

방사선 기술의 의학적 이용

From bench to bed to community and beyond



한국원자력연구원
Korea Atomic Energy Research Institute



한국원자력의학원
KOREA INSTITUTE OF RADIOLOGICAL & MEDICAL SCIENCES

2018년 10월 24일(수) 13:30~18:00

여수 엑스포컨벤션센터 1층, 컨퍼런스홀 4

핵의학의 발전과 동향

범희승

전남대의대 핵의학교실 교수
방사선의학포럼 회장
아시아지역 핵의학협력회의 의장

진단

치료



질병

치료

진단

**200/100
mmHg**

1차 약

고혈압

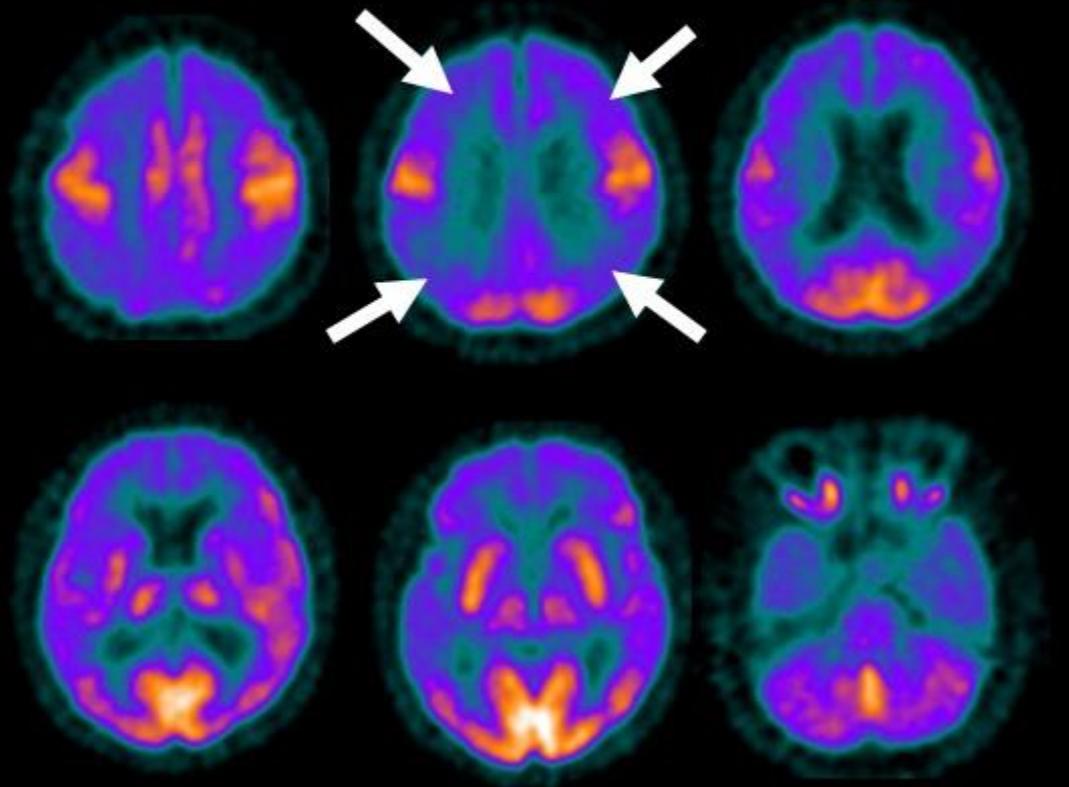
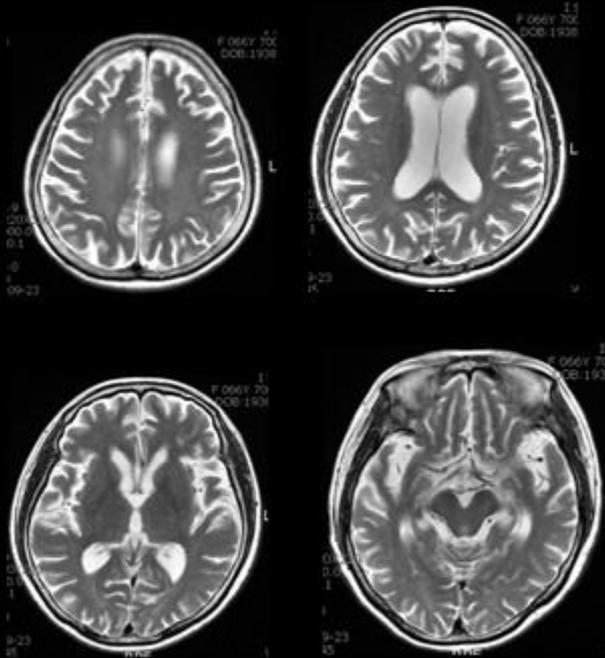


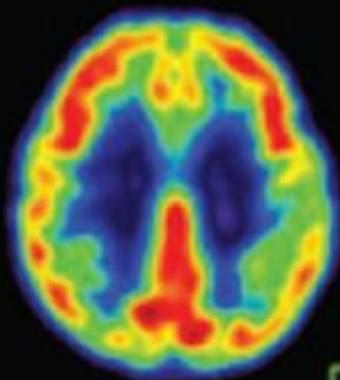
2차 약

**170/90
mmHg**

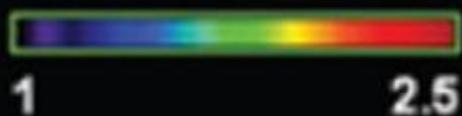
67세 여자, 기억력 장애, 우울증

F-18 FDG Brain PET

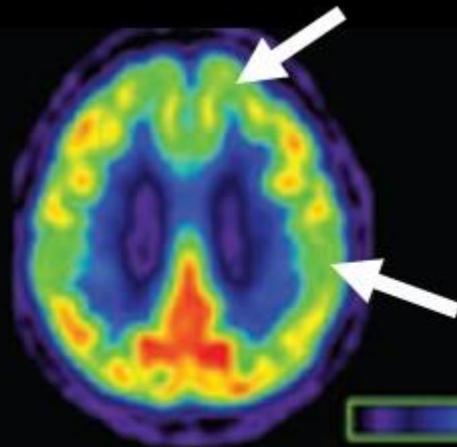




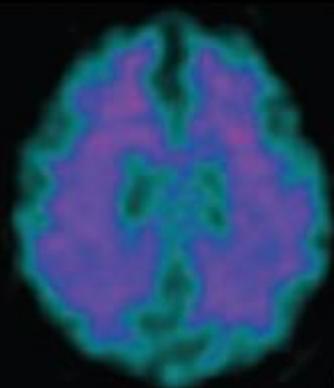
F-18 FDG



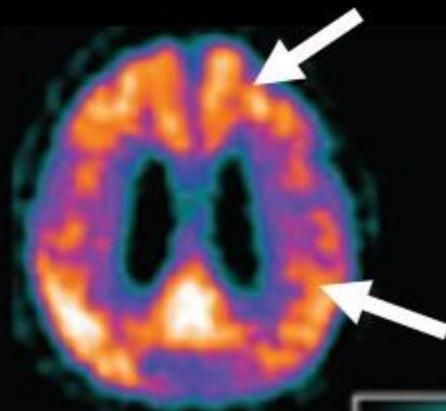
정상인



AD치매

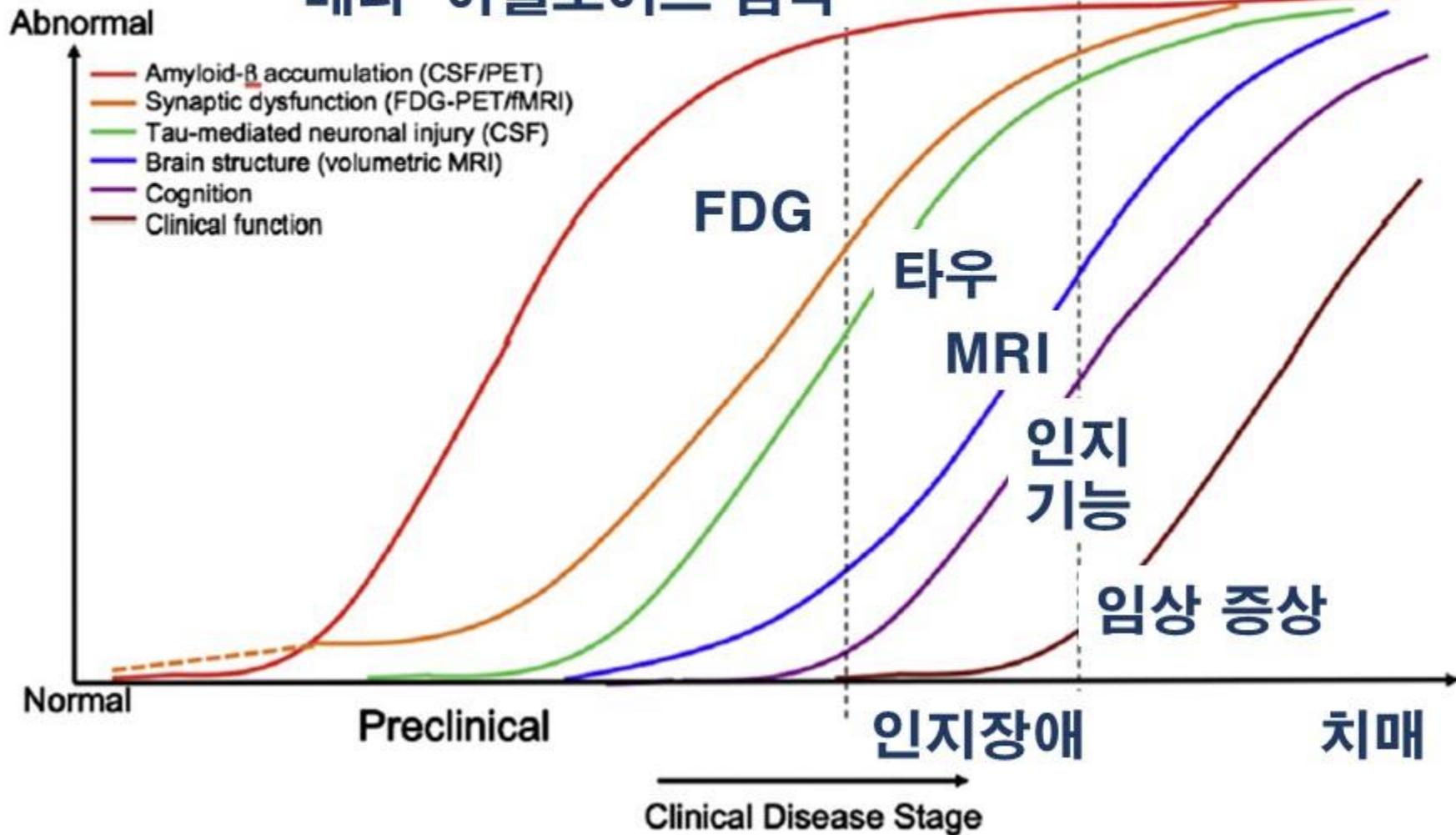


C-11 PIB
amyloid

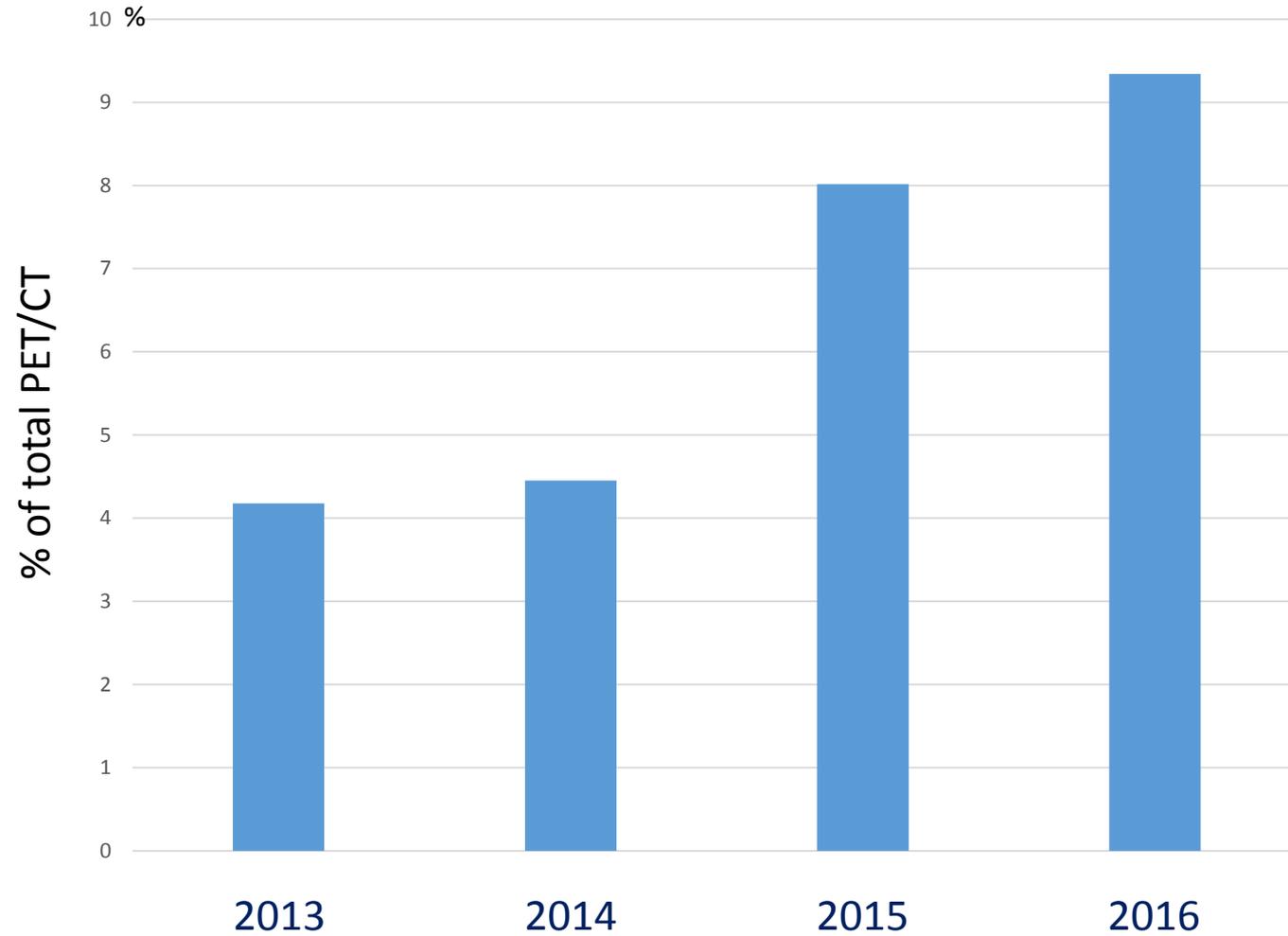


치매 진단

베타-아밀로이드 침착



Growth of Brain PET/CT studies



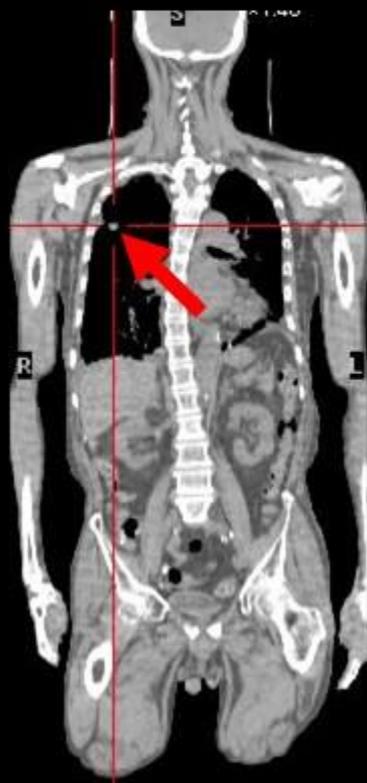
우리나라 사망원인 2017

(단위 : 인구 10만 명당 명, %)

