SPECT/CT Imaging
Quality Assurance by Using ACR Phantom

時間	題目	講員
08:45~09:00	報到	
09:00~09:05	Opening	彭南靖 主任
09:00~10:00	演講: SPECT/CT影像品保與ACR假體實驗作業流程說明	高潘福 主任
10:00~10:20	茶歇	
10:20~12:00	實作: ACR假體放射藥物備製與 SPECT /CT 影像收錄	高潘福 主任 俞長青 放射師 王寶英 放射師
12:00~13:00	討論: 影像品質討論	全體人員

中山醫學大學附設醫院
核子醫學科 高潘福

2017-06-17

核研所 NL 1040368

ACR Accreditation of Nuclear Medicine and PET Imaging Departments*

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American College of Radiology, Reston, Virginia

J Nucl Med Technol 2006; 34:18–24

- The ACR Nuclear Medicine and PET Accreditation Program evaluates the qualifications of personnel, equipment, image quality, and quality control measures.

Accreditation Program

- To improve patient care
- Comprehensive review and evaluation of a facility through peer review
- Voluntary evaluation
- Achieve and maintain a level of practice that promotes the delivery of the highest-quality health care

J Nucl Med Technol 2006; 34:18–24

TABLE 3
Required Annual Performance Tests

- Intrinsic uniformity
- System uniformity
- Intrinsic or system spatial resolution
- Sensitivity
- Energy resolution
- Counting rate parameters
- Multiple-window spatial registration
- Formatter/video display
- Overall system performance for SPECT systems
- System interlocks
- Dose calibrators (accuracy)
- Thyroid uptake and counting systems (energy linearity, energy resolution, and χ^2 test)

J Nucl Med Technol 2006; 34:18–24

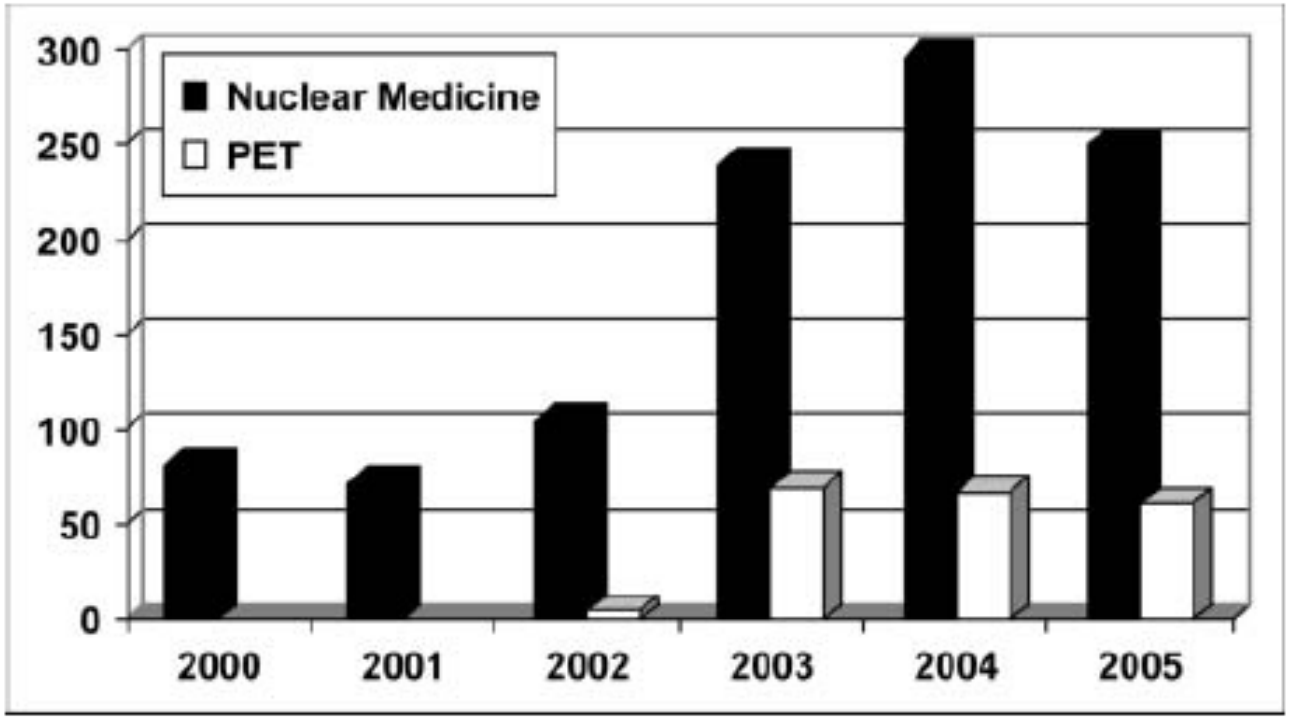

FIGURE 3. Number of units by year that have applied for accreditation (including renewals) as of 30 November 2005.

J Nucl Med Technol 2006; 34:18–24

TABLE 4
Technologist Quality Control Tests

Procedure	Frequency
Intrinsic or system uniformity	Daily
Intrinsic or system spatial resolution	Weekly
Center of rotation	Monthly
High-count floods for uniformity correction for SPECT systems	As recommended by medical physicist
Overall system performance for SPECT systems	Quarterly
Dose calibrators	
Constancy	Daily
Linearity	Quarterly
Leak test	Semiannually
Thyroid uptake and counting systems	Each day of use

J Nucl Med Technol 2006; 34:18–24

•**均勻度測試(extrinsic uniformity with Co-57)**

	UFOV(%)				CFOV(%)			
Detector	1		2		1		2	
Date	Int.	Diff.	Int.	Diff.	Int.	Diff.	Int.	Diff.

Int. = integral difference
Diff. = differential difference
*評定標準：Planar imaging:小於4%

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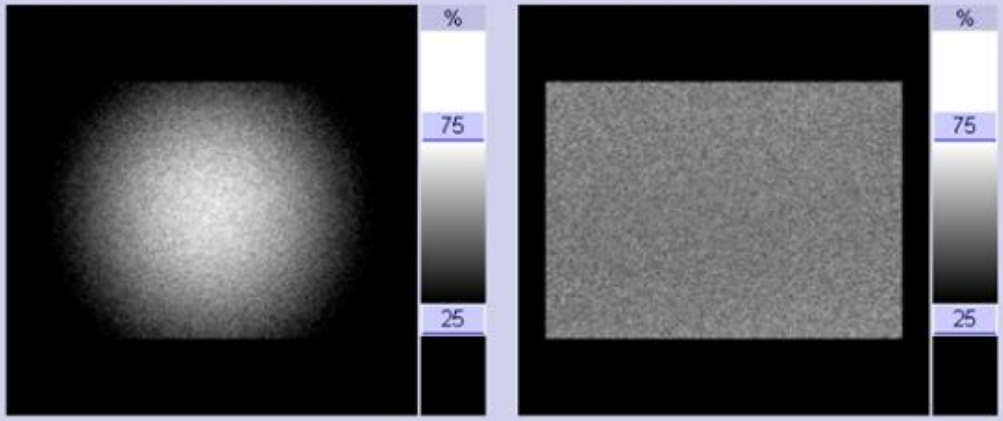
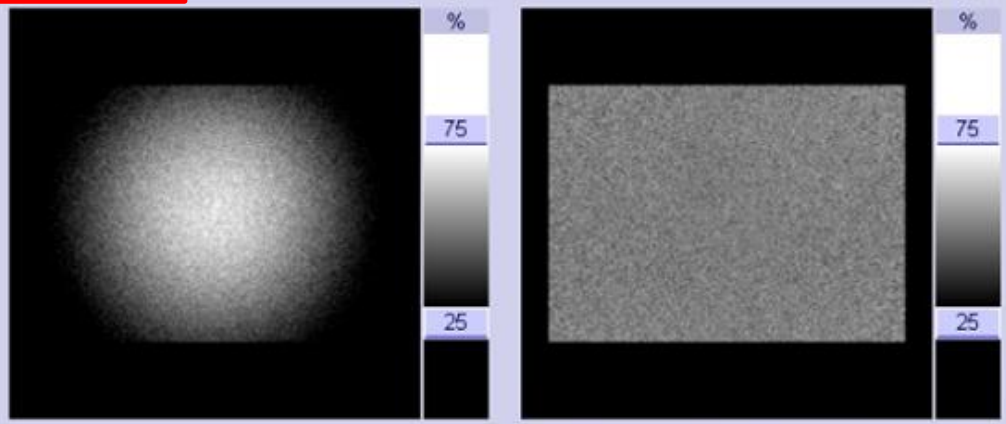
Detector 1



Acquired Flood　　Curvature Corrected Flood

Uniformity	Central FOV	Useful FOV
Integral	1.98 %	2.24 %
Differential	1.18 %	1.54 %

Detector 2



Acquired Flood　　Curvature Corrected Flood

Uniformity	Central FOV	Useful FOV
Integral	1.96 %	2.04 %
Differential	1.19 %	1.50 %

SPECT/PET phantom study for quality assurance

FIGURE 1. Jaszczak Deluxe Flangeless ECT Phantom.

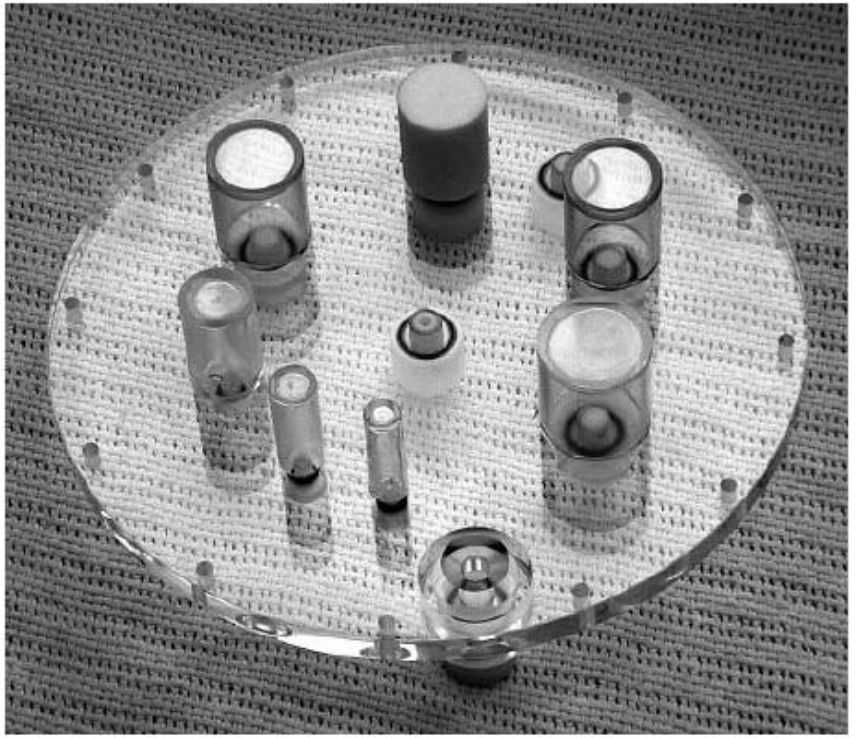
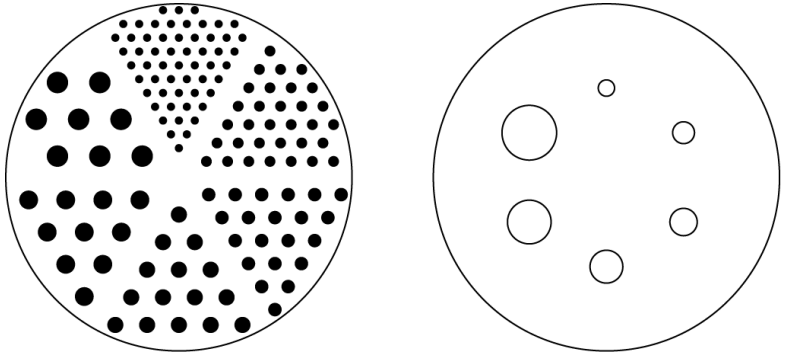
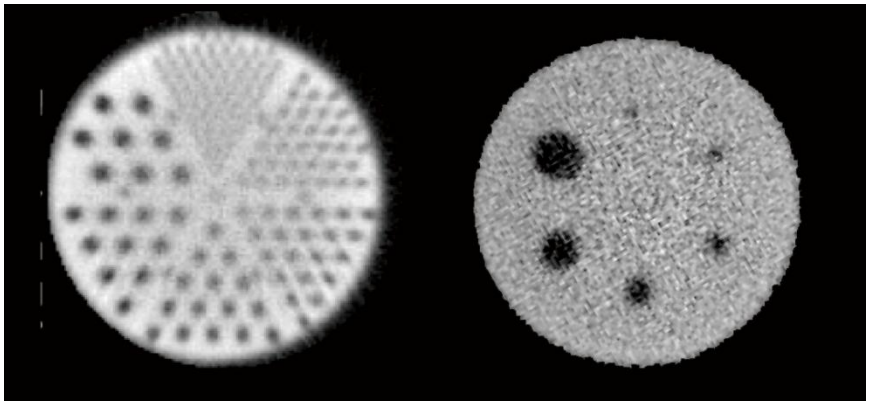


FIGURE 2. Modified faceplate used with Jaszczak Deluxe Flangeless ECT Phantom for PET phantom acquisition.

