occurs 6 wk after therapy.

3. 錸 Rhenium-186 & 188 ($^{186}\text{Re-HEDP}$ & $^{188}\text{Re-HEDP}$)

- Half-life: 3.7 d
- γ emission (137 keV)
- β emission
- Maximum energy: 1.07 MeV
- Mean energy: 0.362 MeV
- Maximum range: 5 mm
- Usual administered activity: 1.3 GBq
- Typical response time: 2-7 d (快)
- Typical response duration: 8-10 wk
- Retreatment interval: >2 mo
- Clearance is predominantly renal.
- Toxicity is limited to temporary myelosuppression.
- ※ Half-life: 16.9 h (最短)
- ※ γ emission (155 keV, 10% abundance)
- β emission
- Maximum energy: 2.1 MeV
- Mean energy: 0.764 MeV
- Maximum range: 10 mm (最長)
- Usual administered activity: 1.3-4.4 GBq
- Typical response time: 2-7 d (快)
- Typical response duration: 8 wk
- Retreatment interval: ?
- ^{188}W generator
- Toxicity was limited to activity-dependent, temporary myelosuppression with a nadir at 6 wk.

4. 鈦 Samarium-153 ($^{153}\text{Sm-EDTMP}$)

- Half-life: 1.9 d
- γ emission (103 keV)
- β emission
- Maximum energy: 0.81 MeV; Mean energy: 0.229 MeV
- Maximum range: 4 mm

- Usual administered activity: 37 MBq/kg
- Typical response time: 2-7 d (快)
- Typical response duration: 8 wk
- Retreatment interval: >2 mo

※ 可同步用於全身造影

- Tumor-to-normal bone ratio: 4:1-7:1
- Pain flare is rare (~10%)

5. 錫 Stannum-117m (^{117m}Sn -DTPA)

- Half-life: 13.6 d
- γ emission (159 keV)
- Conversion electrons
- Maximum energy: 0.13 & 0.16 MeV
- Maximum range: <1 μm (最短)

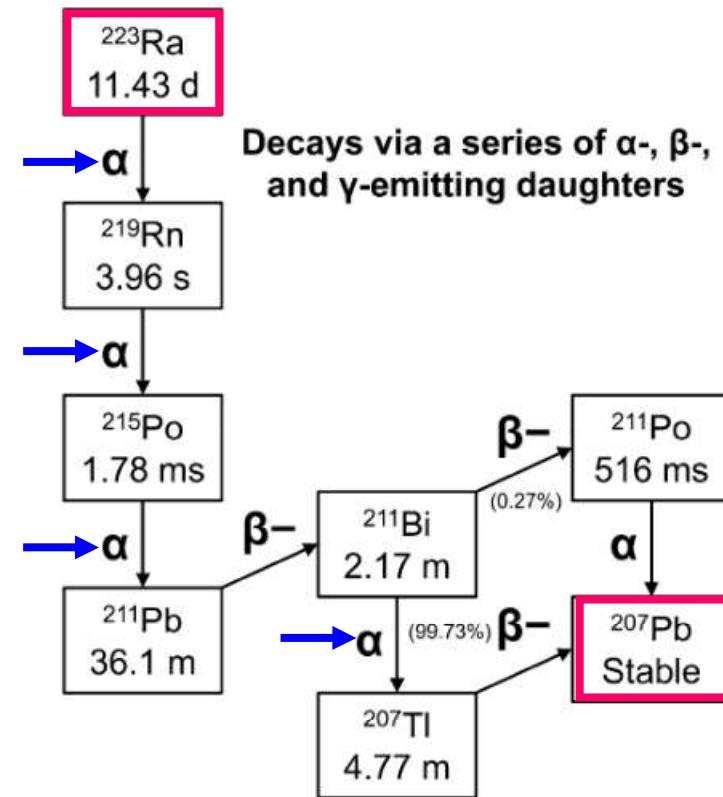
- Usual administered activity: 2-10 MBq/kg
- Typical response time: 5-19 d
- Typical response duration: 12-16 wk
- Retreatment interval: >2 mo

6. 鐳 Radium-223 ($^{223}\text{RaCl}_2$; Xofigo)

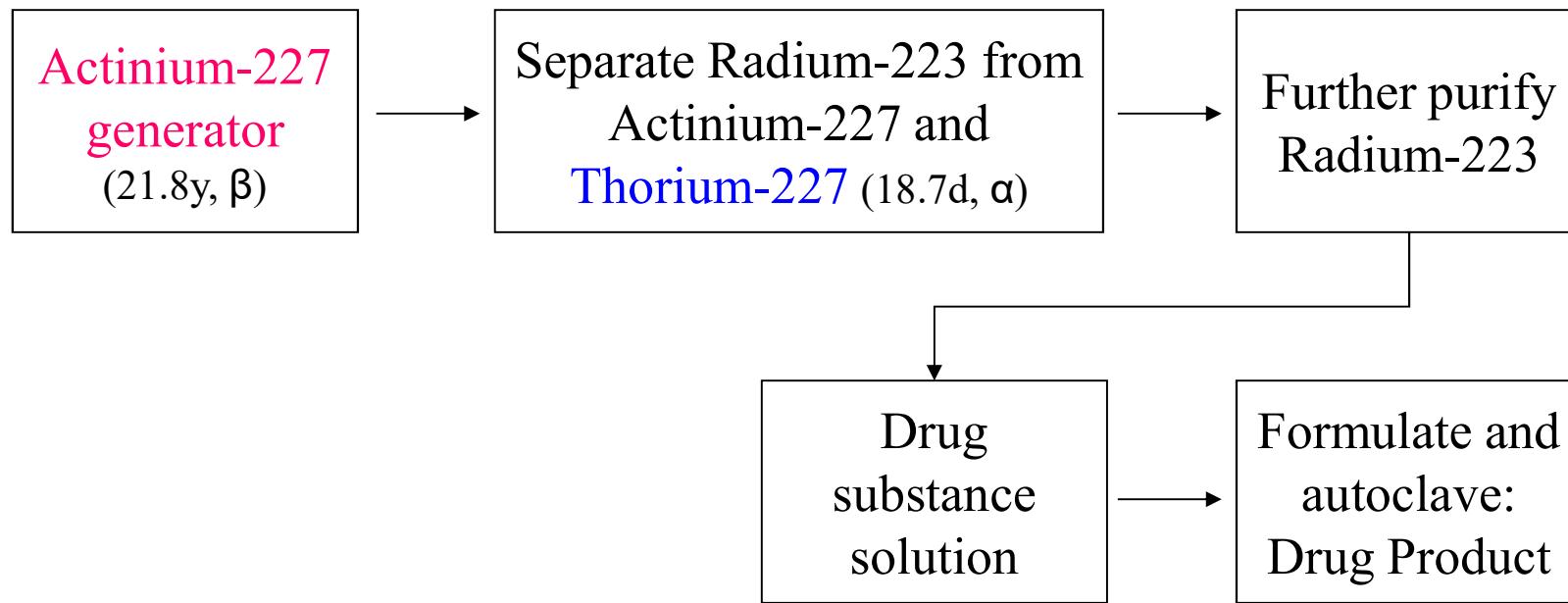
- Half-life: 11.4 d
- γ emission or X-ray (154 keV, 1.1%)
- β emission (3.6%)
- α emission (95.3%)
- Maximum energy: 5.78 MeV (average)
- Maximum range: <10 μm

- Usual administered activity: 50-200 kBq/kg
- Typical response time: <10 d
- Typical response duration: ?
- Retreatment interval: ?

- Actinium-227 generator
- Excretion is predominantly via the gastrointestinal tract.
- Tumor-to-marrow ratio: 30:1



Actinium 鈄 Thorium 鈷



Primary Container Closure System



Primary Container Closure System with Top and Bottom Cap and Wrapping film



Primary Container Closure System placed in the Shielding Container



Type A shipping box



*6 mL solution in 10 mL glass vial

*6 MBq (162 µCi) per vial (1000 kBq/mL) at reference date

*Shelf-life: 28 days

■ 血液學副作用

- 嗜中性白血球低下(2%)
- 血小板低下(3%)
- 貧血(6%)

■ 非血液學副作用

- 腹瀉
- 噫心
- 嘔吐

■ 起始劑量前

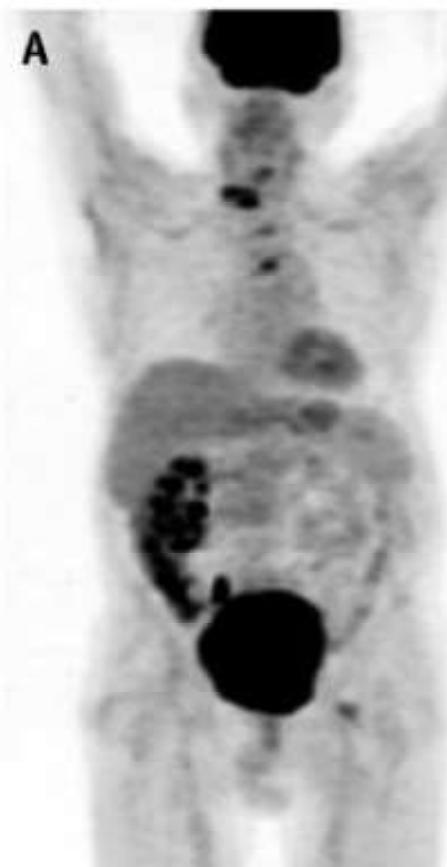
- 嗜中性白血球 $\geq 1.5 \times 10^9/L$
- 血小板 $\geq 100 \times 10^9/L$
- 血紅素 $\geq 10 \text{ g/dL}$