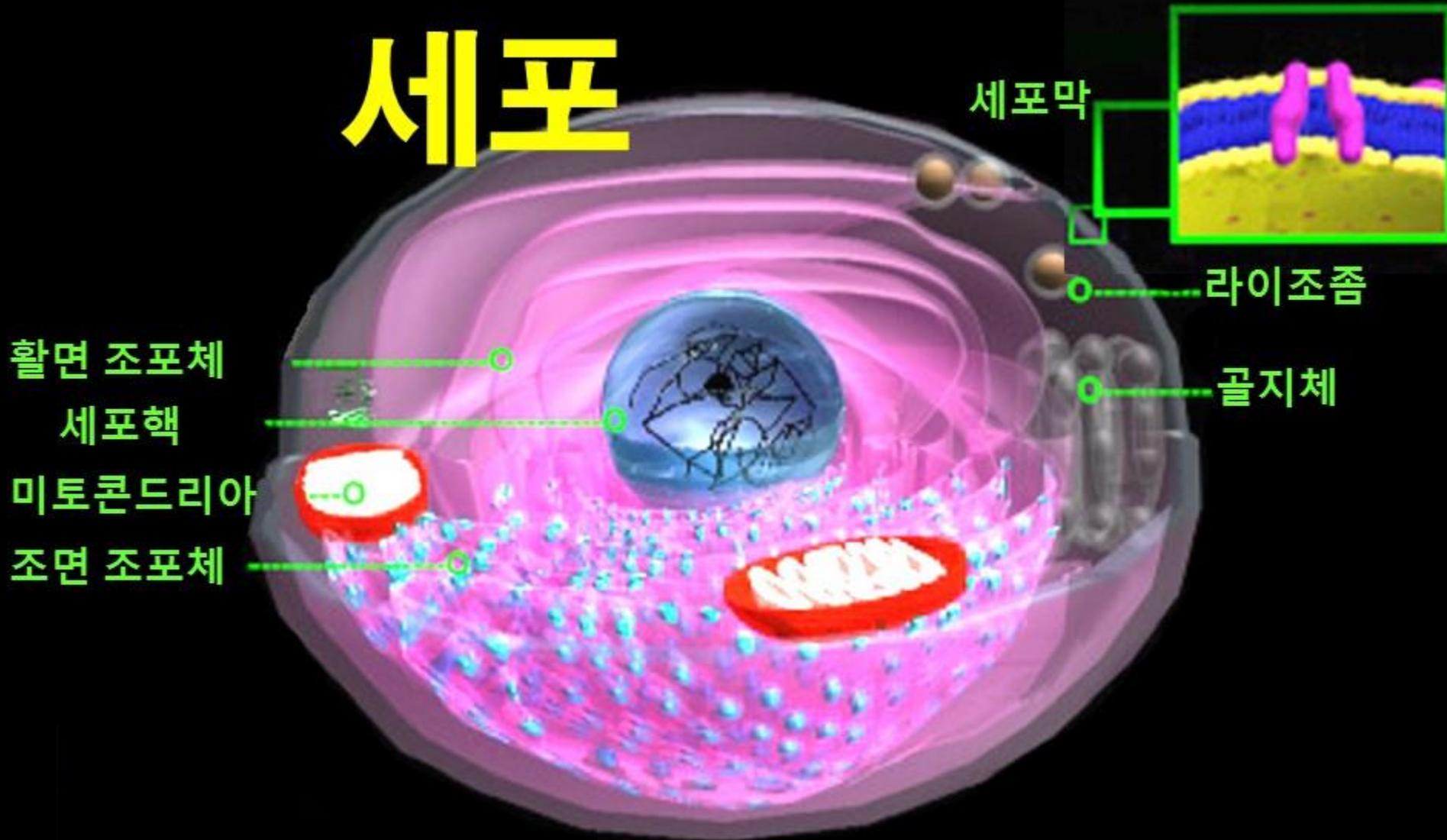
	0세	1-9세	10-19세	20-29세	30-39세	40-49세	50-59세	60-69세	70-79세	80세 이상
1위	술·초콜릿에 기원한 특정병태 139.8 (51.7%)	악성신생물 1.9 (17.0%)	고의적 자해(자살) 4.7 (30.9%)	고의적 자해(자살) 16.4 (44.8%)	고의적 자해(자살) 24.5 (36.9%)	악성신생물 42.5 (28.9%)	악성신생물 126.7 (38.1%)	악성신생물 305.5 (44.1%)	악성신생물 744.9 (34.8%)	악성신생물 1445.7 (17.3%)
2위	선천 기형 변형 및 암배아 이상 45.4 (16.8%)	운수 사고 1.4 (11.9%)	운수 사고 2.7 (17.7%)	운수 사고 5.1 (14.0%)	악성신생물 13.8 (20.7%)	고의적 자해(자살) 27.9 (19.0%)	고의적 자해(자살) 30.8 (9.3%)	심장 질환 61.3 (8.8%)	심장 질환 227.4 (10.6%)	심장 질환 1063.4 (12.7%)
3위	영아 돌연사 증후군 20.0 (7.4%)	선천 기형 변형 및 암배아 이상 1.1 (9.6%)	악성신생물 2.3 (15.3%)	악성신생물 4.0 (11.0%)	운수 사고 4.5 (6.8%)	간 질환 12.2 (8.3%)	심장 질환 28.1 (8.5%)	뇌혈관 질환 45.1 (6.5%)	뇌혈관 질환 186.1 (8.7%)	폐렴 856.7 (10.3%)
4위	심장 질환 7.3 (2.7%)	가해(타살) 0.9 (8.1%)	심장 질환 0.6 (4.0%)	심장 질환 1.5 (4.1%)	심장 질환 4.0 (6.0%)	심장 질환 11.1 (7.5%)	간 질환 25.4 (7.6%)	고의적 자해(자살) 30.2 (4.4%)	폐렴 132.2 (6.2%)	뇌혈관 질환 749.9 (9.0%)
5위	가해(타살) 4.6 (1.7%)	심장 질환 0.6 (5.5%)	익사 사고 0.4 (2.4%)	뇌혈관 질환 0.7 (1.8%)	간 질환 3.0 (4.4%)	뇌혈관 질환 8.8 (6.0%)	뇌혈관 질환 20.1 (6.1%)	간 질환 26.1 (3.8%)	당뇨병 85.6 (4.0%)	고혈압성 질환 285.0 (3.4%)

※ 연령별 사망원인 구성비 = (해당 연령의 사망원인별 사망자 수 / 해당 연령의 총 사망자 수) × 100

암?