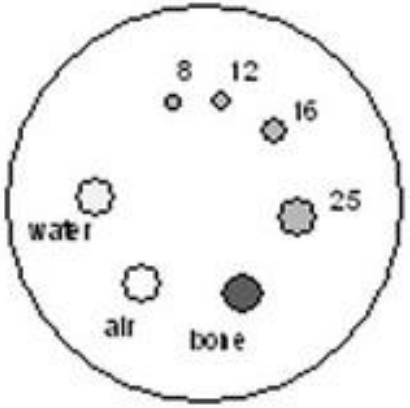
Flangeless Deluxe Jaszczak Phantom™ Model ECT/FL-DLX/P

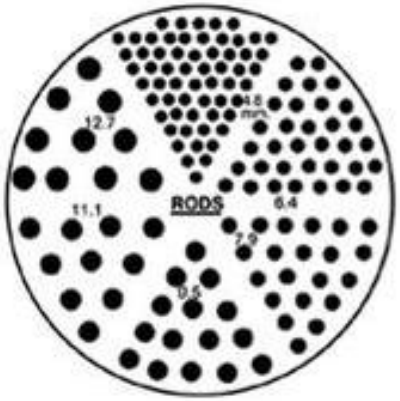


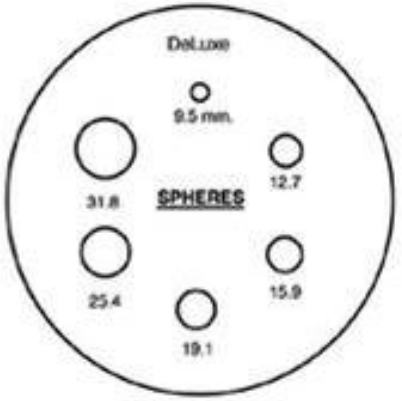


Specifications of Insert and Spheres:
Rod diameters: 4.8, 6.4, 7.9, 9.5, 11.1, and 12.7 mm
Height of rods: 8.8 cm
Solid sphere diameters: 9.5, 12.7, 15.9, 19.1, 25.4 and 31.8 mm

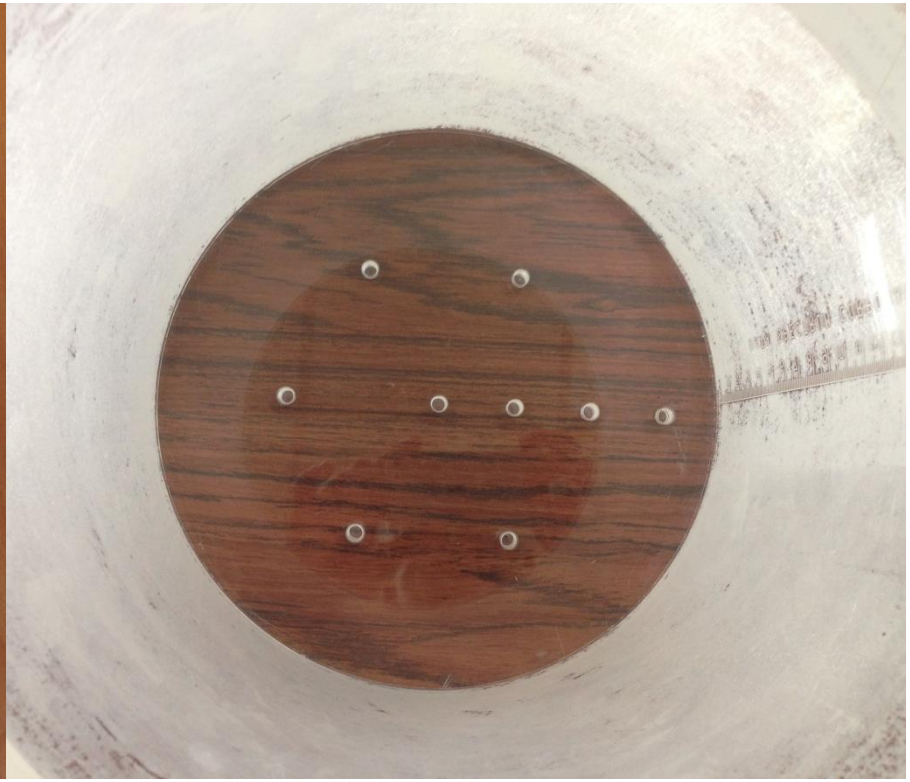
Flangeless Deluxe PET and SPECT Phantoms







Flangeless Deluxe PET Phantoms



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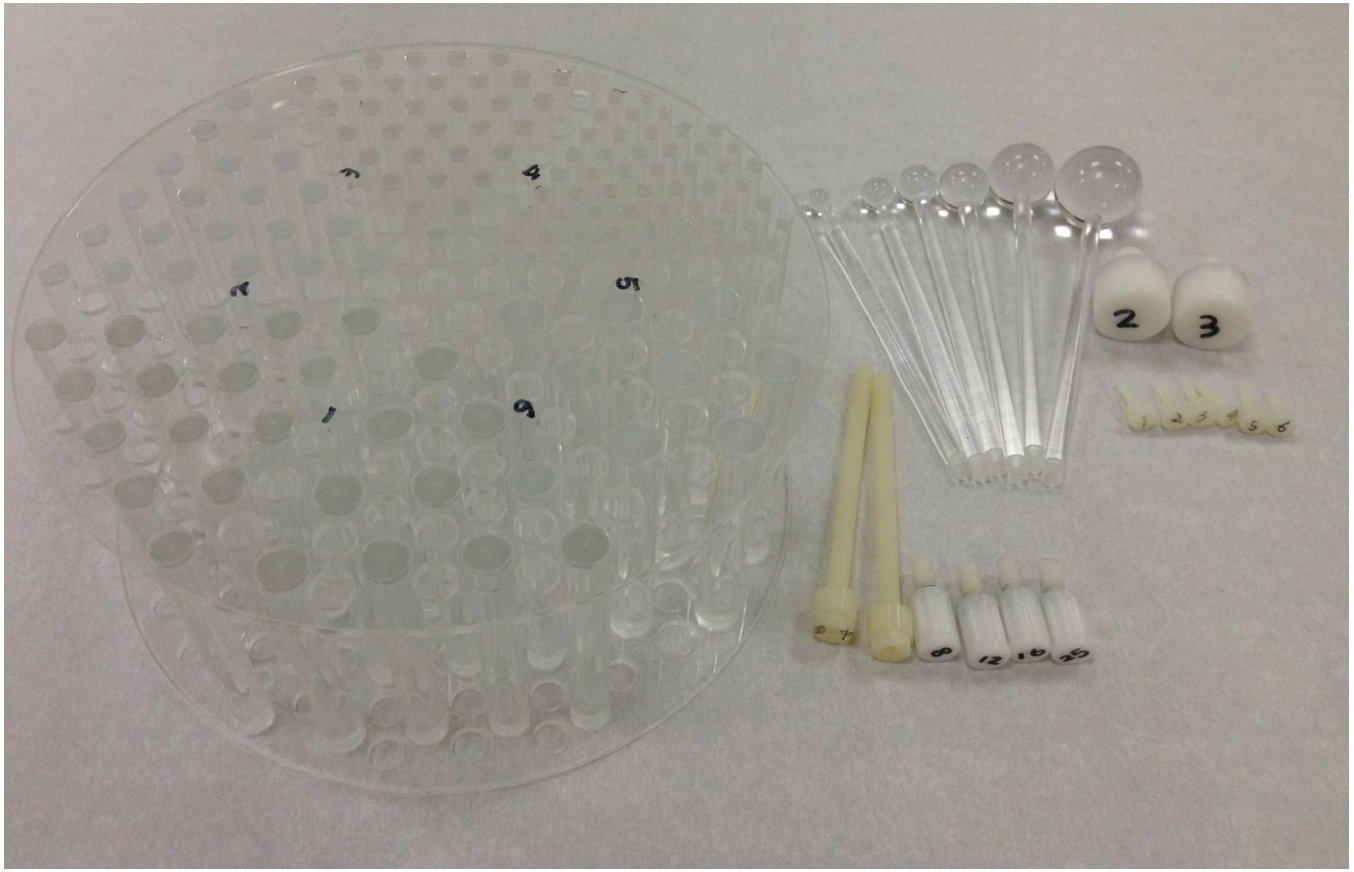
Flangeless Deluxe PET Phantoms



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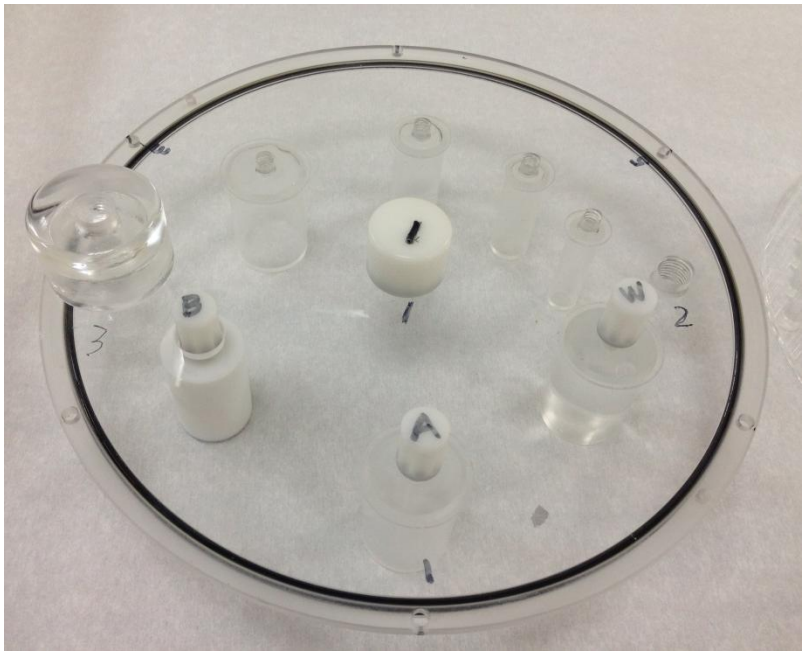
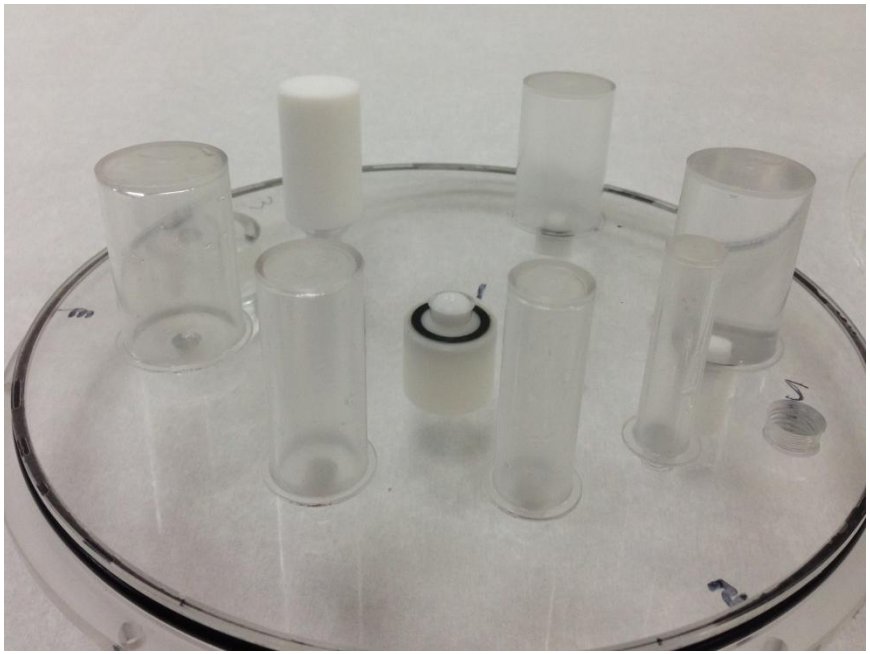
Flangeless Deluxe PET Phantoms