■ 後續劑量前

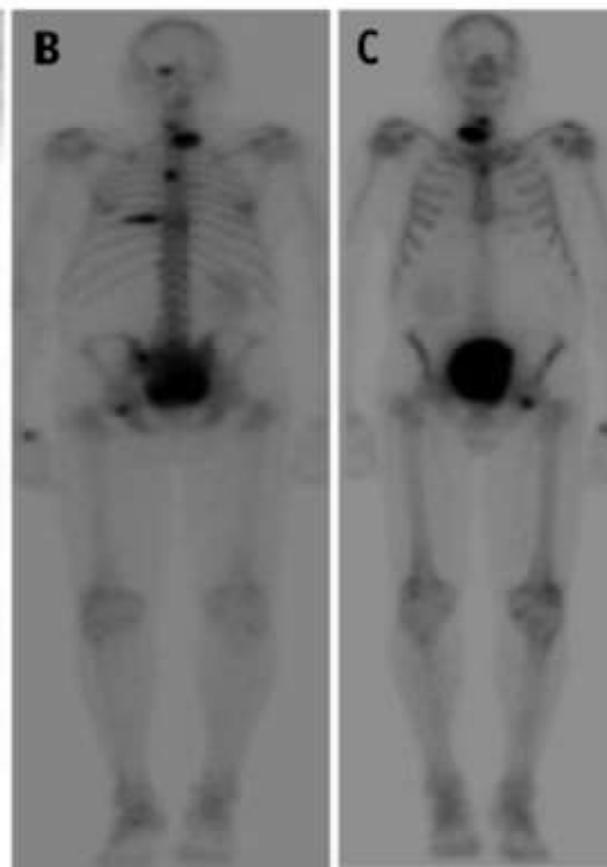
- 嗜中性白血球 $\geq 1 \times 10^9/L$
- 血小板 $\geq 50 \times 10^9/L$