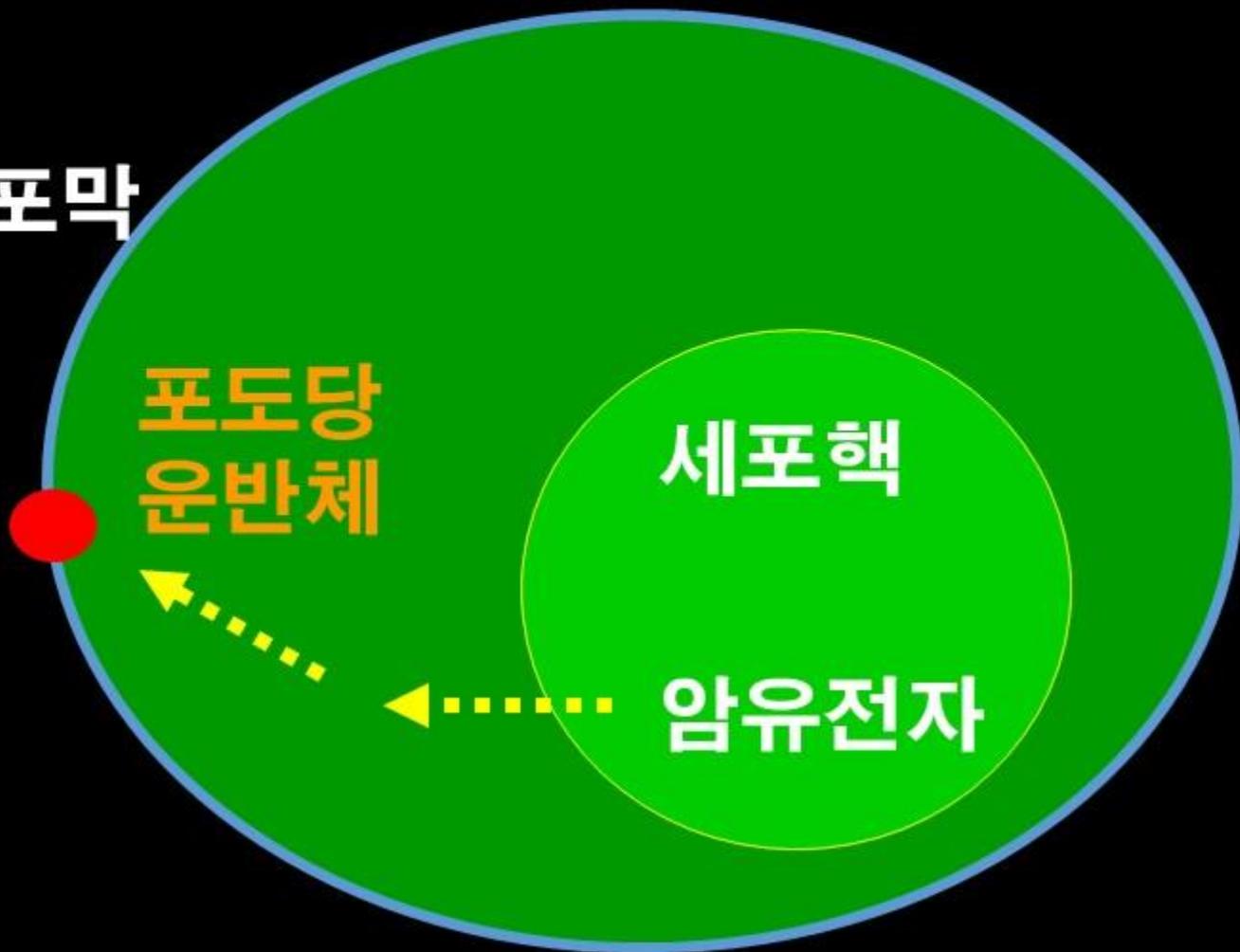


세포



암세포

세포막

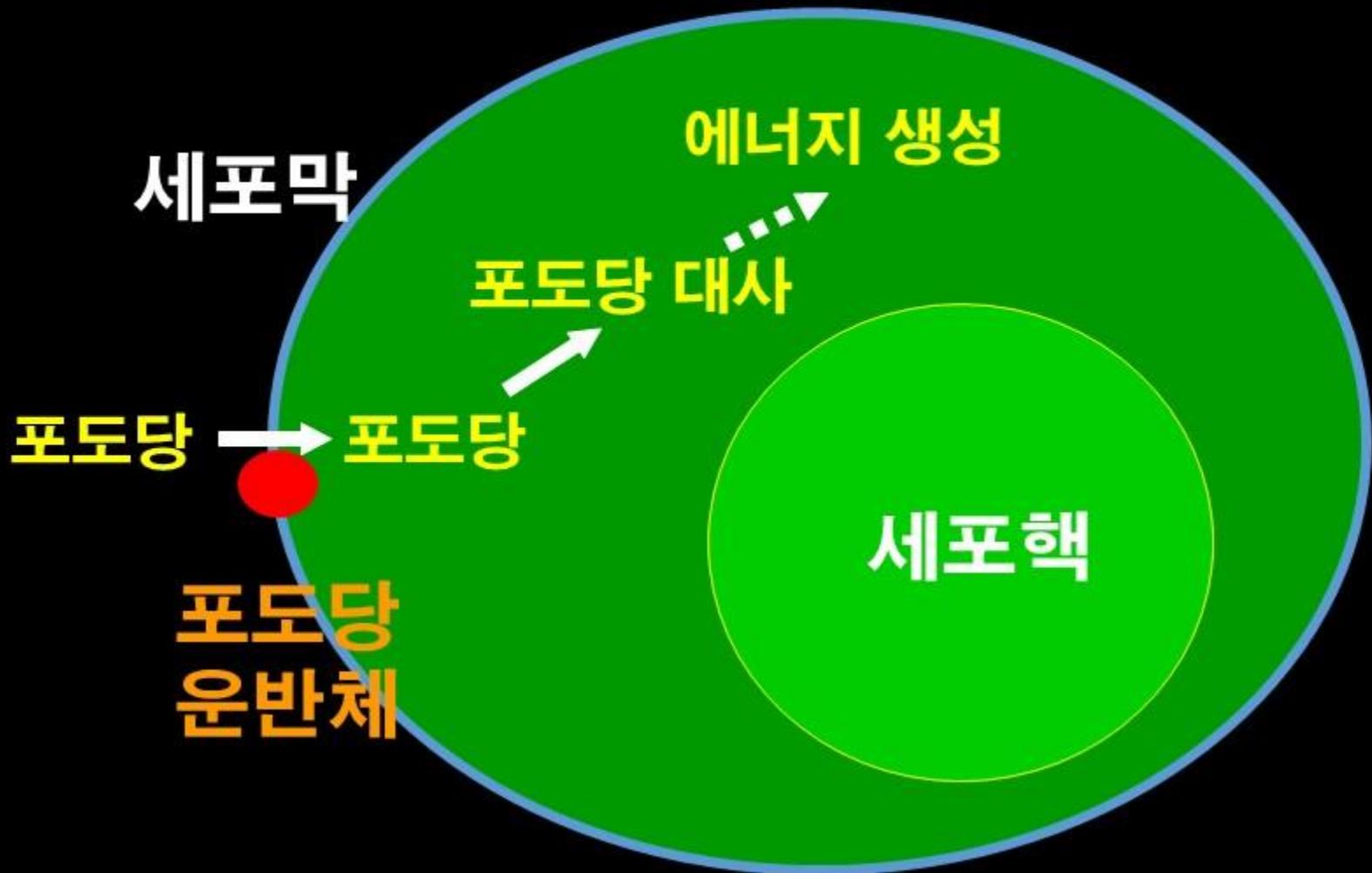


포도당
운반체

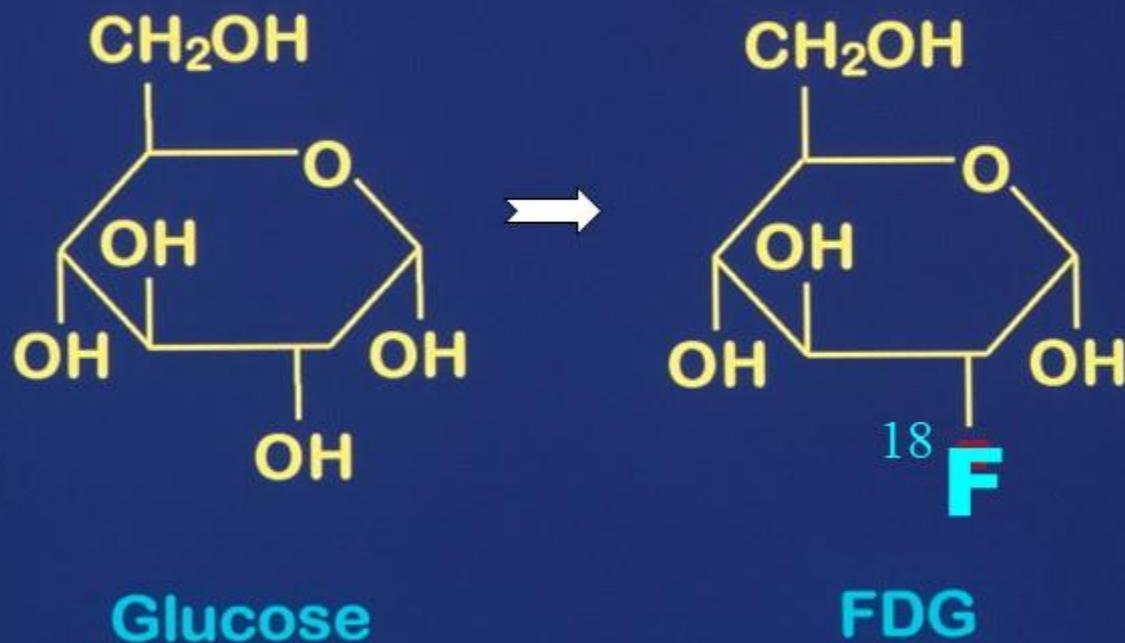
세포핵

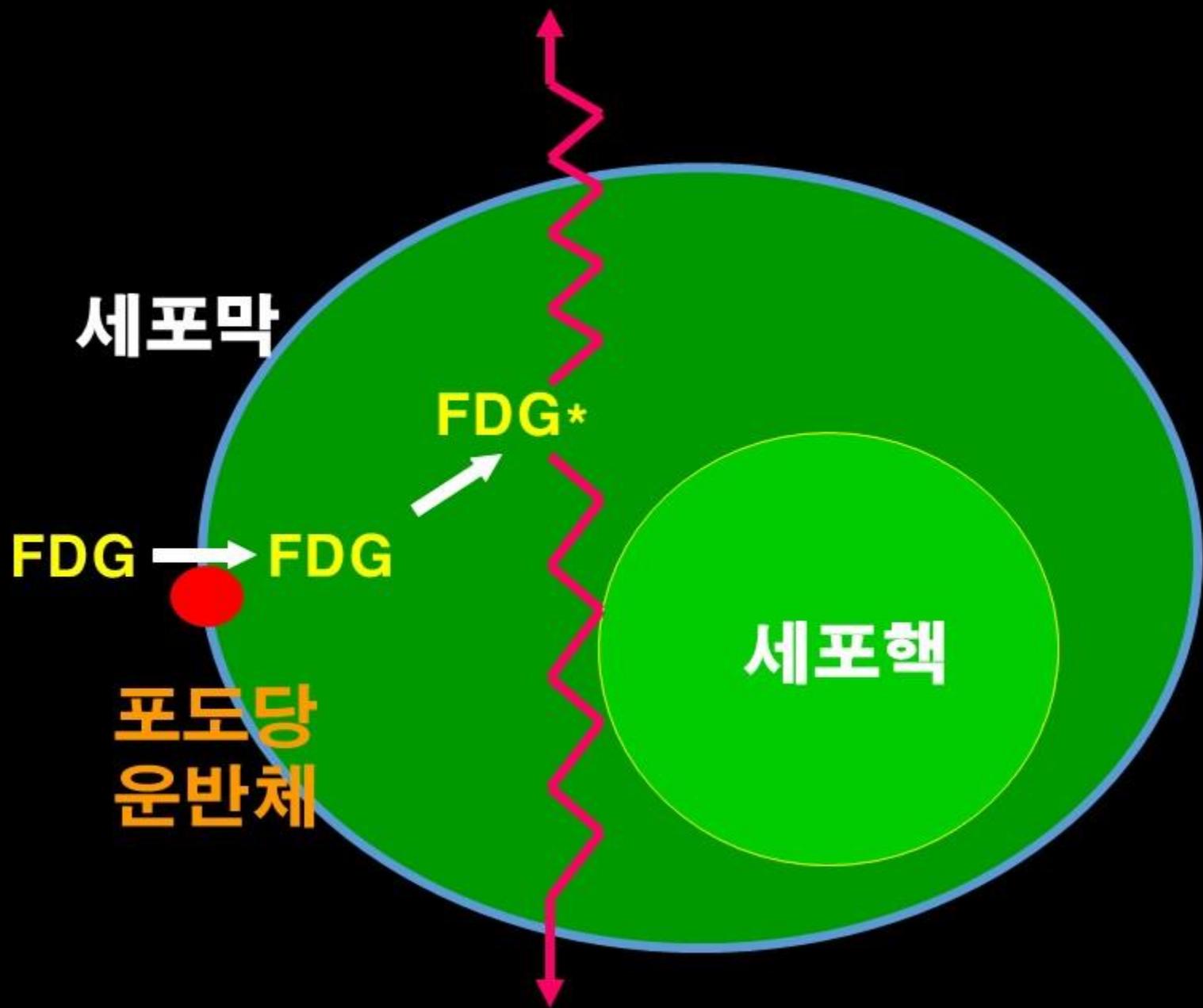
암유전자

암세포



^{18}F -fluorodeoxyglucose (FDG)





세포막

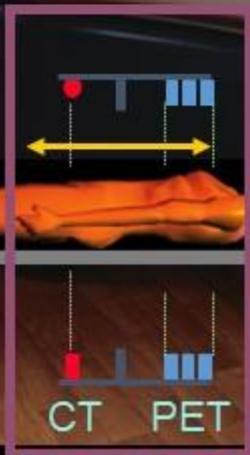
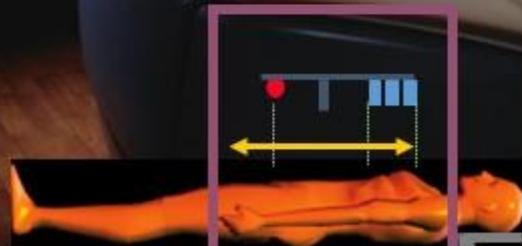
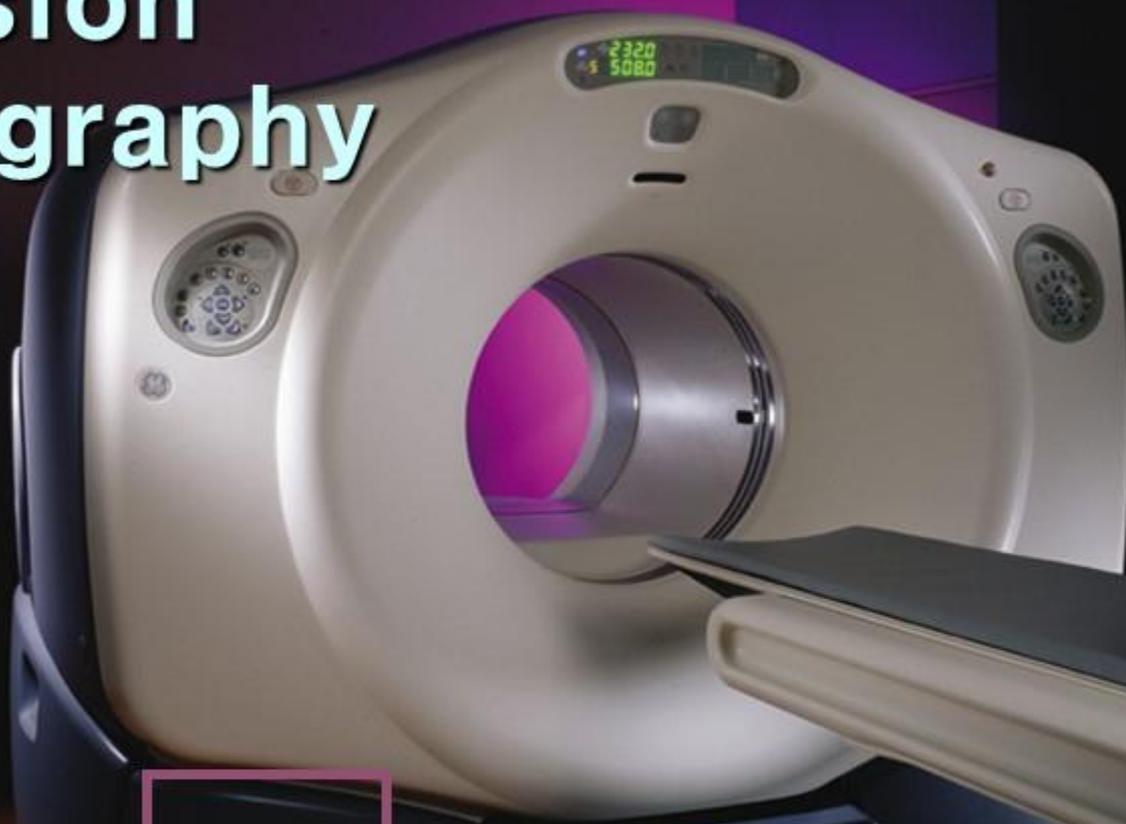
FDG*

FDG → FDG

포도당
운반체

세포핵

Positron Emission Tomography



CT PET

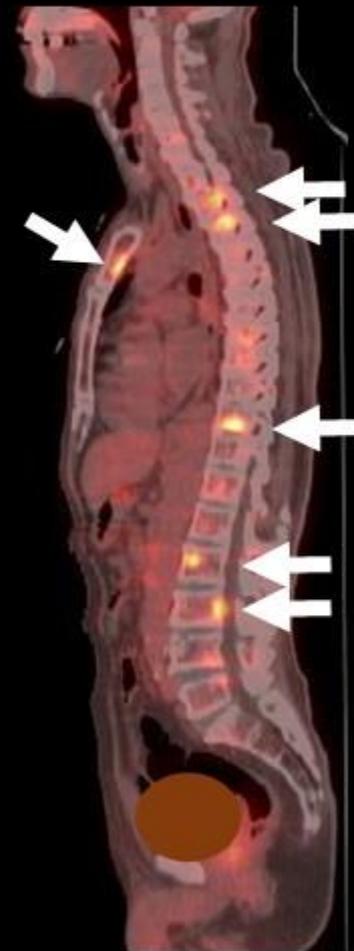


암 아님

암



암이 어디까지 퍼졌나?



