



核子醫學治療(上)

高雄榮民總醫院 核子醫學科

邱宇莉醫師

2019-11-07

大綱

簡介

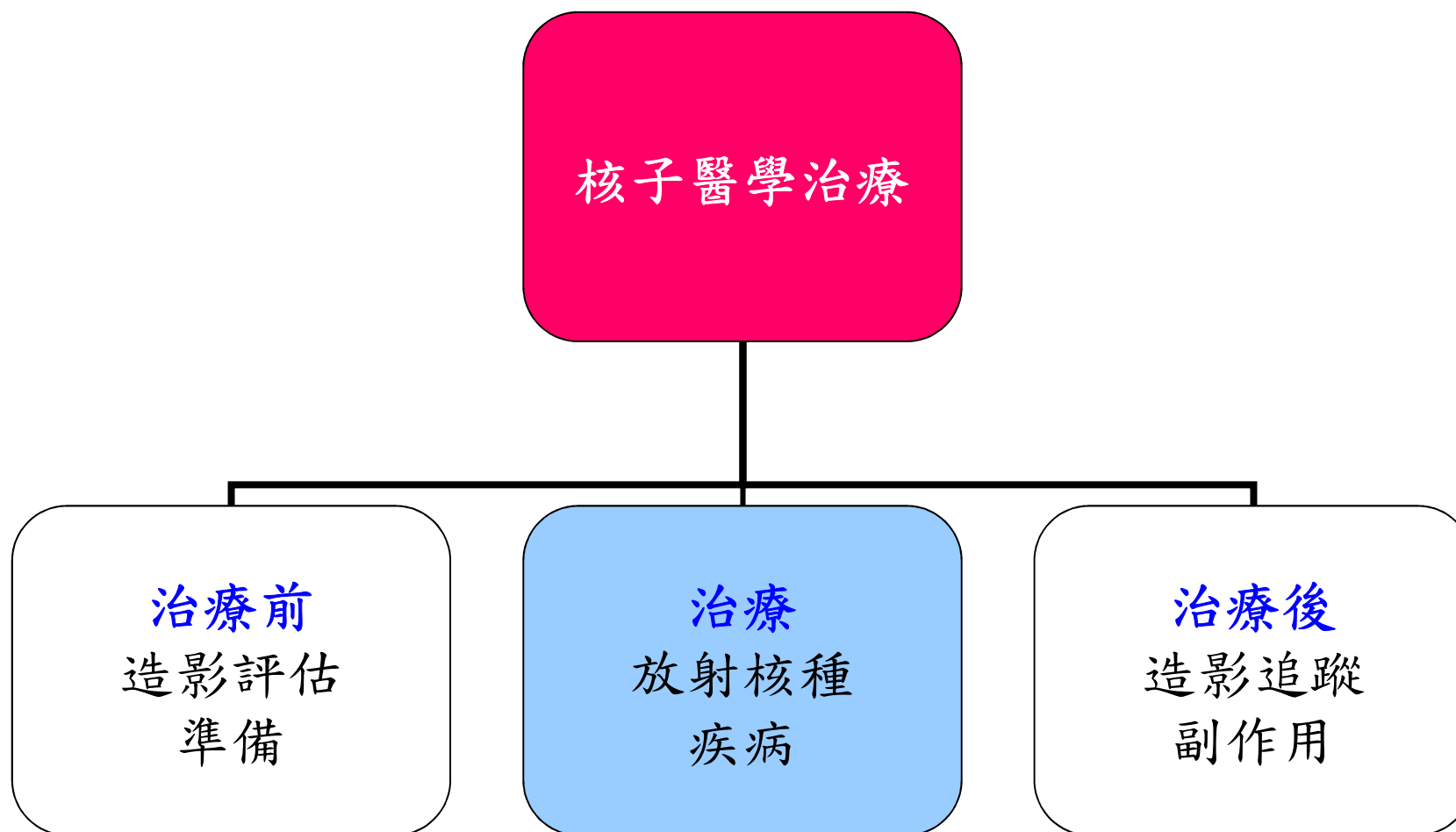
1. 甲狀腺癌&甲狀腺機能亢進 (Thyroid cancer & hyperthyroidism)
2. 骨轉移 (Bony metastasis)
3. 肝癌&肝轉移 (Hepatoma & liver metastasis)
4. 淋巴瘤 (Lymphoma)
5. 神經內分泌瘤 (Neuroendocrine tumor)

總結

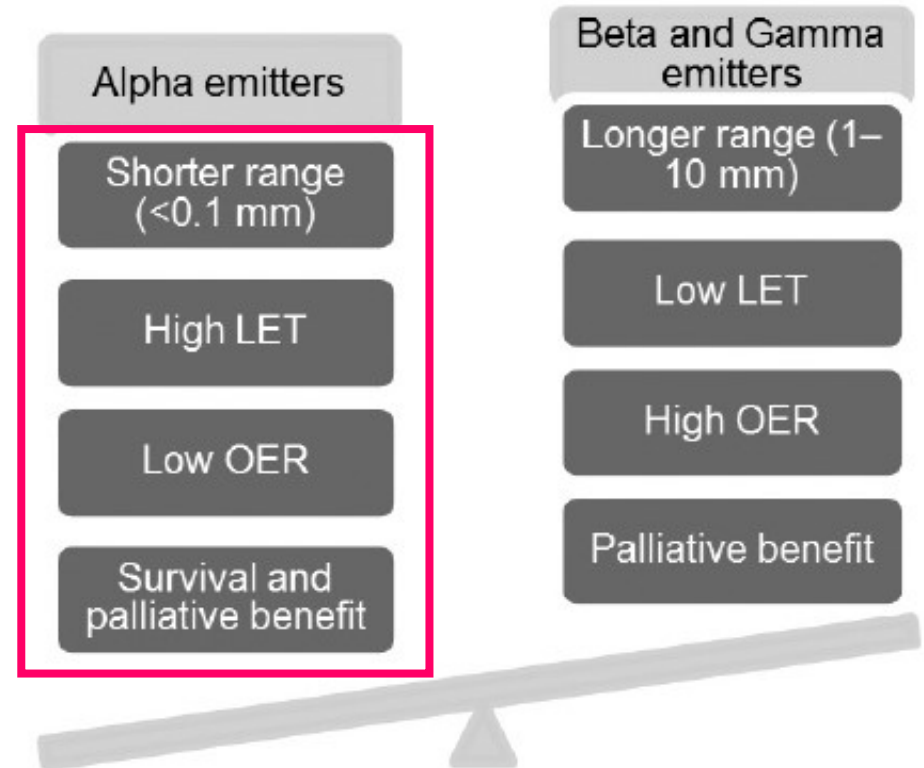


簡介

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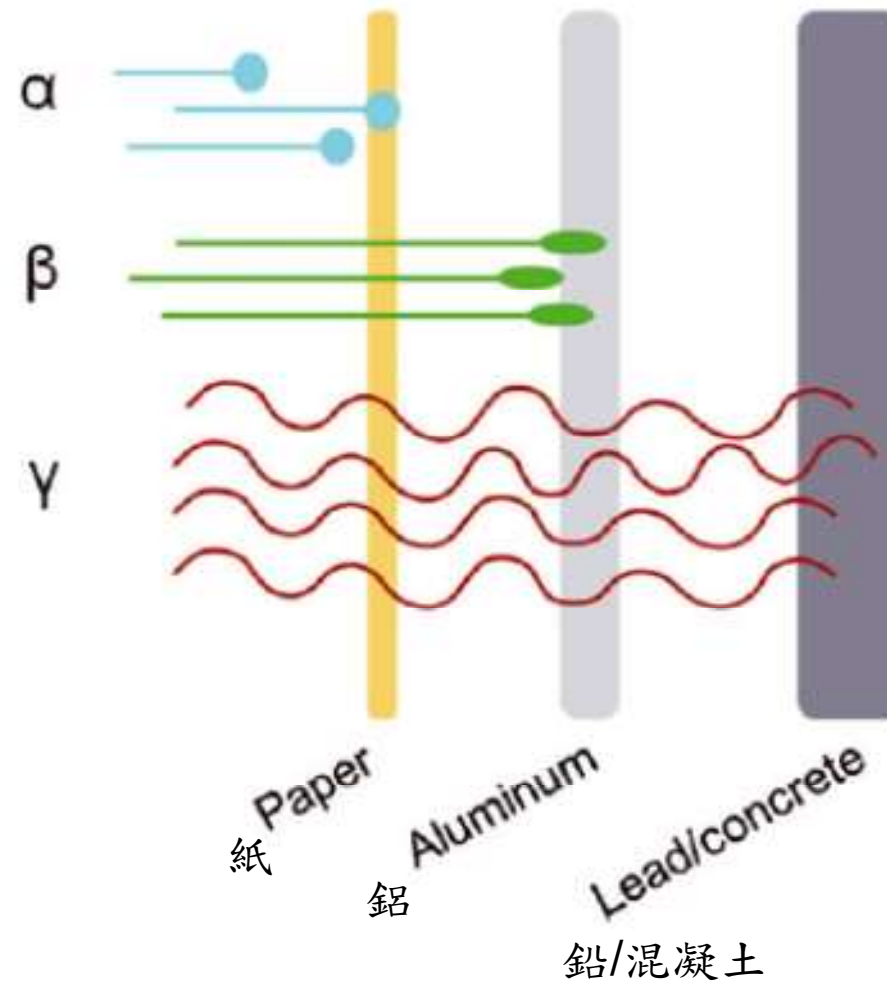


- 口服
 - 靜脈注射
 - 體腔注射 (如: 關節, 腹膜)
-
- α emitters: Ra-223
 - β emitters: 最常見
- (γ emitters: 造影定位, 輻射危害)



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

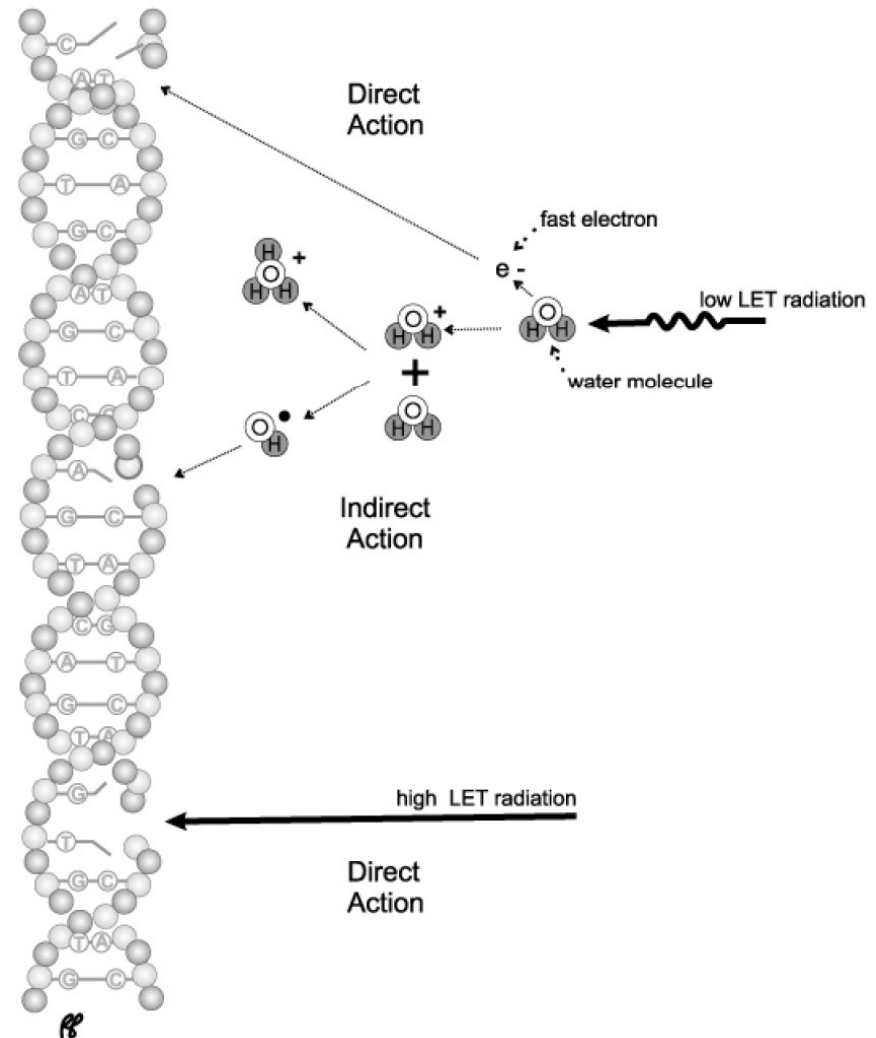
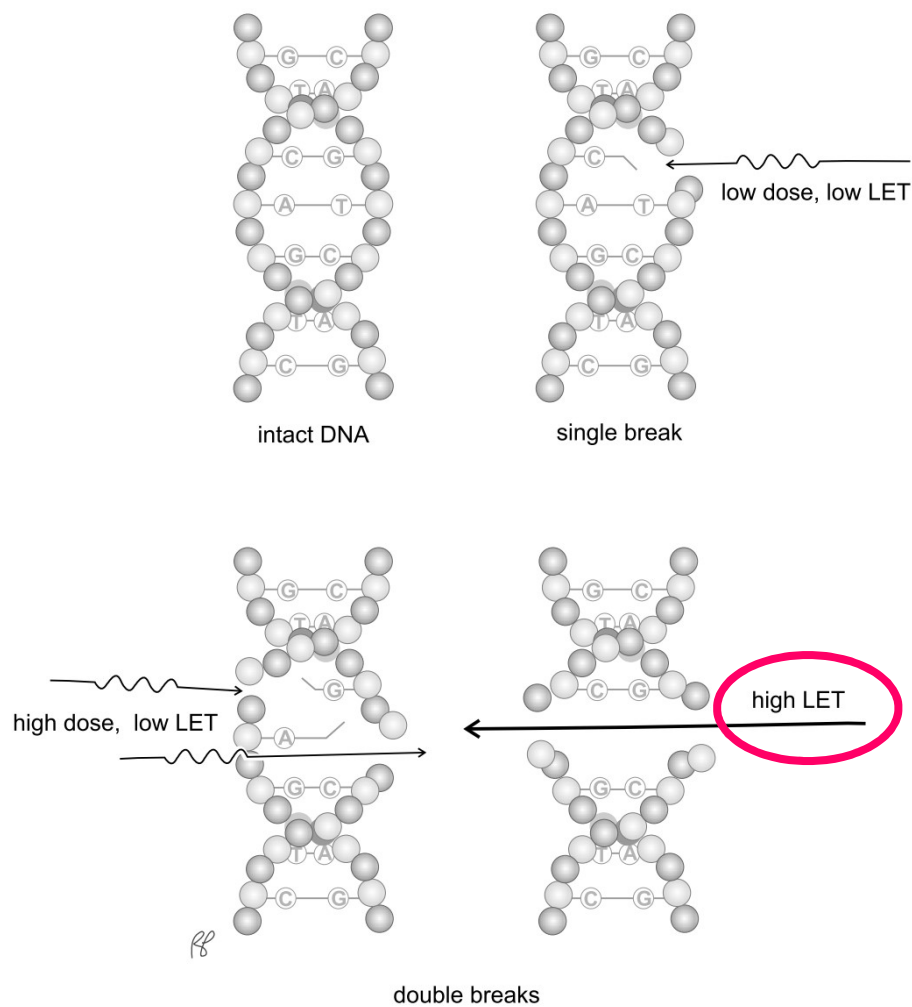
1. 短射程