劑量：55 kBq/kg body weight
每隔四週給予
共6劑注射

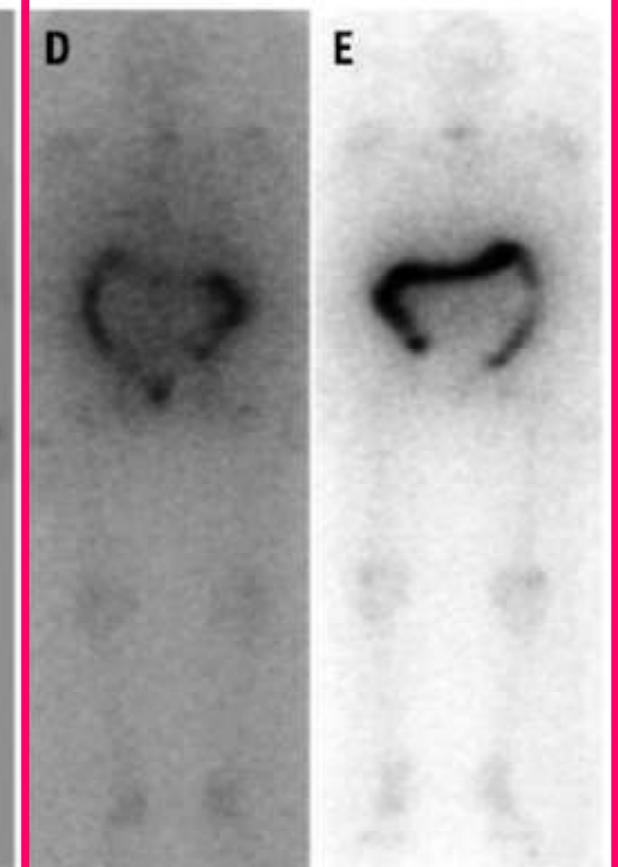
(A) FDG PET scan



(BC) MDP bone scan



(DE) $^{223}\text{RaCl}_2$ scan
24hr after injection





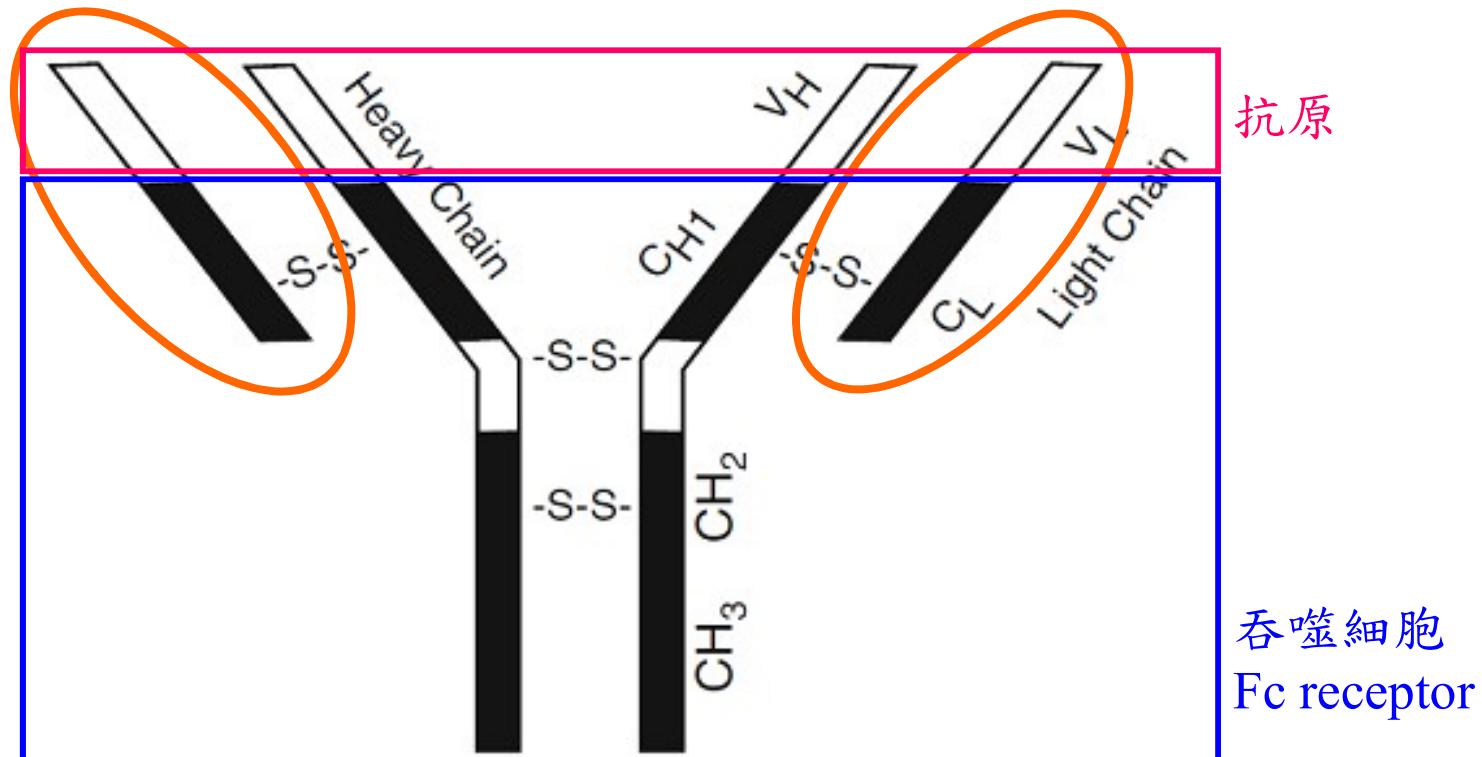
淋巴癌

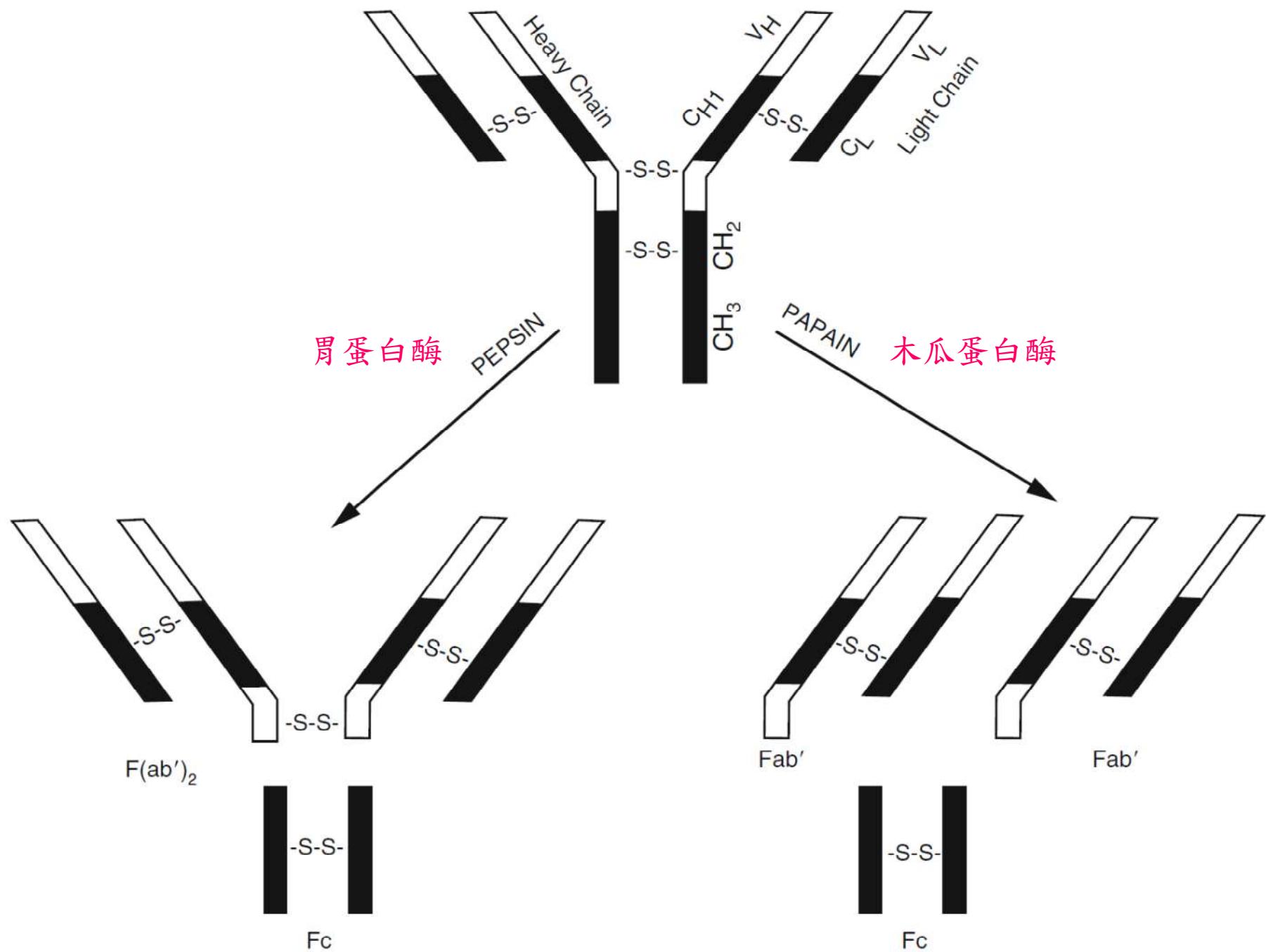
Lymphoma

- 鈀 Y-90 Ibritumomab tiuxetan (Zevalin)
- 碘 I-131 Tositumomab (Bexxar)

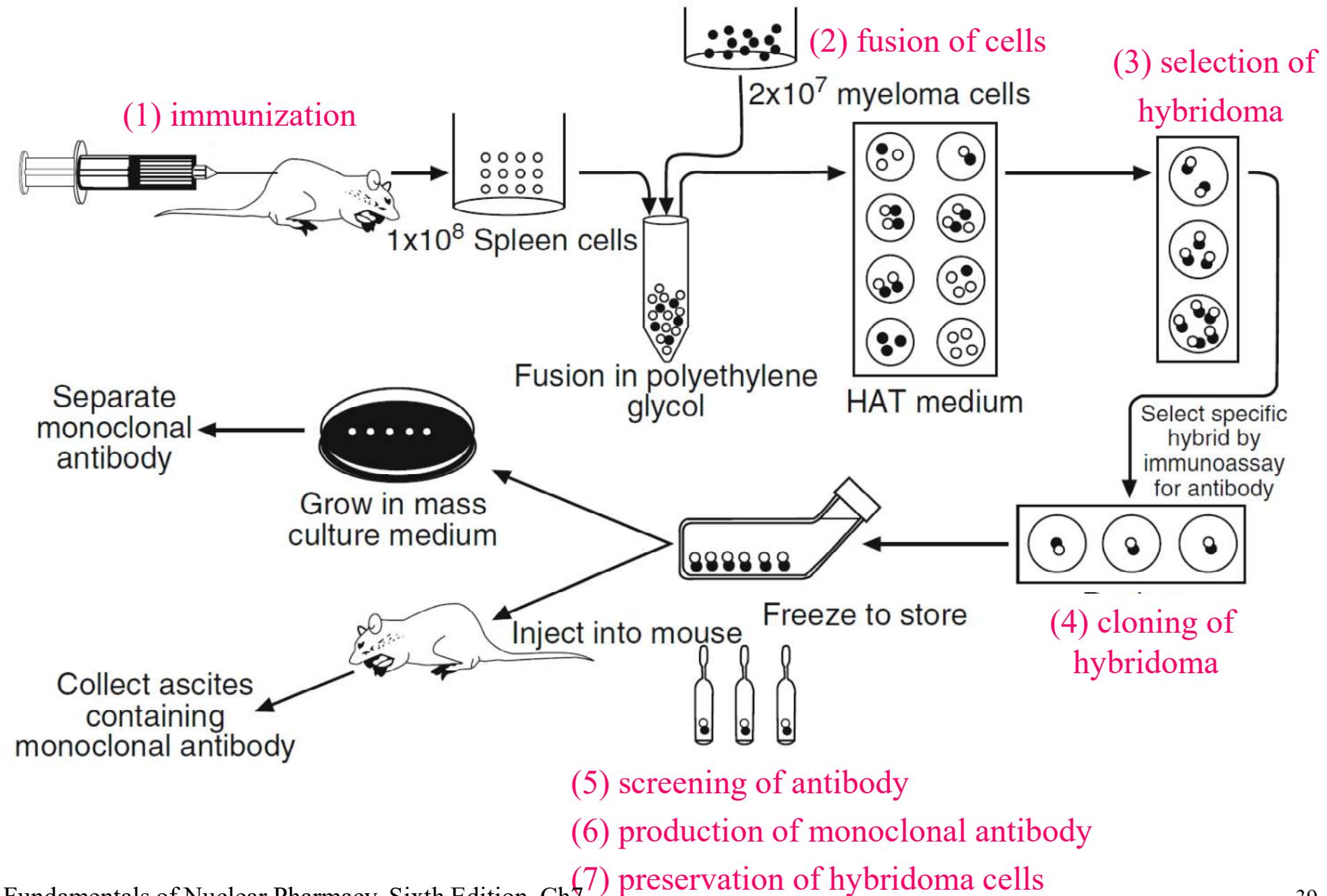
抗體

H: 重鏈
L: 輕鏈
V: 可變區
C: 固定區





105-1 國考



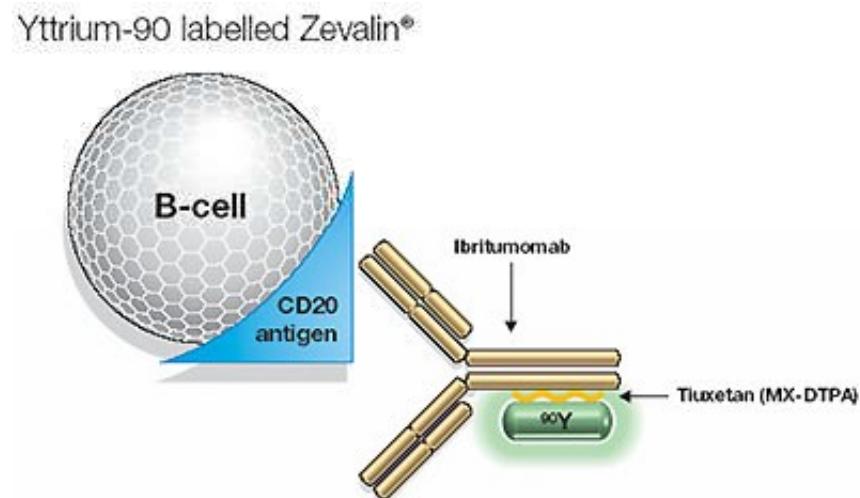
放射標幟單株抗體

藥品(-mab)	儲存溫度	標幟效率	使用期限	臨床應用	備註(抗原-抗體複合物之形成)
^{111}In -capromab pendetide (ProstaScint)	室溫	90%	8 hr	診檢初期的及轉移的前列腺癌	Mab 7E11.C5.3
^{111}In -ibritumomab tiuxetan		>95%		造影(預測 ^{90}Y -Zevalin治療劑量在身體內的分佈)	Anti-CD20 Ab
^{90}Y -ibritumomab tiuxetan (Zevalin)		>95%		治療(non-Hodgkin's lymphoma)	Anti-CD20 Ab
$^{99\text{m}}\text{Tc}$ -arcitumomab (CEA-Scan)	2-8°C	>90%	4 hr	診查結腸直腸癌(胚胎抗原)	IMMU-4 快速的血漿清除&尿液排泄
$^{99\text{m}}\text{Tc}$ -sulesomab (LeukoScan)	2-8°C	>90%	4 hr	偵測感染&發炎(顆粒細胞)	IMMU-MN3 人類抗老鼠類抗體(HAMA)

釔 Yttrium-90 (Zevalin) & 碘 Iodine-131 (Bexxar)

<Monoclonal antibody>

- Half-life: 64 h (2.7 d)
- No γ emission
- β emission
- Maximum energy: 2.281 MeV
- Mean energy: 0.933 MeV
- Path length of **5 mm** in soft tissue
(about 100-200 cell diameters)
- $^{89}\text{Y}(\text{n},\gamma)^{90}\text{Y}$



EANM procedure guideline of radio-immunotherapy for B-cell lymphoma with ^{90}Y -radiolabeled ibritumomab tiuxetan
http://www2.alasbimnjournal.cl/alasbimn/CDA/sec_a/0,1205,SCID%253D14549%2526PRT%253D14544%2526LNID%253

1. Rituximab (Rituxan) (CD20單株抗體, D1 & D7) (250 mg/m², spleen & normal B cells)
2. ¹¹¹In-Ibritumomab tiuxetan (造影, D1-3, 2-24h/48-72h) (5 mCi)
3. ⁹⁰Y-Ibritumomab tiuxetan (Zevalin) (治療, D7-9) (0.4 mCi/kg over 10 min, Max: 32 mCi)
 - Overall response rate: 75% (complete response: 15% only)
 - 血小板低下/嗜中性白血球低下(90%), 無力(35%), 噁心(25%), 頸抖(20%)
 - PLT <100,000/mm不能接受治療