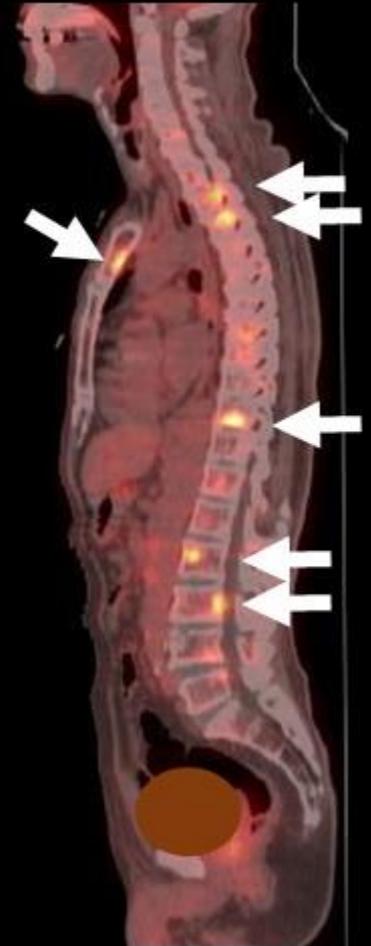
치료 방법



수술



수술+방사선



항암제

**암환자 1/5에서
PET/CT 검사 전에
예측하지 못한 곳에
전이병소가 있었음.**

**PET/CT로 발견한
원격 전이 병소의
1/4 가량은
다른 검사법으로
발견할 수 없었음.**

**PET/CT 검사 후
절반 가량에서
치료방침이 바뀌었음.**

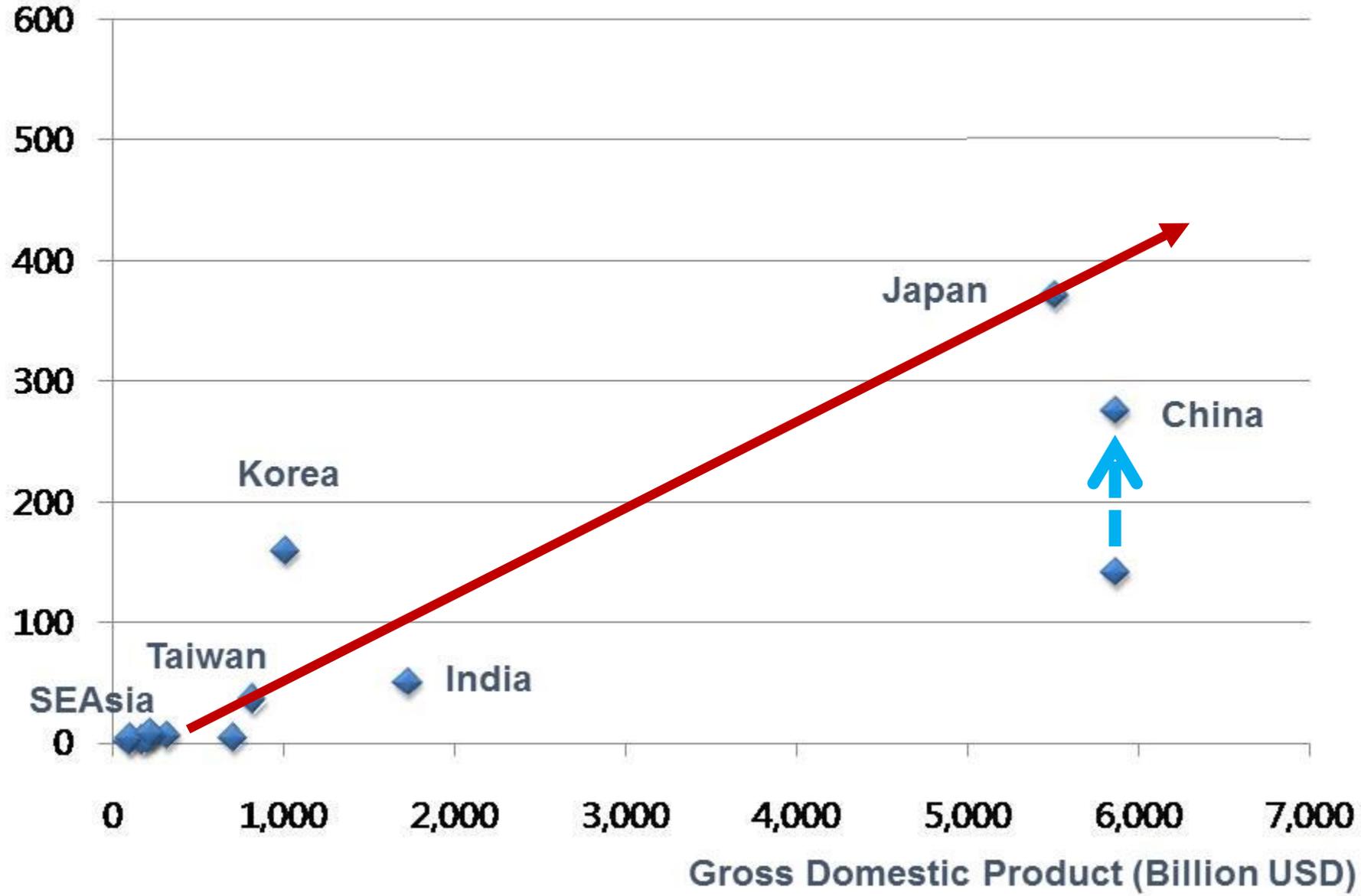
Clinical PET in ASIA



PET vs. GDP

PET & PET/CT

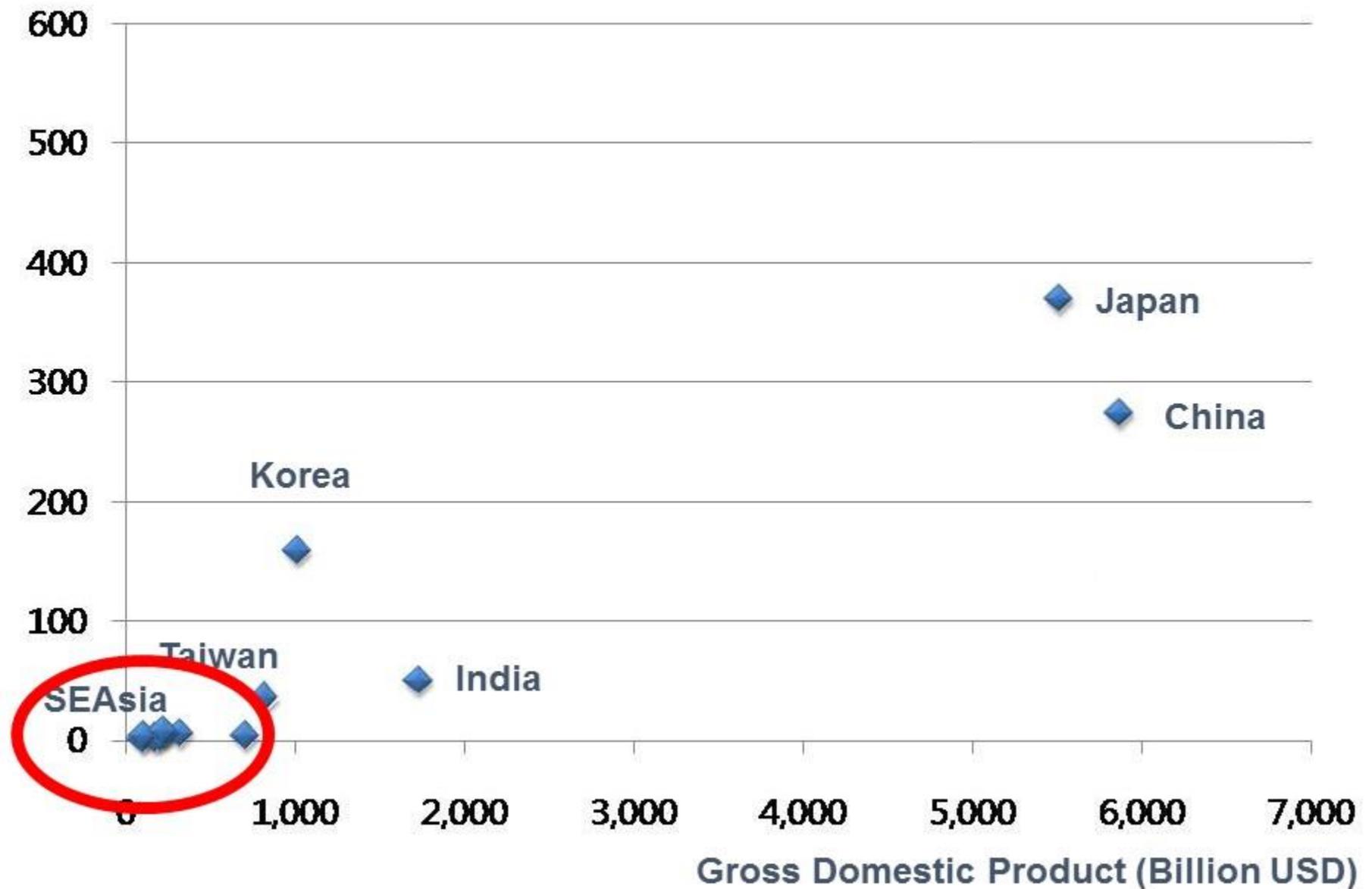
Gross Domestic Product



PET vs. GDP

PET & PET/CT

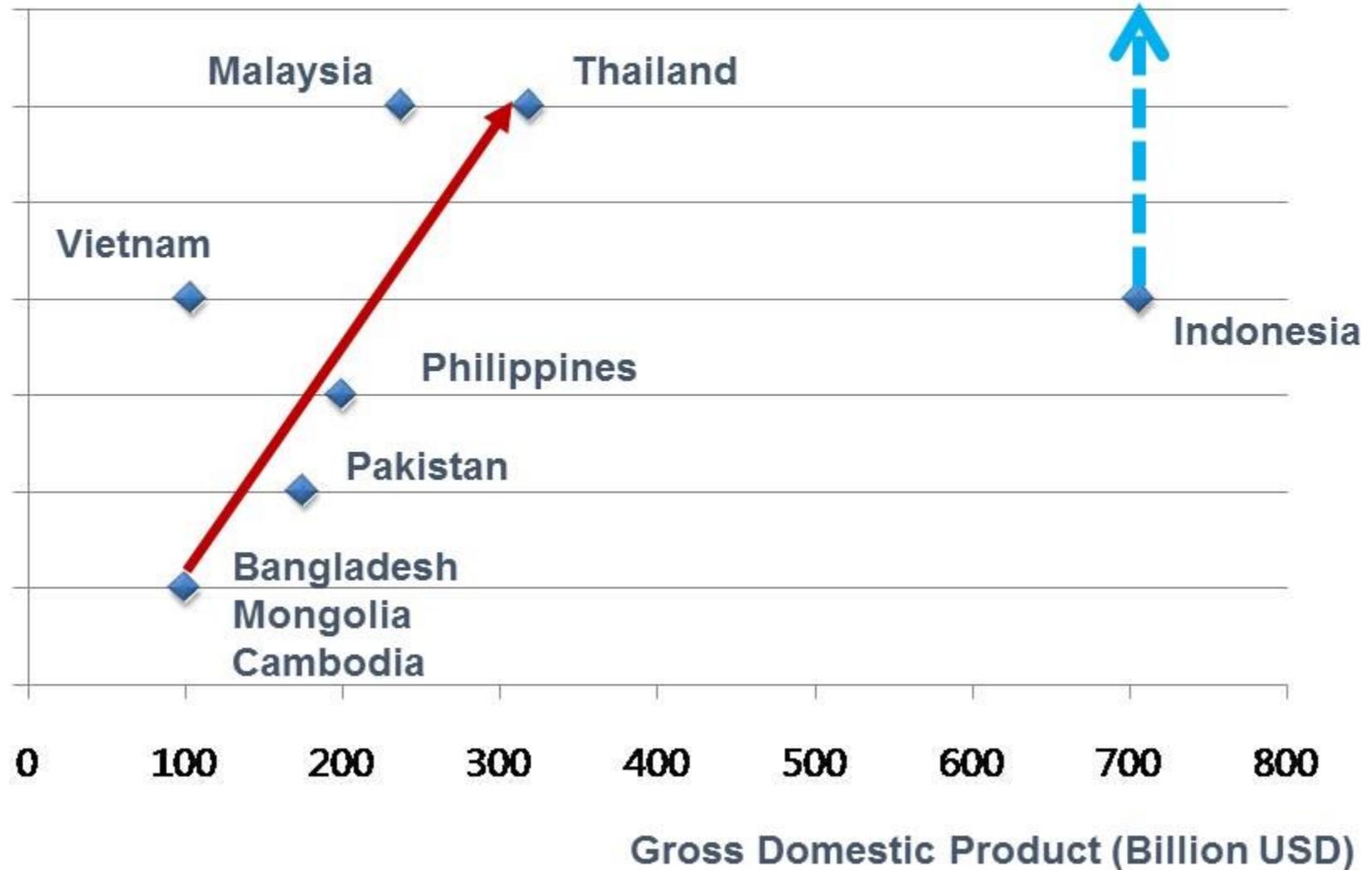
Gross Domestic Product



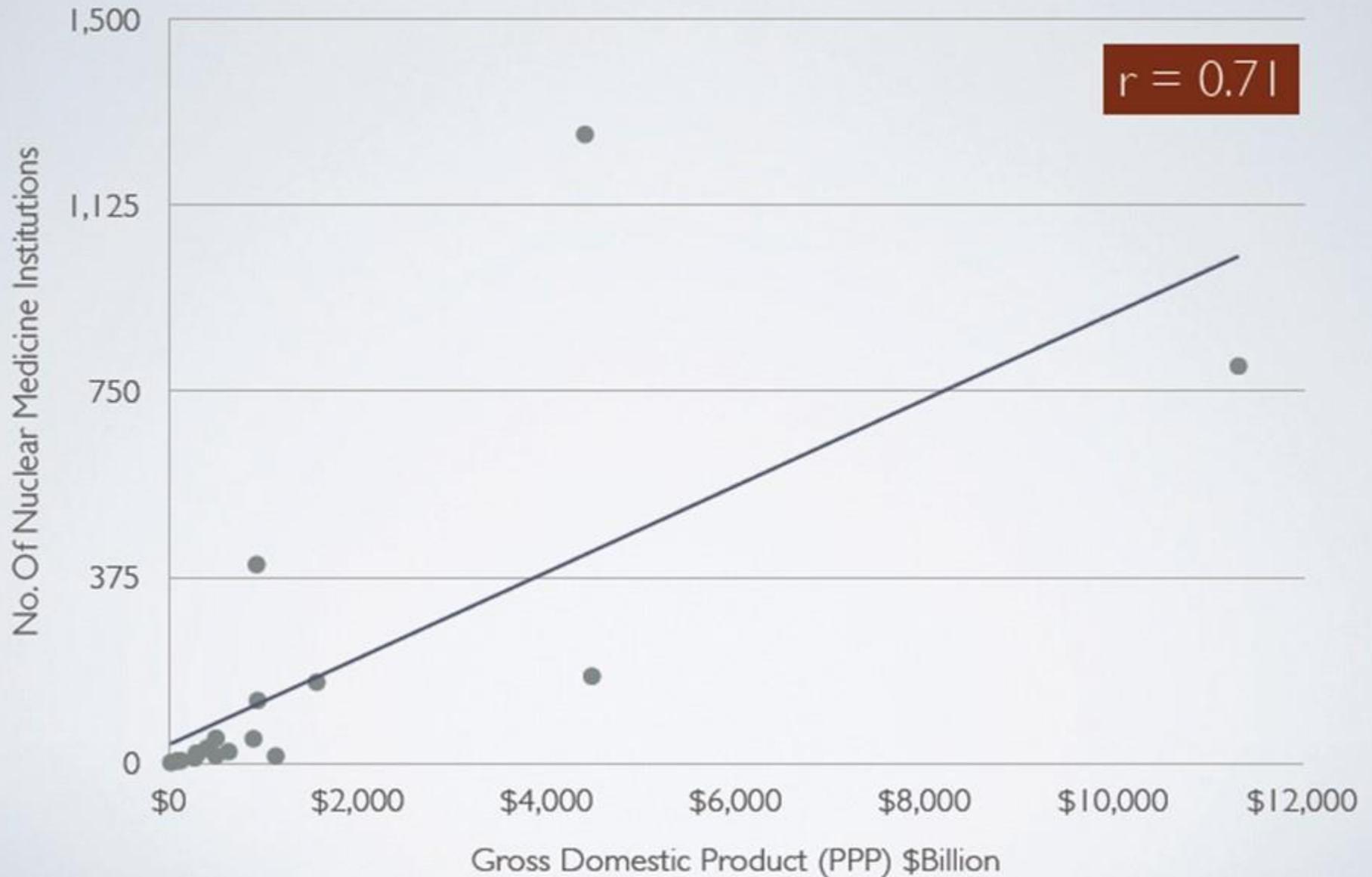
PET vs. GDP in South East Asia

PET & PET/CT

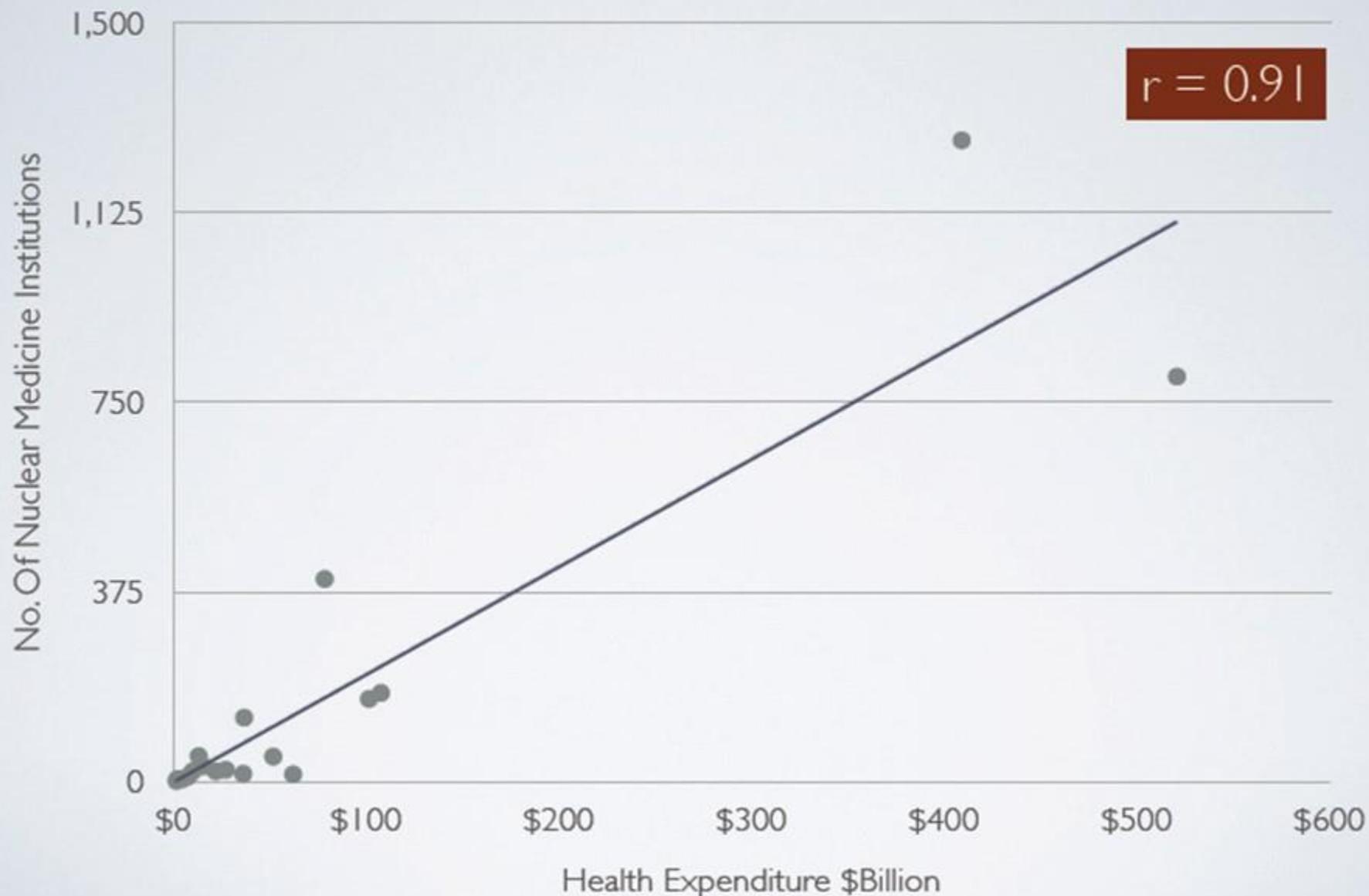
Gross Domestic Product



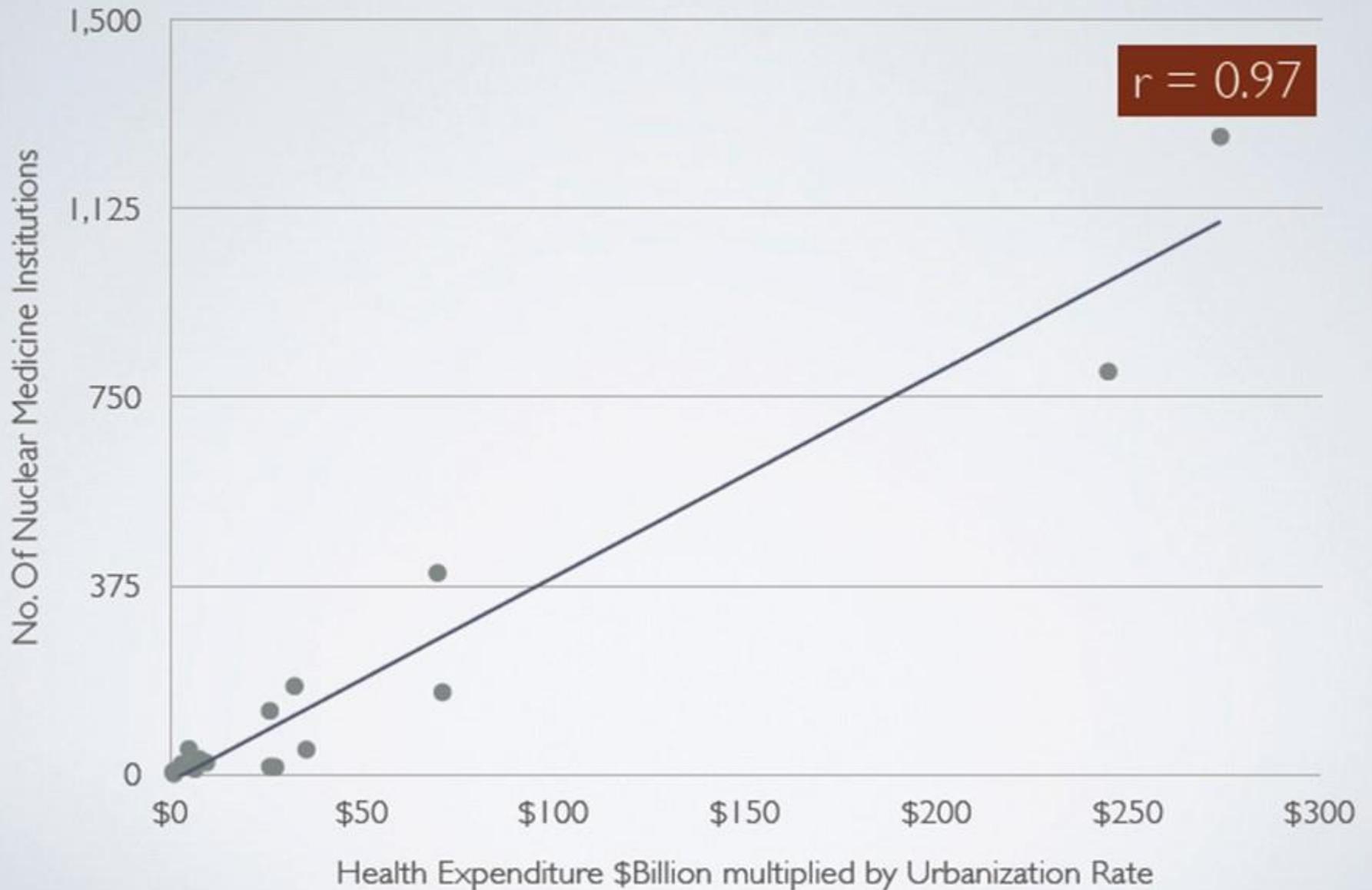
Nuclear Medicine Institutions and GDP



Nuclear Medicine and Health Expenditure



Nuclear Medicine and Urban Health Expenditure