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藥物濃度泡製

決定背景值(background, B.G.)和熱區(hot area)的藥物比例

以臨床影像B.G.和hot area的比值約為1：4 (此比例是我們用來配置藥物活性的依據)

計算假體所使用的藥物劑量

由臨床上可知道一位70kg的患者施打的藥物劑量約為20mCi，而假體加水重量約為8.7kg，背景容積約為5575c.c，則假體使用的藥物劑量約為20x(6.5/70)=1.85mCi. ，估算以2.0 mCi 計算。

藥物濃度泡製

計算B.G.和hot area使用的藥物分配

首先我們已知假體的背景容積約為5575c.c. 另外取一袋約150c.c.生理食鹽水。所使用的藥物活度為2.0mCi，而欲達到B.G.和hot area的比值約為1：4則計算如下：

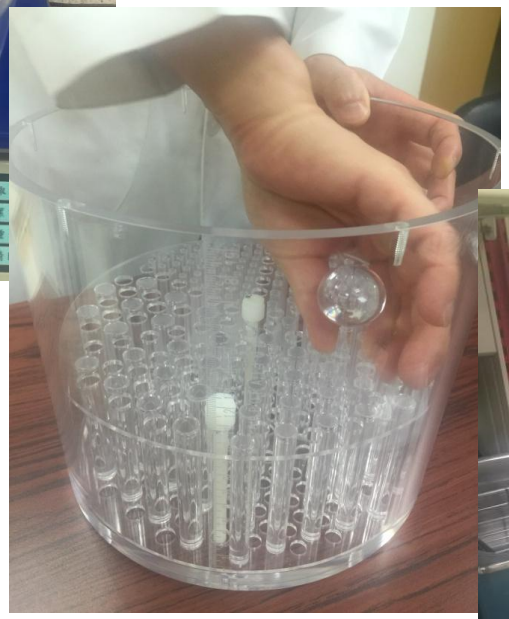
當 (2.0-x)/5560：x/150 要符合B.G.和hot area的比值 1：4

則可知 x=0.2mCi (即hot area 所需劑量)

2.0 – 0.2 = 1.8 mCi (為B.G..所需劑量)

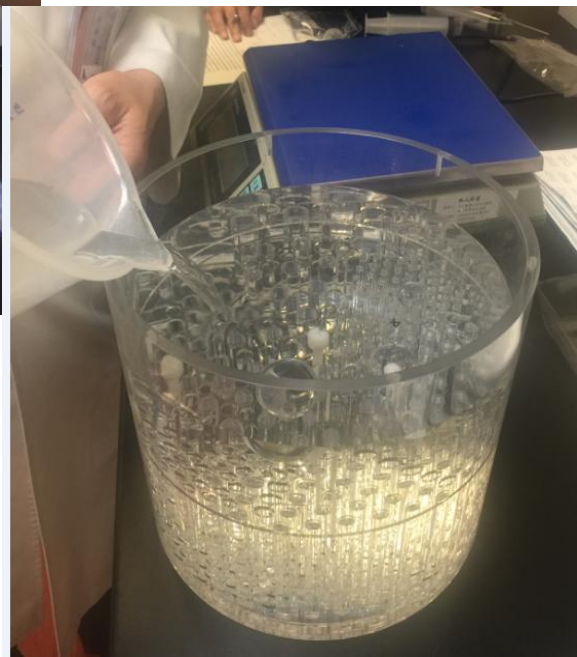
隨後將1.8 mCi Tc-99m灌入假體當中(需輕微搖晃使其均勻)；另外將0.2 mCi Tc-99m灌入生理食鹽水中(需輕微搖晃使其均勻)隨後抽出，打入代表假體的hot area區域。依上述步驟即完成藥物配置。

假體備製過程



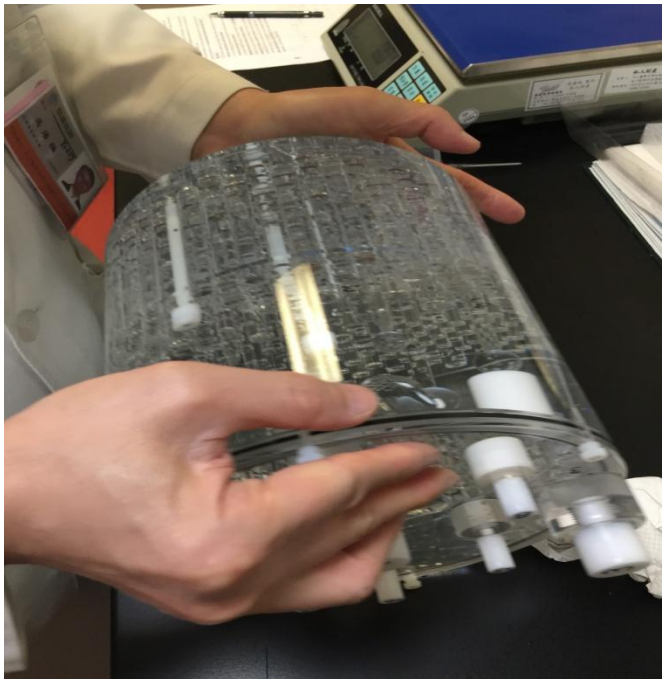
務必抓住圓球下方的長桿子旋轉固定

注入純水



測量背景部分的總體積

Flangeless Deluxe PET Phantoms Preparation



背景裝滿後務必滾動假體，使氣泡集中，
再緩緩扶正直立使氣泡向注入口集中。

灌注放射活性時務必使用
軟針頭，避免刺壞假體。

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Flangeless Deluxe PET Phantoms Preparation

將測量好的放射活性，注入水袋中稀釋濃度，混合均勻後再抽出溶液，注入hot spheres 中。

抽藥後務必要將硬針換成軟針頭，再注射入假體。

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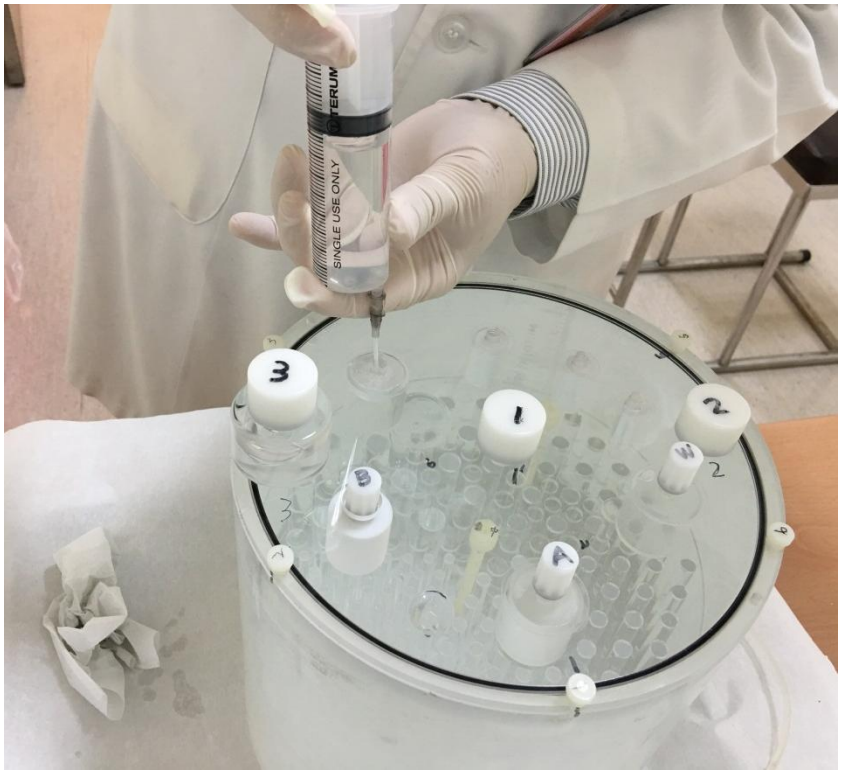

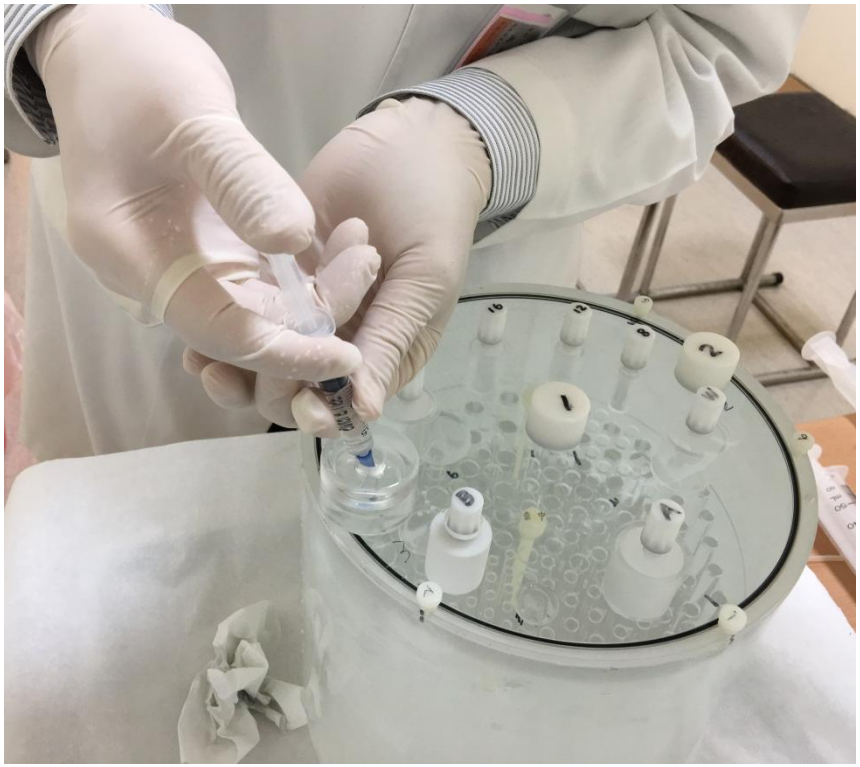

背景溶液最後再補滿超過注入口，
再封起來，才不會有氣體再進入。

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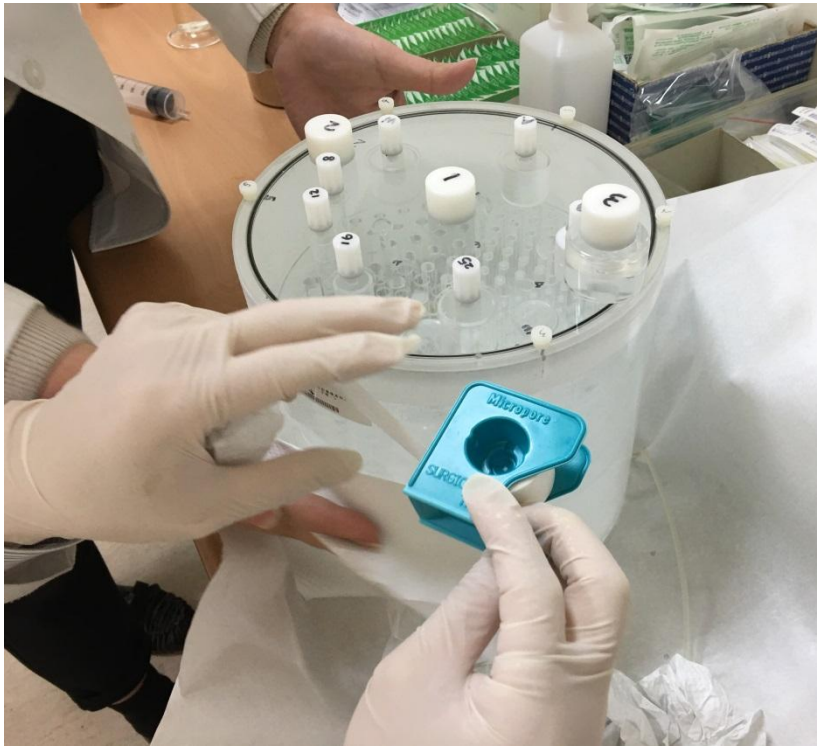
Flangeless Deluxe PET Phantoms Preparation