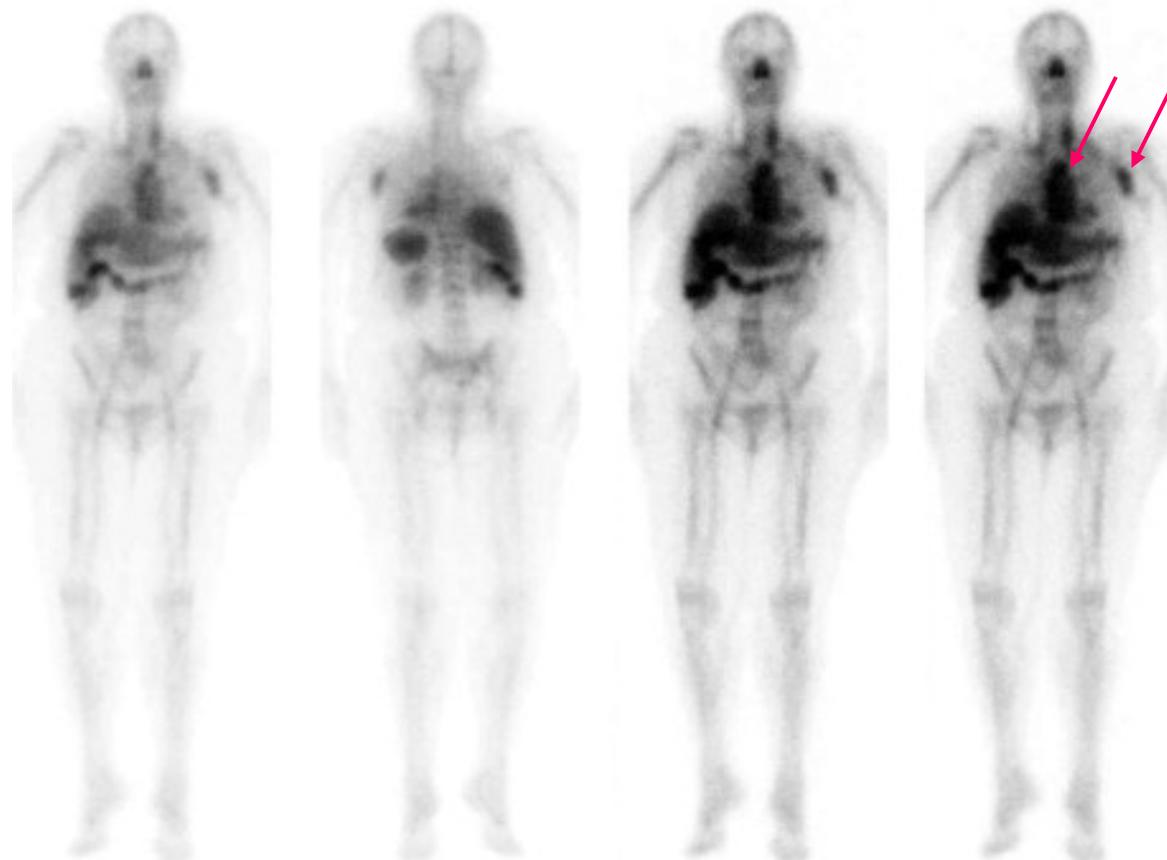
- (1) Tositumomab (D1 & D7) (450 mg in 50 mL NS over 60 min)
- (2) ¹³¹I-Tositumomab (Bexxar) (造影, D1-7, 1h/2-4d/6-7d) (5 mCi in 30 ml NS over 20 min)
- (3) ¹³¹I-Tositumomab (Bexxar) (治療, D7-14) (whole body dose: 0.75 Gy)
 - Response rate: pre-treated patients 54-71%, newly diagnosed patients 95%
 - Before receiving I-131: SSKI

- ^{111}In -ibritumomab tiuxetan (Zevalin) dosimetry images (72-hour postinjection)

1. **Tumor activity**

2. Expected activity: (1) moderately high: liver/spleen
(2) low or very low: kidneys/bladder/bowel

3. **Unacceptable activity**: (1) diffuse lung $> D^1$ cardiac blood pool
(2) diffuse lung/kidney/intense bowel $> D^{2/3}$ liver



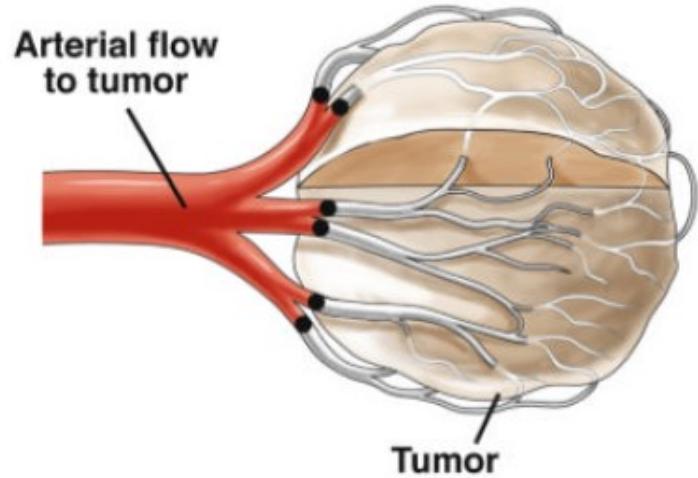


肝癌&肝轉移

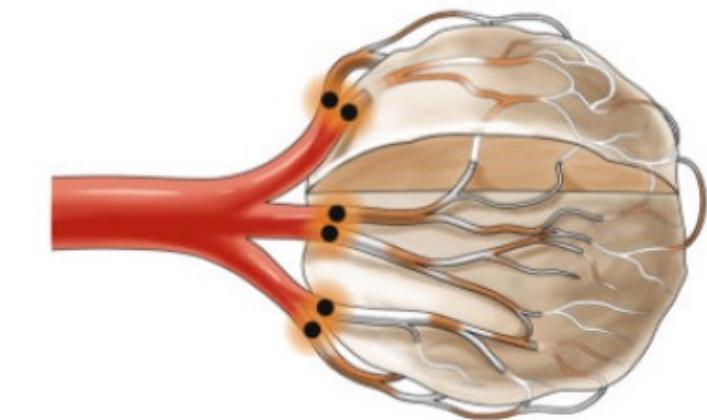
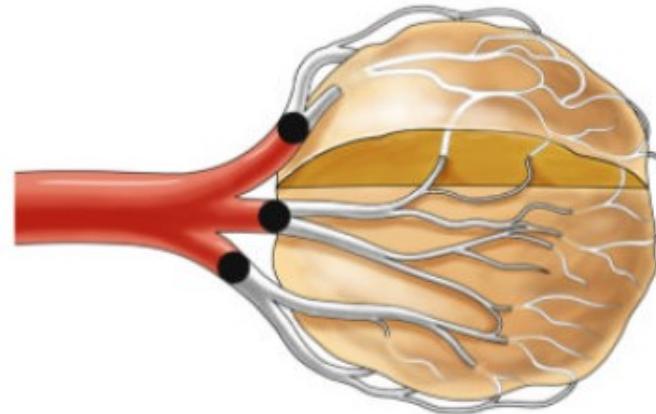
Hepatoma & liver metastasis