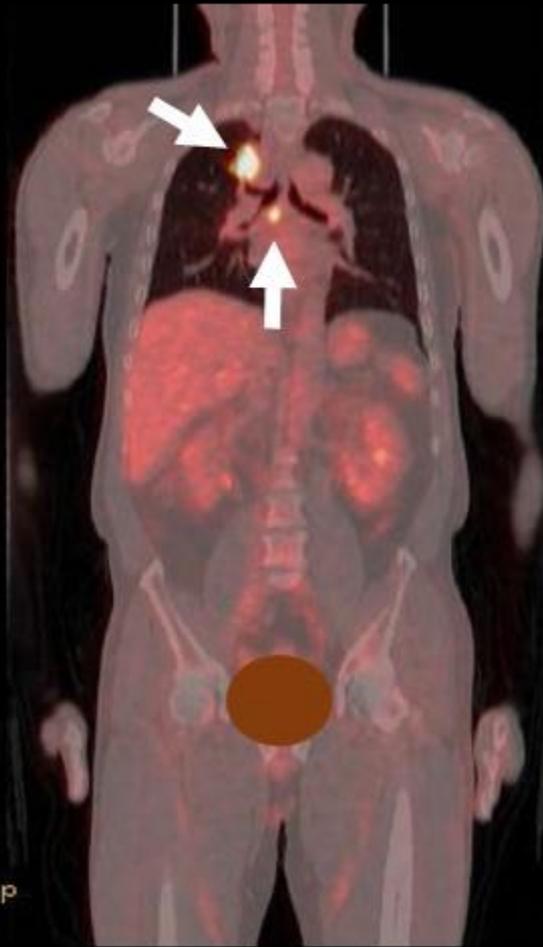
Correlates of Number of Institutions with PET-CT

Parameter	Pearson r
Gross Domestic Product (GDP)	0.64
Health Expenditure (GDP \times HE%)	0.87
Health Expenditure \times Urbanization Rate	0.93

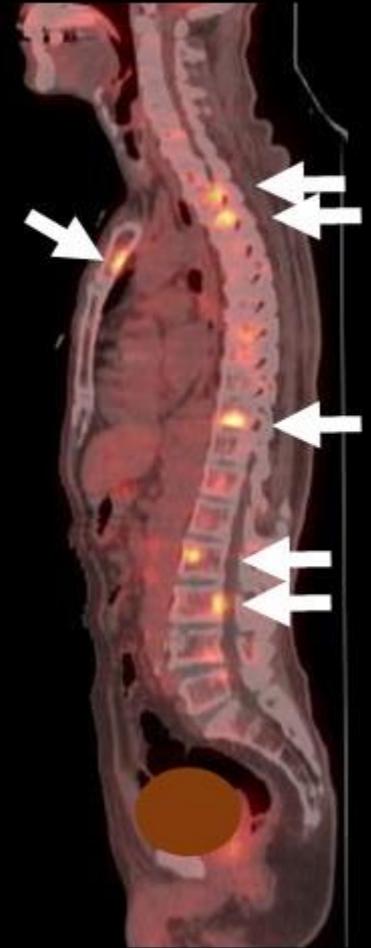
치료 방법



수술

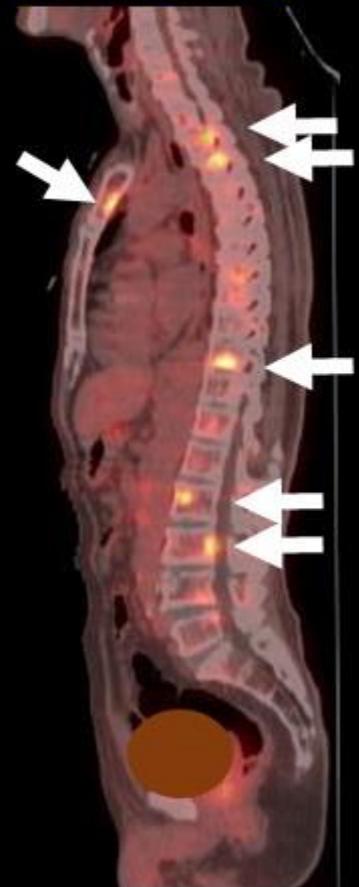


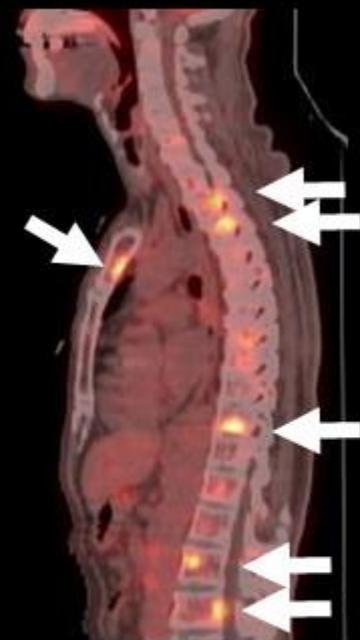
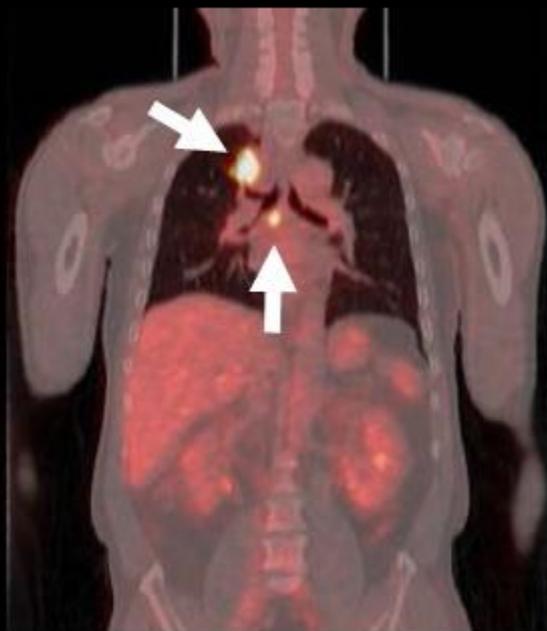
수술+방사선



항암제

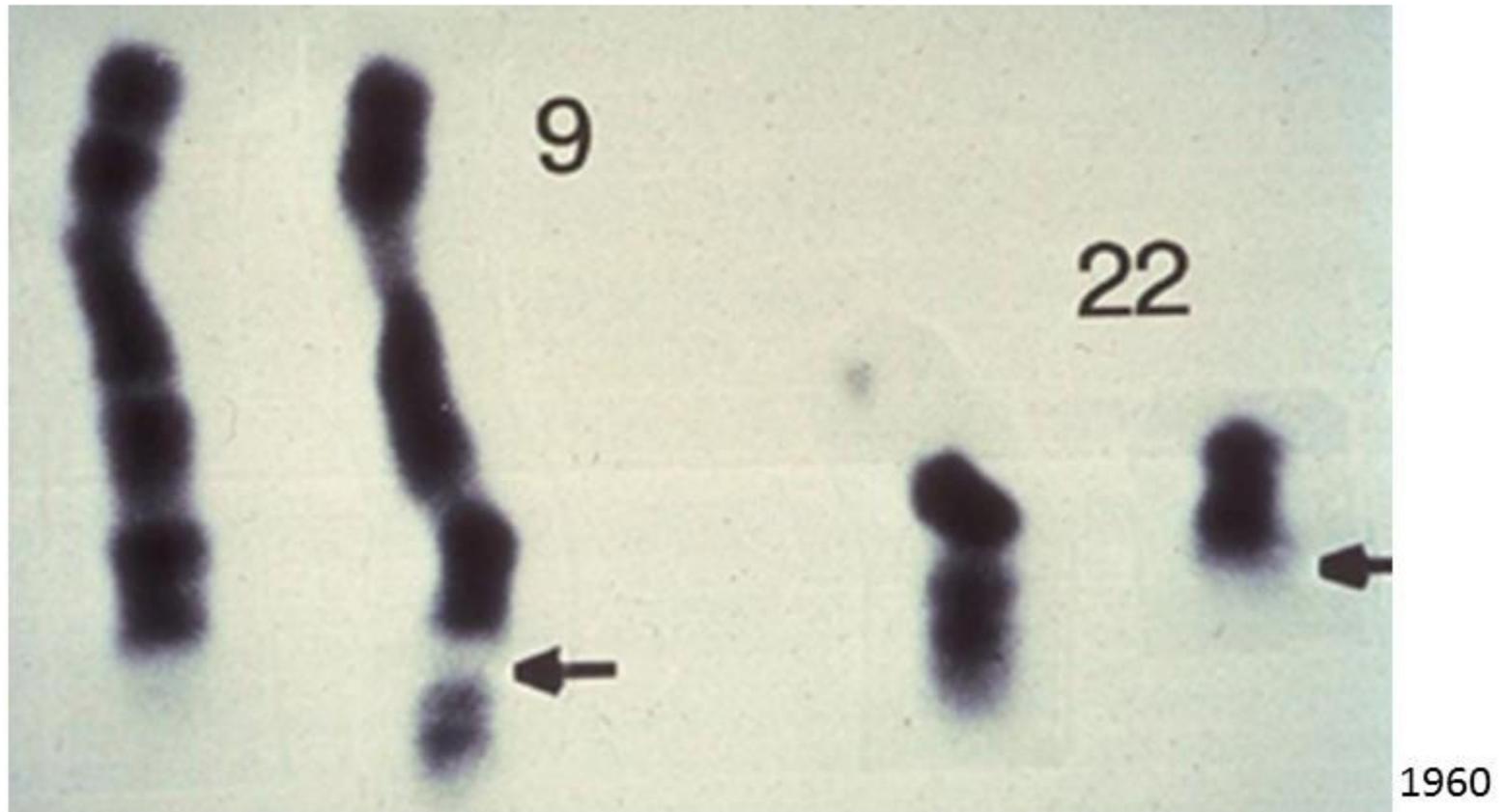
찾아낼 수 있다면 찾아가서 다 없앨 수도 있을까?



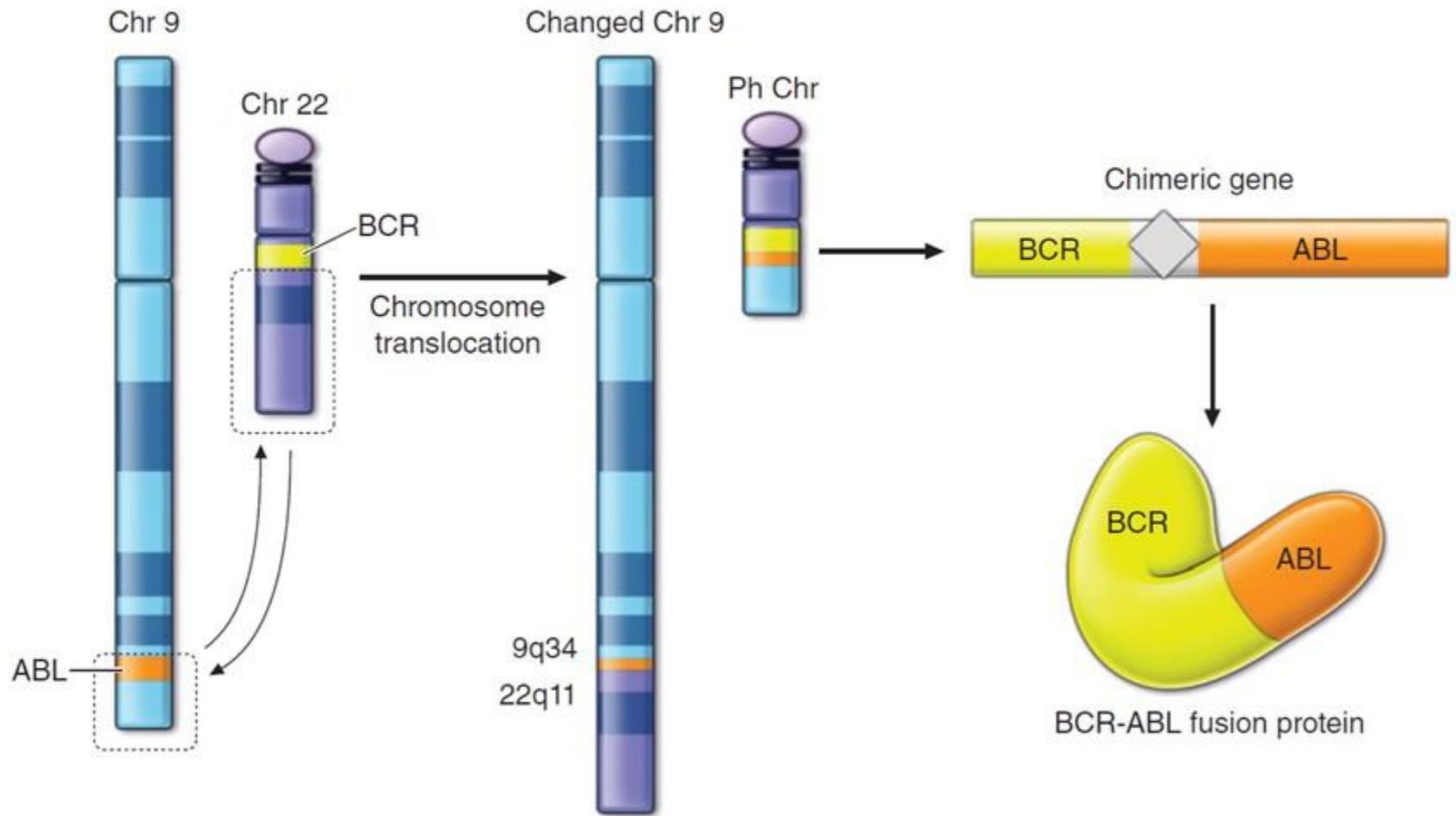


**표적이 확실하면
치료할 방법이 있다**

Philadelphia chromosome in CML patients



© Peter C. Nowell, MD, Department of Pathology and Laboratory in the Perelman School of Medicine at the University of Pennsylvania.