沿著假體上蓋子邊緣貼上一圈紙膠帶再沿著假體上的尺標貼上垂直的紙膠帶，作為造影擺位時雷射定位使用。

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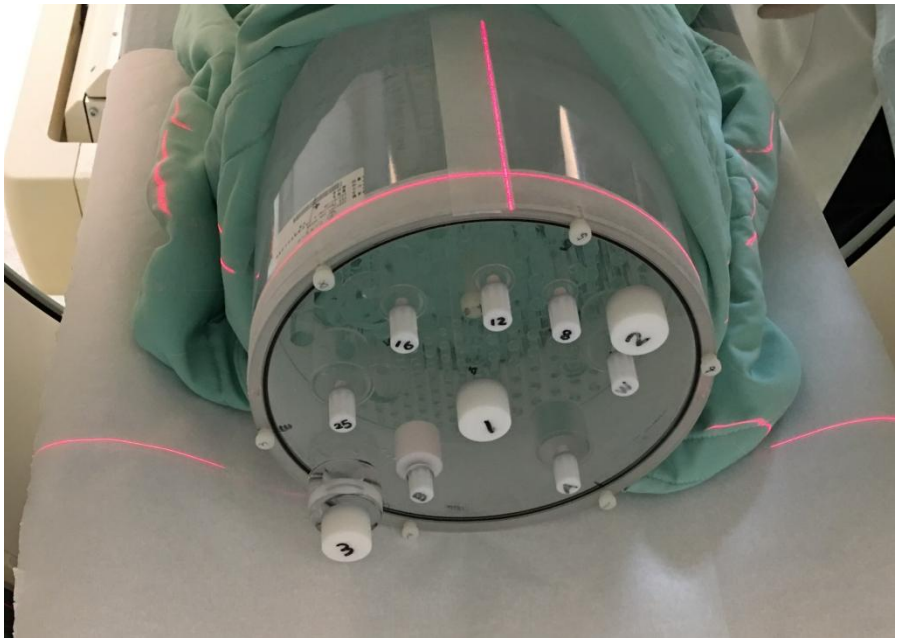
Flangeless Deluxe PET Phantoms Preparation



鋪上抗汙紙，再固定假體在造影床上或head holder上(注意平衡假體重量，在holder的身體部分用重物壓住)，沿著假體蓋子邊緣和垂直的紙膠帶的尺標，作為造影擺位時雷射定位使用。

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Phantom positioning

- Align the phantom parallel to the axis of the table;
- Use a bubble level（水平儀） to position the phantom in the horizontal plane;

SPECT/CT acquisition protocol

SPECT:

Collimator: LEHR

Detector rotation: 360 degree for each head

Steps: 60

Time: 30 sec/step

Window: 140 keV, width: 15%

Matrix size: 128 x 128

Zoom: 1

Step-and-shoot

Total acquisition time: about 36 min

Radius-of-rotation: as small as possible

14 cm with head holder, 22 cm on table

CT:

Attenuation correction: CTAC vs. Change's

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實作課程

分兩組：A (俞長青)， B (王寶英)

劑量計算

A組=1:5 總劑量 10 mCi

B組=1:10 總劑量 6 mCi

測量劑量 → 假體填充 → 擺位造影

藥物濃度泡製-A

計算B.G.和hot area使用的藥物分配

首先我們已知假體的背景容積約為5575c.c. 另外取一袋約100c.c.生理食鹽水。所使用的藥物活度為10.0mCi，而欲達到B.G.和hot area的比值約為1：5則計算如下：

當 (10.0-x)/5575：x/100 要符合B.G.和hot area的比值 1：5

則可知 x=0.82mCi (即hot area 所需劑量)

10.0 – 0.82 = 9.18 mCi (為B.G..所需劑量)

隨後將9.18 mCi Tc-99m灌入假體當中(需輕微搖晃使其均勻)；另外將0.82 mCi Tc-99m灌入生理食鹽水中(需輕微搖晃使其均勻)隨後抽出，打入代表假體的hot area區域。依上述步驟即完成藥物配置。

藥物濃度泡製-B

計算B.G.和hot area使用的藥物分配

首先我們已知假體的背景容積約為5575c.c. 另外取一袋約100c.c.生理食鹽水。所使用的藥物活度為6.0mCi，而欲達到B.G.和hot area的比值約為1：10則計算如下：

當 (6.0-x)/5575：x/100 要符合B.G.和hot area的比值 1：10

則可知 x=0.91mCi (即hot area 所需劑量)

6.0 – 0.91 = 5.09 mCi (為B.G..所需劑量)

隨後將5.09 mCi Tc-99m灌入假體當中(需輕微搖晃使其均勻)；另外將0.91 mCi Tc-99m灌入生理食鹽水中(需輕微搖晃使其均勻)隨後抽出，打入代表假體的hot area區域。依上述步驟即完成藥物配置。

Integral uniformity is based on the maximum and minimum pixel counts in the image and is defined as

$$\text{Integral Uniformity (\%)} = 100 \times \frac{\text{max. pixel count} - \text{min. pixel count}}{\text{max. pixel count} + \text{min. pixel count}} \quad (14\text{-}21)$$

This is calculated for the UFOV and CFOV. Integral uniformity values are typically 2% to 4%.

Differential uniformity is based on the change in counts of five consecutive pixels across all rows and columns of the image. It is defined as

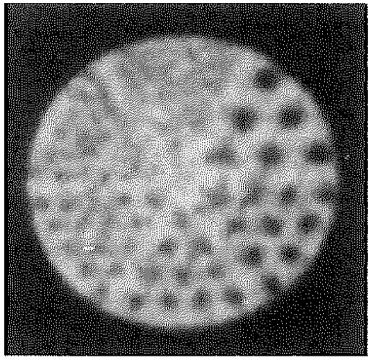
$$\text{Differential Uniformity (\%)} = 100 \times \frac{(\text{high} - \text{low})}{(\text{high} + \text{low})} \quad (14\text{-}22)$$

where "high" refers to the maximum count difference for any five consecutive pixels (row or column) in the image and "low" refers to the minimum count different for any five consecutive pixels. This usually is reported for the UFOV.

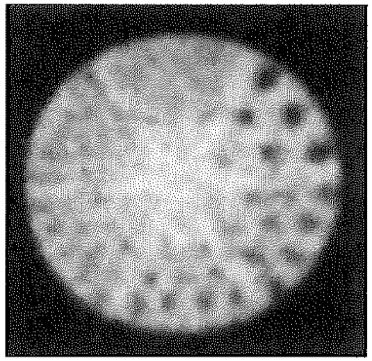
STANDARD COLD RODS

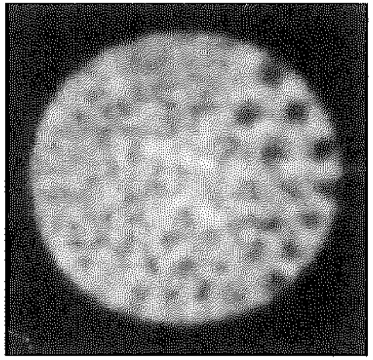
HIGH RESOLUTION COLLIMATOR
Approximately 8 million cnts

LOW ENERGY, ALL PURPOSE COLLIMATOR.
Approximately 10 million cnts.

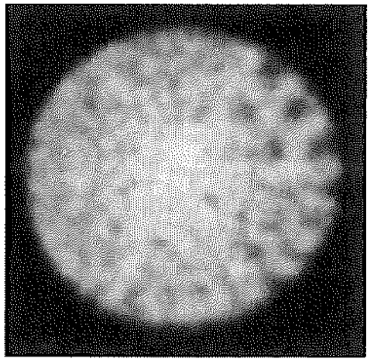


ROR
14cm



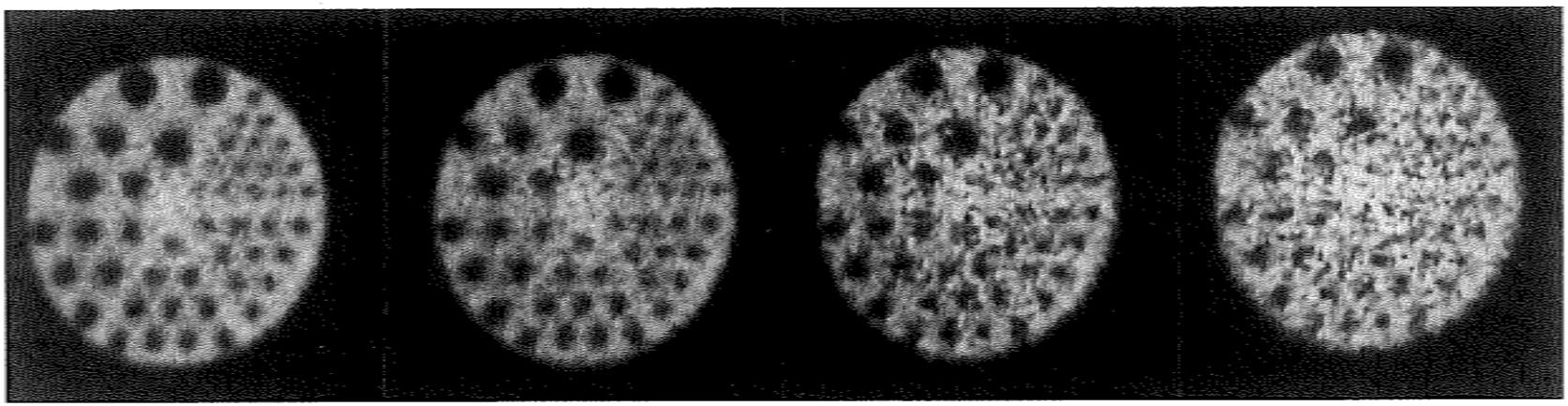


ROR
22cm



ROR: radius-of-rotation; an effective slice thickness of approximately 8 cm.

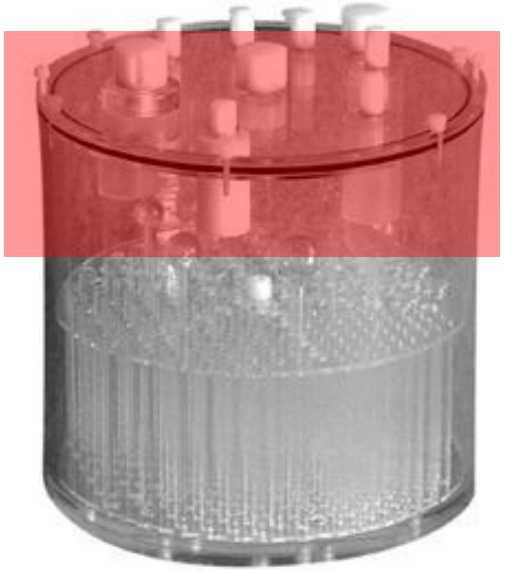
Effect of Total Count in Slice

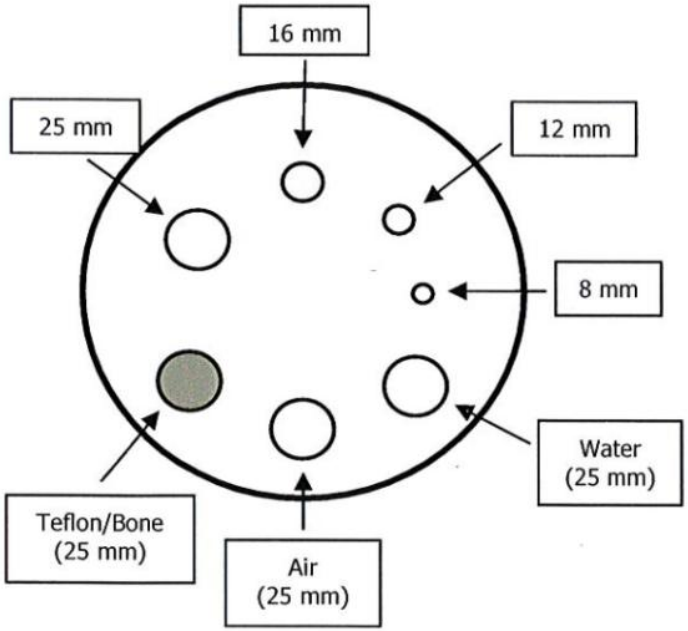


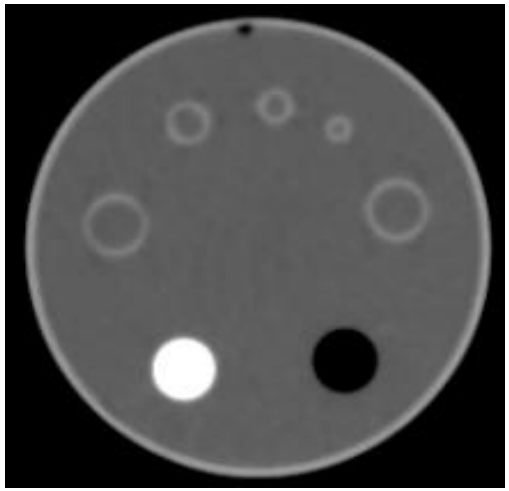
11 Million **5.5 Million** **2 Million** **1. Million**

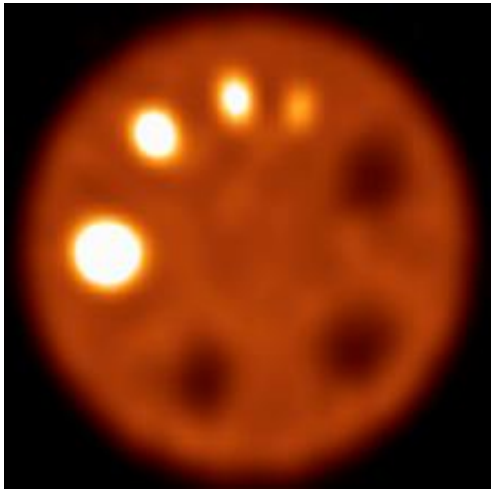
Data Spectrum's Benchmark Phantom (Model ECT/BEN/P) was used. Radius-of-rotation was equal to 14 cm. The actual scan times ranged from 4 to 22 minutes using a dual head SPECT system. The effective slice thickness varied from 12.8 mm (for the lowest count density image) to 25.4 mm (for the highest count density image). The numbers given are the total number of detected events acquired and used to reconstruct each transaxial sectional image shown (i.e., the sum of all counts for all projections for that particular slice). The SPECT system was "moderately" well-calibrated. It is suggested that at least 8 Million counts per slice (for the Cold Rods) be used in evaluating the SPECT system for image quality and artifact susceptibility, although this is not, of course, neither a definite lower value nor a definite upper limit. Even higher count density studies might be useful, dependent on the particular application. To increase the counts acquired per slice, the pixel slice thickness may be increased by summing several adjacent transverse images through the rods.