■釔 Y-90 microsphere

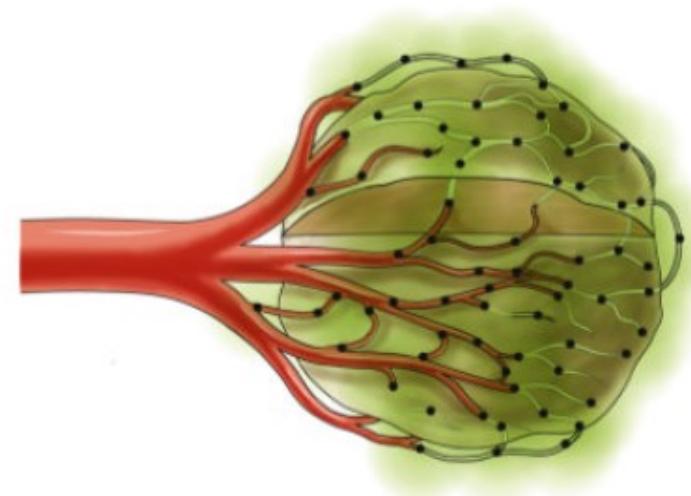
Arterial embolization
(TAE) 100-300 μm



Conventional chemoembolization
(cTACE) 300-500 μm



Drug-eluting bead chemoembolization
(DEB-TACE) 100-300 μm

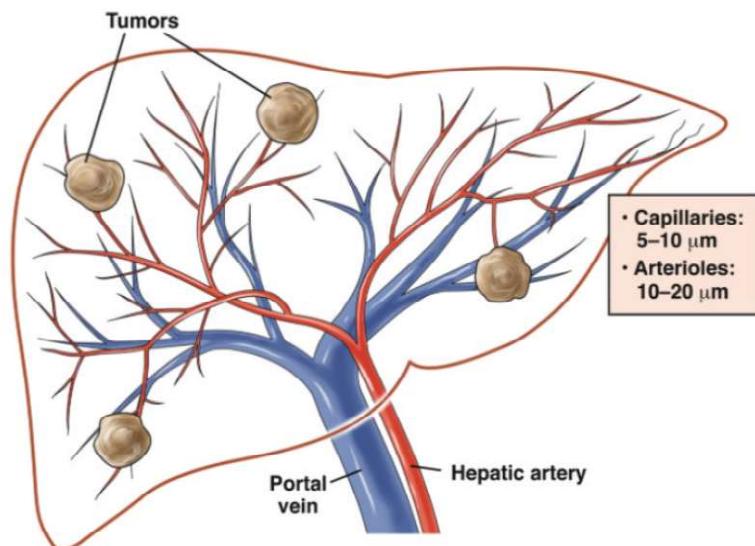


Radioembolization
(TRE) 20-60 μm

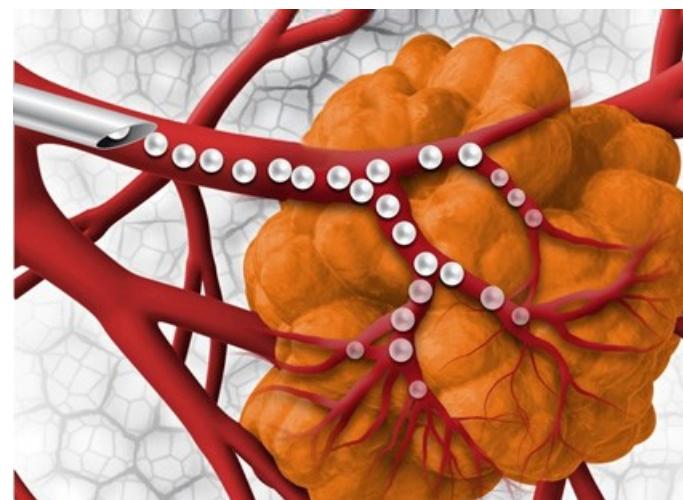
钇 Yttrium-90 microsphere (SIR-Spheres/TheraSphere)

< Resin or glass microspheres>

- Microsphere: 20-60 μm
 - MAA: 10-90 μm
 - sulfur colloid 0.1-1 μm
- ※ 禁忌症: portal vein thrombosis

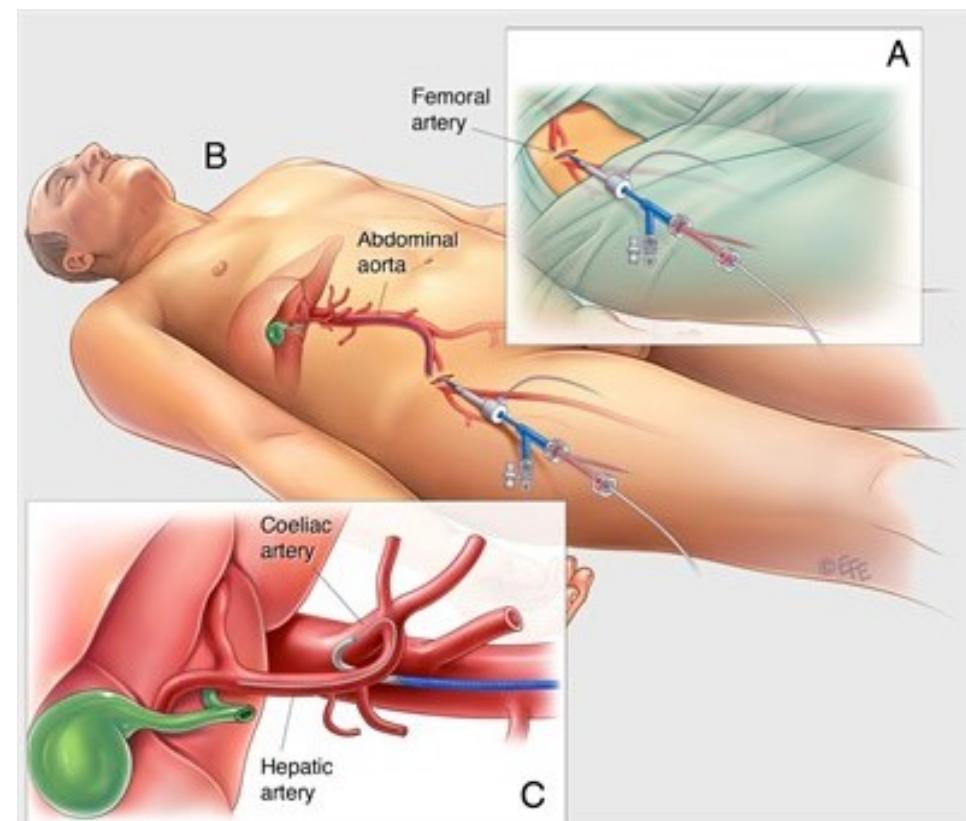


選擇性體內放射療法
Selective internal radiation therapy (SIRT)



Chemoembolization and radioembolization for hepatocellular carcinoma. Clin Gastroenterol Hepatol. 2013;11(6):604-611
<http://www.leberkrebstherapie.org/patients/sirt-therapie-patients>

- CT: tumor resectability, extent of disease, extent of extrahepatic disease, hepatic vascular anatomy, arteriovenous shunting
- Angio-CT: map tumor-perfusion vessel, embolize collateral vessels, assess portal vein patency
- Angiographic catheter into hepatic artery



(1) ^{99m}Tc -MAA (造影)

1. 肺分流(lung shunting):

(1) >10% → 降低劑量 (radiation pneumonitis)

(2) >20% → 禁忌症

2. 胃腸分流: 胃, 十二指腸, 膽囊

3. 腫瘤正常組織吸收比(T/N ratio)

(2) ^{90}Y -microsphere (治療) (3 GBq/81 mCi in 5-mL vial; 1.5-2.5 GBq/40-70 mCi)

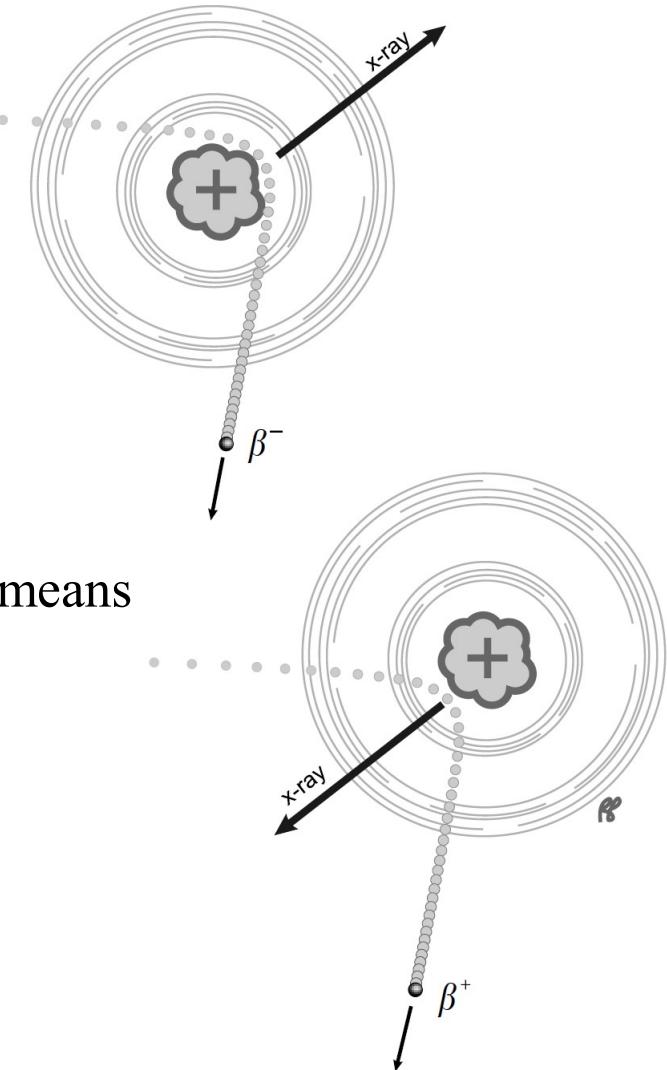
very slow infusion rate (avoid reflux into gastroduodenal artery)