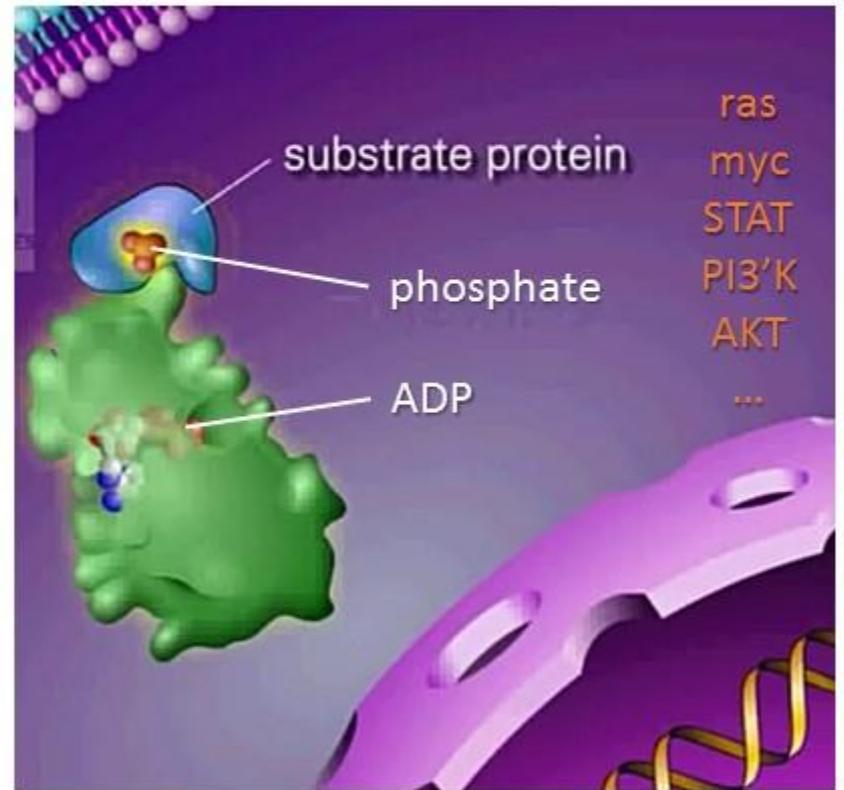
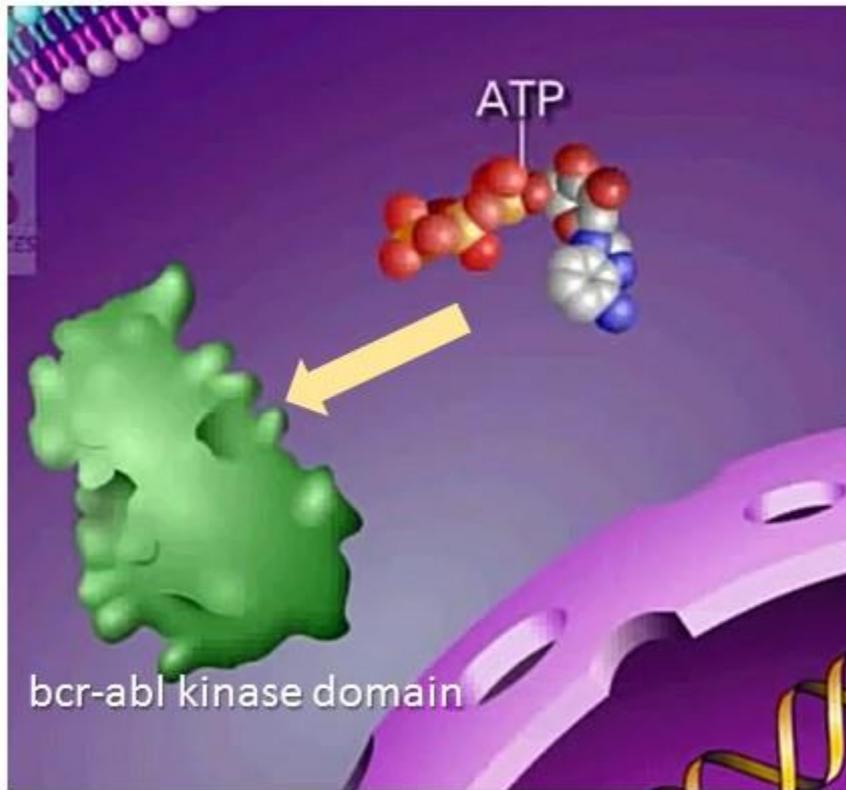


bcr-abl 단백질과 글리벡

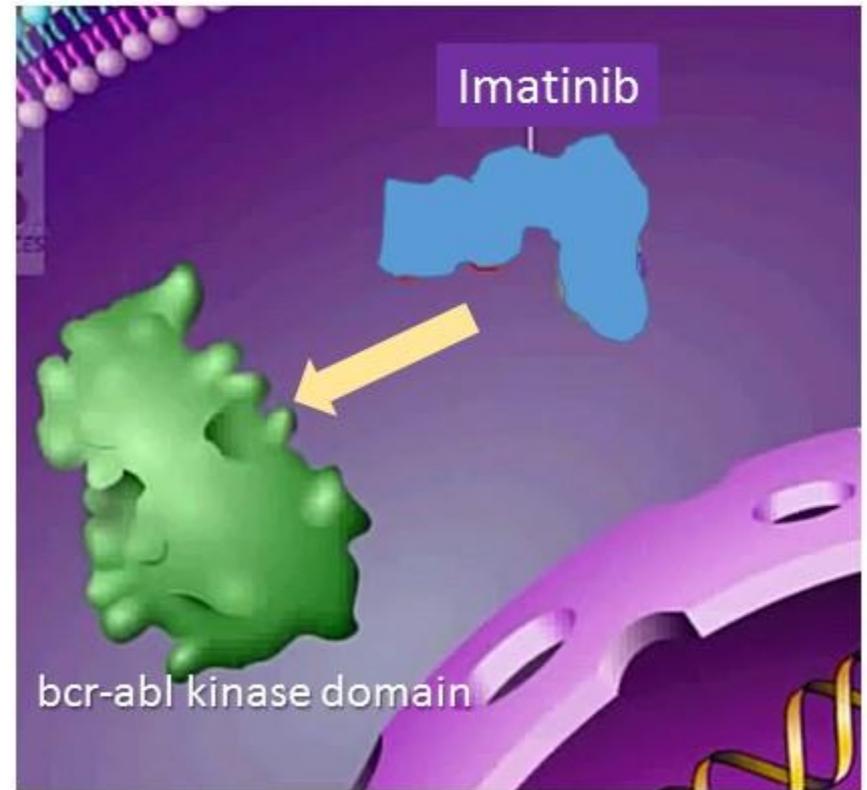
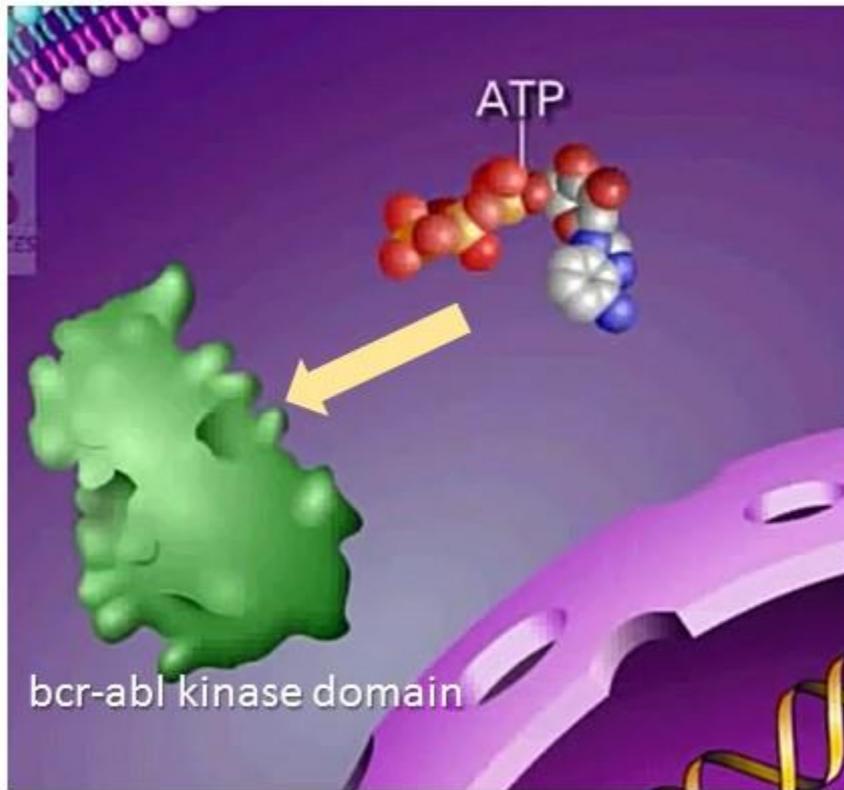
HHMI

HHMI

백혈병(CML) 발병



Imatinib (Gleevec)



**죽음의 병이었던
만성골수성백혈병!**

1998년

**글리벡 임상시험에 참여한
환자 전원이 호전되어
(95%는 완치)
임상시험 조기 종료!!**

표적이 확실하면

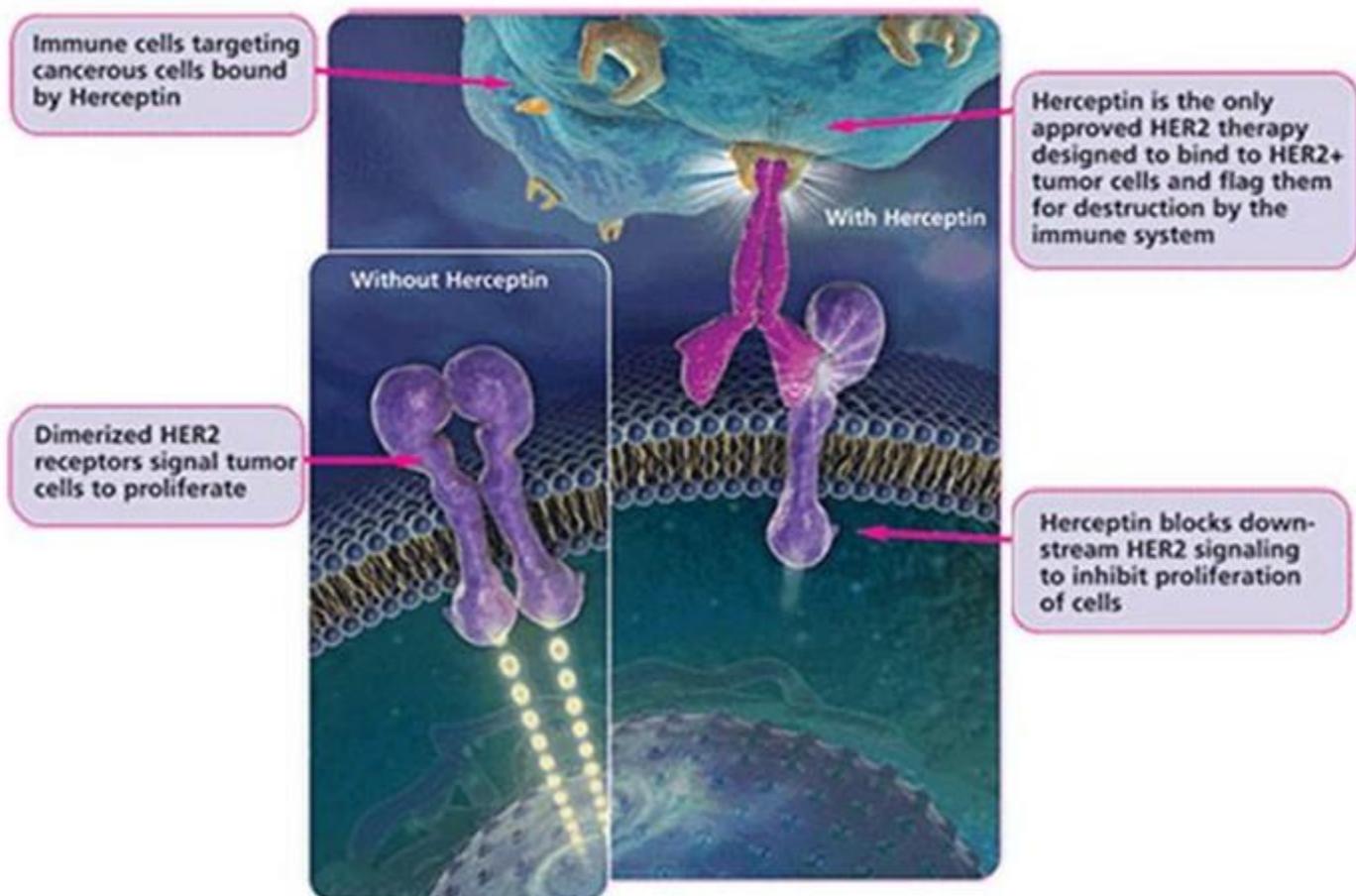
죽음의 병도

치료할 수 있다!

HER2 receptor



Trastuzumab (Herceptin)



International Nonproprietary Names (INN) for pharmaceutical substances

Tyrosine kinase inhibitors **-tinib** Imatinib

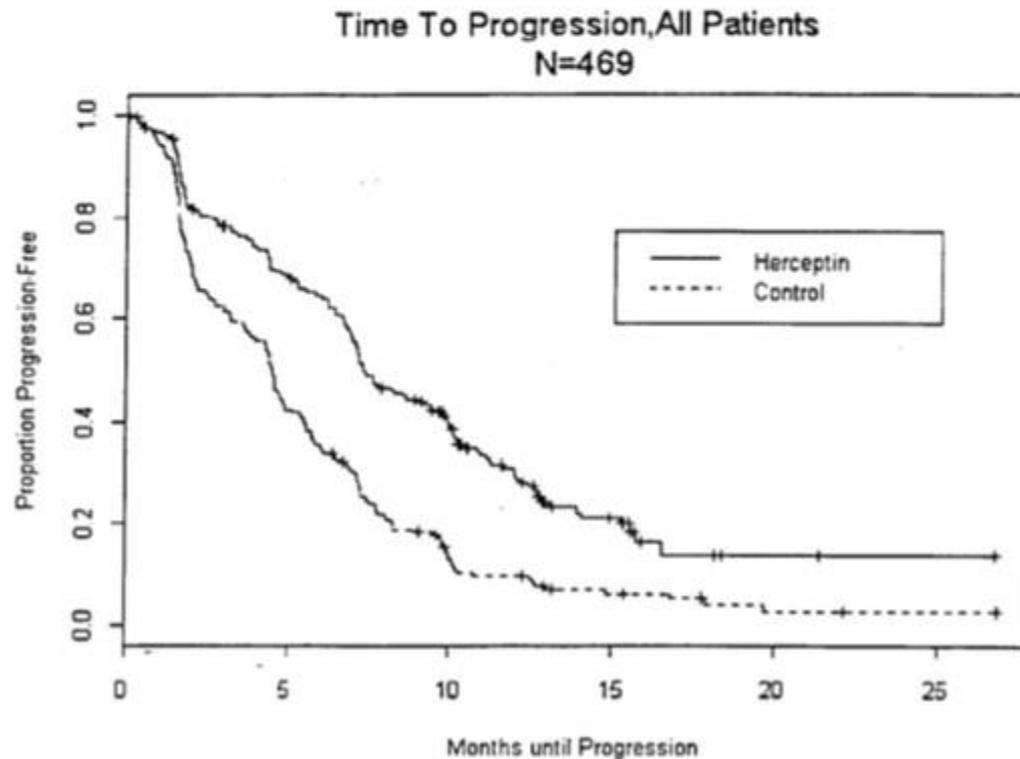
Monoclonal antibodies **-mab**

Substems to describe antibody origin

Chimeric	-xi-	Ritux imab
Humanized	-zu-	Trastuz umab
Human	-u-	Panitum umab
Mouse	-o-	Solit omab

- 20-25% of people with breast cancer are HER2-positive
- Response rate of Herceptin + chemotherapy 45%
chemotherapy alone 29%

생존률 약간 증가

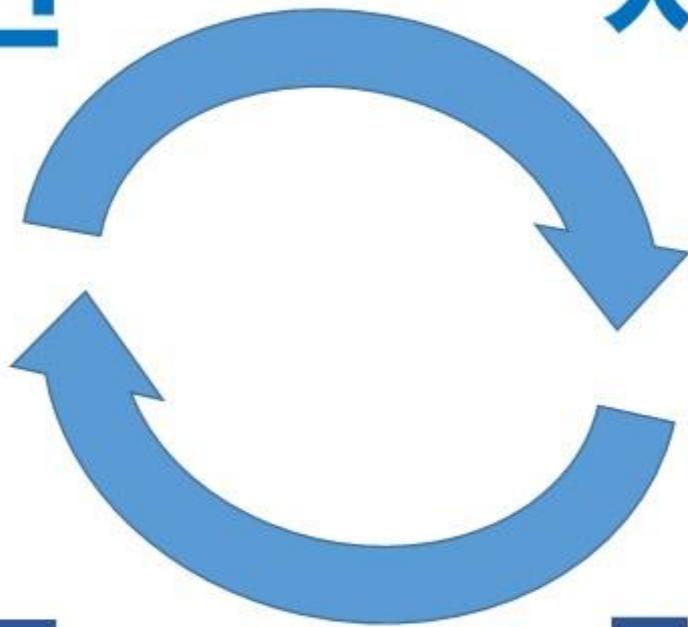


약으로 잘 안될 때 방사선으로는 되지 않을까?