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

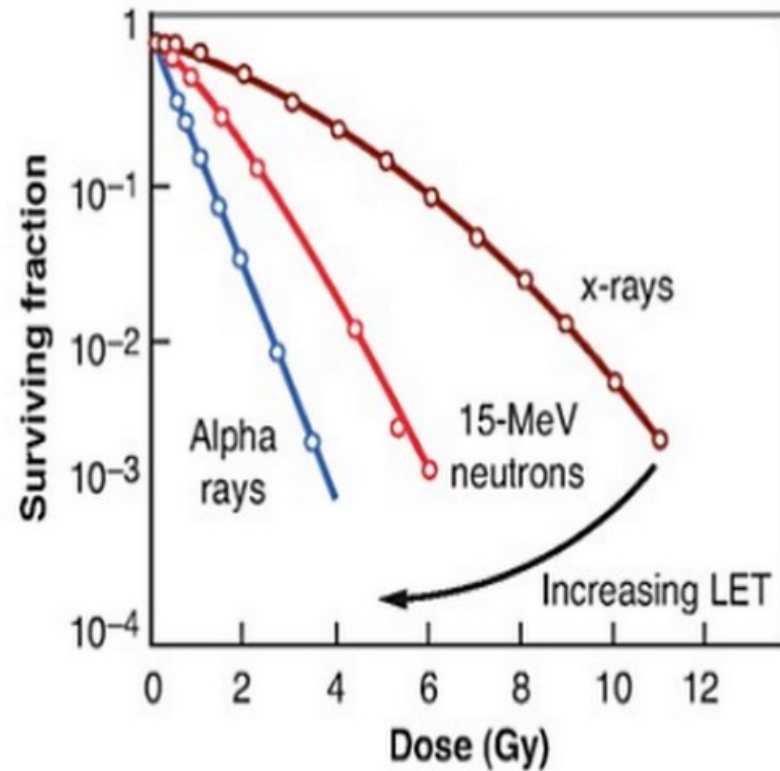
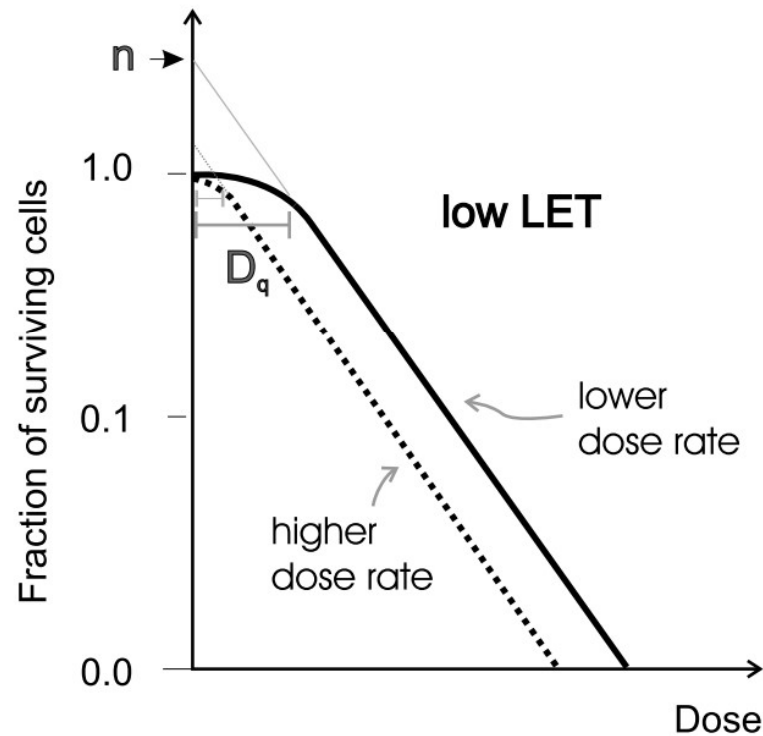
2. 高直線能量轉移 (LET; linear energy transfer)

雙股vs. 單股斷裂；直接vs.間接作用



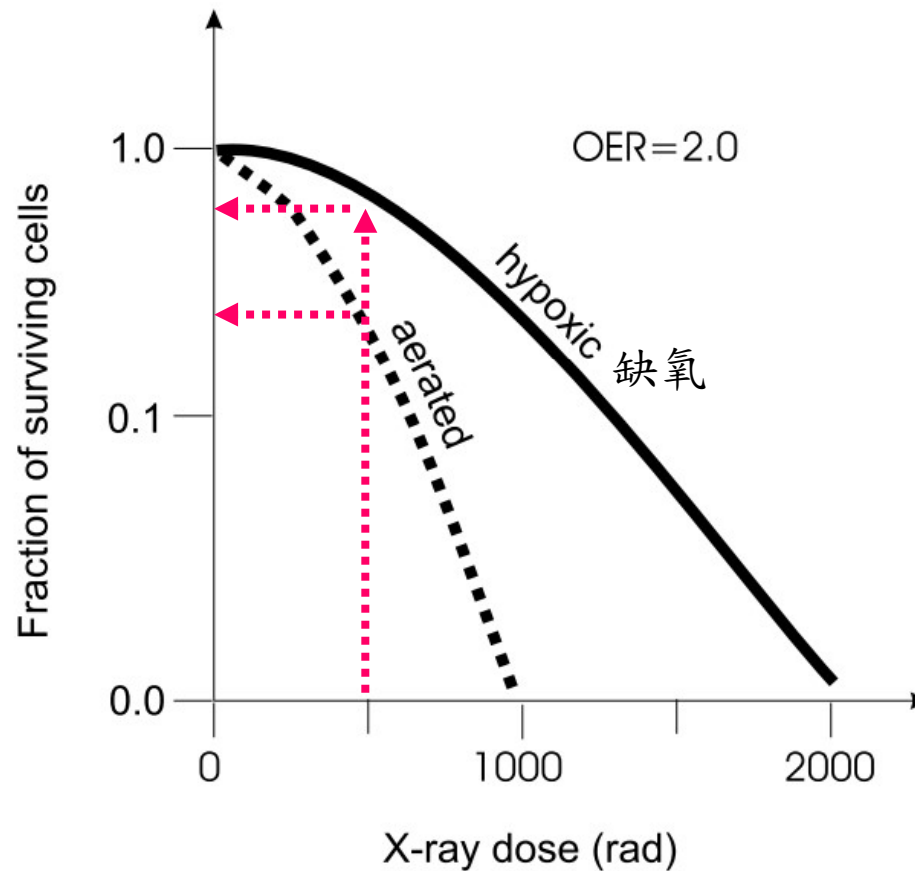
2. 高直線能量轉移 LET (linear energy transfer)

劑量率對細胞存活的影響

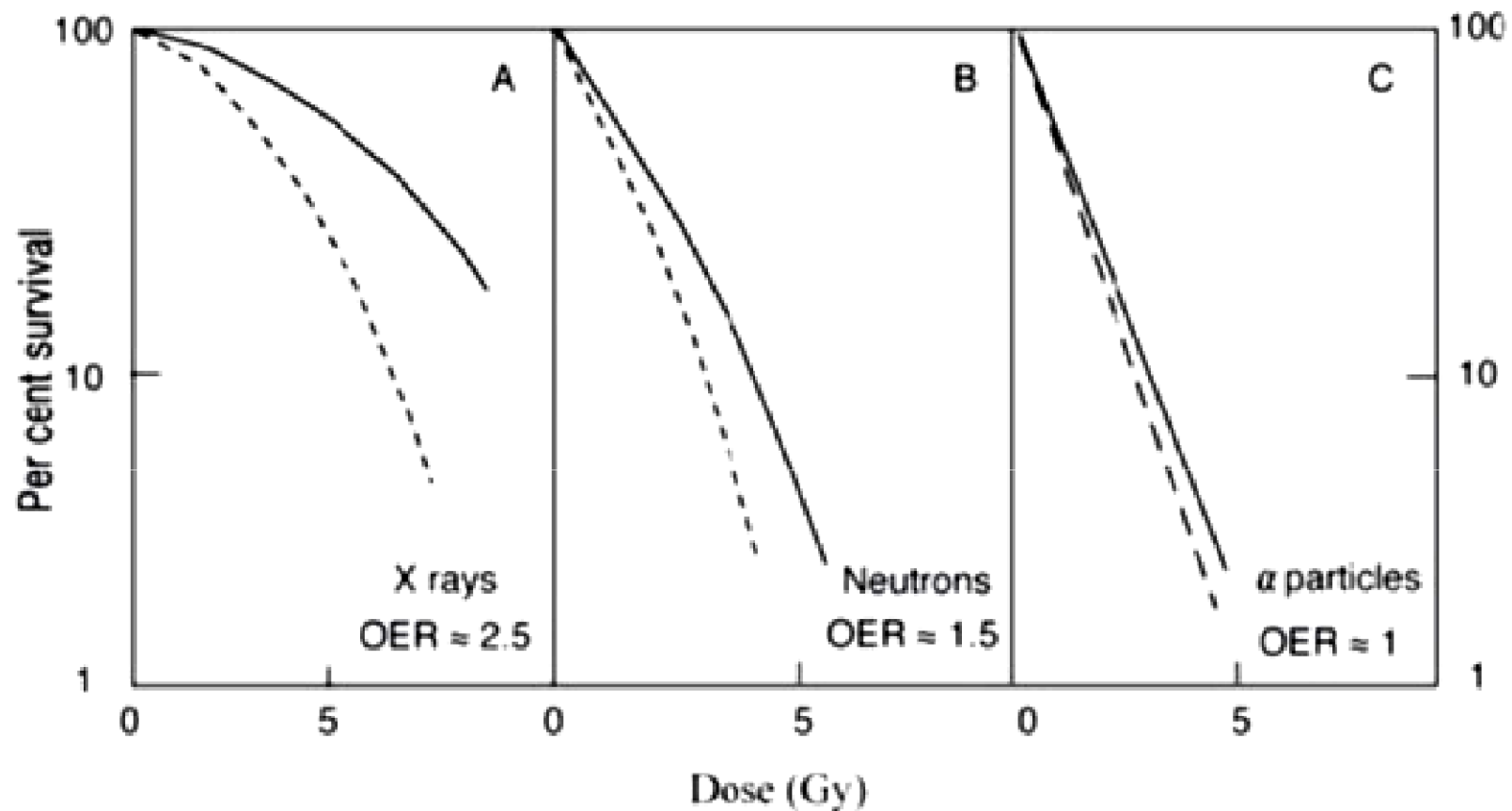


3. 低氧增強比 OER (oxygen enhancement ratio)

低LET輻射氧對細胞存活曲線的影響



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



$$\text{OER} = \frac{\text{Dose to produce a given effect without oxygen}}{\text{Dose to produce the same effect with oxygen}}$$



1. 甲狀腺癌&甲狀腺機能亢進

Thyroid cancer & hyperthyroidism

■ 碘 I-131

週期表

說明

1H
 氫
 1.008

原子序
 元素符號
 元素名稱
 原子量

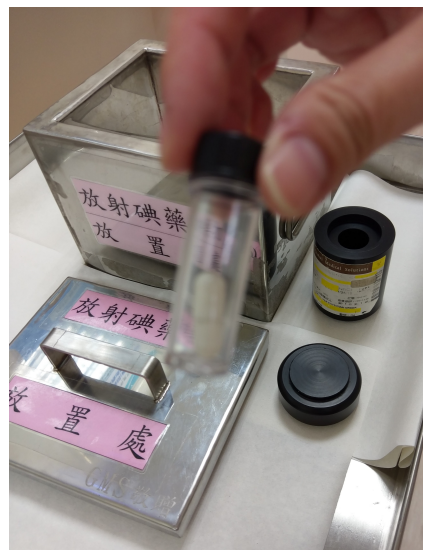
氣體
 液體
 固體
 人造元素

惰性氣體

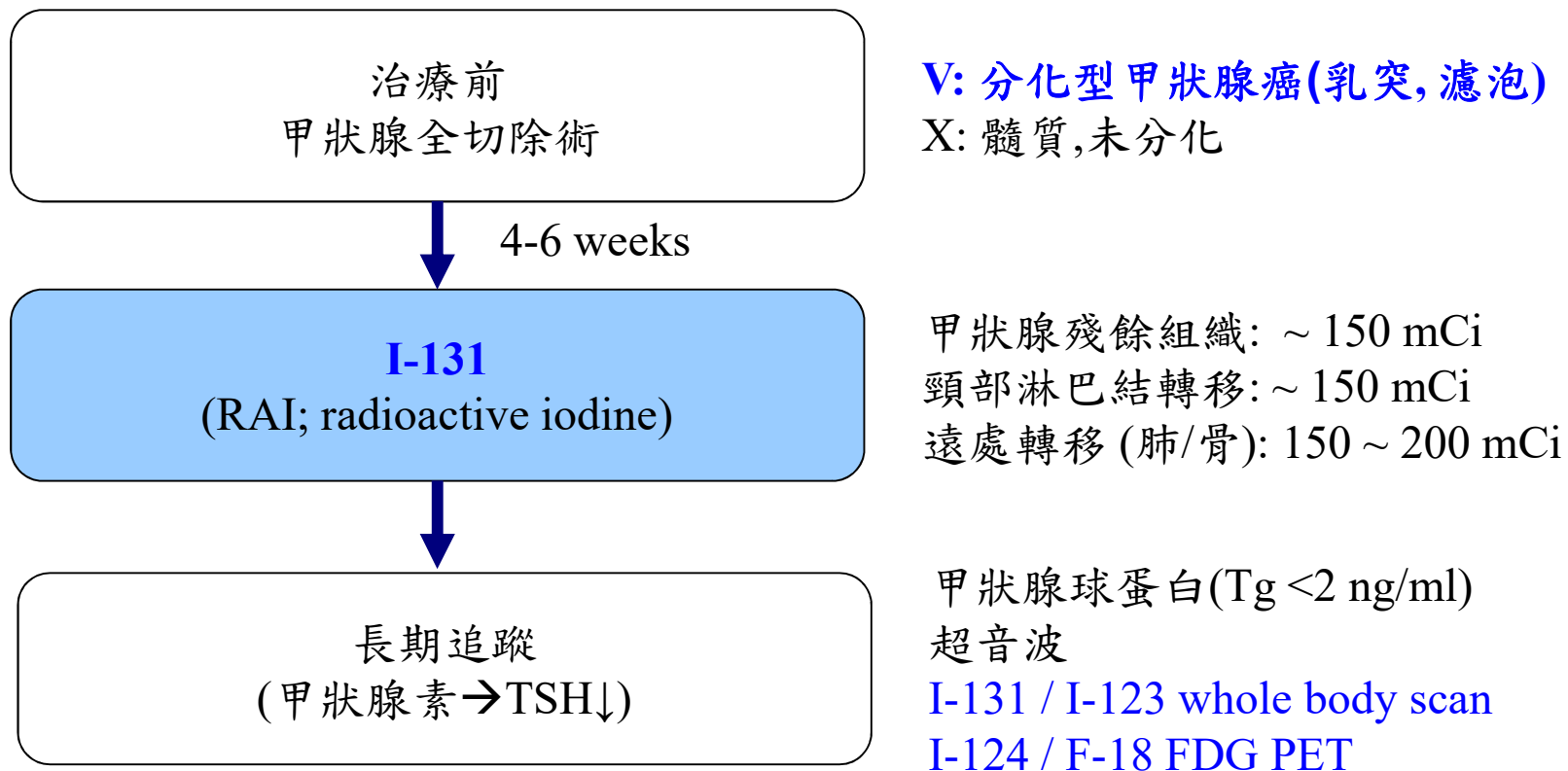
1 IA		金屬										非金屬										18 VIIA							
1 1H 1.008 氫		2 IIA																						18 2He 4.003 氦					
2 3Li 6.941 鋰		4Be 9.012 鈹		過渡元素																				13 5B 10.81 硼	14 6C 12.01 碳	15 7N 14.01 氮	16 8O 16.00 氧	17 9F 19.00 氟	18 10Ne 20.18 氖
3 11Na 22.99 鈉		12Mg 24.31 鎂		3 III B	4 IV B	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 13Al 26.98 鋁	14 14Si 28.09 矽	15 15P 30.97 磷	16 16S 32.07 硫	17 17Cl 35.45 氯	18 18Ar 39.95 氬										
4 19K 39.10 鉀		20Ca 40.08 鈣		21Sc 44.96 鈦	22Ti 47.88 鈦	23V 50.94 鈦	24Cr 52.00 鉻	25Mn 54.94 錳	26Fe 55.85 鐵	27Co 58.93 鈷	28Ni 58.69 鎳	29Cu 63.55 銅	30Zn 65.39 鋅	31Ga 69.72 鎵	32Ge 72.59 鍺	33As 74.92 砷	34Se 78.96 硒	35Br 79.90 溴	36Kr 83.80 氪										
5 37Rb 85.47 銣		38Sr 87.62 銣		39Y 88.91 鈾	40Zr 91.22 鈳	41Nb 92.91 鈳	42Mo 95.94 鉬	43Tc 98.91 鎝	44Ru 101.1 鈷	45Rh 102.9 銑	46Pd 106.4 鈀	47Ag 107.9 銀	48Cd 112.4 鎘	49In 114.8 銦	50Sn 118.7 錫	51Sb 121.8 銻	52Te 127.6 碲	53I 126.9 碘	54Xe 131.3 氙										
6 55Cs 132.9 銻		56Ba 137.3 鋇		57-71 鐳系元素		72Hf 178.5 鈳	73Ta 180.9 鉭	74W 183.9 鎢	75Re 186.2 錒	76Os 190.2 銱	77Ir 192.2 銲	78Pt 195.1 鉑	79Au 197.0 金	80Hg 200.6 汞	81Tl 204.4 鉍	82Pb 207.2 鉛	83Bi 209.0 鉍	84Po (210) 釷	85At (210) 砹	86Rn (222) 氣									
7 87Fr (223) 銣		88Ra (226) 鐳		89-103 鐳系元素		104Unq (261) 鈳	105Unp (262) 鈳	106Unh (263) 鈳	107Uns (262) 鈳	108Uno (265) 鈳	109Une (266) 鈳																		
鐳系元素		57La 138.9 鈳	58Ce 140.1 鈳	59Pr 140.9 鈳	60Nd 144.2 鈳	61Pm 144.9 鈳	62Sm 150.4 鈳	63Eu 152.0 鈳	64Gd 157.3 鈳	65Tb 158.9 鈳	66Dy 162.5 鈳	67Ho 164.9 鈳	68Er 167.3 鈳	69Tm 168.9 鈳	70Yb 173.0 鈳	71Lu 175.0 鈳													
鈳系元素		89Ac (227) 鈳	90Th 232.0 鈳	91Pa (231) 鈳	92U 238.0 鈳	93Np (237) 鈳	94Pu 239.1 鈳	95Am 243.1 鈳	96Cm 247.1 鈳	97Bk 247.1 鈳	98Cf 252.1 鈳	99Es 252.1 鈳	100Fm 257.1 鈳	101Md 256.1 鈳	102No 259.1 鈳	103Lr 260.1 鈳													