1. SPECT/CT: 當天或隔天; 制動輻射(bremsstrahlung; braking radiation)

2. 副作用: 嘔心, 腹痛, 食慾降低, 疲累, 發燒

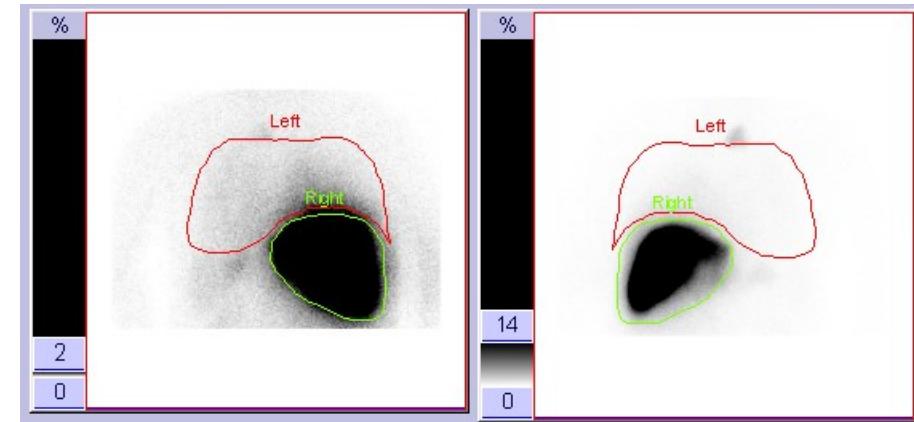
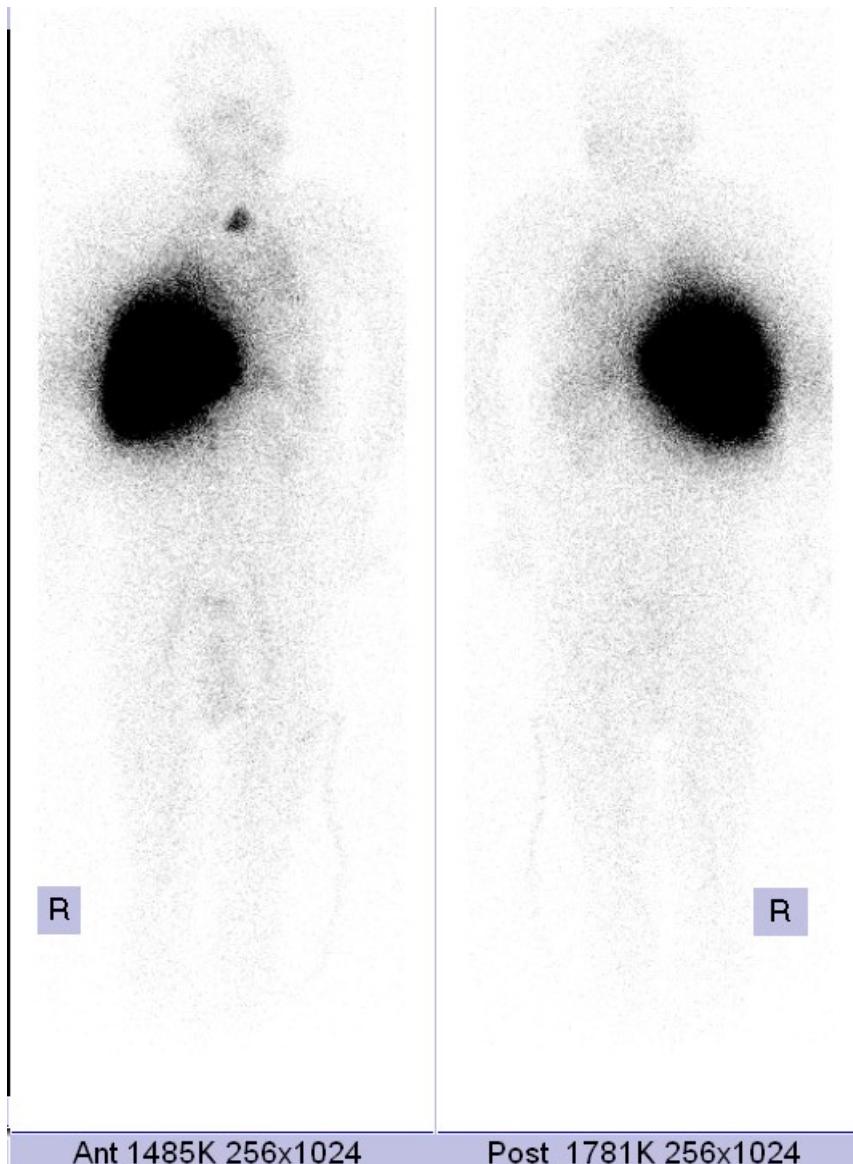
制動輻射 Bremsstrahlung

- Small charged particles such as electrons or positrons may be deflected by nuclei as they pass through matter, which may be attributed to the positive charge of the atomic nuclei.
- This type of interaction generates x-radiation known as **bremsstrahlung**, which in German means “braking radiation.”



肝肺分流(lung shunting)

甲狀腺, 唾液腺, 胃, 膀胱



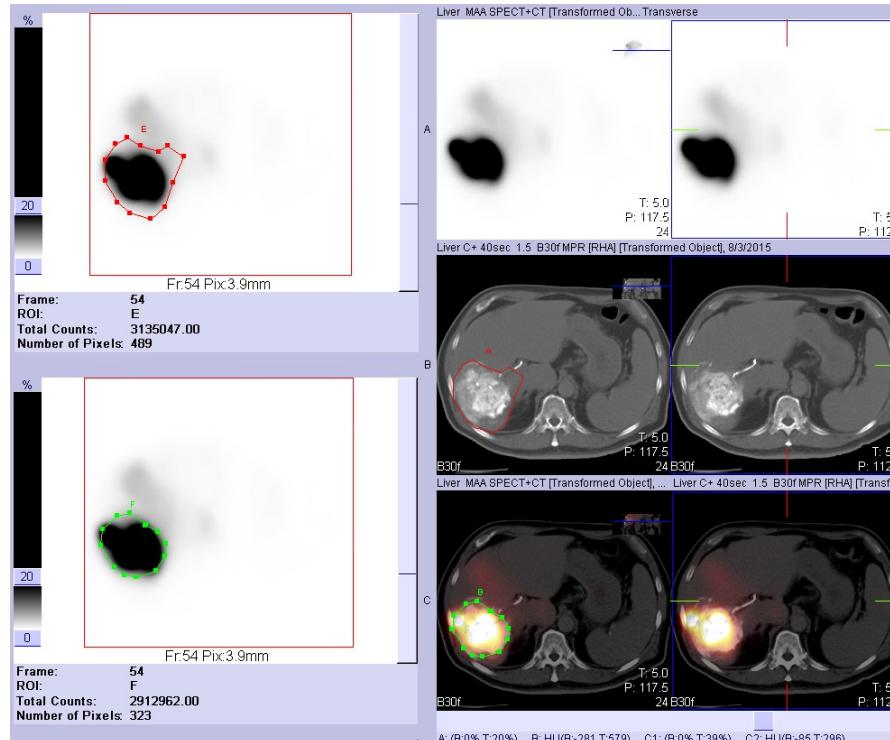
Perfusion		Geometric Mean	
(Counts)		(Counts)	
POST		Lung	Liver
Left	Right		
134K	3861K		
Total	134K	3861K	
		Total	139K
			3454K
(% Ratios)		(% Ratios)	
Left	Right	Lung	Liver
3.36	96.64		
Total	96.64		
		Total	3.87
			96.13
ANT			
(Counts)			
Left	Right		
149K	3165K		
Total	149K	3165K	
(% Ratios)			
Left	Right		
4.50	95.50		
Total	95.50		

腫瘤正常組織吸收比(T/N ratio)