진단

치료



치료

진단

진단

치료

진단 동시 치료

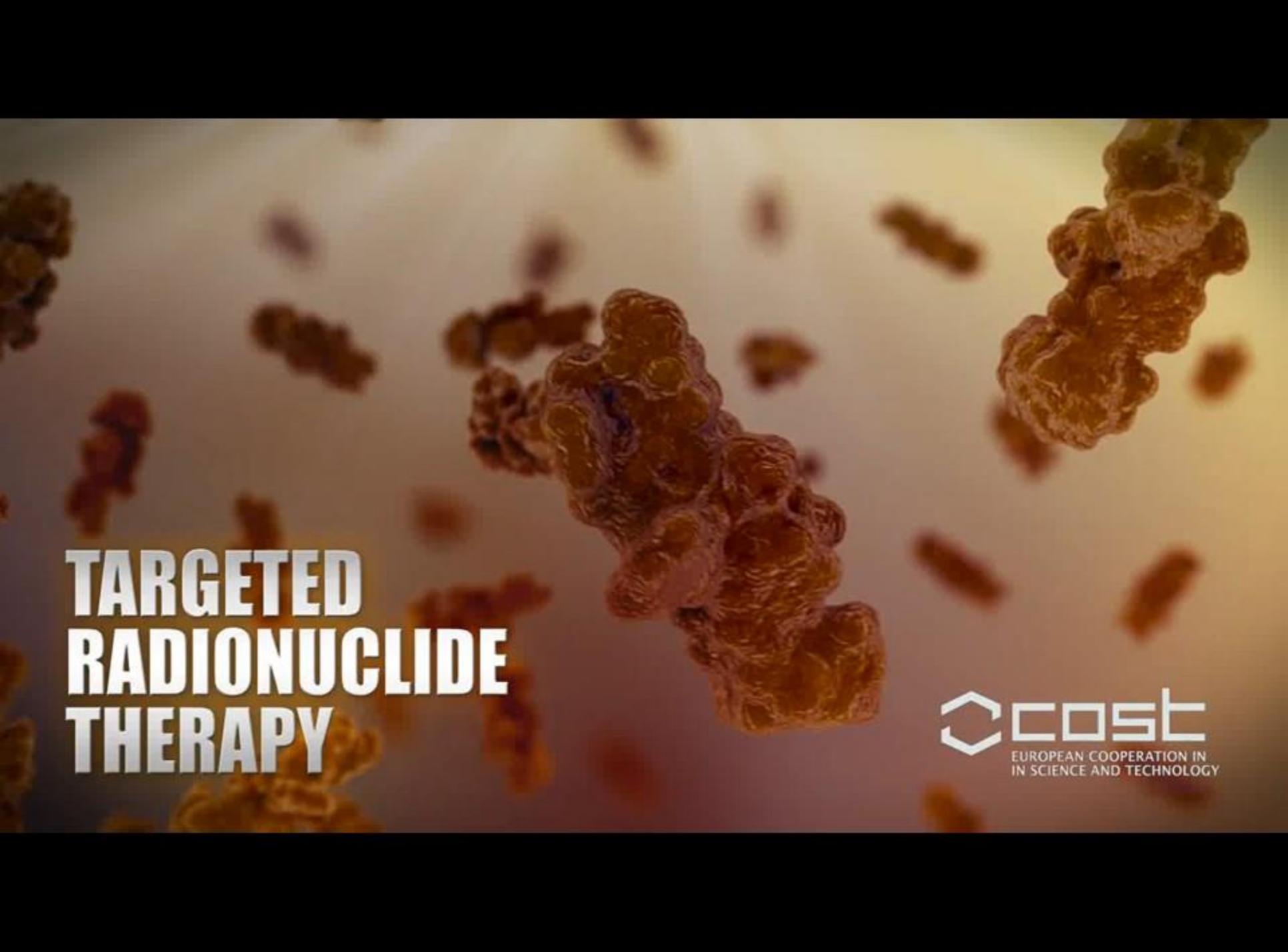
Theranosis

치료

진단

Therapy

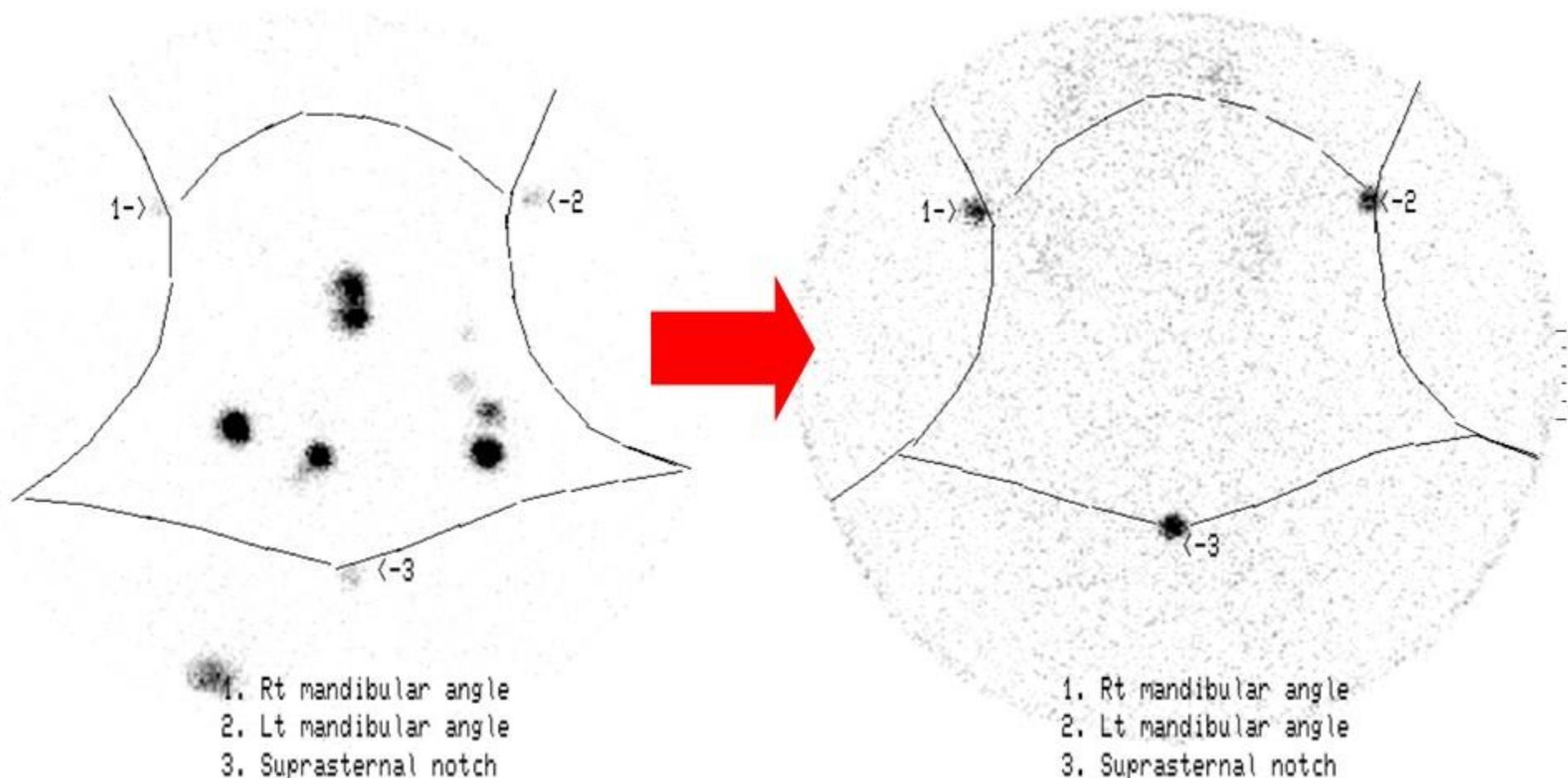
Diagnosis

A microscopic view of several elongated, brownish, textured structures, likely cells or biological samples, against a warm, golden-brown background. The structures are out of focus, with one in the center being more prominent.