	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), 糞便 (some)



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



- 治療前: $\uparrow$ TSH ($>30 \mu\text{IU/mL}$)
 - 低碘飲食 (low iodine diet): 1-2 weeks
 - 停用甲狀腺素 (thyroid hormone withdrawal; THW): 3-4 weeks
 - 基因重組人類甲促素 (recombinant human TSH; rhTSH; Thyrogen): 0.9 mg QD *2 days

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

- 治療釋放：
 - 體外1公尺輻射劑量率: $\leq 70 \mu\text{Sv/h}$ (7 mrem/h)
 - 口服藥物劑量: $\leq 33 \text{ mCi}$ (1.2 GBq)
 - 對家屬會照護者的有效劑量: $\leq 5 \text{ mSv/y}$ (0.5 rem/y)

- 治療後
 - 照相: 4-10 days
 - 補充甲狀腺賀爾蒙: 3-5 days
 - 懷孕: 6-12 months
 - 再次治療: 6-12 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

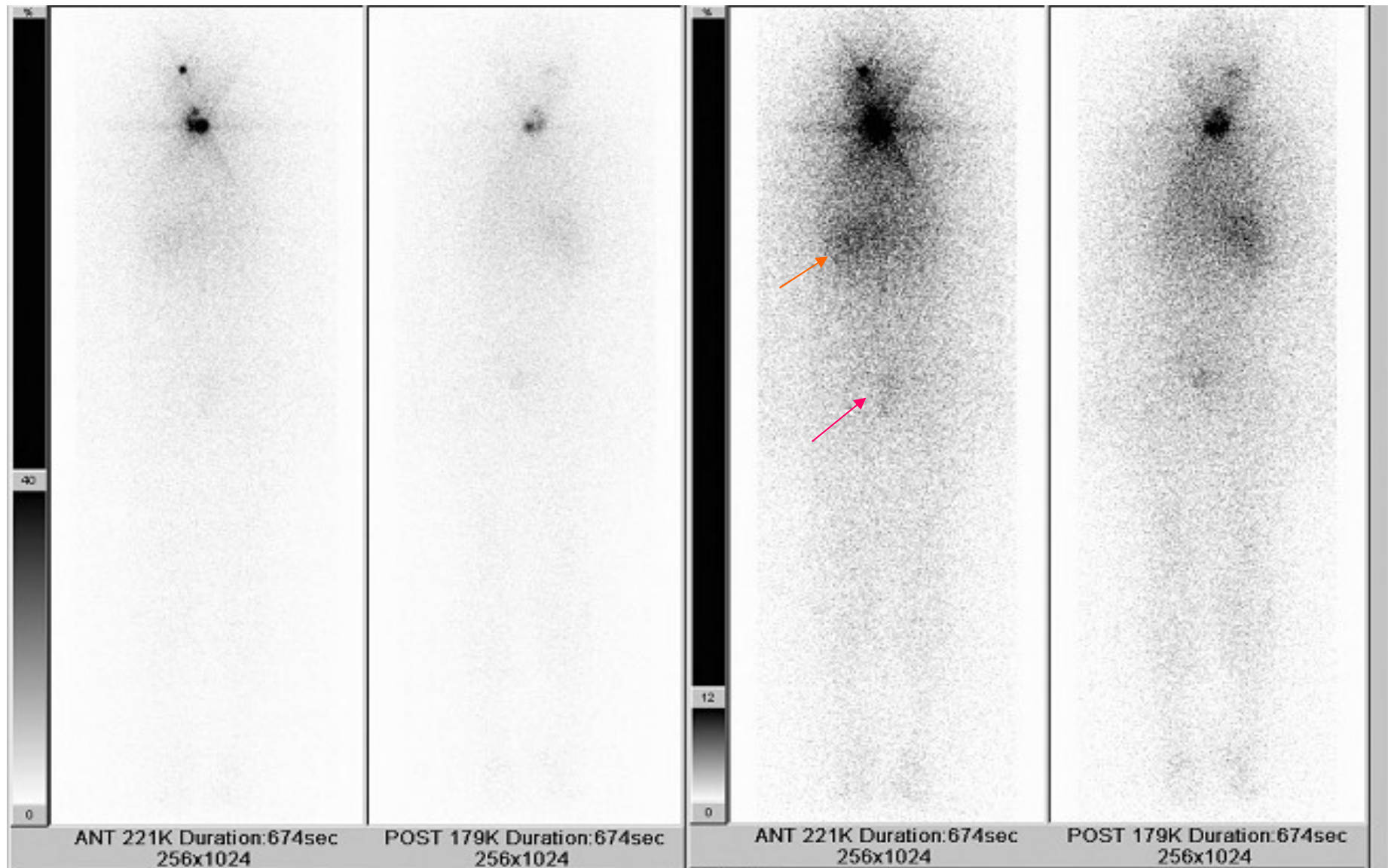
※早期副作用(短暫,輕微)

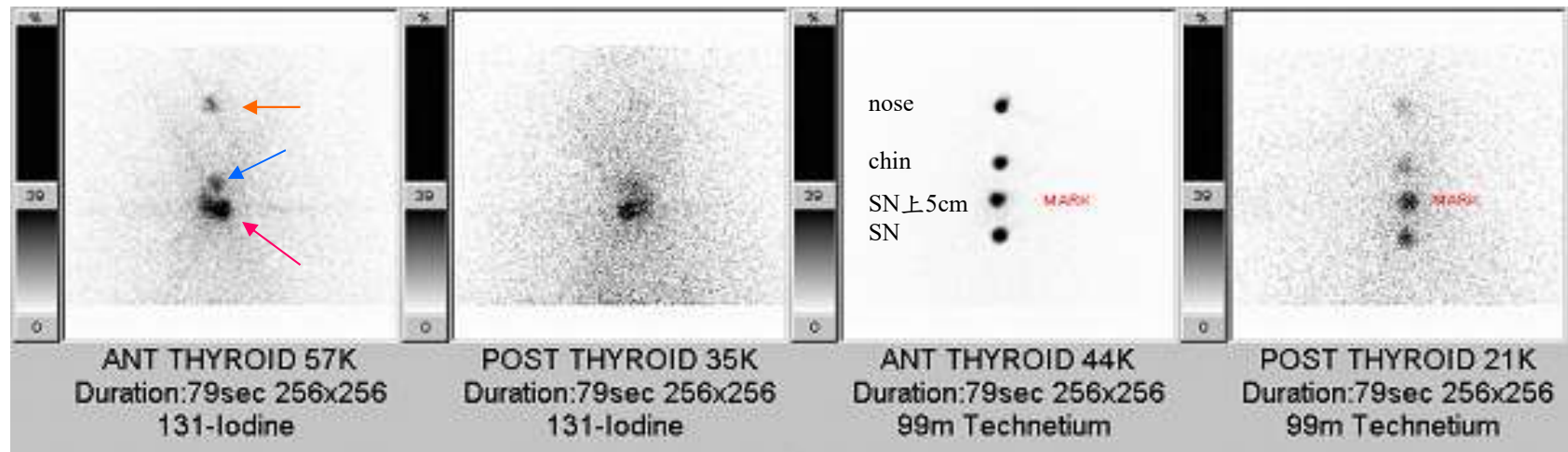
1. 口腔黏膜炎
2. 噁心(rare)
3. 嘔吐 (occasional)
4. 唾液腺炎
5. 喪失味覺
6. 味覺改變(金屬味)(unusual)
7. 甲狀腺炎(脖子疼痛&腫脹)
8. 白血球/血小板↓
→↑感染or出血

※晚期副作用

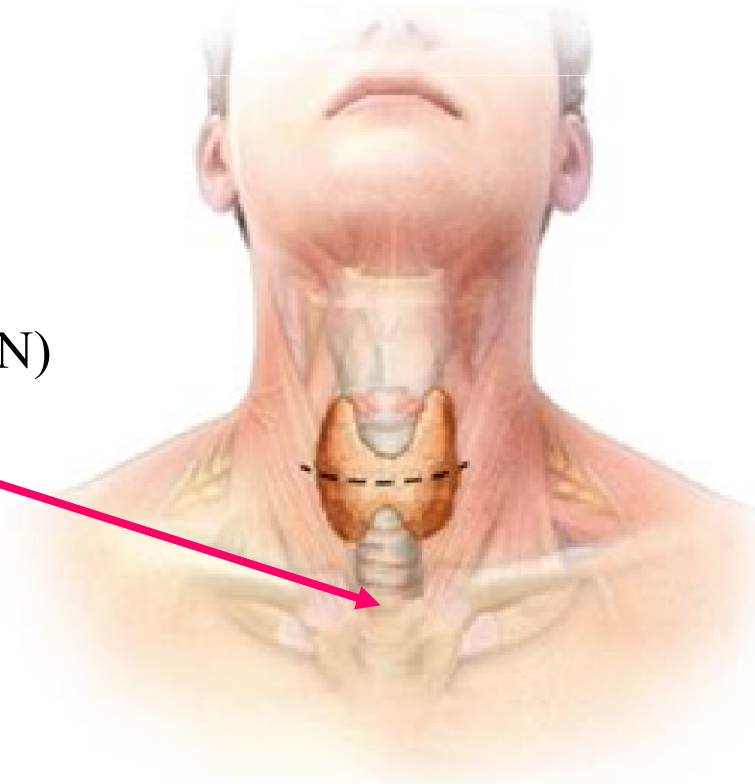
1. 不孕
2. 永久性唾液腺損傷:
 - 口乾
 - 唾液腺結石
 - 過度齲齒
 - 味覺障礙
 - 結膜乾燥
 - 溢淚
3. 癌症:
 - 胃癌
 - 膀胱癌
 - 大腸癌
 - 唾液腺癌
 - 黑色素瘤
 - 白血病

52歳♀,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. 胸骨切迹上5cm
4. 胸骨切迹(sternal notch; SN)



碘Iodine-131 (^{131}I -NaI)

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

治療前
抗甲狀腺藥物.手術切除

T3, T4, TSH, anti TSH receptor Ab
I-131/I-123/Tc-99m uptake & scan

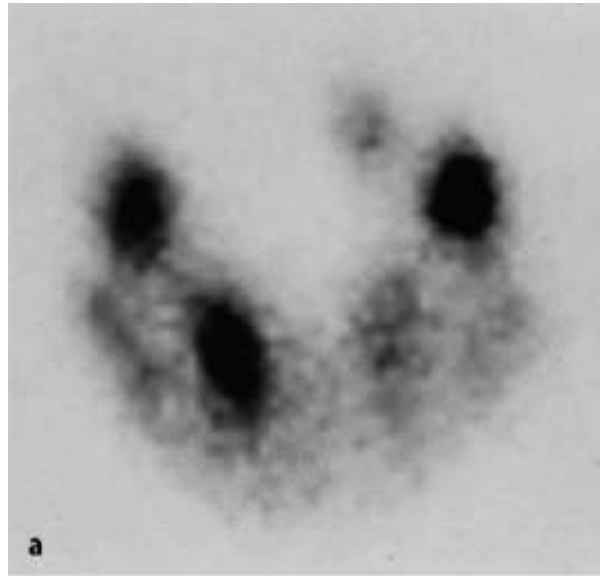
I-131
(RAI; radioactive iodine)

80-220 $\mu\text{Ci/g}$
Graves disease: 10-15 mCi
Nodular goiter: 20-30 mCi

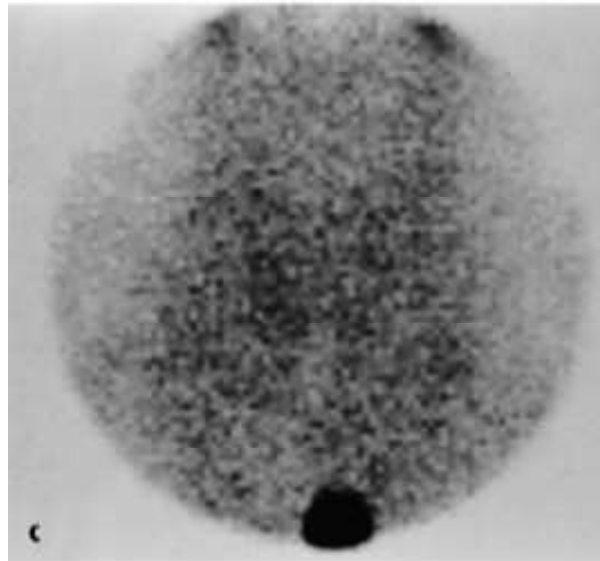
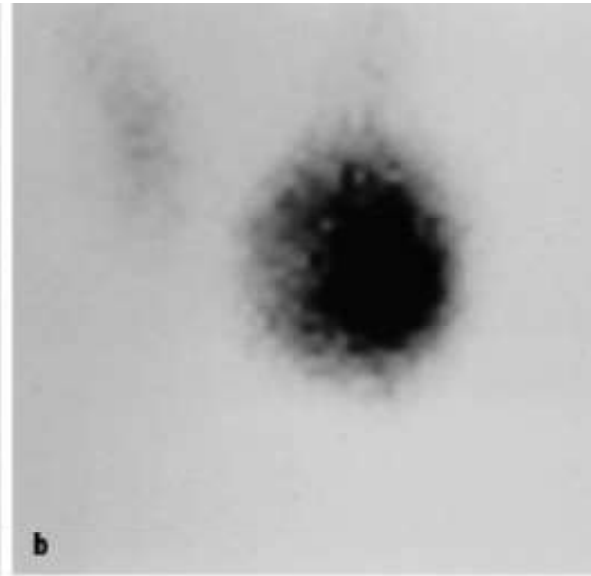
長期追蹤

甲狀腺機能低下
補充甲狀腺素

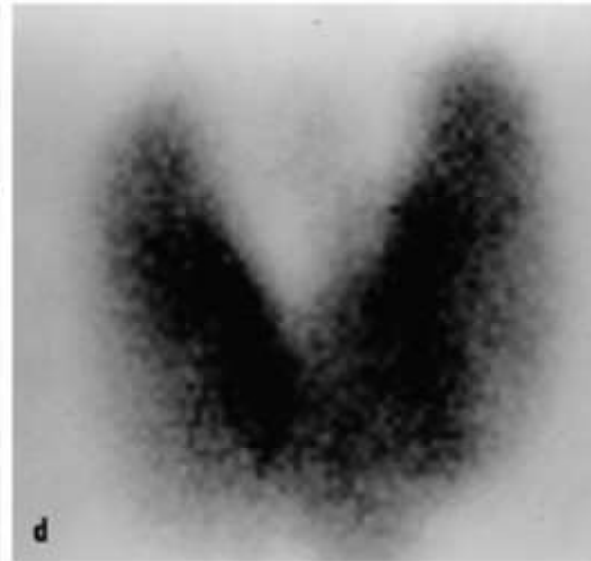
✓ 結節性甲狀腺腫
Multinodular goiter



孤立性高功能甲狀腺結節 ✓
Solitary hyperfunctioning thyroid nodule



甲狀腺炎 Thyroiditis



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

- 無證據顯示:

1. 增加甲狀腺癌或其他癌症風險
2. 增加不孕症風險
3. 增加出生缺陷風險



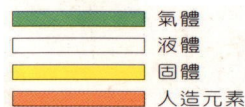
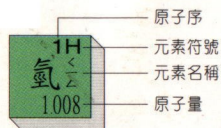
2. 骨轉移

Bony metastasis

- 銥 Sr-89
- 鐳 Ra-223
- 釷 Re-186/Re-188
- 釷 Sm-153
- 錫 Sn-117m
- 磷 P-32 (真性紅血球增多症)

週期表

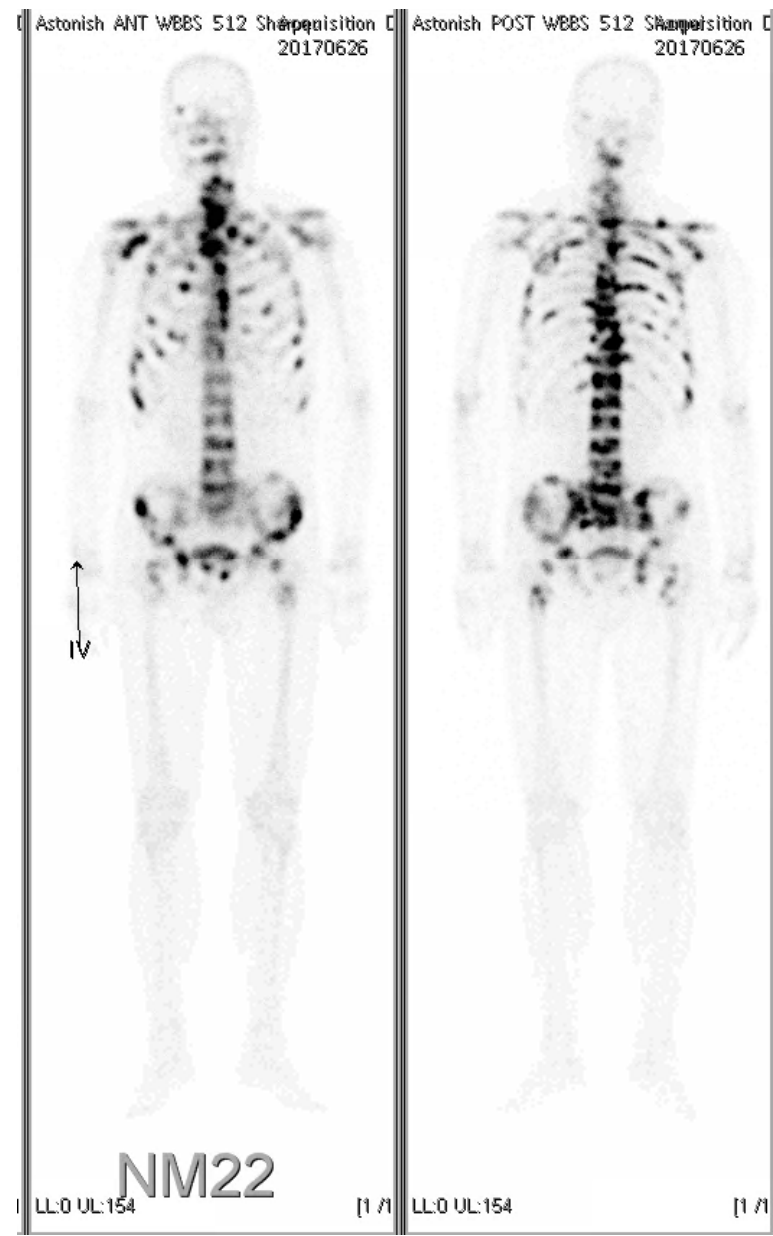
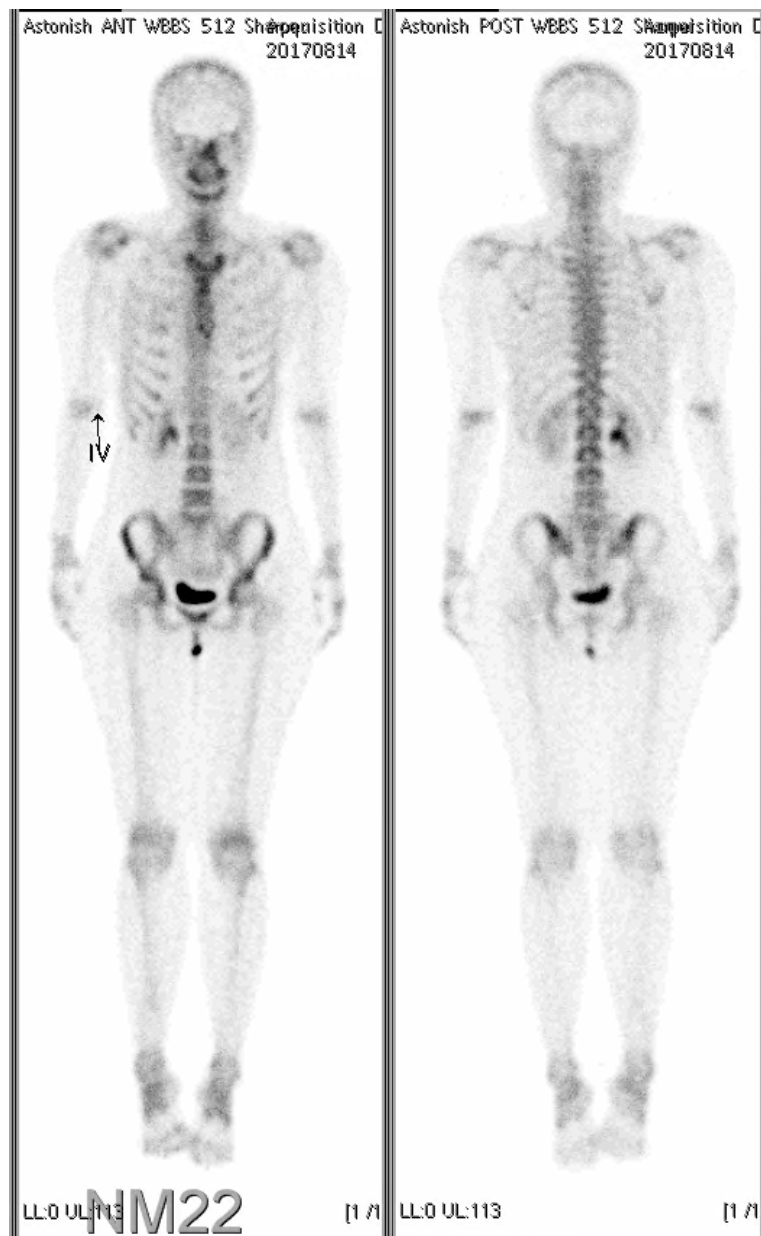
說明



説明																		元素名		原子量		固體		人造元素		惰性氣體																																									
1																		2		3																		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18	
I A																		II A		III B																		IV B		V B		VI B		VII B		VIII B		VIII B		VIII B		I B		II B		III A		IV A		V A		VI A		VII A		VIII A	
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正常

骨轉移 



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 μm	159
²²³ Ra	11.4 d	5.78 (α) (average)		<10 μm	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. 鍶 Strontium-89 ($^{89}\text{SrCl}_2$)

※ Half-life: 50.5 d (最長)

※ No γ emission

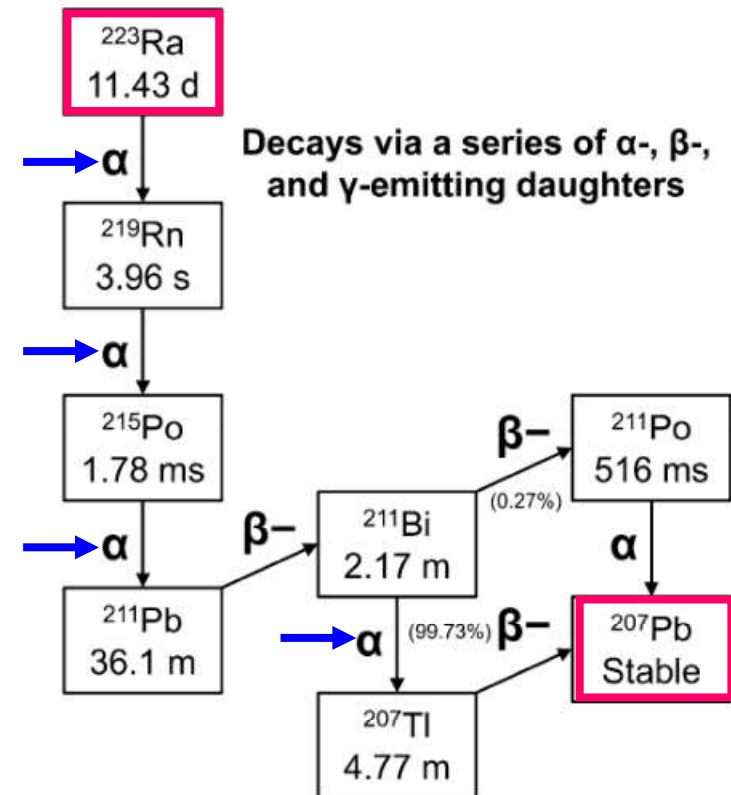
- β emission
- Maximum energy: 1.4 MeV; Mean energy: 0.583 MeV
- Maximum range: 7 mm

- 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.

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

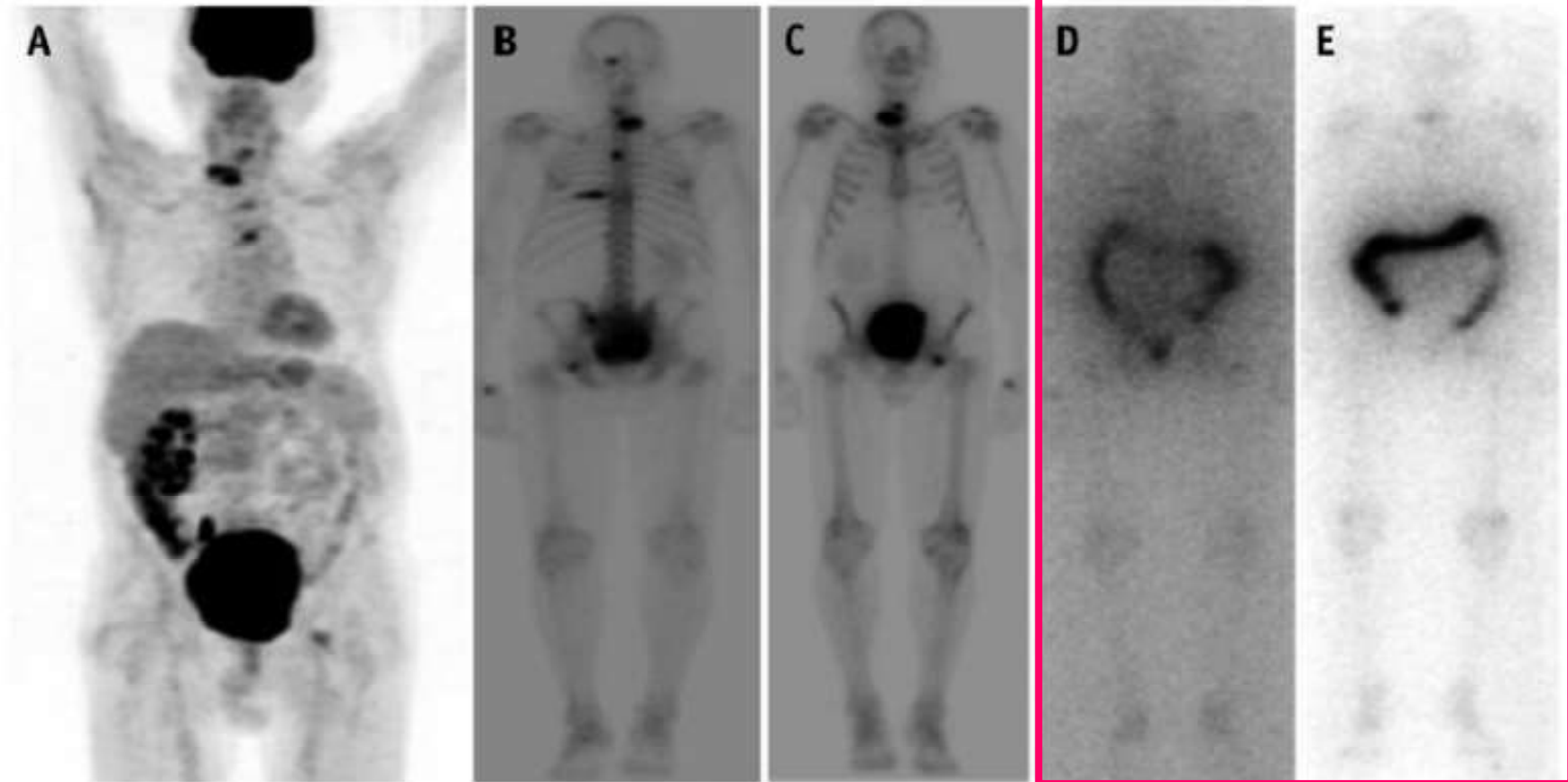
- Half-life: 11.4 d
- γ emission or X-ray (154 keV, 1.1%)
- β emission (3.6%)
- α emission (95.3%)
- Maximum energy: 5.78 MeV (average)
- Maximum range: $<10\mu\text{m}$
- Usual administered activity: 50-200 kBq/kg
- Typical response time: <10 d
- Typical response duration: ?
- Retreatment interval: ?
- Actinium-227 generator
- Excretion is predominantly via the gastrointestinal tract.
- Tumor-to-marrow ratio: 30:1

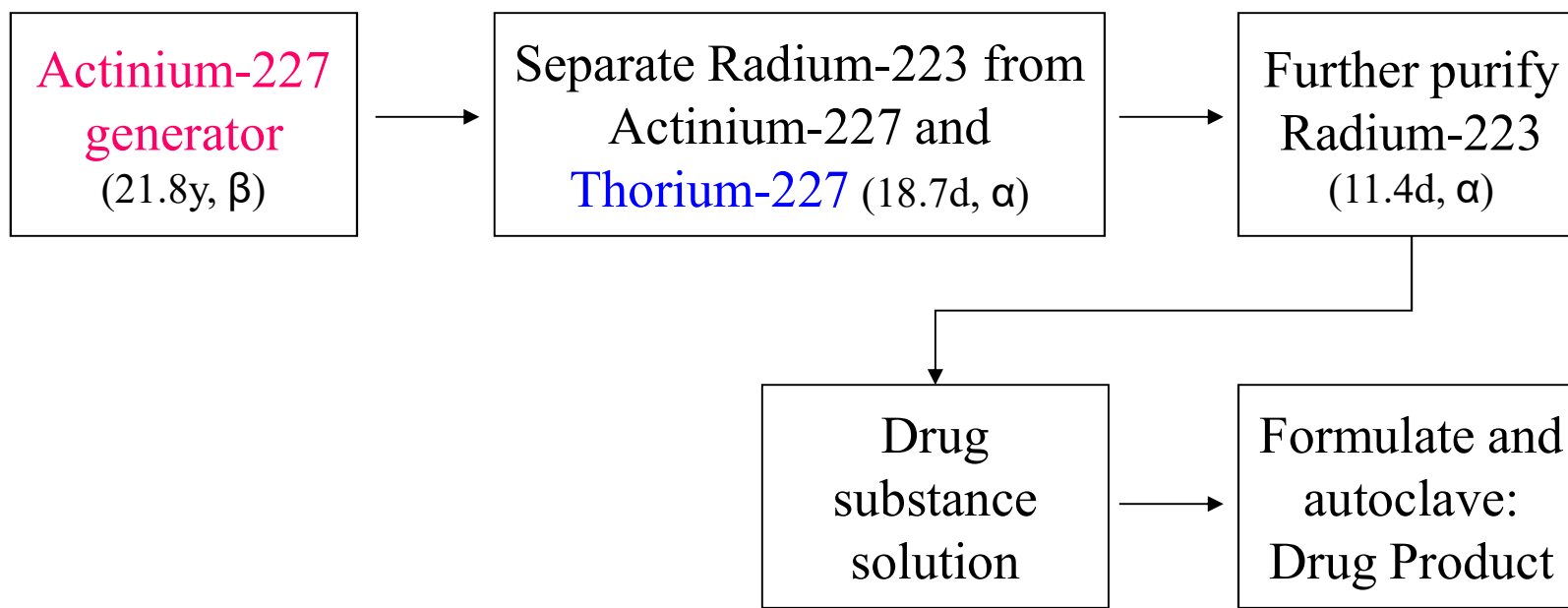


(A) FDG PET scan

(BC) MDP bone scan

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





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 (1100 kBq/mL) at reference date