6.17 in RHA territory

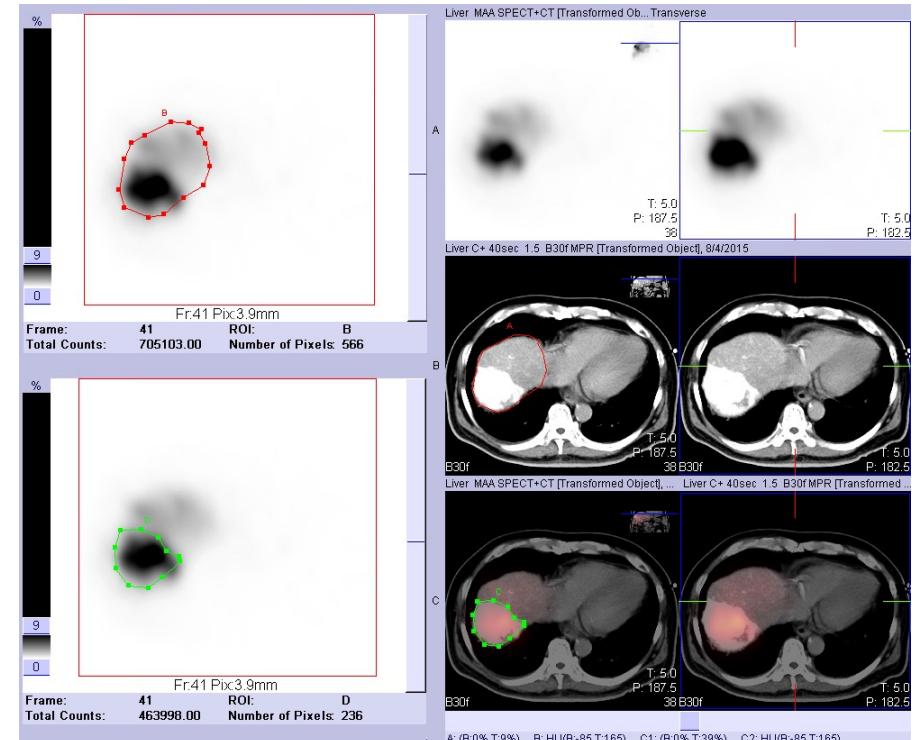
3.5 mCi

^{99m}Tc -MAA

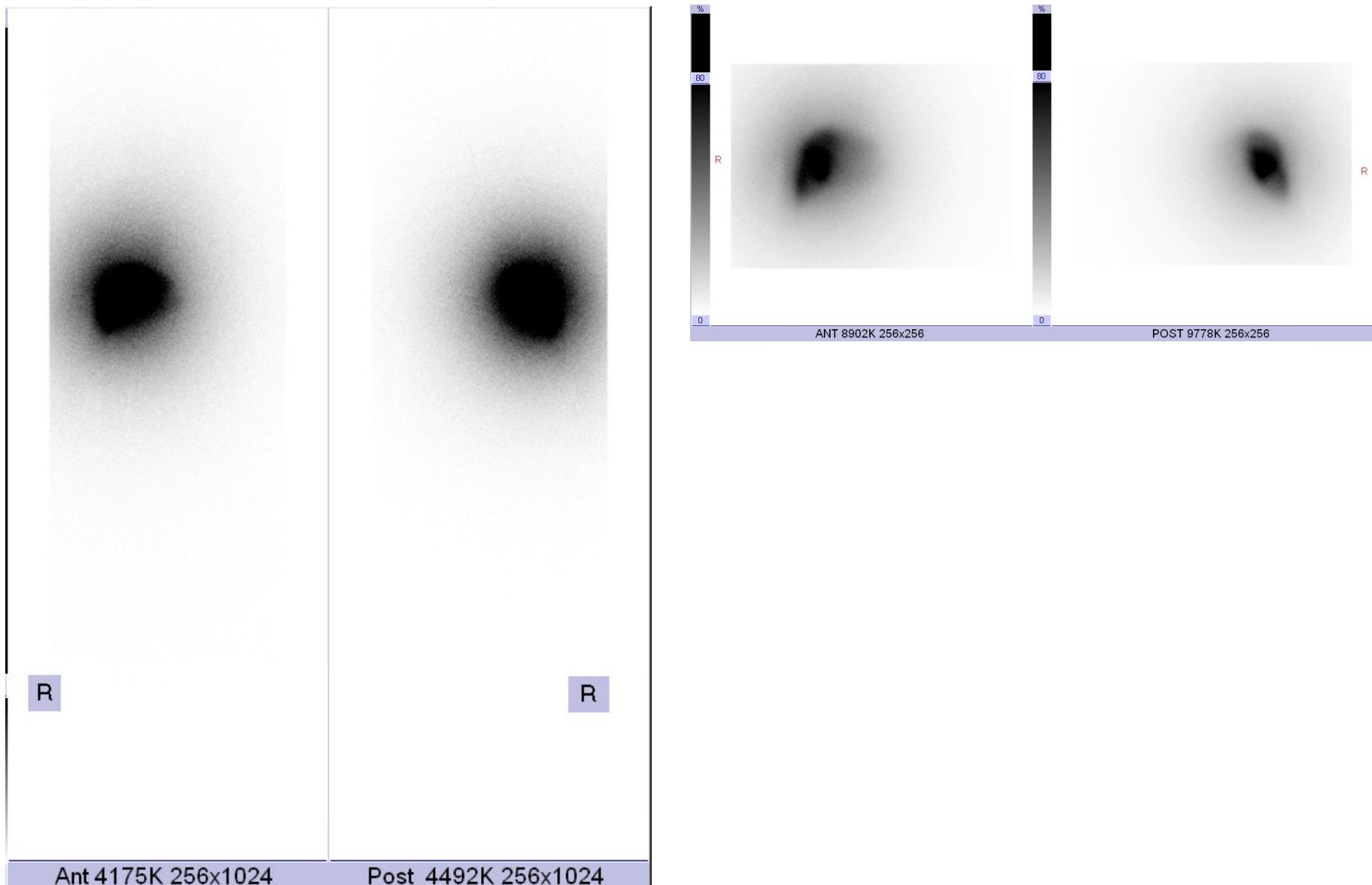


3.26 in LHA territory

1.5 mCi



制動輻射(bremsstrahlung radiation)



制動輻射(bremsstrahlung radiation)

腫瘤正常組織吸收比(T/N ratio)

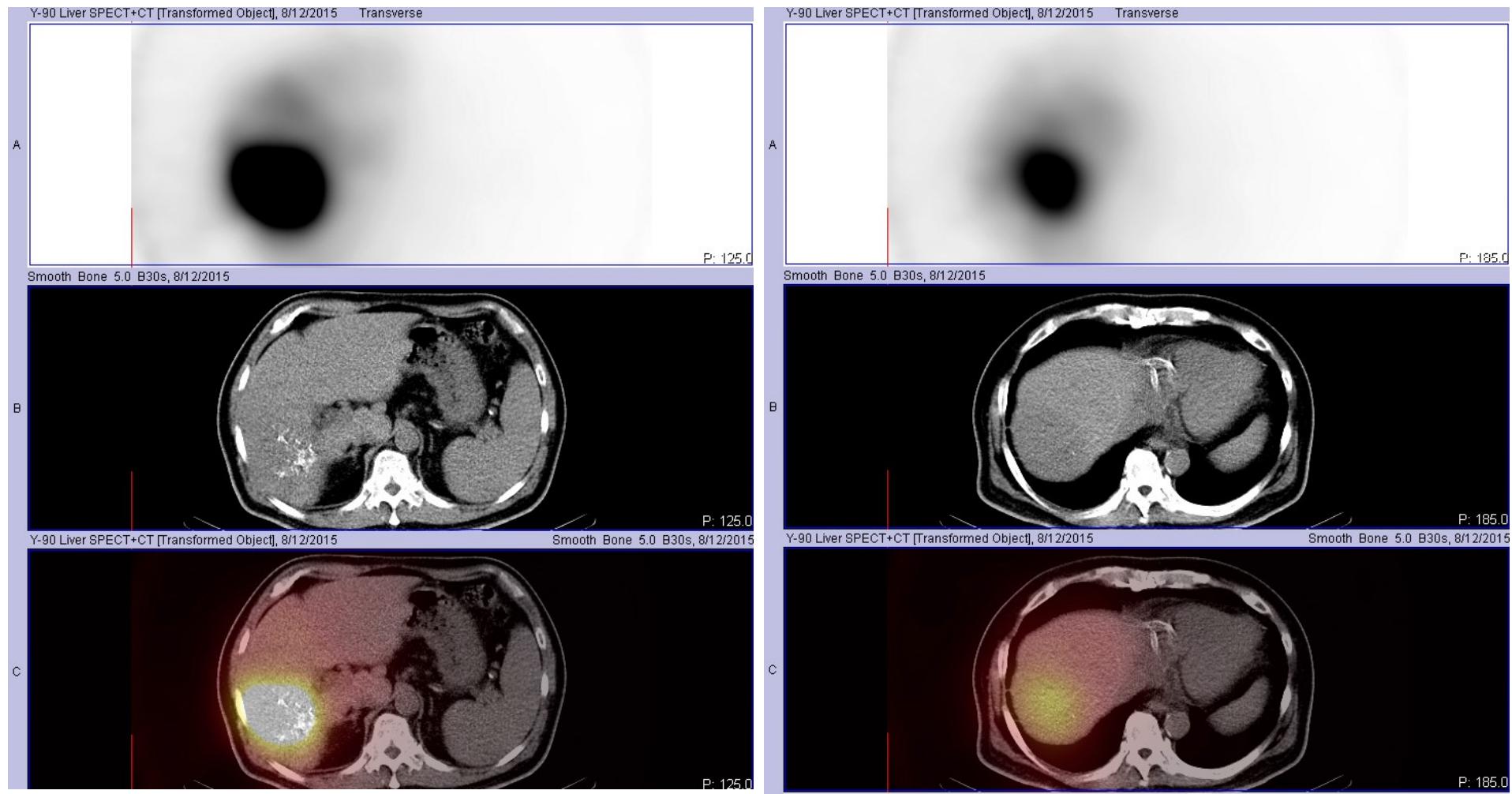
6.17 in RHA territory

1.9 GBq

Y-90 microsphere

3.26 in LHA territory

1.13 GBq





神經內分泌瘤

Neuroendocrine tumor

- 碘 ^{131}I -MIBG
- 鈦 ^{90}Y -DOTATOC
- 鎿 ^{177}Lu -DOTA

神經內分泌瘤 (neuroendocrine tumor)

- 嗜鉻性細胞瘤 (pheochromocytoma)
- 神經母細胞瘤 (neuroblastoma)
- 副神經節瘤 (paraganglioma)
- 類癌瘤 (carcinoïd tumor)
- 甲狀腺髓質癌 (medullary thyroid carcinoma)

■ ^{131}I -NP-59 (造影):

- 腎上腺皮質
- 1 mCi
- 5-7 days
- 庫辛氏病
(Cushing's disease)
- 腎上腺留鹽激素過多症
(hyperaldosteronism)
- 上腎上腺瘤