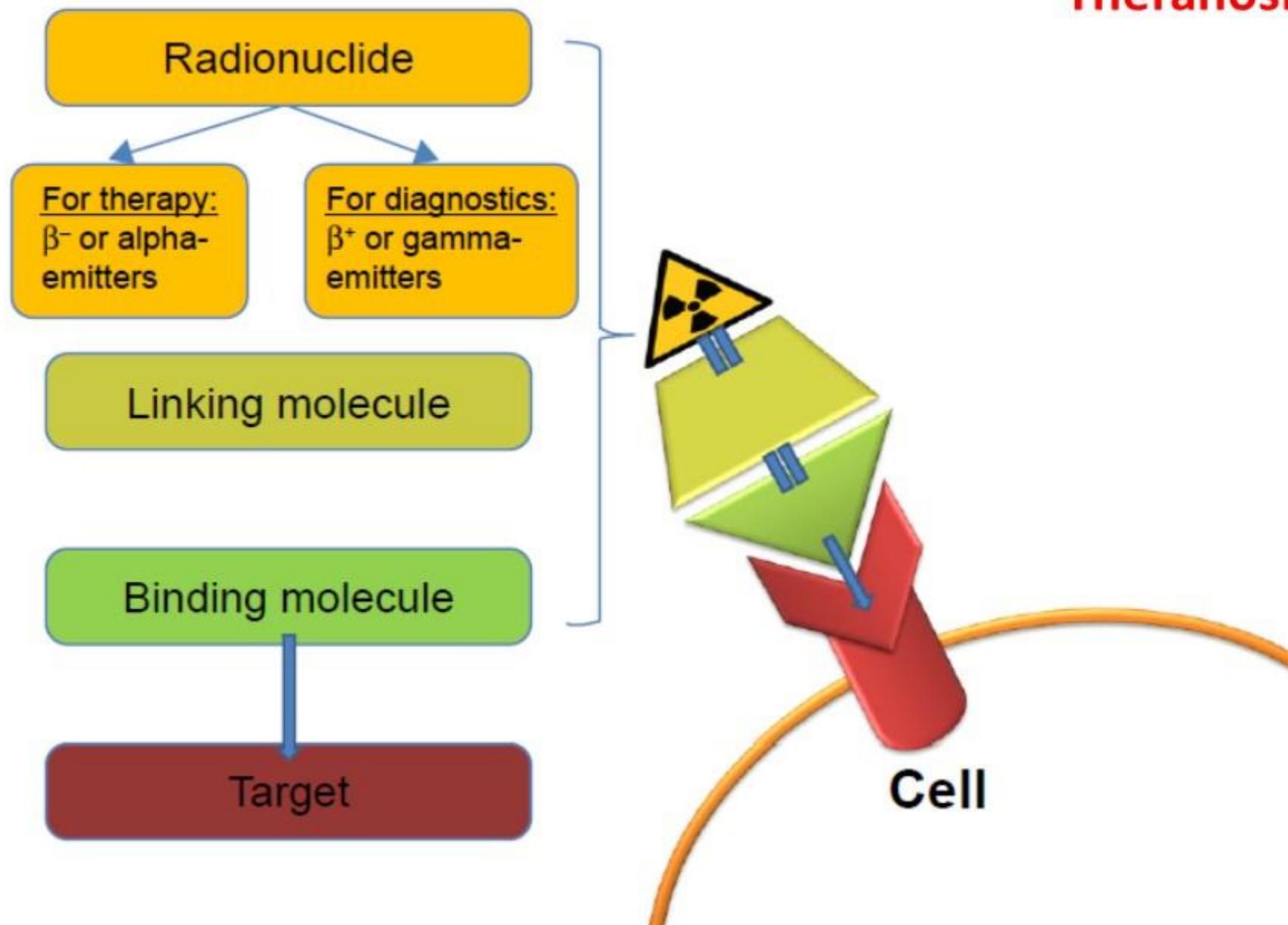
TARGETED RADIONUCLIDE THERAPY

 **cost**
EUROPEAN COOPERATION IN
IN SCIENCE AND TECHNOLOGY

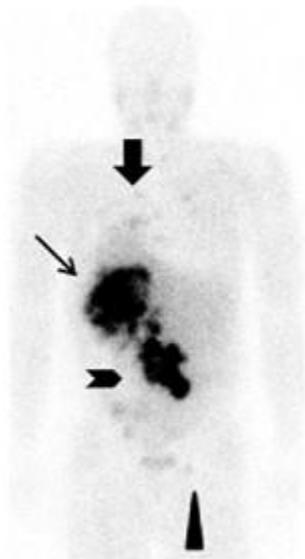
방사성요오드 - 갑상선암 진단동시치료



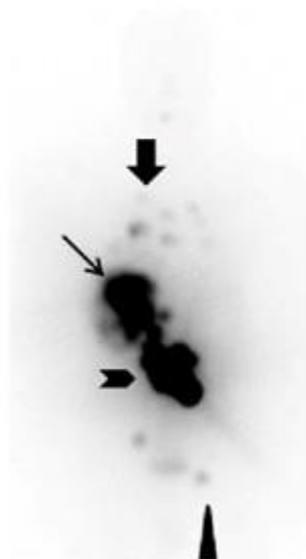
Theranosis



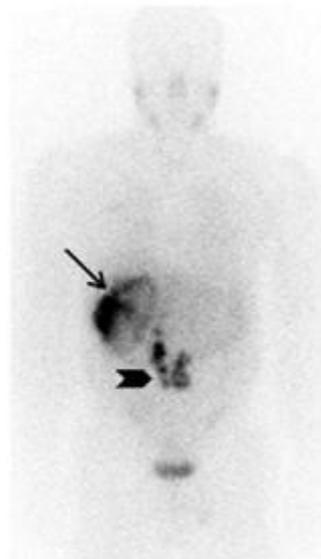
mIBG - 갈색세포암 진단동시치료



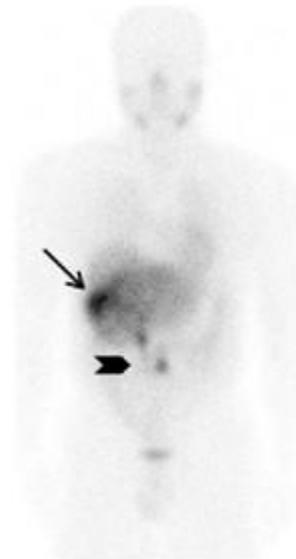
I-123 MIBG
Baseline



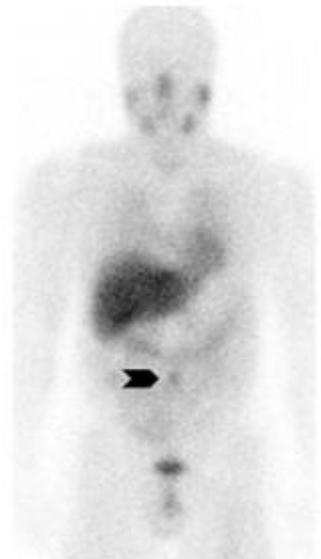
I-131 MIBG
1st Rx



I-123 MIBG
Post Rx 2

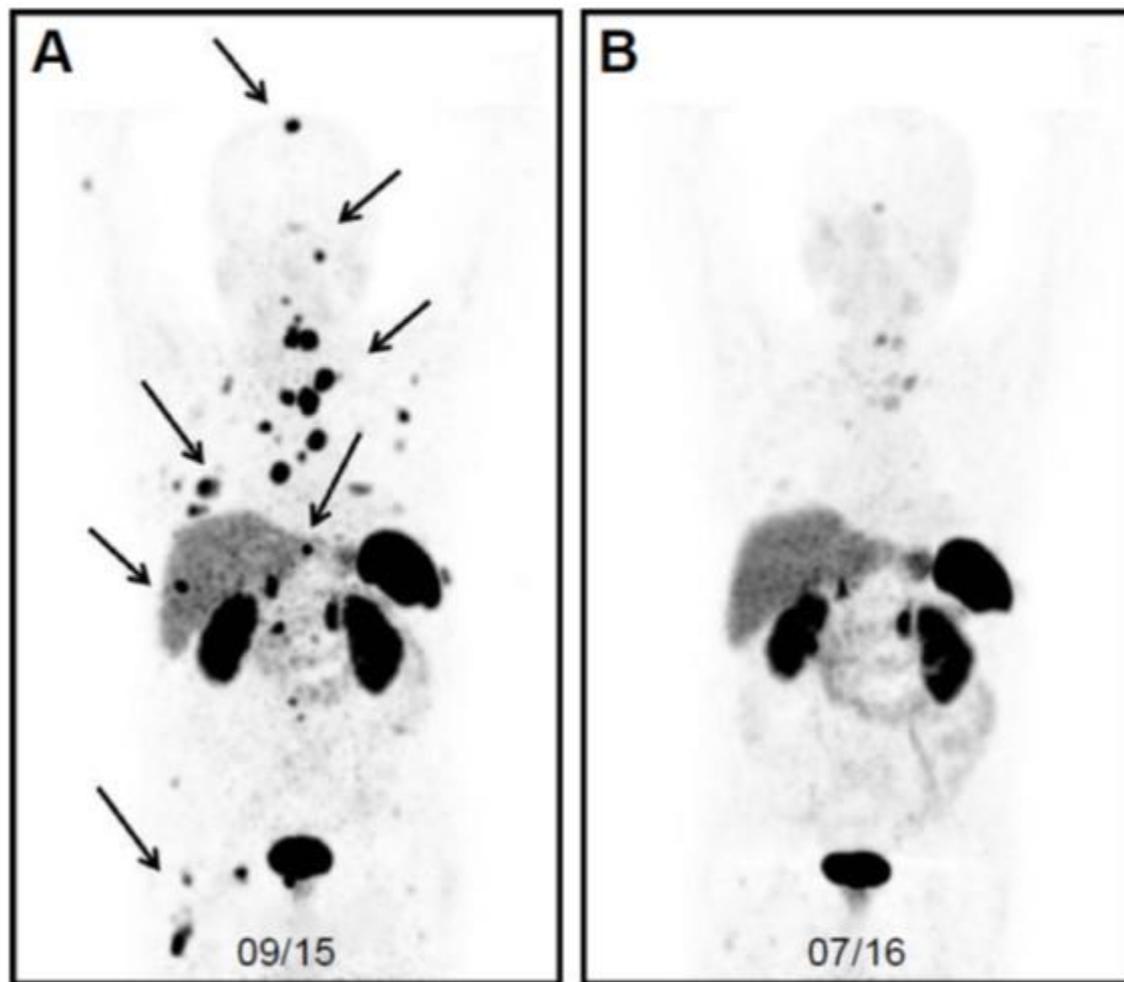


I-123 MIBG
Post Rx 4



I-123 MIBG
Post Rx 4 and
surgery

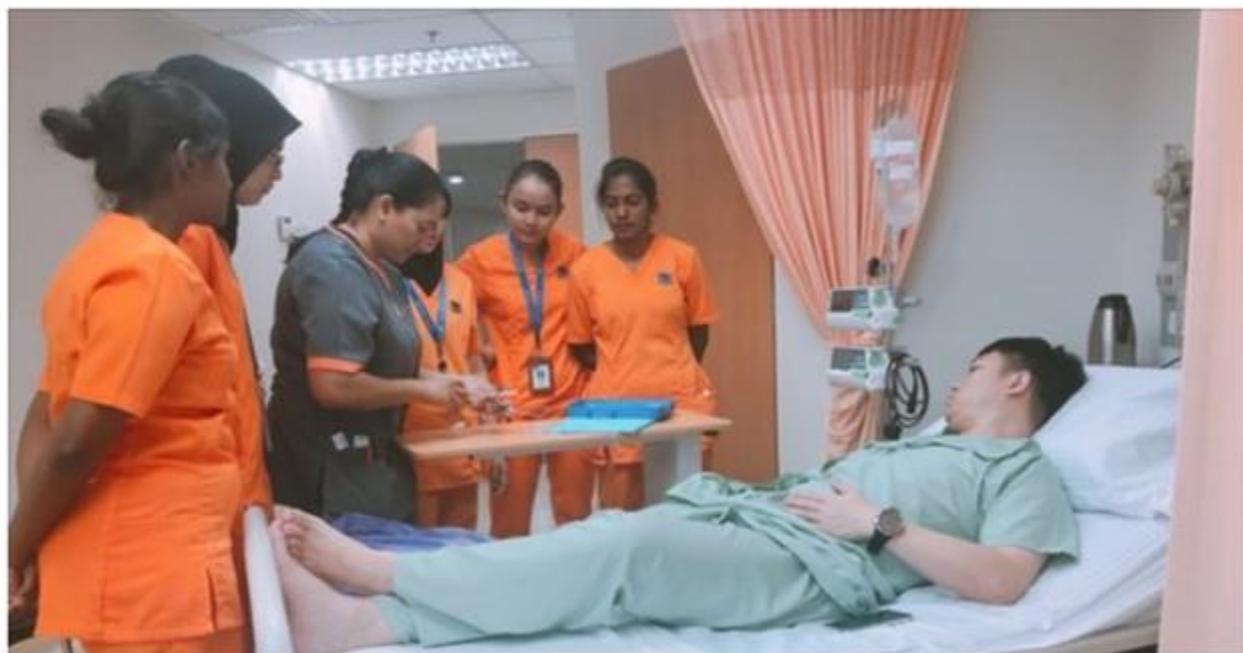
SSA - 신경내분비암 진단동시치료



규제 막혀 ... '잡스 암' 고치러 해외 가는 환자들

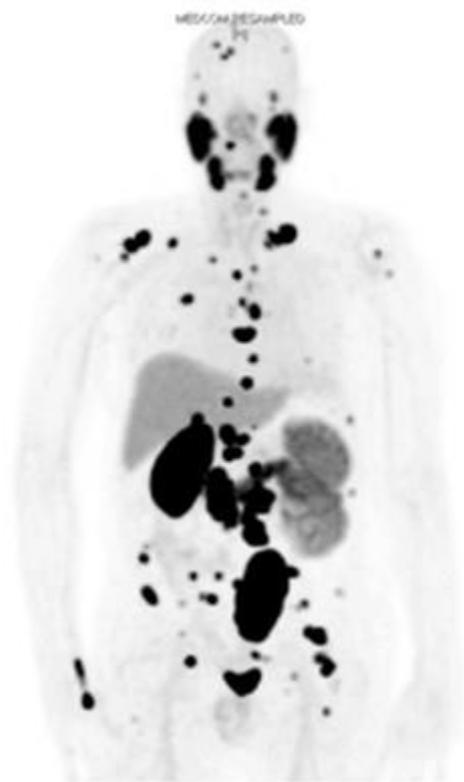
[중앙일보] 입력 2018.08.27 00:02 | 종합 18면 지면보기▶

 이승호 기자

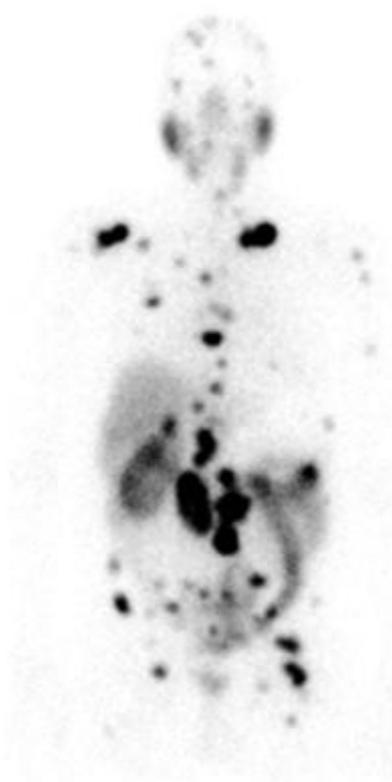


희귀암인 췌장 신경내분비종양을 앓고 있는 황모씨(오른쪽)가 지난 1월 말레이시아 현지 병원에서 루테숨 치료를 받고 있다.[사진 한국신경내분비종양환우회]

PSMA - 전립선암 진단동시치료



10/2015
 ^{68}Ga -PSMA-11 (MIP)



11/2015
 ^{177}Lu -PSMA-617 (GM)



01/2016
 ^{177}Lu -PSMA-617 (GM)



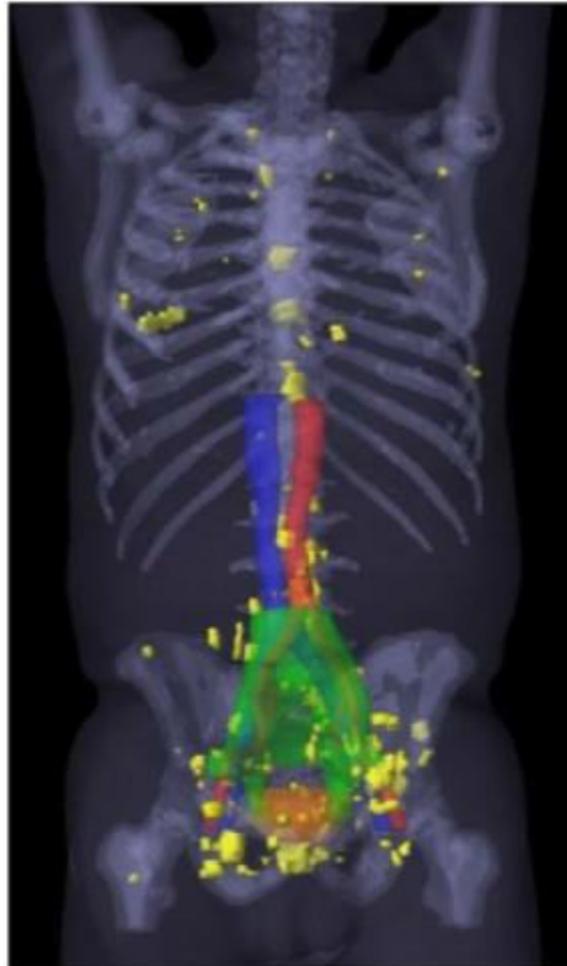
04/2016
 ^{177}Lu -PSMA-617 (GM)

루테숨은 다른 말기암 치료에도 사용된다. 장태안 분당서울대병원 신경외과 교수는 7년 전 전립선암 3기 진단을 받았다. 지난해부터 해외에서 5차례 루테숨 치료를 받았다. 장 교수는 "지난해 '항암치료 외엔 할 수 있는 게 없다'는 말을 듣고 루테숨 치료를 시작했다. 지금은 상태가 상당히 나아졌다"고 말했다. 국내 대형병원도 기술은 있지만 치료는 할 수 없다. 루테숨이 식품의약품안전처 사용 허가를 받지 못해서다.

서일식 한국신경내분비종양환우회 회장은 "몸 상태가 좋지 않은 말기 암 환자는 해외로 가는 비행기를 타는 것만으로도 큰 부담"이라며 "현지 도착 직후 쇼크가 와 곧바로 중환자실로 이송된 경우도 있다"고 말했다. 안기종 환자단체연합회 대표는 "국내 진료가 아니라서 재난적 의료비 등 건강보험을 통한 지원을 못 받는다"고 말했다.



PSMA PET 3D-MAP OF 52/270 (19%) RECURRENT PROSTATE CANCER PATIENTS WITH LESIONS OUTSIDE OF THE RADIOTHERAPY TARGET VOLUMES



n = 270

**SRT
CANDIDATES**

- PSMA PET/CT
- Radical prostatectomy
- Biochemical recurrence
- No prior radiation therapy
- PSA <1 ng/ml



PSMA PET-blinded contouring
of salvage radiotherapy target volumes on CT
including prostate bed + pelvic lymph nodes



- 132/270 patients (49%) with positive ^{68}Ga -PSMA PET/CT
- 52/270 patients (19%) with at least one PSMA-positive lesion not covered by the target volumes:
 - 33/270 (12%) extra-pelvic lesion (ex: bone 9%)
 - 19/270 (7%) pelvic lesion (ex: perirectal 6%)



^{68}Ga -PSMA PET/CT would have a major impact on radiotherapy planning in at least 19% of patients with prostate cancer early failure (PSA < 1) after surgery

RADIOPHARMACEUTICAL OF THE YEAR

²²⁵Actinium-PSMA-617

CRPC

DIFFUSE BONE
DISEASE

ALREADY TREATED
WITH EVERYTHING

PSA > 400



CRPC

AFTER 1 CYCLE

PSA = 3

Alpha Therapy

^{211}At astatine

^{224}Ra ^{212}Pb ^{212}Bi lead

^{213}Bi bismuth

^{223}Ra radium

^{225}Ac actinium

Table 1 Overview of theranostic agents

Theranostic molecule	Iodine	mIBG	SSA	PSMA-ligands	Benzamide/ arylcarboxamide
Target	Thyroid cancer cells	Neurosecretory granules	SSTR, especially the subtype SSTR2	PSMA	Melanin
Planar imaging/ SPECT or PET	¹³¹ I and ¹²³ I ¹²⁴ I	[¹³¹ I]-mIBG, [¹²³ I]-mIBG [¹²⁴ I]-mIBG	SSA labeled with indium-111 [⁶⁸ Ga]Ga-DOTA-TATE [⁶⁸ Ga]Ga-DOTA-TOC [⁶⁸ Ga]Ga-DOTA-NOC	[¹²³ I]-MIP-1072 [⁶⁸ Ga]Ga-PSMA-11 [⁶⁸ Ga]Ga-PSMA-617	[¹²³ I]-BA52 [¹⁸ F]F-ICF15002
Therapeutic agent	¹³¹ I	[¹³¹ I]-mIBG	[¹⁷⁷ Lu]Lu-DOTA-TATE [¹⁷⁷ Lu]Lu-DOTA-TOC [⁹⁰ Y]Y-DOTA-TOC [⁹⁰ Y]Y-DOTA-TATE	[¹⁷⁷ Lu]Lu-J591 [⁹⁰ Y]Y-J591 [¹³¹ I]-MIP-1095 [¹⁷⁷ Lu]Lu-PSMA-617	[¹³¹ I]-BA52 [¹³¹ I]-ICF15002
Indication	Thyroid cancer	Neuroblastomas, pheochromocytomas, paragangliomas, medullary thyroid carcinomas, and other NEN	NEN, especially GEP-NEN	Metastatic prostate cancer	Metastatic melanoma

Abbreviations: mIBG, metaiodobenzylguanidine; SSA, somatostatin analogs; SSTR, somatostatin receptors; NEN, neuroendocrine neoplasia; GEP, gastroenteropancreatic system; SPECT, single photon emission computed tomography; PET, positron emission tomography.

방사선 기술의
의학적 이용



한국원자력연구원
Korea Atomic Energy Research Institute



한국원자력의학원
KOREA INSTITUTE OF RADIOLOGICAL & MEDICAL SCIENCES

2018년 10월 24일(수) 13:30~18:00

여수 엑스포컨벤션센터 1층, 컨퍼런스홀 4

From bench to bed to community and beyond

핵의학의 발전과 동향

진단

치료

진단 동시 치료

Theranosis

치료

진단



한국원자력연구원
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KOREA INSTITUTE OF BIOLOGICAL & MEDICAL SCIENCES

방사선 기술의 의학적 이용

From bench to bed to community and beyond