ACR for PET phantom

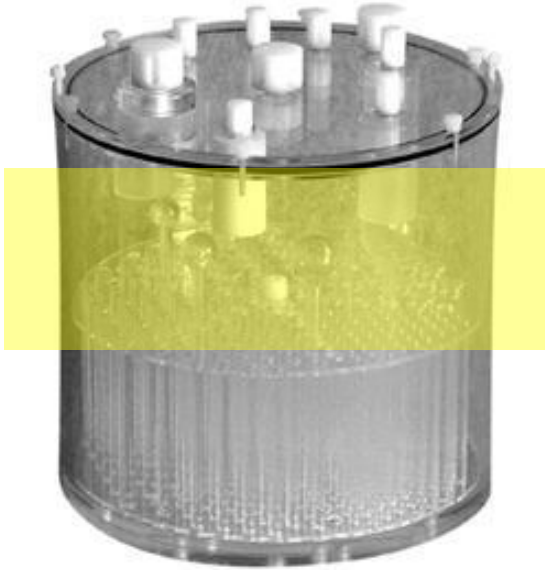


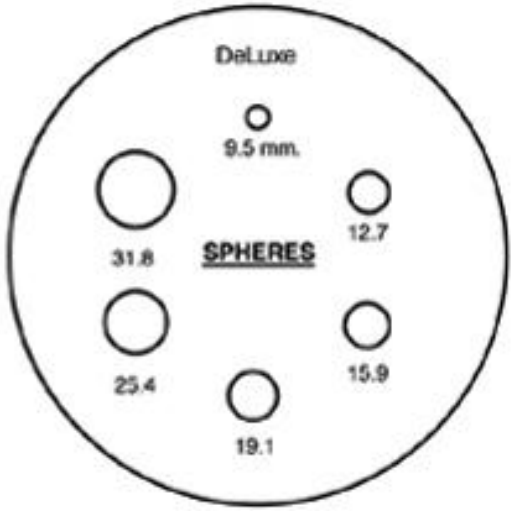


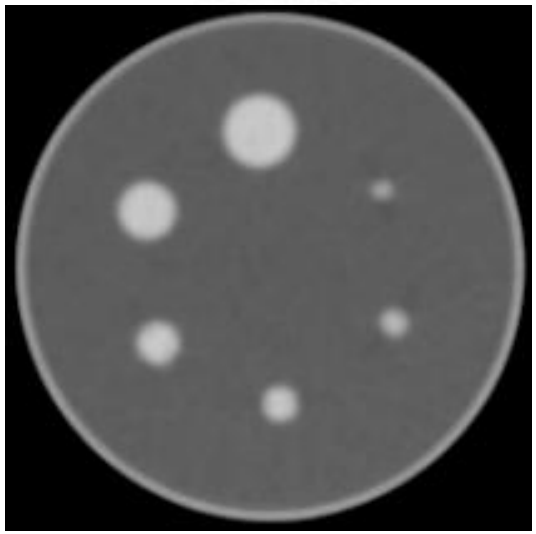


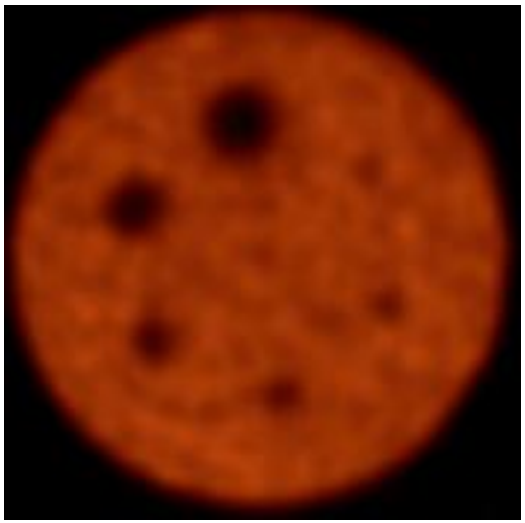


ACR for PET phantom

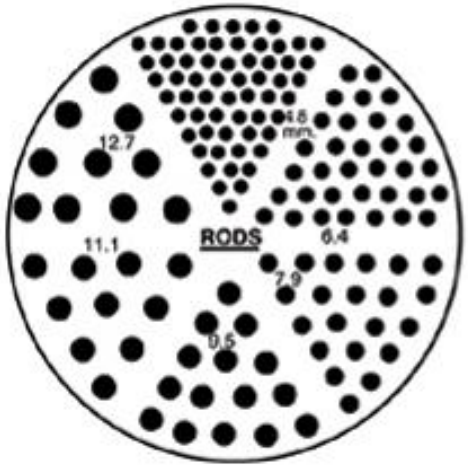


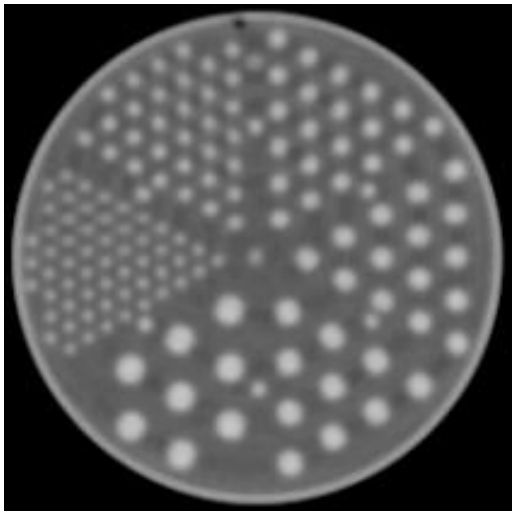


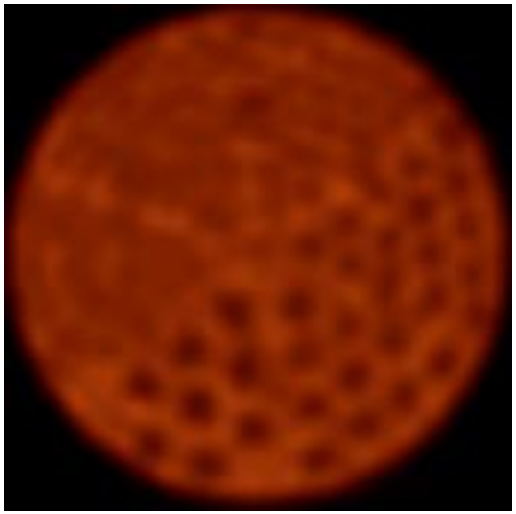




ACR for PET phantom







單光子電腦斷層掃描儀(SPECT, SPECT/CT)

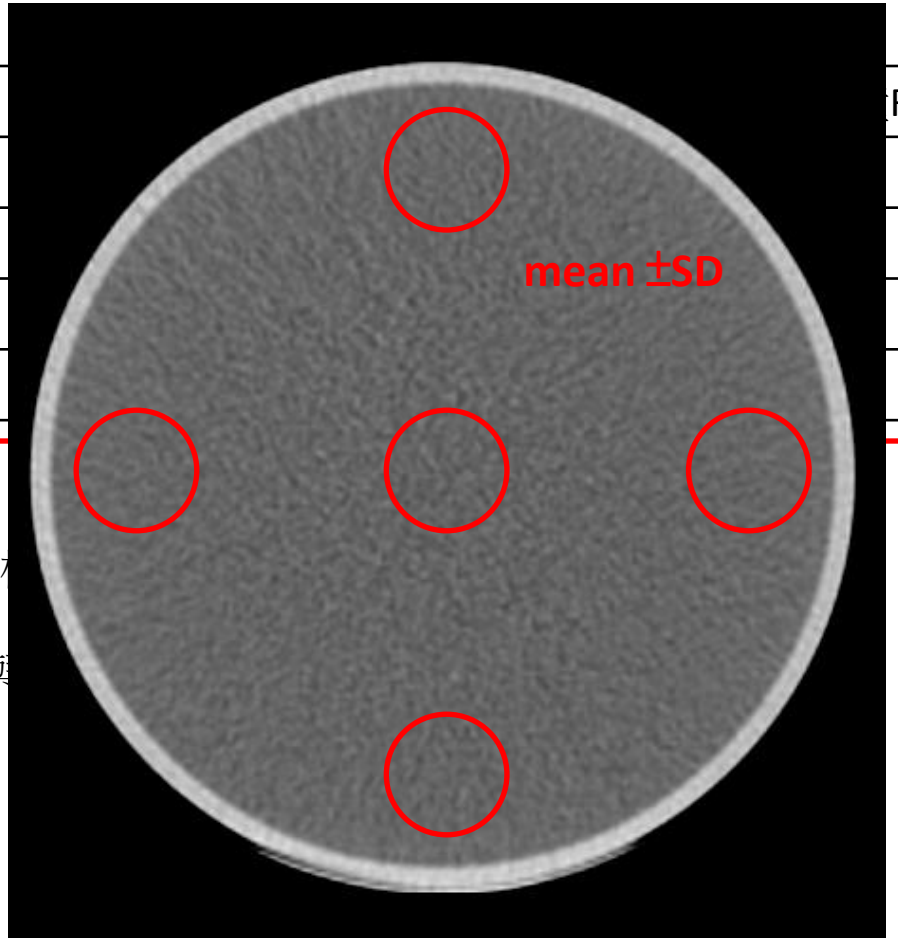
所在地點：_____ 測試日期：實驗當天、及前後一天

裝機日期：_____

廠牌/型號：_____

水假體影像評估(CT影像)

	中心ROI		3點鐘ROI		ROI
Date	Mean	SD	Mean	SD	SD



• 水假體影像評估(CT影像)

*判定標準：

(1) 水的CT值應介於0±7HU，或符合廠商規格

(2) 雜訊值(標準差)符合廠商規格標準。

(3) 影像均勻度邊緣的四個ROI之平均CT值與中心ROI之平均CT值差異皆小於5HU或符合廠商規範。

(4) ROI大小、位置依照廠商標準。

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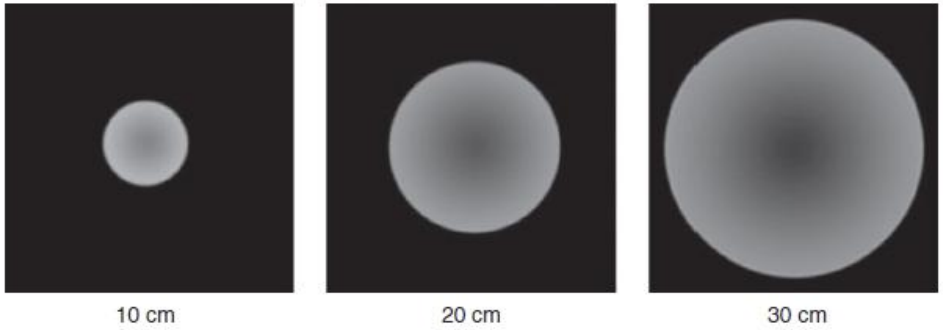
Attenuation