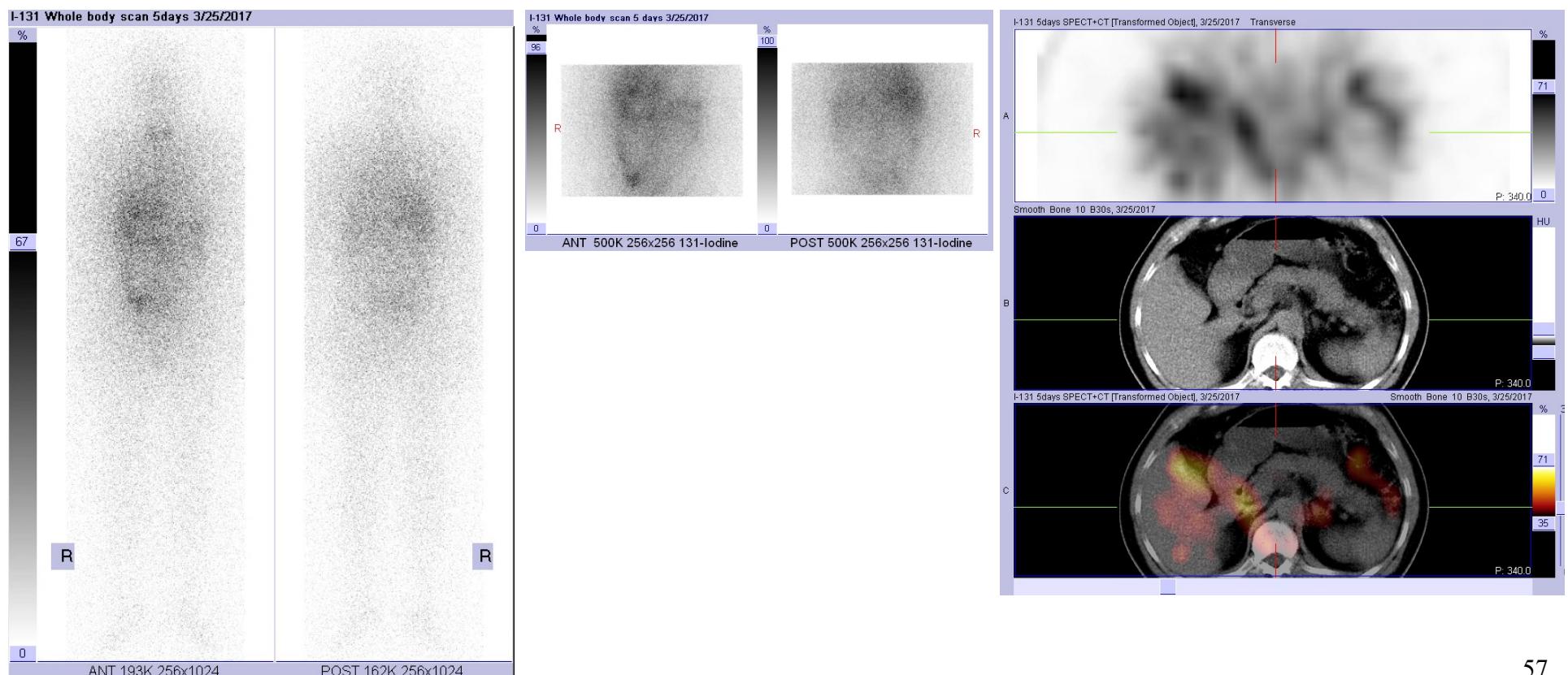
**Cholesterol analog (膽固醇)

■ ^{131}I -MIBG (造影&治療):

- 腎上腺髓質
- 0.5 mCi
- 48 hr & 72 hr
- 噻鉻母細胞瘤
(pheochromocytoma)

**Norepinephrine analog (正腎上腺素)

- I-131 NP-59 (造影)
 - 停藥：hypothalamic-pituitary-adrenal axis (eg: glucocorticoids)
renin-angiotensin-aldosterone axis (eg: spironolactone)
 - 保護甲狀腺：Lugol's solution (5%, 3 drops BID, D-2 ~ D+7)或SSKI
 - 抑制腎上腺皮質賀爾蒙：dexamethasone (1 mg QID, D-7 ~ D+7)
 - 降低腸道活性(liver, gallbladder and biliary secretion to colon)：緩瀉劑

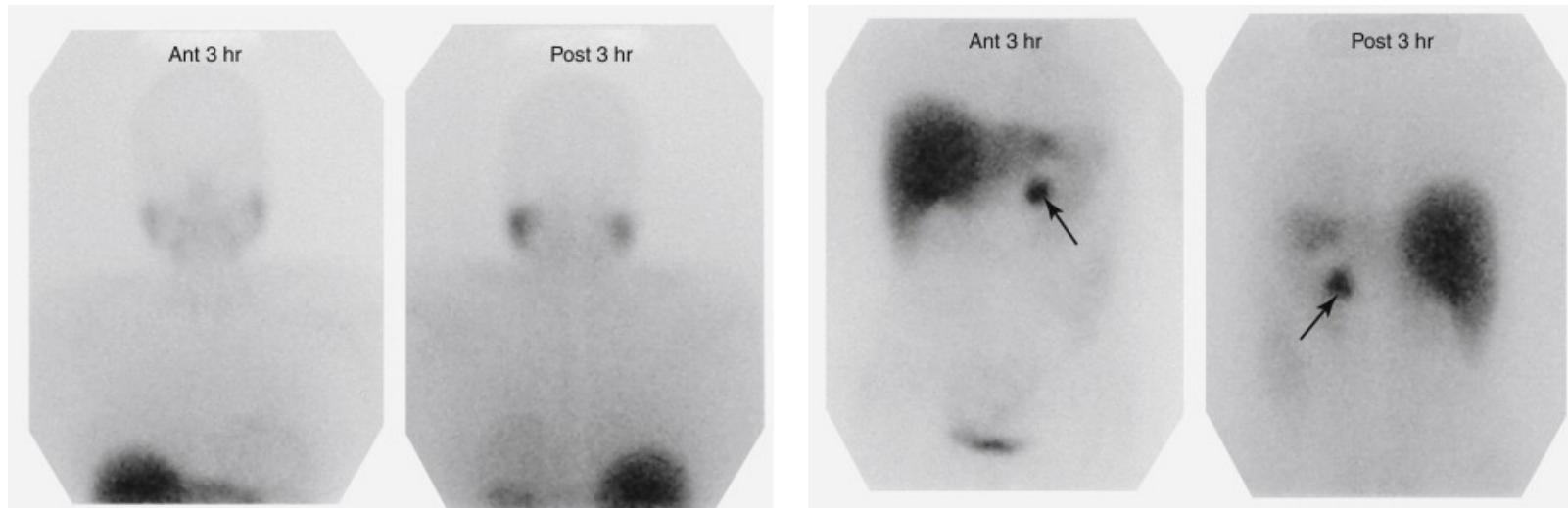


1. $^{131}\text{I}/^{123}\text{I}$ -MIBG (造影) 40-80 MBq (1.2-2.2 mCi)/400 MBq (10.8 mCi), slow infusion (>5 min)

2. ^{131}I -MIBG (治療) 3.7-11.2 MBq (100-300 mCi), slow infusion (45 min ~ 4 hr)

- 早期副作用: 噫心, 嘔吐, 短暫骨髓抑制, 腎功能變差, 血壓不穩定
- 晚期副作用: 甲狀腺功能低下, 持續骨髓抑制, 白血病或其他癌症
- 利用放射性碘製劑進行核醫造影檢查前(2-3天), 可給與患者 Lugol's solution 或 SSKI 來保護甲狀腺

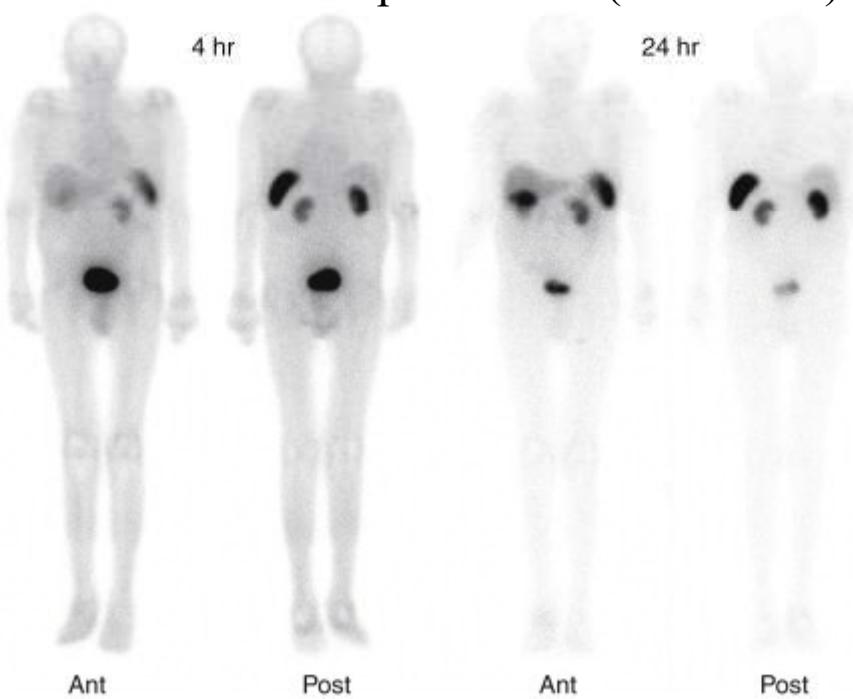
^{123}I -MIBG (造影)



釔 ^{90}Y -DOTATOC & 鎇 ^{177}Lu -DOTA (Lutetium)

- Somatostatin analog (抑體素)
- DOTATOC: DOTA Tyr3-octreotide
- 神經母細胞瘤 (neuroblastoma)

^{111}In -pentreotide (Octreotide)



- ^{111}In -DTPA-Octreotide (造影)
- ^{68}Ga -DTPA-Octreotide (造影)
- ^{90}Y -DOTATOC (治療)
- ^{177}Lu -DOTA (治療)

總結

1. 甲狀腺癌&甲狀腺機能亢進 (Thyroid cancer & hyperthyroidism)

- 碘 I-131

2. 骨轉移 (Bony metastasis)

- 鋰 P-32: 真性紅血球增多症(polycythemia vera)
- 銷 Sr-89, 錸 Re-186/Re-188, 鈦 Sm-153, 錫 Sn-117m, 鐳 Ra-223

3. 淋巴癌 (Lymphoma)

- 鈇 Y-90 Ibritumomab tiuxetan (Zevalin)
- 碘 I-131 Tositumomab (Bexxar)

4. 肝癌&肝轉移 (Hepatoma & liver metastasis)

- 鈇 Y-90 microsphere (SIR-Spheres/TheraSphere)

5. 神經內分泌瘤 (Neuroendocrine tumor)

- 碘 ^{131}I -MIBG: 腎上腺髓質；嗜鉻母細胞瘤(pheochromocytoma)
- 鈇 ^{90}Y -DOTATOC & 鎿 ^{177}Lu -DOTA: 神經母細胞瘤 (neuroblastoma)