*Shelf-life: 28 days

NCCN guidelines Version 2. 2017

- 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
- 噁心
- 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

3. 銼 Rhenium-186 & 188 (^{186}Re -HEDP & ^{188}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. 釷 Samarium-153 (^{153}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: $<1\mu\text{m}$ (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. 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) ($74\text{--}111\text{ MBq/m}^2$; $2\text{--}3\text{ mCi/m}^2$)



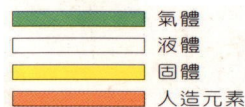
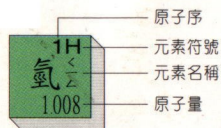
3. 肝癌&肝轉移

Hepatoma & liver metastasis

- 釔 Y-90 microsphere

週期表

說明



惰性氣體

18

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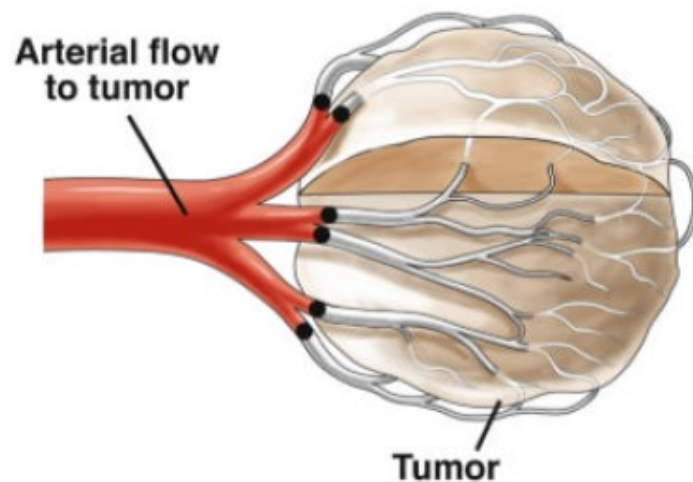
釔 Yttrium-90 microsphere (SIR-Spheres/TheraSphere)

- 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)
- $^{89}\text{Y}(n,\gamma)^{90}\text{Y}$, $^{90}\text{Sr}/^{90}\text{Y}$ generator
- Microsphere:
 - 樹脂resin: 20-60 μm
 - 玻璃glass: 20-30 μm
vs. MAA: 10-90 μm
vs. Sulfur colloid: 0.1-1 μm
- 禁忌症: 門靜脈栓塞

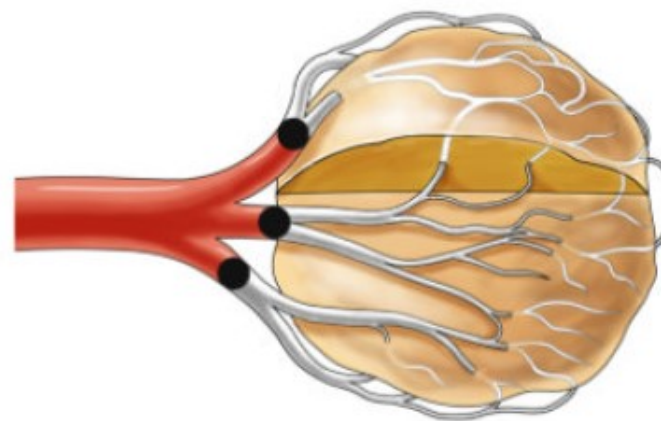
產品名稱	SIR-Spheres	TheraSphere
生產廠商、城市、國家	Sirtex Medical, Sydney, Australia	MDS Nordion, Ottawa, Canada
成份	樹脂	玻璃
Y-90微球生產	與樹脂結合，附著在球體表面	嵌入玻璃基質中
球體大小(μm)	20-60 (32.5 ± 2.5)	20-30 (25 ± 5)
每個微球活性(Bq)	40-70	2,500 (在參考時間)
每GBq的球體數量(百萬)	20 (平均)	0.4 (在參考時間)
保存期限(shelf-life)	1天	12天
比重(specific gravity)	低 (1.6 g/cc)	高 (3.6 g/cc)
栓塞效果	中等	輕微
可用活性(GBq)	3	3, 5, 7, 10, 15, 20
每瓶藥的球體數量(百萬)	40-80	1.2-8 (在校準時)

產品名稱	SIR-Spheres	TheraSphere
適應症	•美國：肝癌；美國以外(特別是歐洲和澳洲)：無法切除的肝臟腫瘤(肝癌和轉移) •大腸直腸轉移伴有肝內氟尿苷(floxuridine)等化學藥物治療效果不佳	•美國：大腸直腸癌；美國以外(特別是歐洲和澳洲)：肝癌和轉移 •肝癌伴有適當擺位的導管
配藥	需要	不需要
一藥瓶給兩個以上患者	可能	不可能
顯影劑導引藥物注射	需要	不需要
劑量計算	•Empirical •BSA •Partition or multi-compartmental method	•Mono-compartmental MIRD (partitional)
給藥途徑	經肝動脈導管 Hepatic ports (罕見)	經肝動脈導管
離院時的特殊輻防措施	可能有尿液污染	無

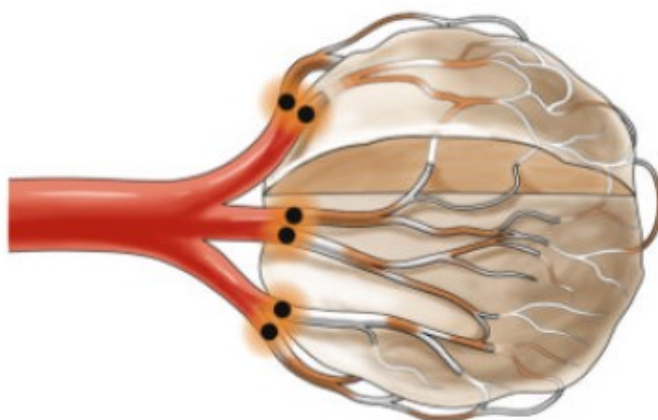
Arterial embolization
(TAE) 100-300 μm



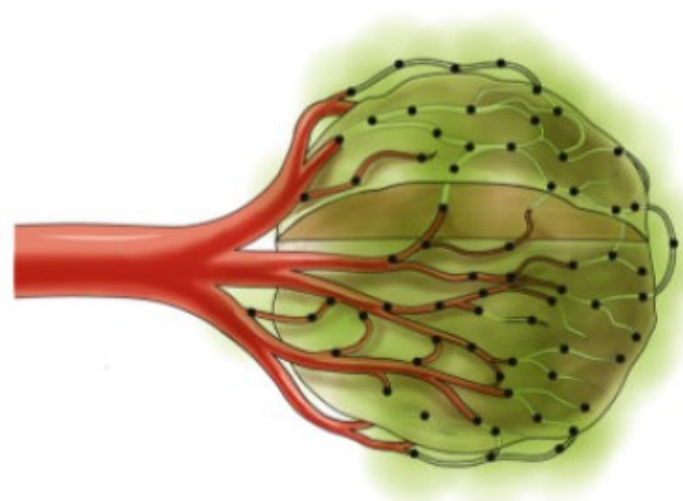
Conventional chemoembolization
(cTACE) 300-500 μm



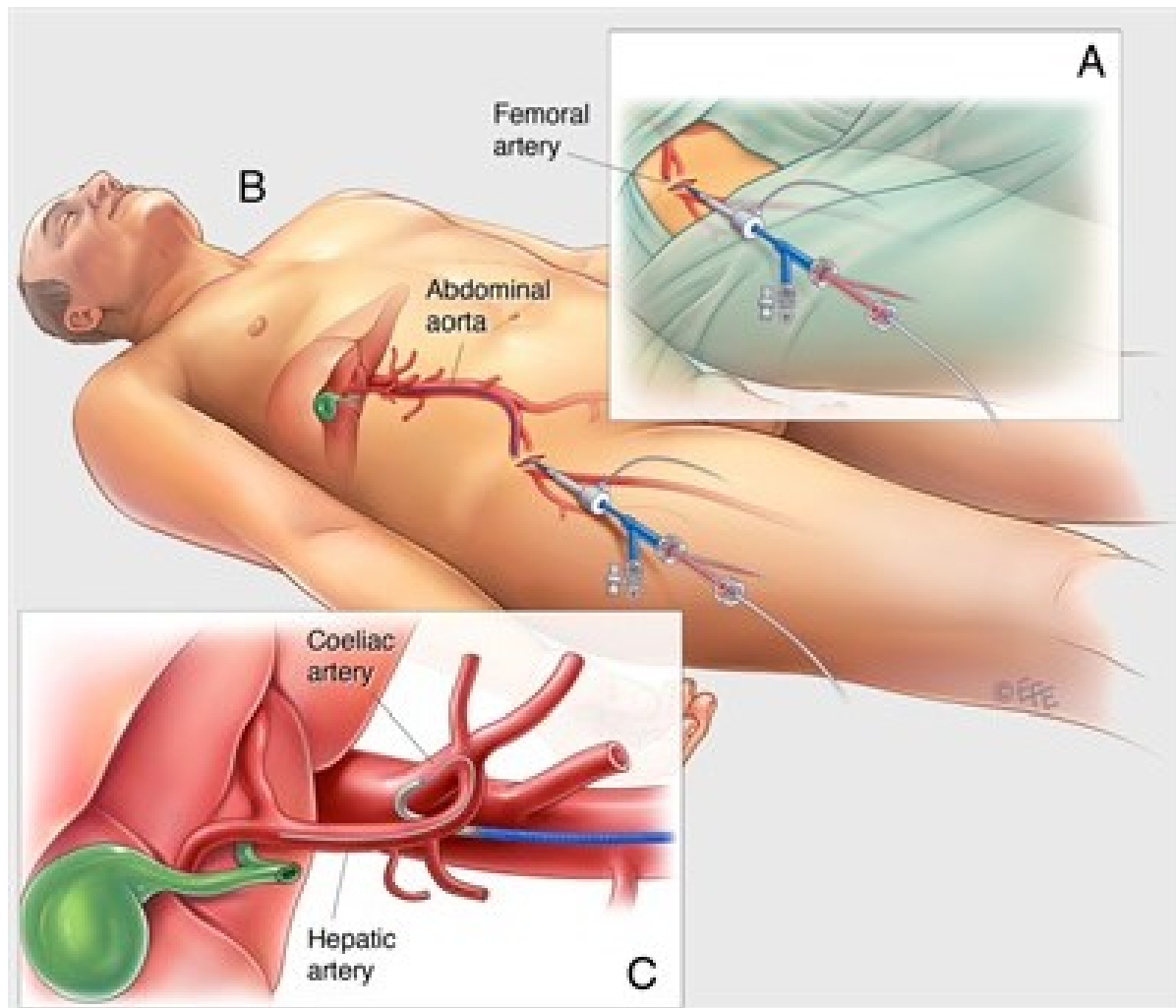
Drug-eluting bead chemoembolization
(DEB-TACE) 100-300 μm



Radioembolization
(TRE) 20-60 μm



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



將樹脂微球由運送瓶取出(左)，以壓克力圓柱型套筒將樹脂微球由瓶內抽取出來，再置入執行治療瓶中(右)。



透過器械與生理食鹽水注射，將釷-90樹脂微球經由動脈導管注射進入肝臟腫瘤。

(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)

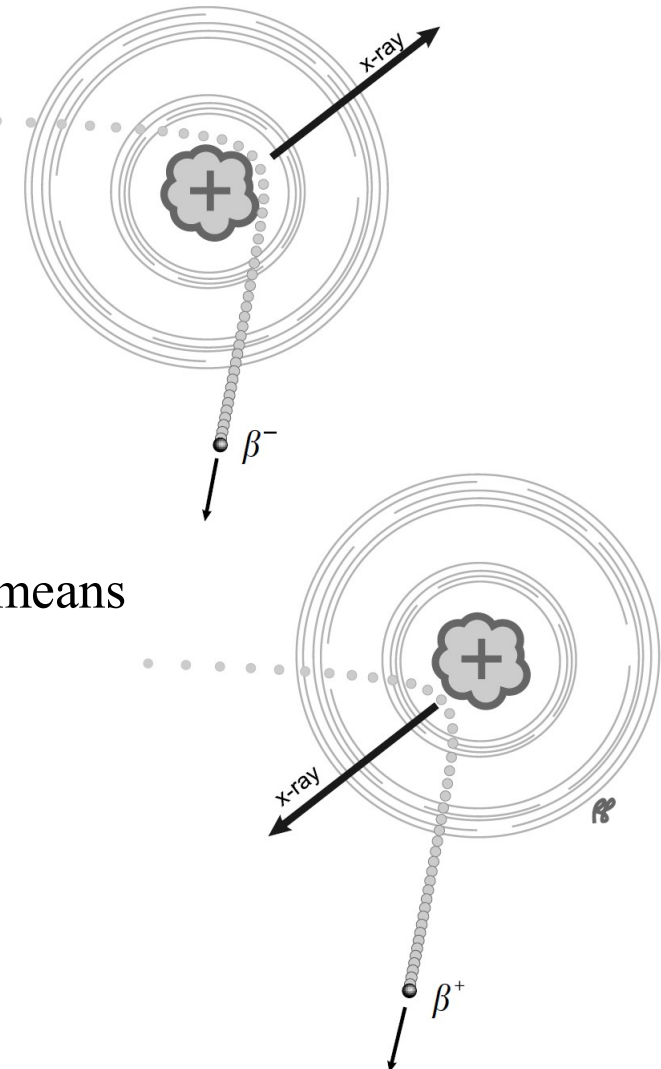
very slow infusion rate (avoid reflux into gastroduodenal artery)

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

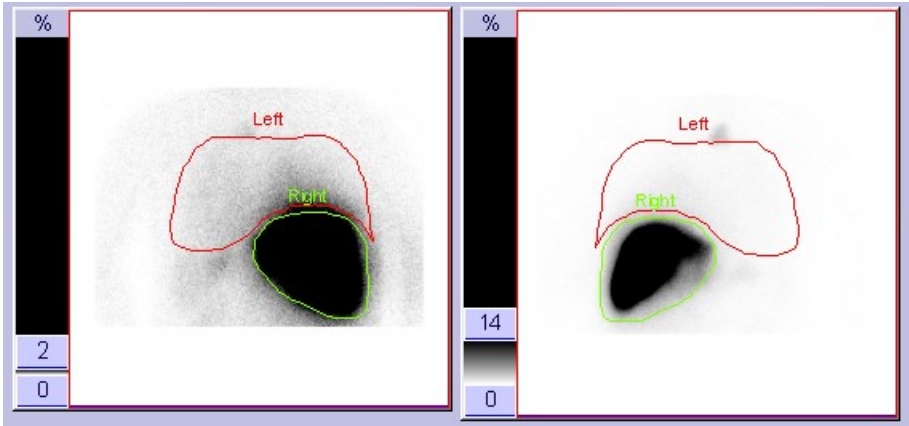
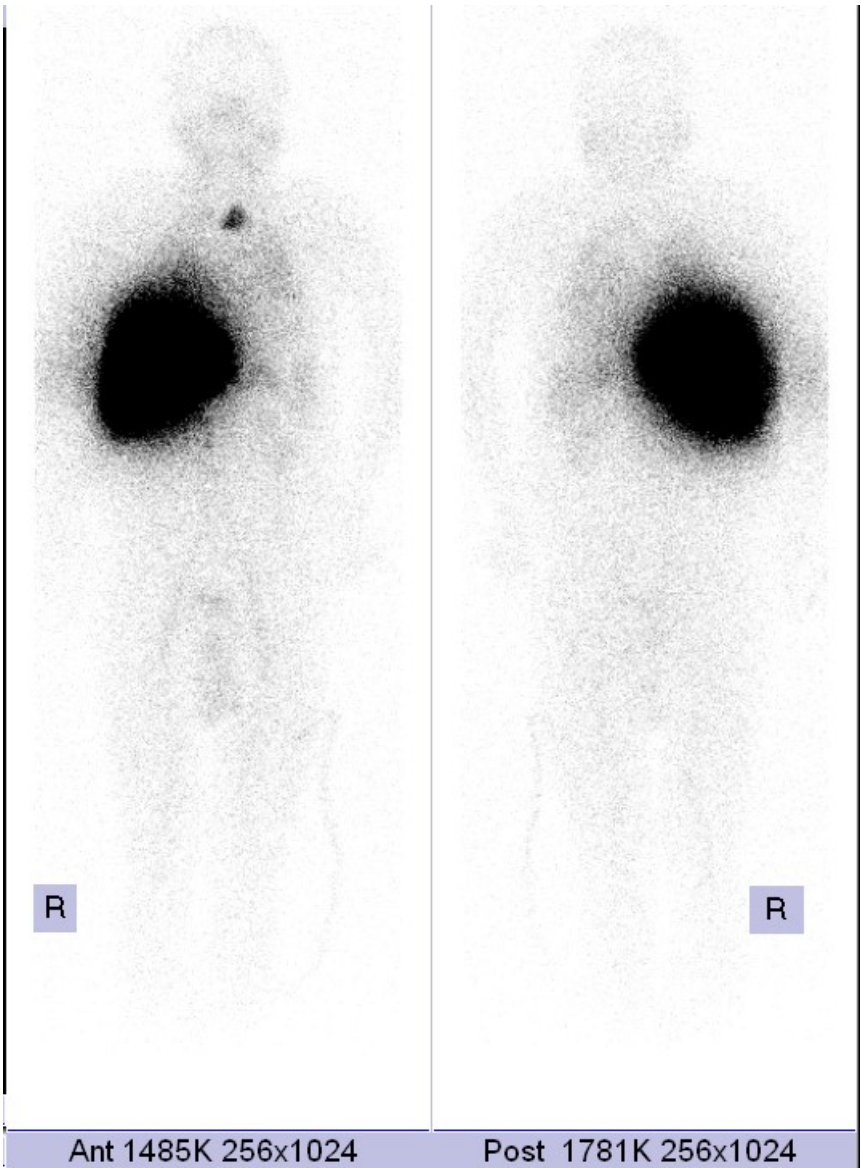
2. 副作用: 噁心, 腹痛, 食慾降低, 疲累, 發燒