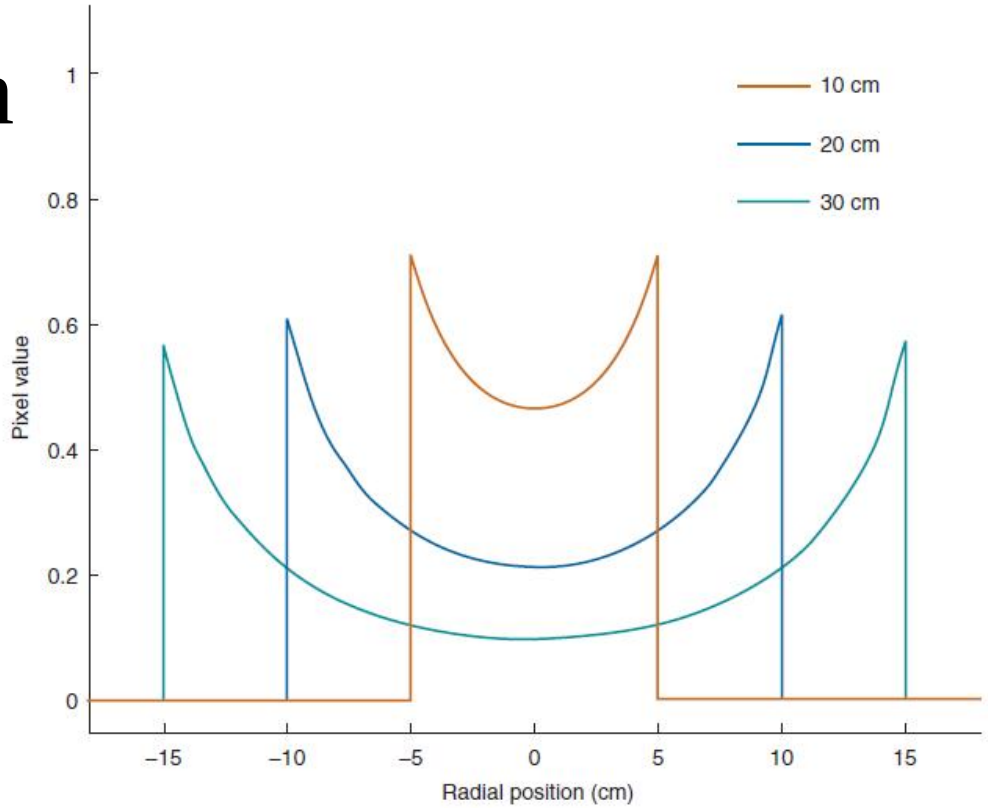


FIGURE 17-10 *Top,* Simulated SPECT images of water-filled cylinders of different diameters containing uniform concentrations of ^{99m}Tc (140 keV). *Bottom,* Count profiles through the centers of the images. The strong dependence of attenuation on cylinder size is evident.

Physics in Nuclear Medicine 4ed. pp290.

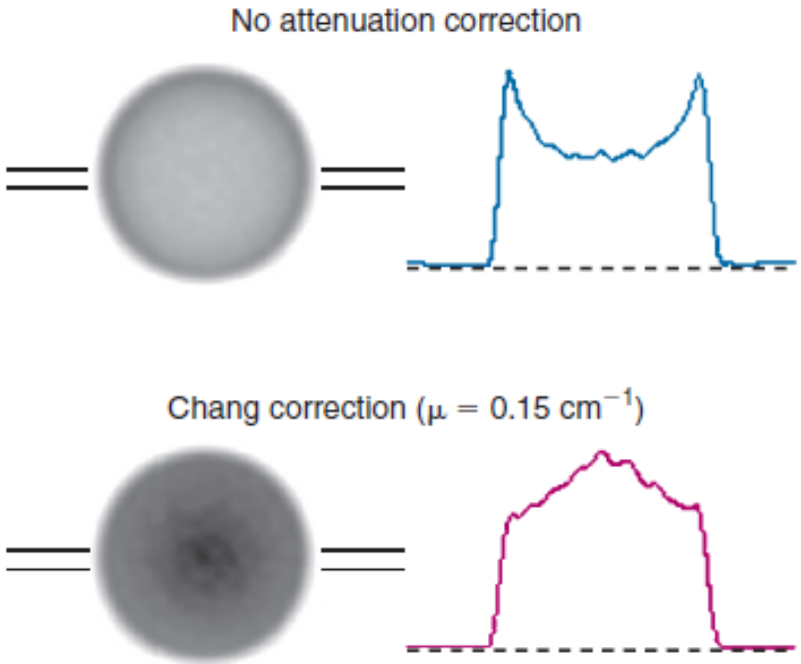


FIGURE 17-12 SPECT images of a 20-cm diameter cylinder containing a uniform concentration of ^{99m}Tc with and without attenuation correction (Chang method with narrow-beam attenuation coefficient of $\mu = 0.15$ cm^{-1}). Profiles are through the center of the images. The apparent overcorrection of attenuation is due to scattered events in the dataset. (*Courtesy Dr. Freek Beekman, Delft University of Technology, The Netherlands.*)

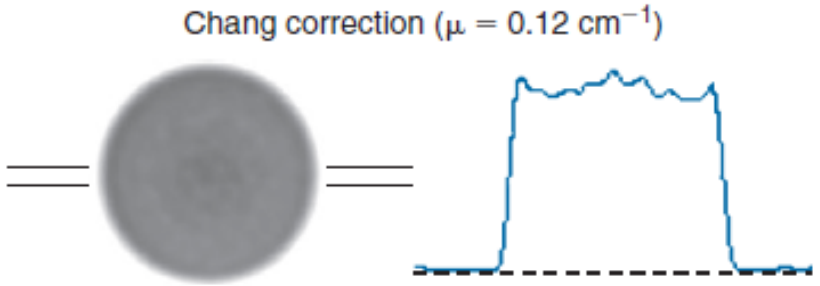


FIGURE 17-16 Effect of Chang attenuation correction on 20-cm uniform cylinder data in Figure 17-12 using a broad-beam attenuation coefficient of $\mu = 0.12$ cm^{-1}. Note the improvement in the uniformity of the profile, which is due to compensation for scattered events. (*Data courtesy Dr. Freek Beekman, Delft University of Technology, The Netherlands.*)

Physics in Nuclear Medicine 4ed. pp294, 297.

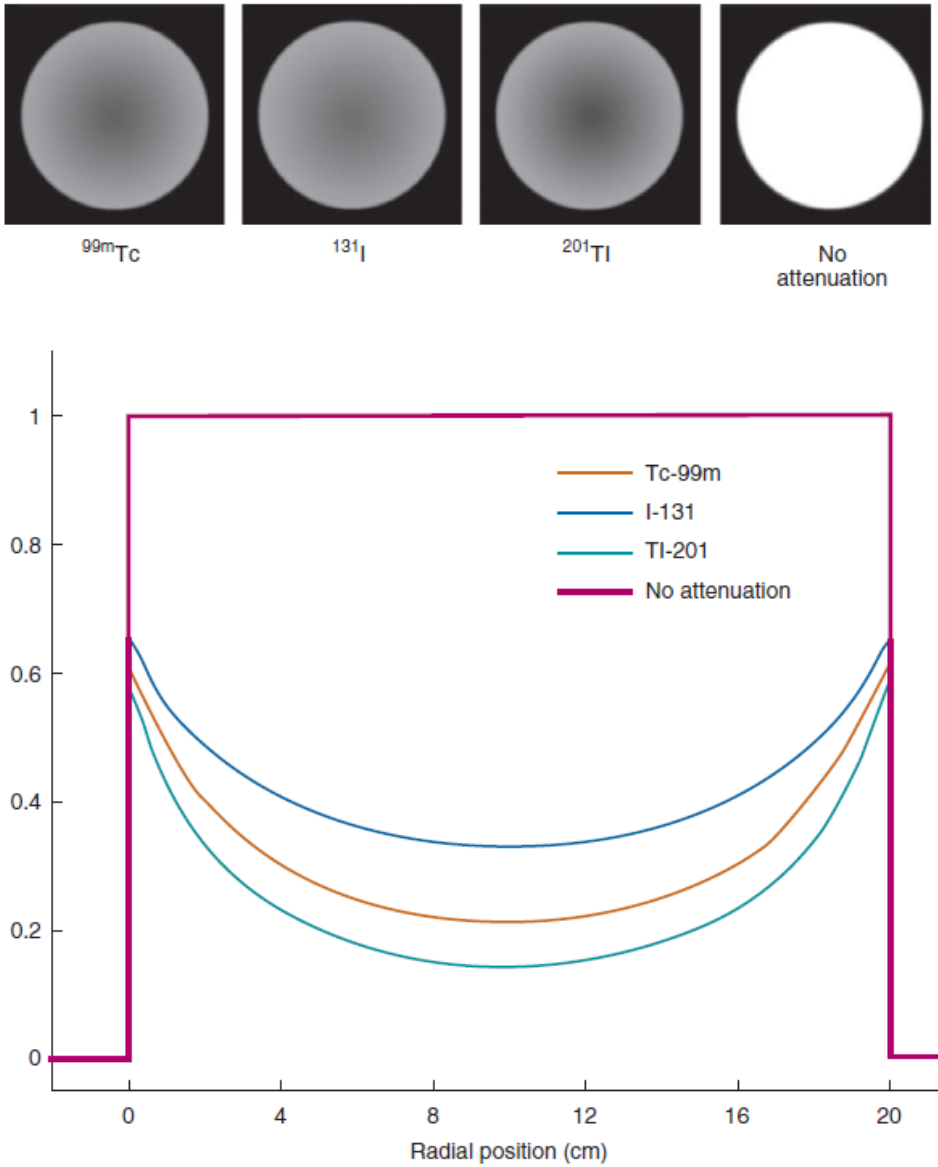


FIGURE 17-9 *Top,* Simulated SPECT images of 20-cm diameter water-filled cylinders containing uniform concentrations of ^{99m}Tc (140 keV), ^{131}I (364 keV), and ^{201}Tl (70 keV). *Bottom,* Arithmetic mean of count profiles through the center of the simulated images. Note the reduction in image intensity at all points in the image caused by attenuation, with the largest reduction occurring at the center of the cylinder. The amount of attenuation is energy dependent, with greatest attenuation occurring at the lower γ-ray energies.

Physics in Nuclear Medicine 4ed. pp289.

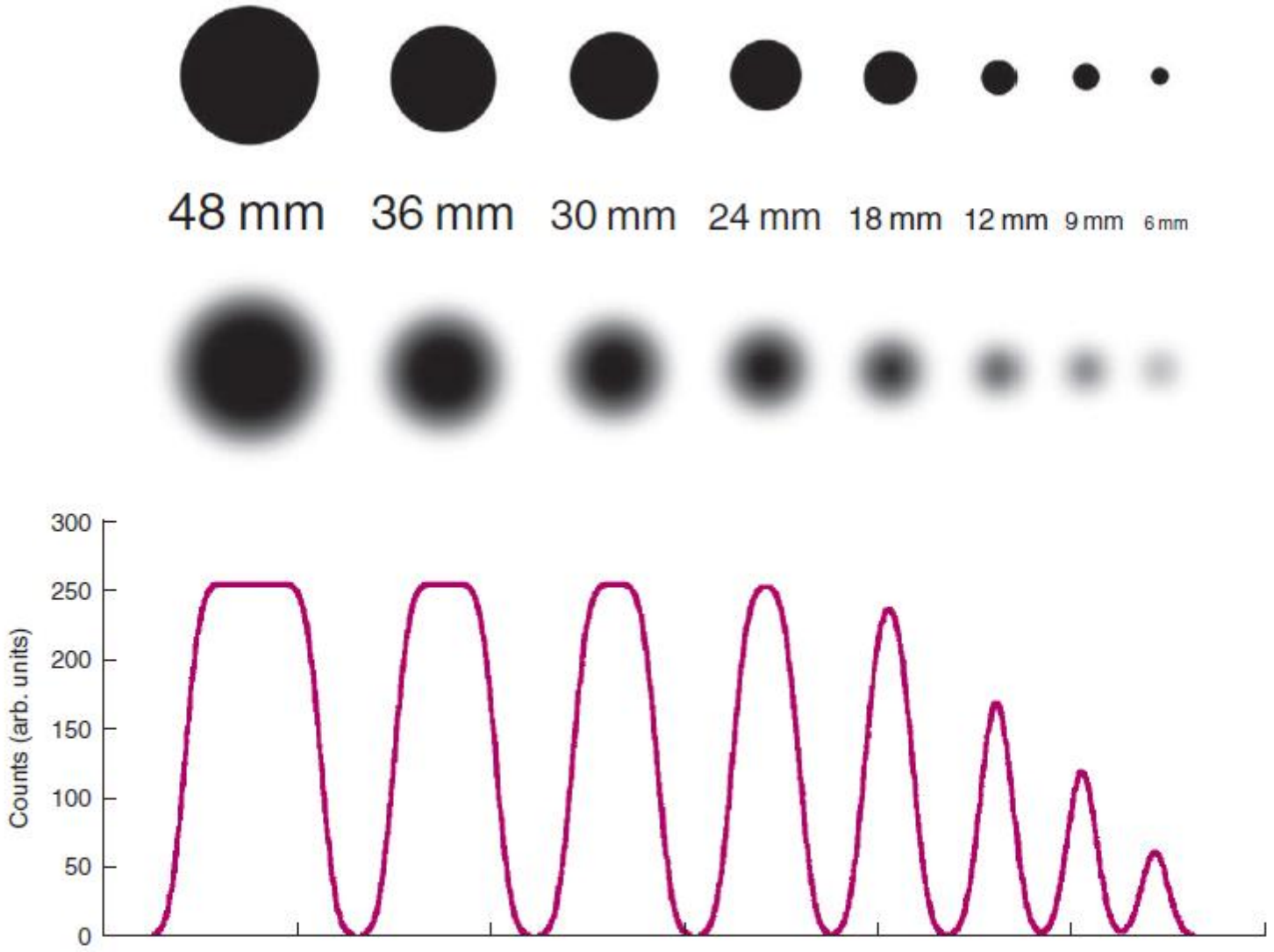


FIGURE 17-18 Illustration of partial-volume effect. The cylinders shown in the *top row* have diameters ranging from 48 mm down to 6 mm, and each contains the same concentration of radionuclide. The *middle row* shows a simulation of the images that would result from scanning these cylinders on a SPECT system with an in-plane spatial resolution of 12-mm full width at half maximum. The cylinders are assumed to have a height much greater than the axial resolution. The *bottom row* shows count profiles through the center of the images. Although each cylinder contains the same concentration of radionuclide, the intensity, and therefore the apparent concentration, appears to decrease when the cylinder size approaches and then becomes smaller than the resolution of the SPECT system. The integrated area under the count profiles does, however, accurately reflect the total amount of activity in the cylinders.

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•均勻度測試**(extrinsic uniformity with Co-57)**

	UFOV(%)				CFOV(%)			
Detector	1		2		1		2	
Date	Int.	Diff.	Int.	Diff.	Int.	Diff.	Int.	Diff.
1/30	2.24	1.54	2.04	1.50	1.98	1.18	1.96	1.19

Int. = integral difference

Diff. = differential difference

*評定標準：Planar imaging:3%~5%

SPECT imaging:1%

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SPECT high-count-flood uniformity test

Flood-field uniformities of 1% or better are desirable for gamma camera detectors used for SPECT. To detect nonuniformities at this level, it is necessary that sufficient counts be acquired to ensure that the measurement is not limited by counting statistics. Poisson counting statistics dictate that 10,000 counts are required per image element to reach an uncertainty of 1% in a planar image (Equation 9-6). If an image matrix of 64 × 64 is used, a total of ~41 million counts will be required in the uniformity image.

= 10,000 x 64 x 64 = 40,960,000

計算matrix size of 128 x 128

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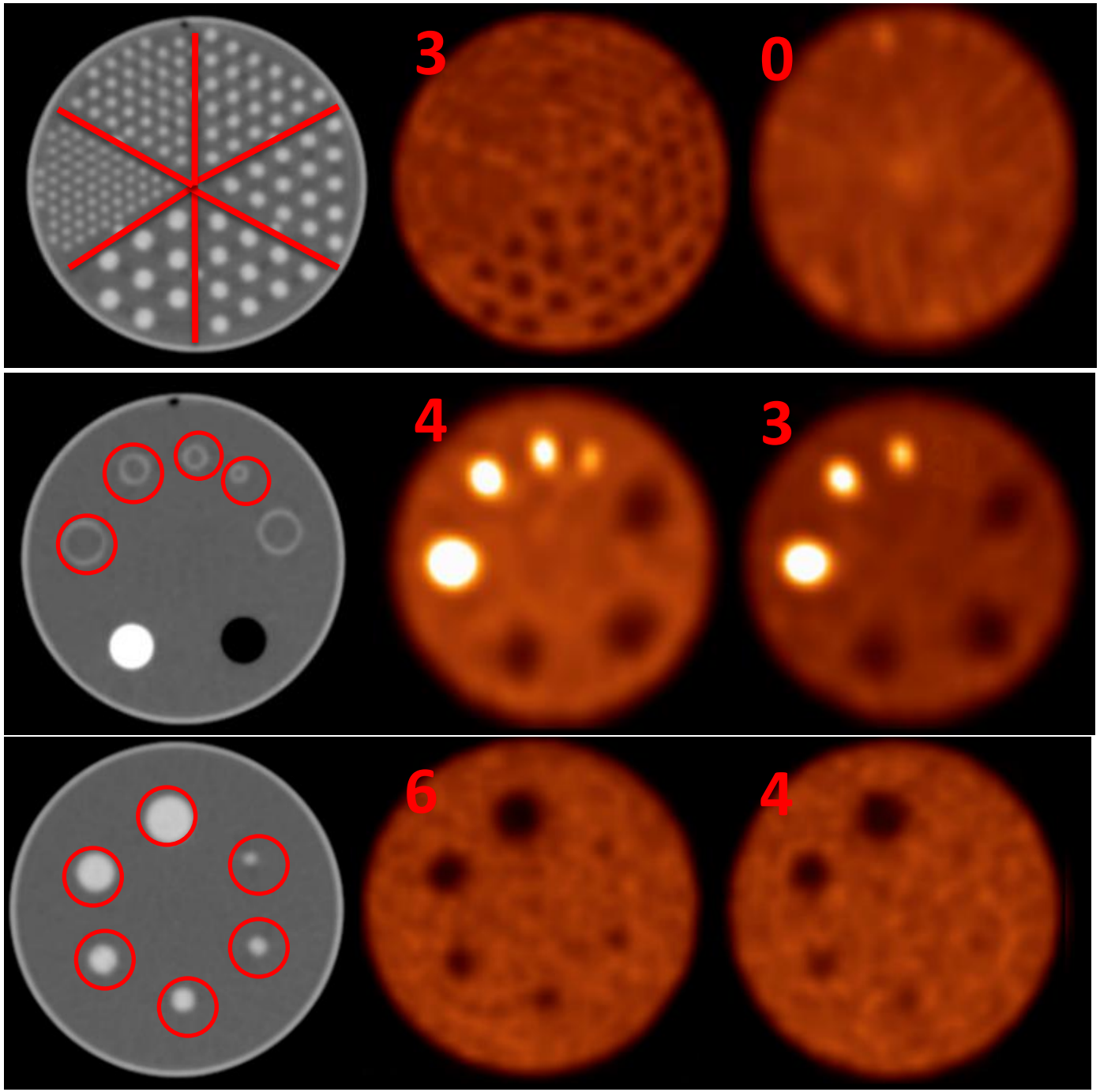
依照不同造影儀器的取像參數，並填入重組參數

SPECT (Machine name/ model)			
Acquisition parameters		Reconstruction parameters	
Matrix size	128 x 128	FBP or IR	IR
Mode	step and shoot	Filter	Butterworth
Steps (360°/head)	60	Cut-off	0.5
Sec/steps	30	Attenuation correction	CT & Chang's
Energy width	140keV ± 7.5%		
thickness (CT)	5mm		
Zoom	1	中山醫學大學附設醫院 核子醫學科	
LEAP or LEHR	LEHR		


3
0
4
3
6
4

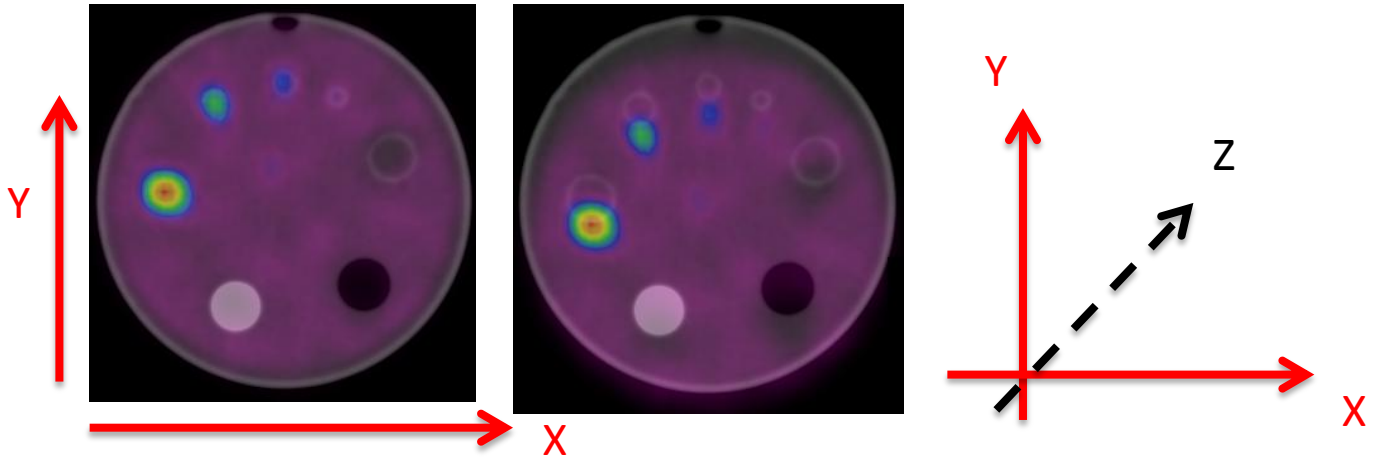
評分項目： Image alignment

Advice	X axis			Y axis			Z axis		
	direction	steps	Level	direction	steps	Level	direction	steps	Level
SPECT									

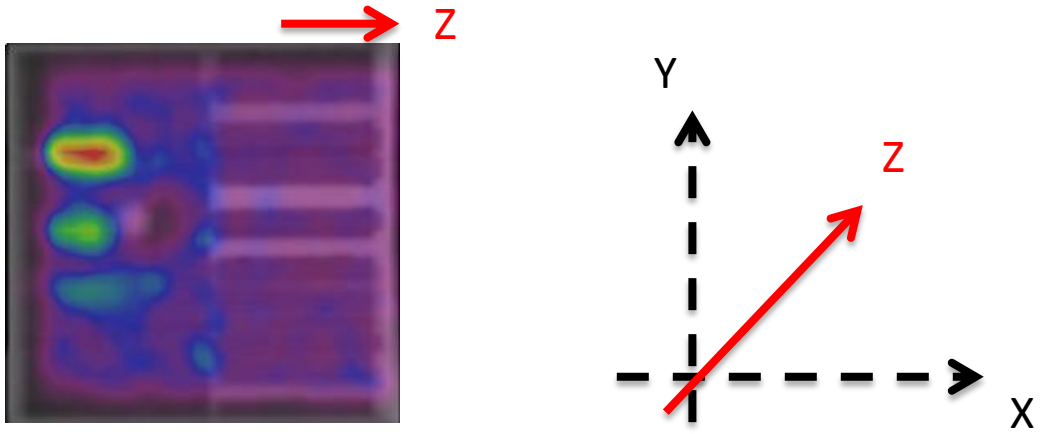
*備註：看hot spheres. 以move核醫影像(SPECT)→ fit CT 。

*以下圖為例：右圖的SPECT影像需向上移動才可fit CT影像，若在X,Y,Z方向需要調整才能well-alignment則在direction欄位填入+；若無須調整則填入-。

*根據調整的步數填入steps欄位。



*橫切圖(transverse view)評定X,Y軸；coronary 和sagittal view評定Z軸



*橫切圖(transverse view)評定X,Y軸；coronary 和sagittal view評定Z軸

Advice	X axis			Y axis			Z axis		
	direction	steps	Level	direction	steps	Level	direction	steps	Level
SPECT	0	0	0	+	10	Severe	+	5	moderate