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		
POST		
(Counts)	Left	Right
Total	134K	3861K
(% Ratios)	Left	Right
Total	3.36	96.64
ANT		
(Counts)	Left	Right
Total	149K	3165K
(% Ratios)	Left	Right
Total	4.50	95.50

Geometric Mean		
(Counts)	Lung	Liver
Total	139K	3454K
(% Ratios)	Lung	Liver
Total	3.87	96.13

腫瘤正常組織吸收比(T/N ratio)

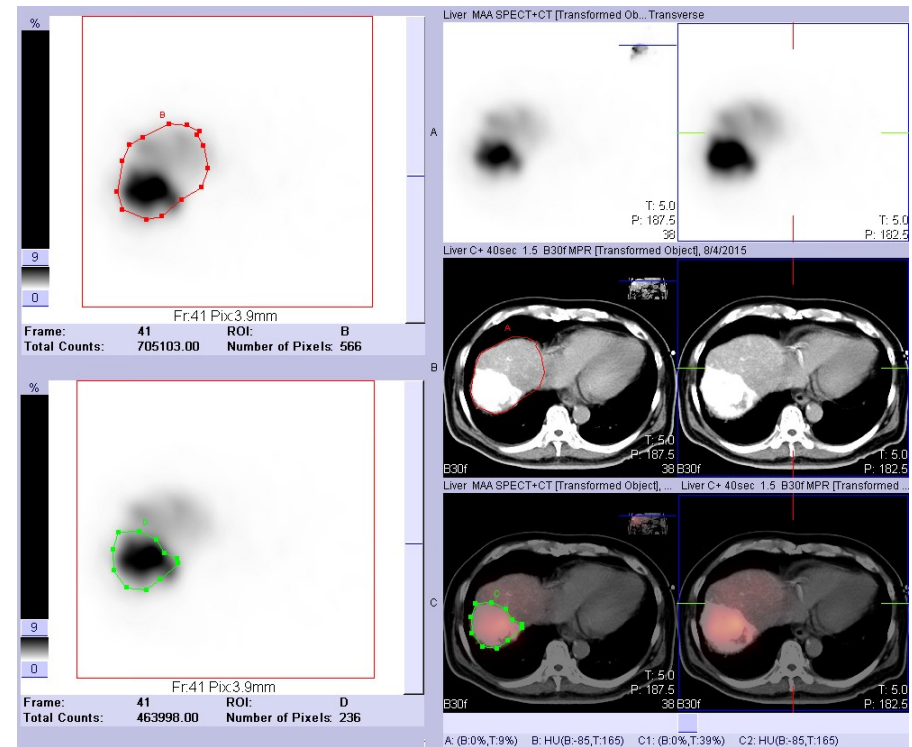
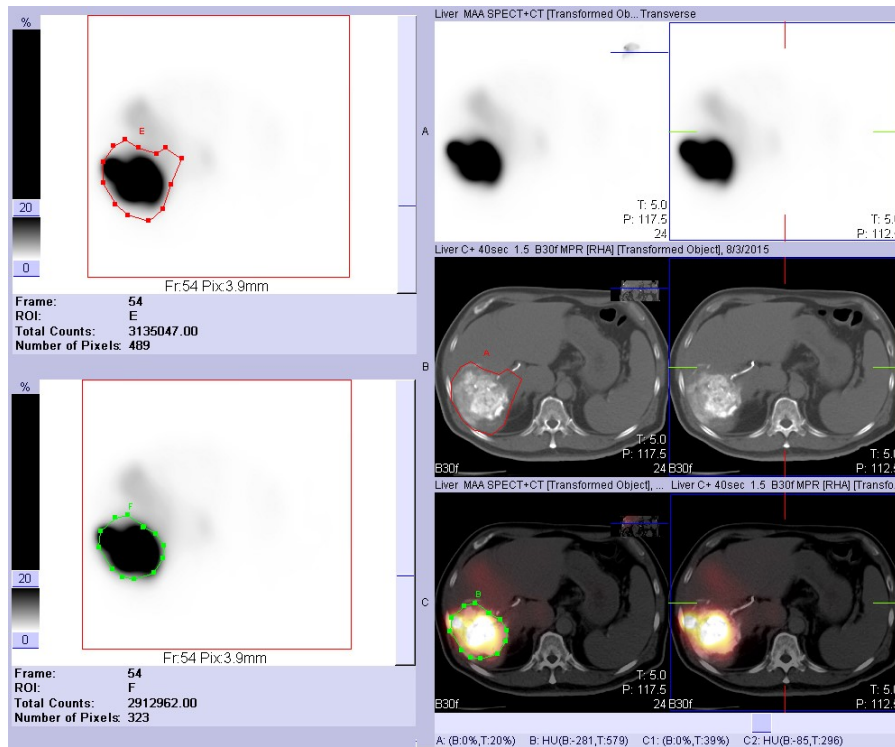
6.17 in RHA territory

3.5 mCi

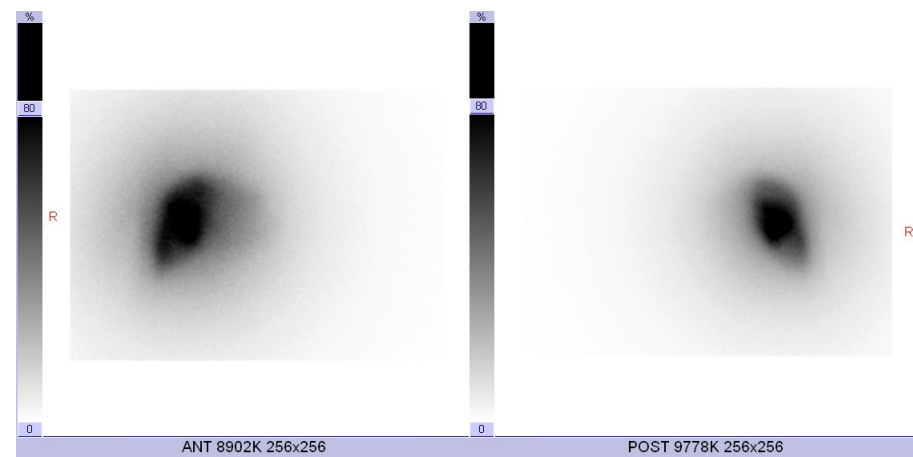
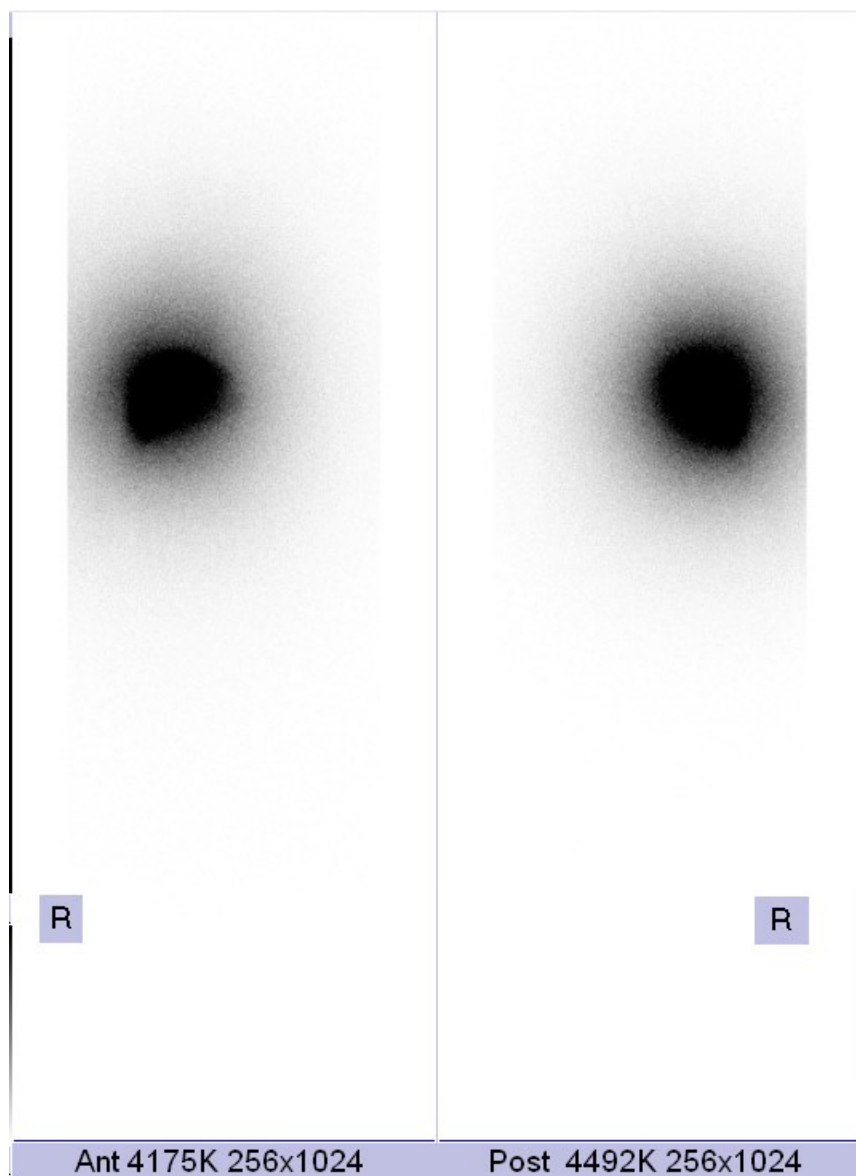
^{99m}Tc -MAA

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)

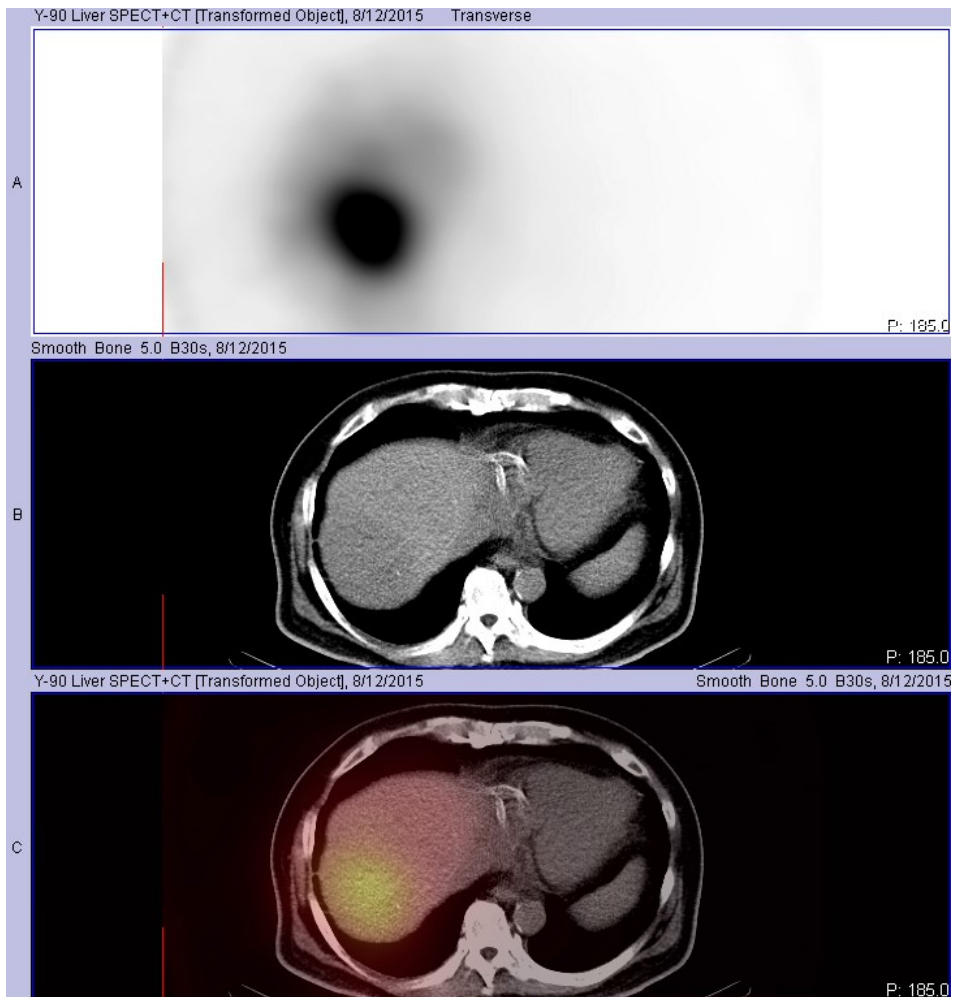
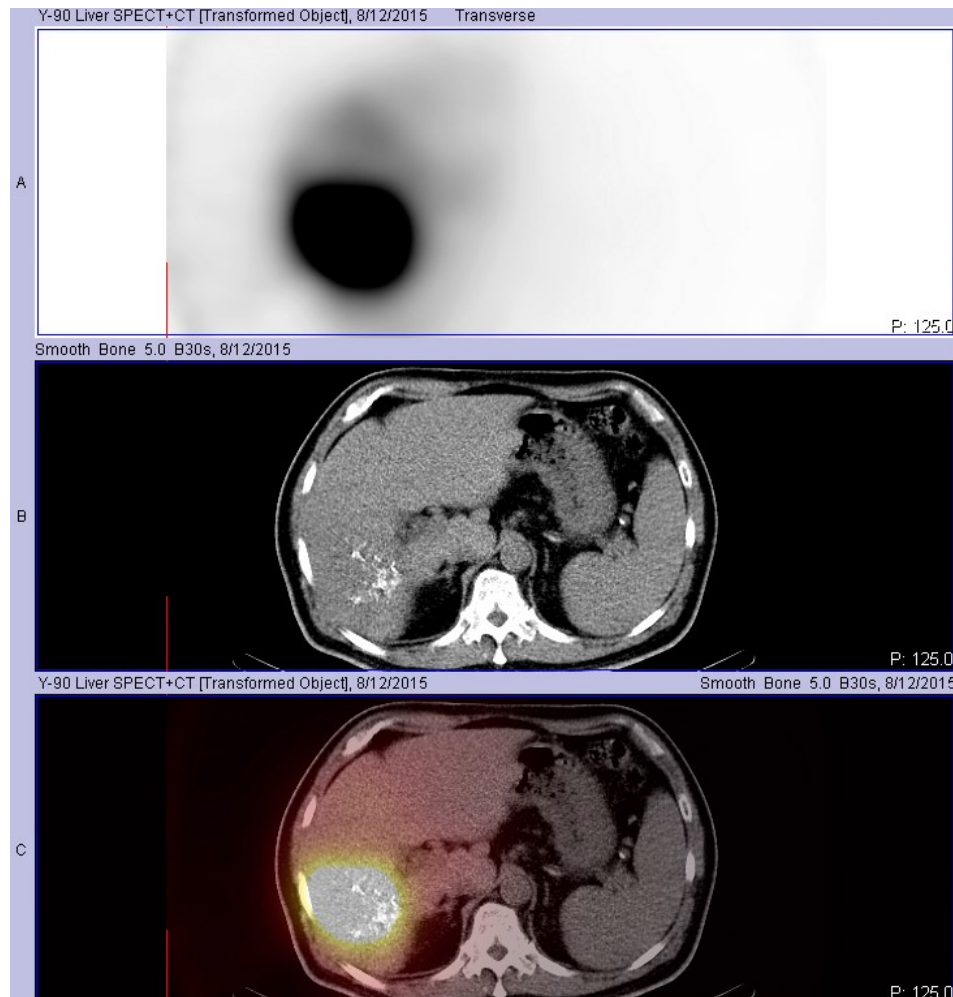
6.17 in RHA territory

3.26 in LHA territory

1.9 GBq

Y-90 microsphere

1.13 GBq





4. 淋巴瘤

Lymphoma

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

週期表

說明

1H
 氫
 1.008

原子序
 元素符號
 元素名稱
 原子量

氣體
 液體
 固體
 人造元素

惰性氣體

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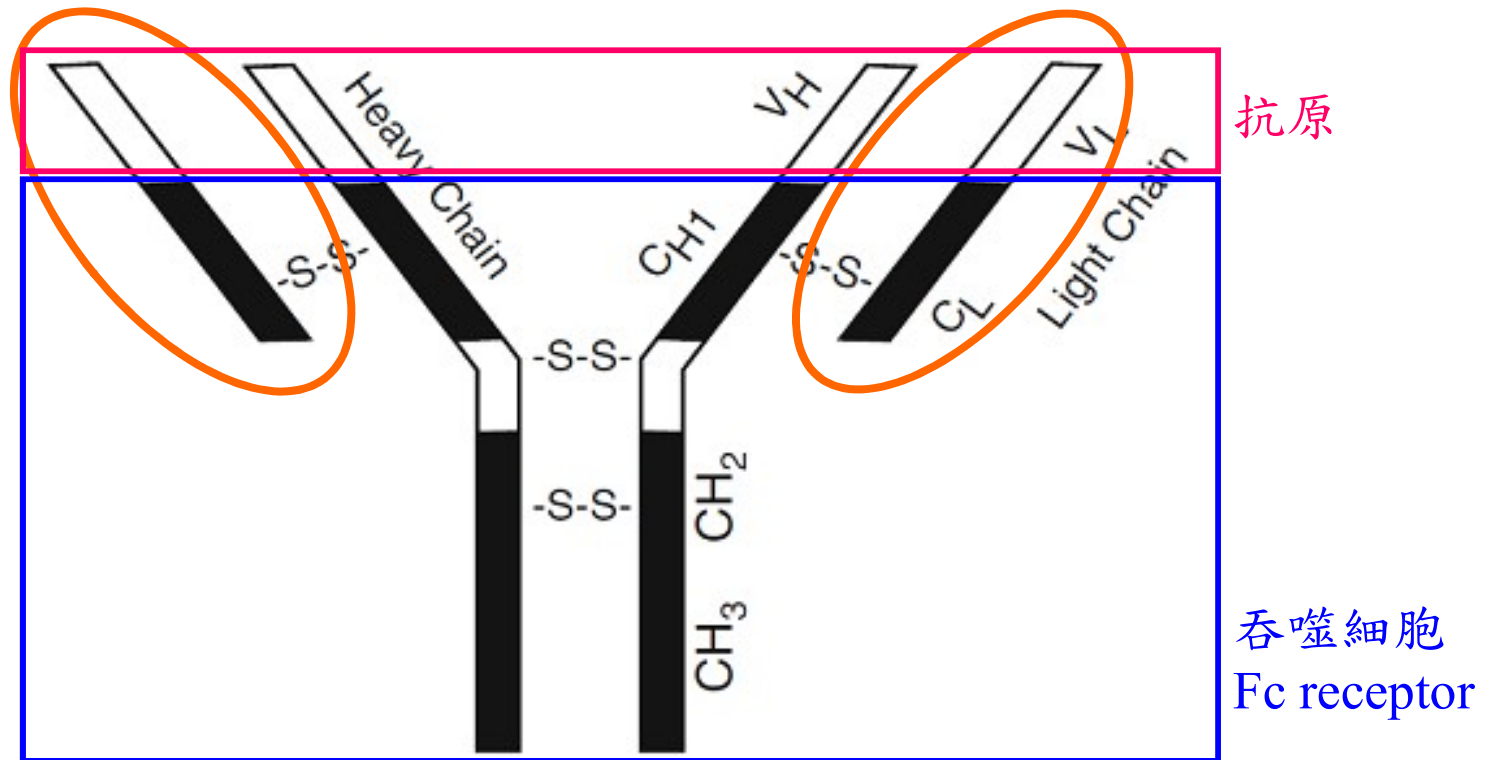
抗體

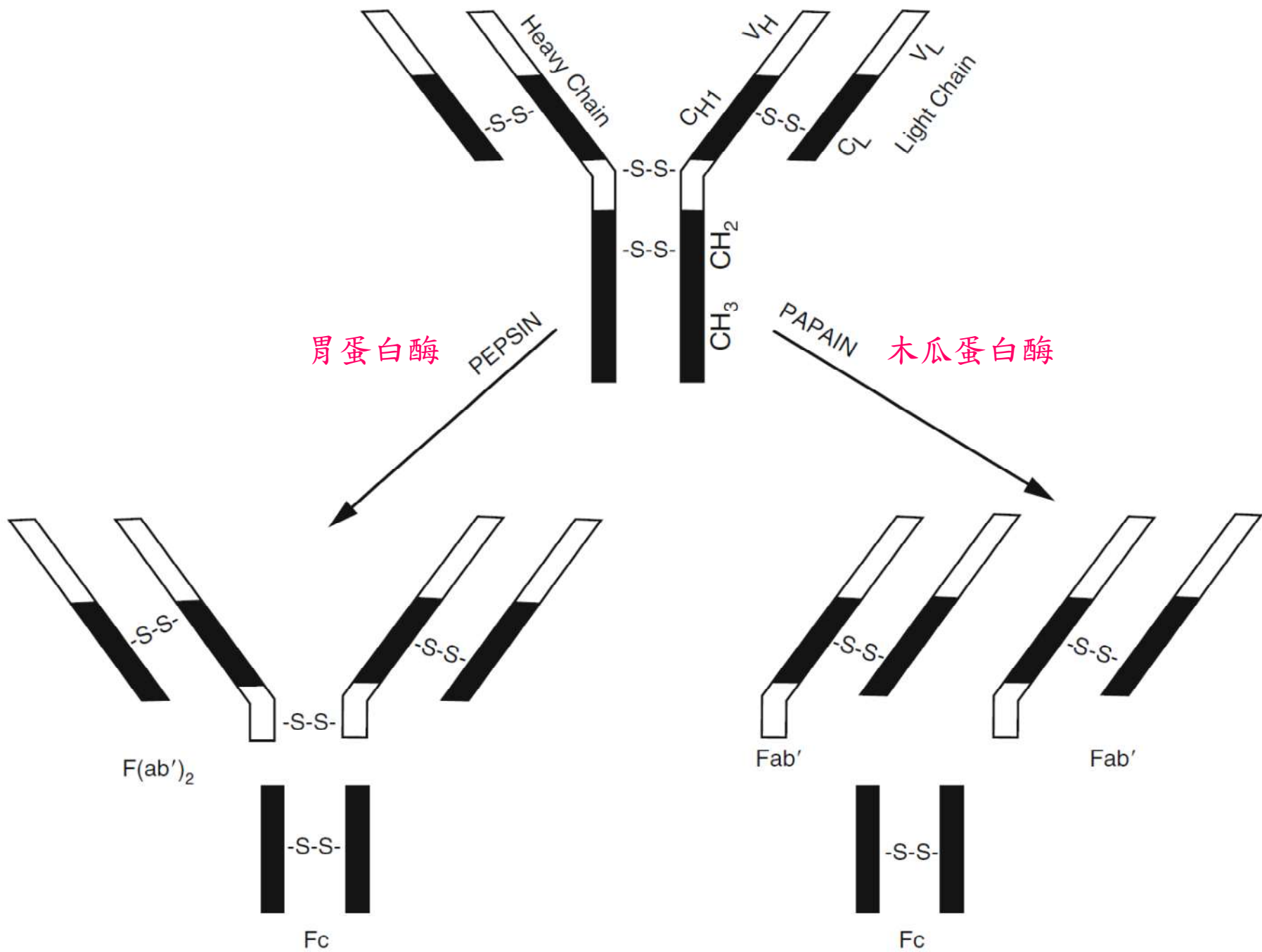
H: 重鏈

L: 輕鏈

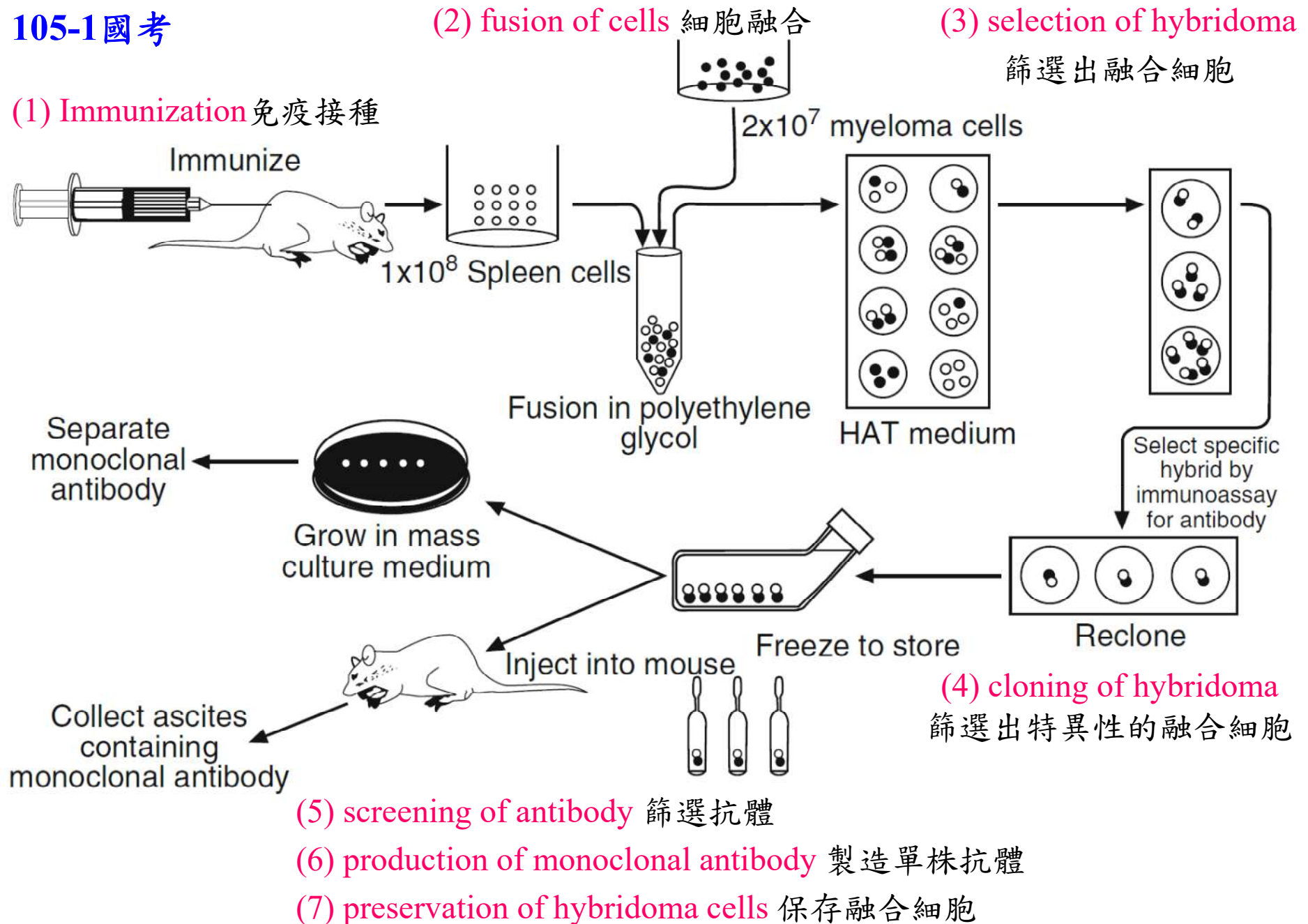
V: 可變區

C: 固定區





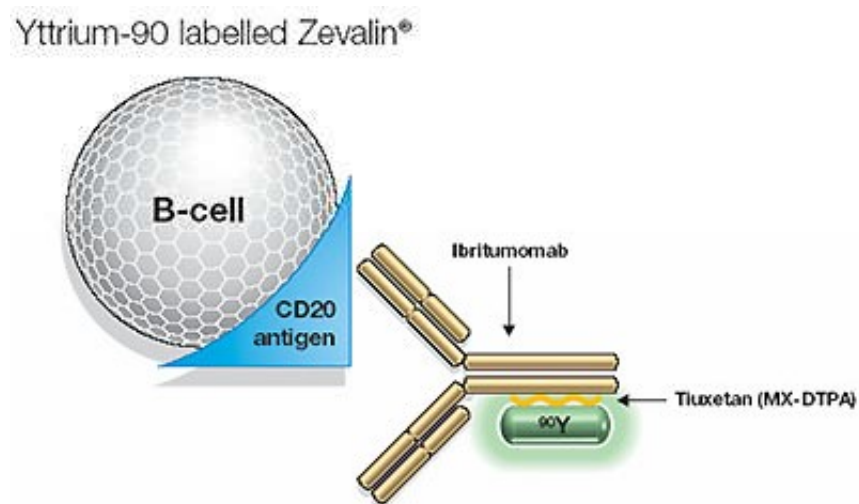
105-1國考



釷 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)
- $^{89}\text{Y}(n,\gamma)^{90}\text{Y}$, $^{90}\text{Sr}/^{90}\text{Y}$ generator



放射標幟單株抗體

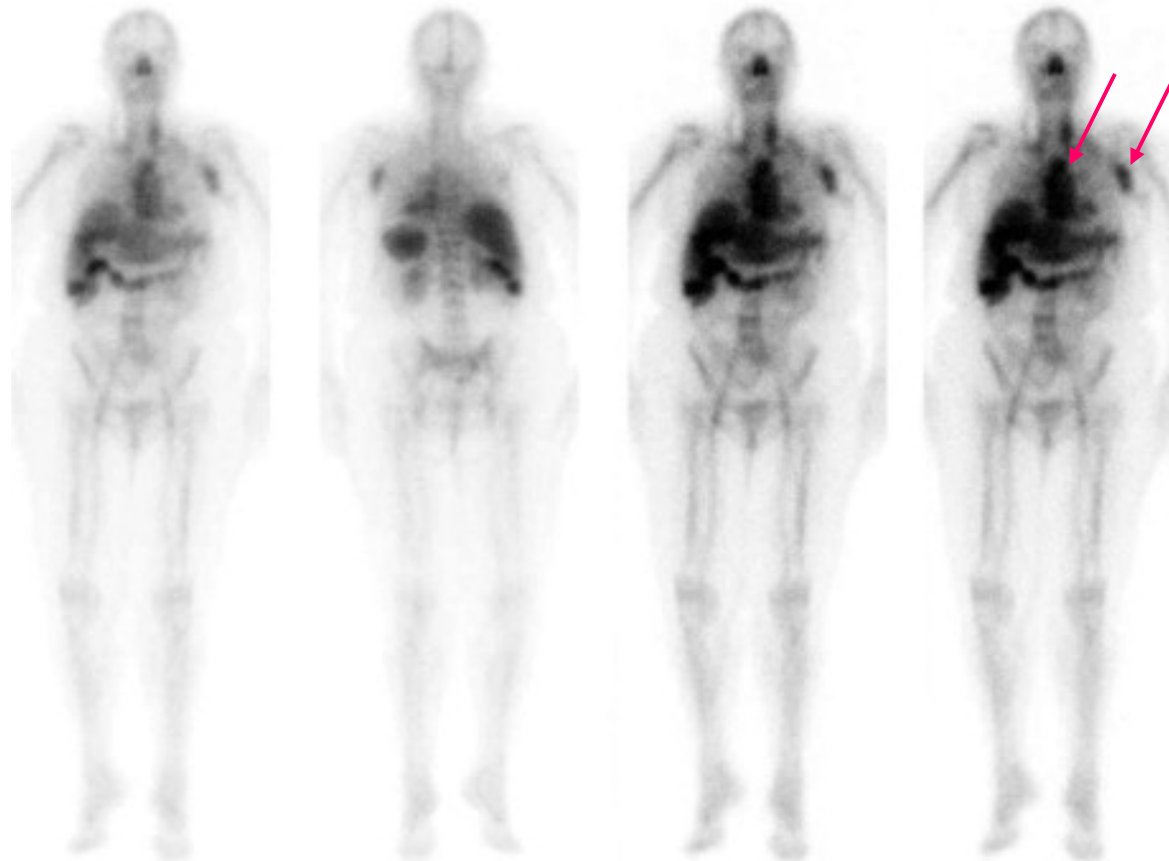
藥品(-mab)	儲存溫度	標幟效率	使用期限	臨床應用	備註(抗原-抗體複合物之形成)
^{111}In -capromab pendetide (ProstaScint)	室溫	90%	8 hr	診檢初期的及轉移的前列腺癌	Mab 7E11.C5.3
^{111}In -ibritumomab tiuxetan		>95%		造影(預測 ^{90}Y -Zevalin治療劑量在身體內的分佈)	Anti-CD20 Ab
^{90}Y -ibritumomab tiuxetan (Zevalin)		>95%		治療(non-Hodgkin's lymphoma)	Anti-CD20 Ab
$^{99\text{m}}\text{Tc}$ -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)

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%), 顫抖(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 $>^{D1}$ cardiac blood pool
(2) diffuse lung/kidney/intense bowel $>^{D2/3}$ liver





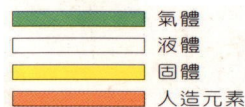
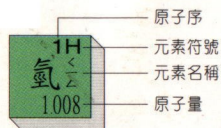
5. 神經內分泌瘤

Neuroendocrine tumor

- 碘 I-131 MIBG
- 釷 Y-90 DOTATOC
- 銩 Lu-177 DOTA

週期表

說明



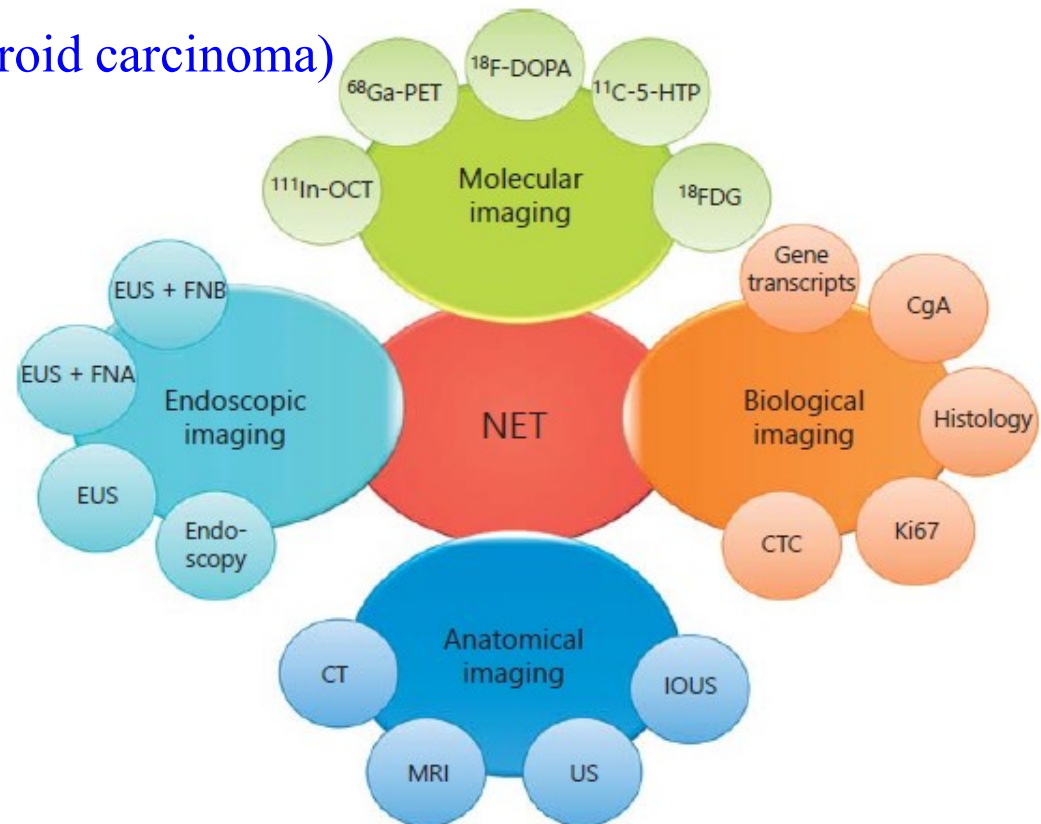
惰性氣體

18

1		金屬										非金屬						18	
I A												III A IV A V A VI A VII A						VIII A	
1	2	過渡元素										13	14	15	16	17	18		
氫	鈹											硼	碳	氮	氧	氟	氖		
1.008	9.012											10.81	12.01	14.01	16.00	19.00	20.18		
3	4	11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
鈉	鎂	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鋁	矽	磷	硫	氯	氬
22.99	24.31	47.88	47.88	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39	69.72	72.59	26.98	28.09	30.97	32.07	35.45	39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
鉀	鈣	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	砷	硒	溴	氪	41	42
39.10	40.08	44.06	47.88	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39	69.72	72.59	74.92	78.96	79.90	83.80	85.47	87.62
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
銣	銣	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	鈦	銣	碲	碘	氙	銣	銣
85.47	87.62	88.91	91.22	92.91	95.94	98.91	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3	132.9	137.3
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
銣	銣	銣系元素	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣
132.9	137.3		178.5	180.9	183.9	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	(210)	(210)	(222)	(223)	(226)
87	88	89-103	104	105	106	107	108	109											
銣	銣	銣系元素	銣	銣	銣	銣	銣	銣											
(223)	(226)		(261)	(262)	(263)	(262)	(265)	(266)											
銣系元素																			
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71					
銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣				
138.9	140.1	140.9	144.2	144.9	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.0	175.0					
銣系元素																			
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103					
銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣	銣				
(227)	232.0	(231)	238.0	(237)	239.1	243.1	247.1	247.1	252.1	252.1	257.1	256.1	259.1	260.1					

神經內分泌瘤 (neuroendocrine tumor, NET)

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



■ ^{131}I -NP-59 (造影):

*Cholesterol analog (膽固醇)

- ☐ 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

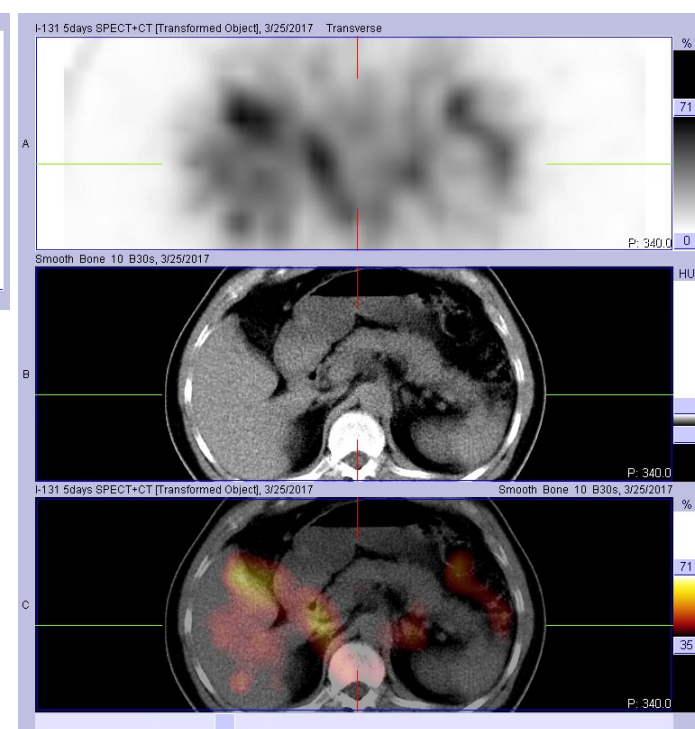
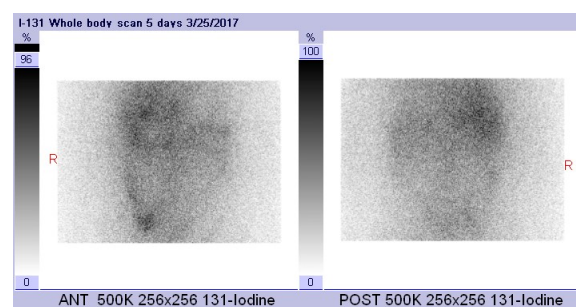
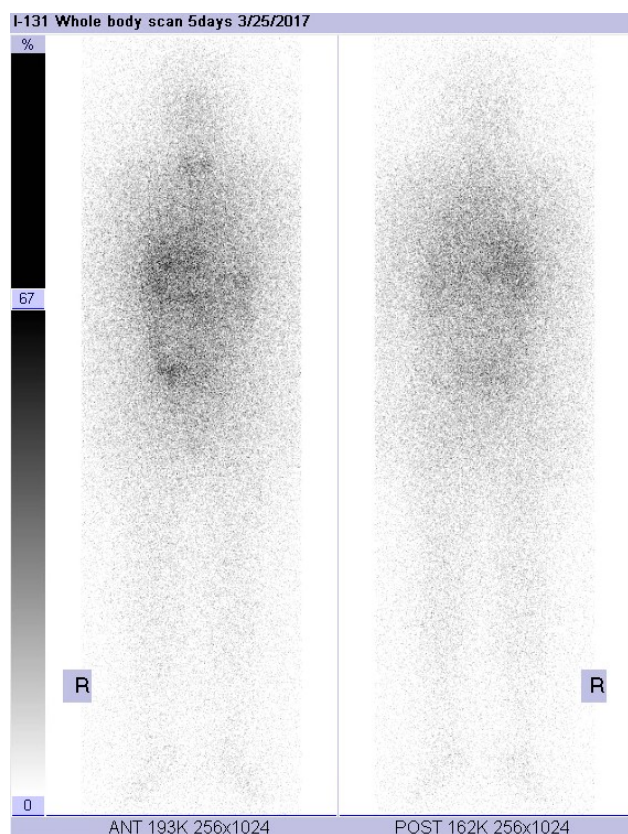
■ ^{131}I -MIBG (造影&治療):

*Norepinephrine analog (正腎上腺素)

- ☐ 腎上腺髓質
- ☐ 1.2-2.2 mCi / 100-300 mCi
- ☐ 48 hr & 72 hr
- ☐ 嗜鉻母細胞瘤
(pheochromocytoma)

- 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

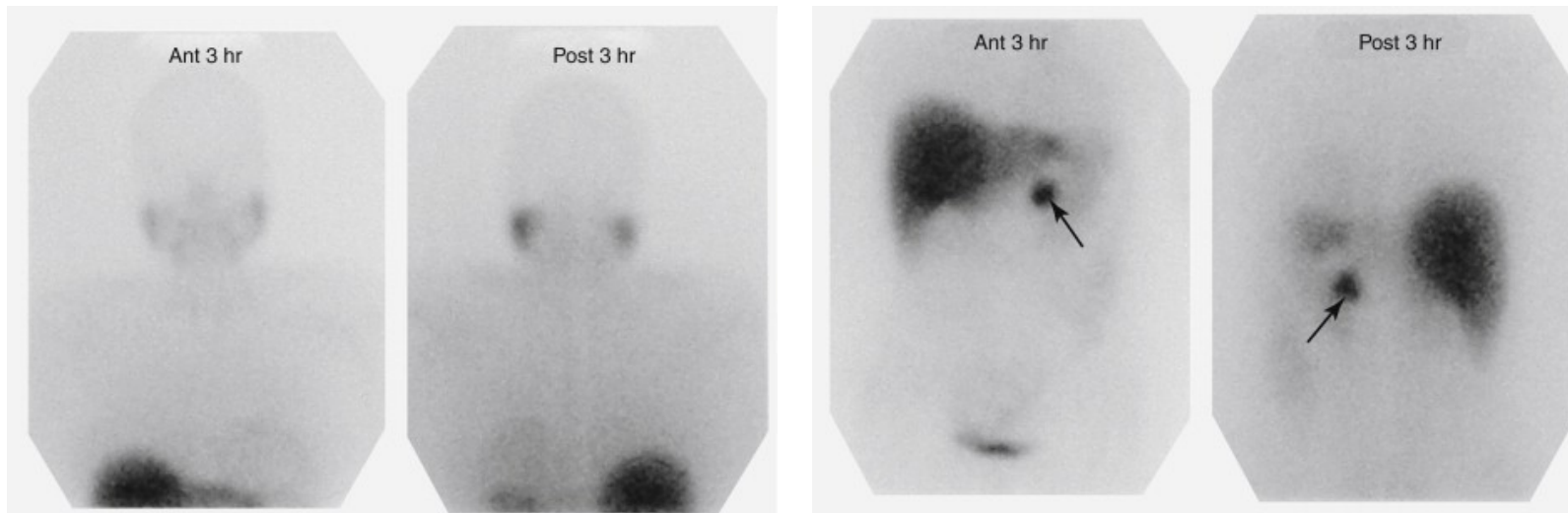


1. $^{131}\text{I}/^{123}\text{I}$ -MIBG (造影) 40-80 MBq (1.2-2.2 mCi)/400 MBq (10.8 mCi), slow infusion (>5 min)

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:噁心,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

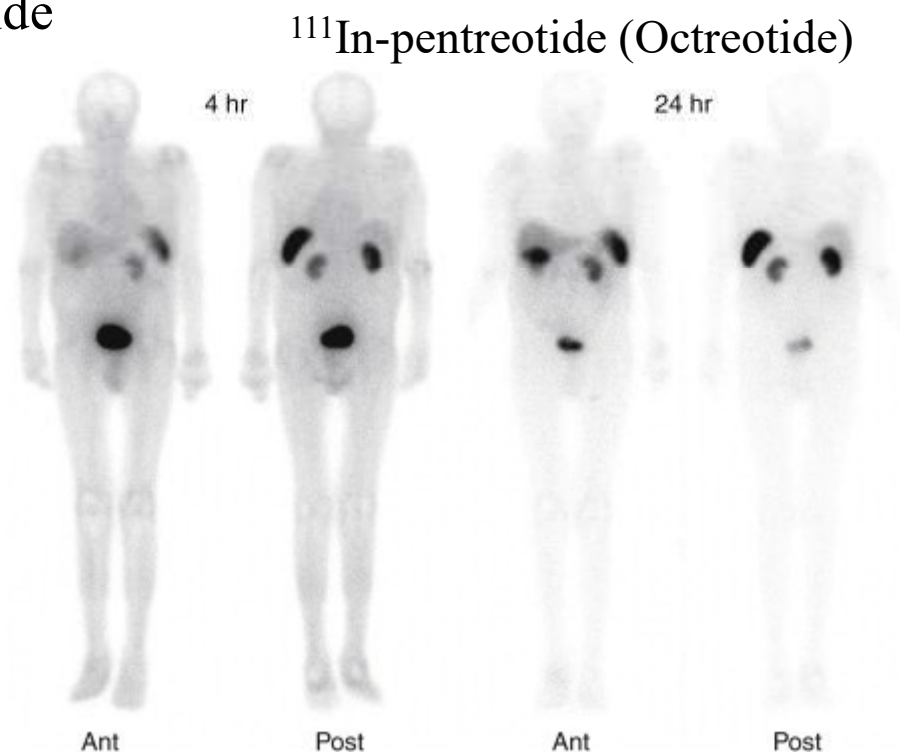
^{123}I -MIBG (造影)



鉕 ^{90}Y -DOTATOC & 鎳 ^{177}Lu -DOTA (Lutetium)

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

- ^{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)

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

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

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

4. 淋巴瘤 (Lymphoma)

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

5. 神經內分泌瘤 (Neuroendocrine tumor)

- 碘 I-131 MIBG: 嗜鉻母細胞瘤 (pheochromocytoma)
- 釷 Y-90 DOTATOC & 鐳 Lu-177 DOTA: 神經母細胞瘤 (neuroblastoma)