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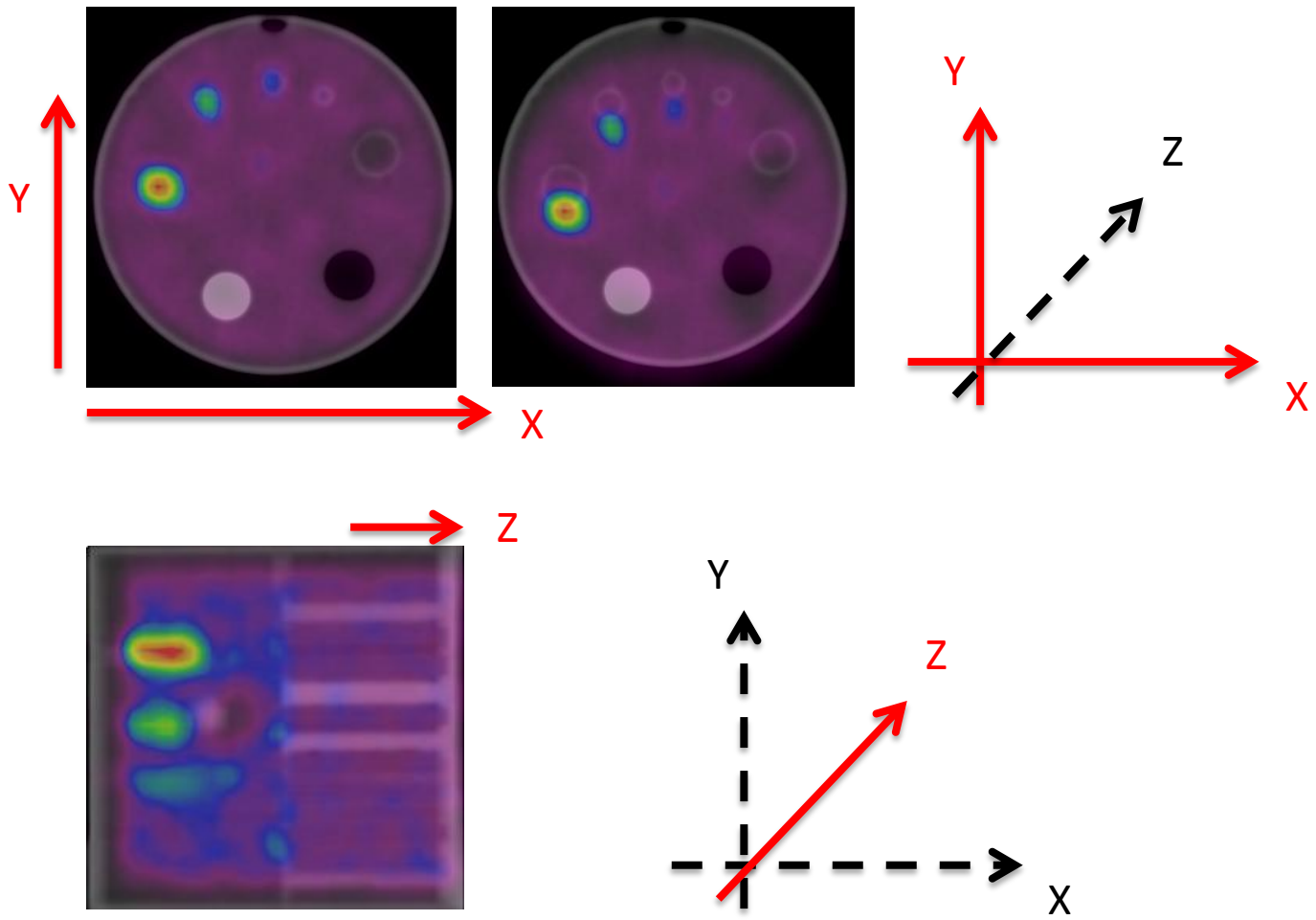
Image Alignment

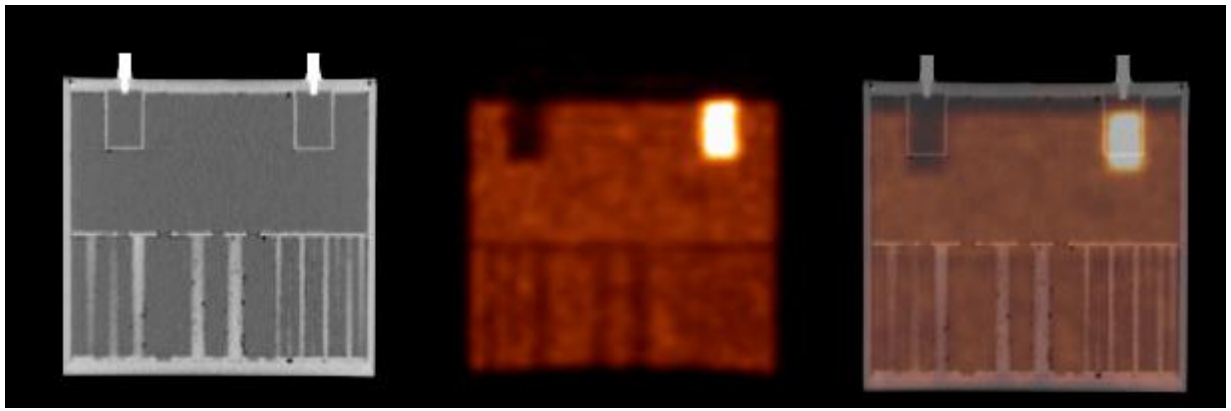


*橫切圖(transverse view)評定X,Y軸；coronary 和sagittal view評定Z軸

Trouble Shooting - Alignment

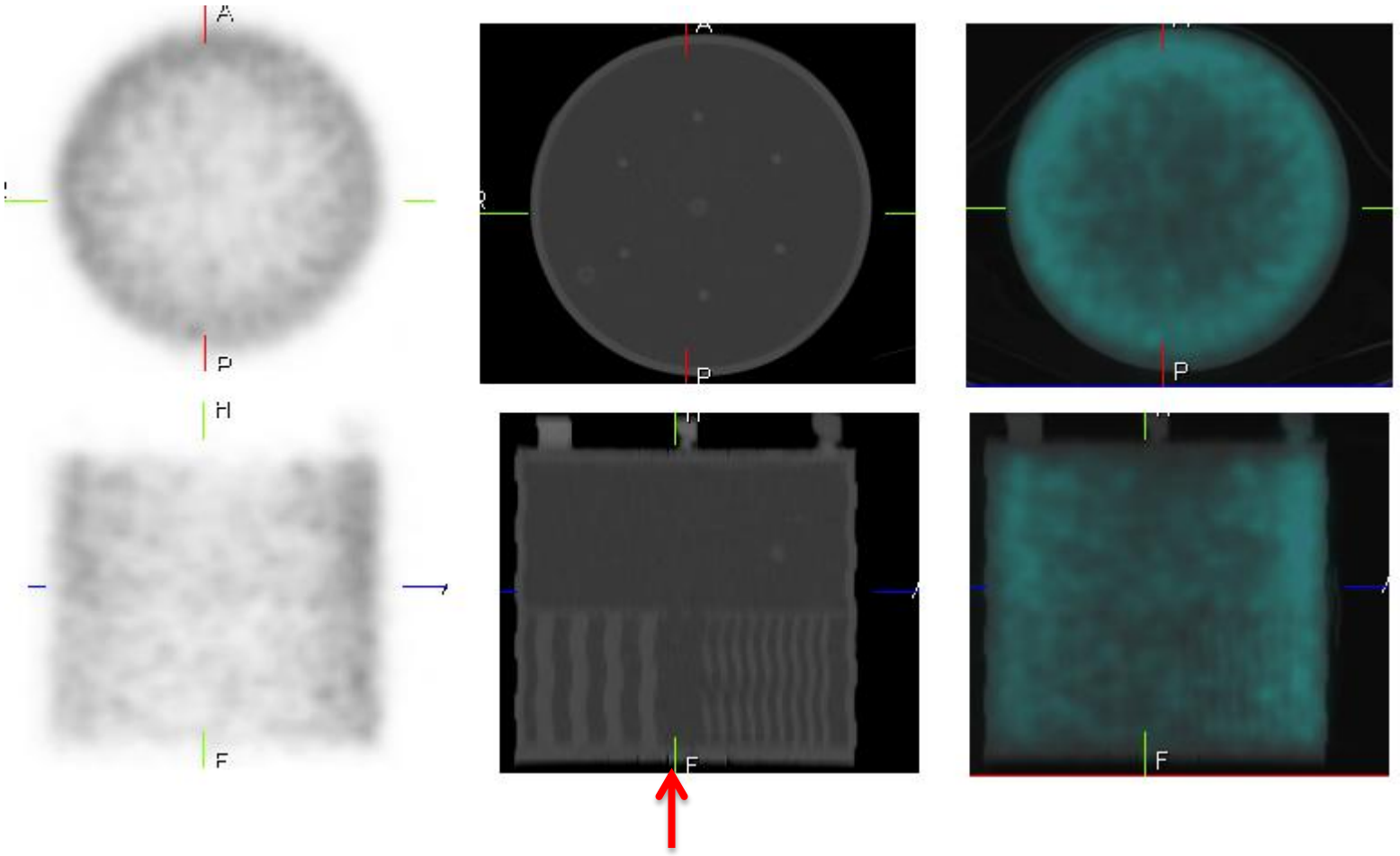
- Mis-alignment:
  - Attenuation correction incorrect
  - Localization incorrect

Alignment: 10.2±0.9 mm

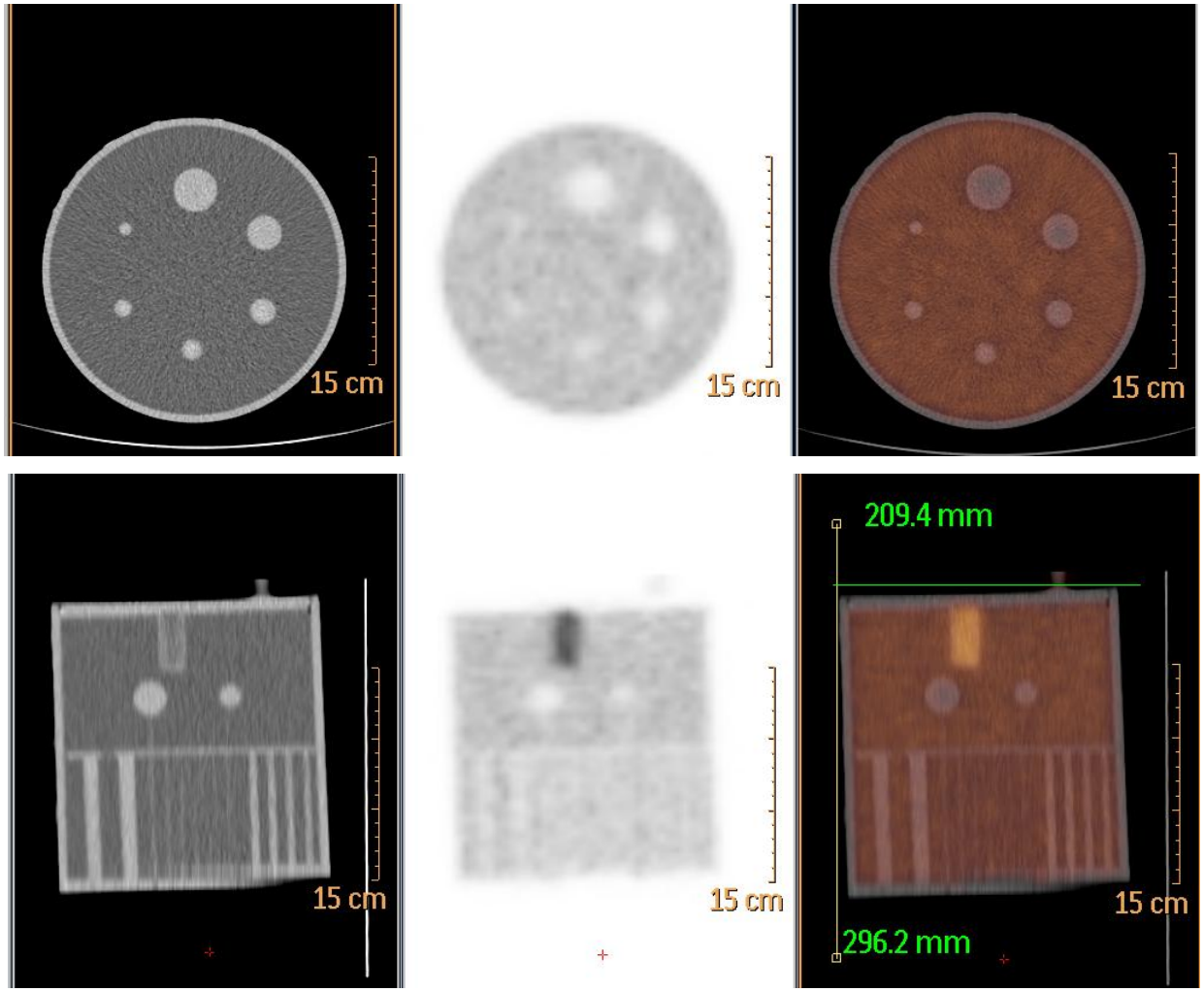


Set up QC procedure and standard?

Trouble Shooting: ACR phantom CT Motion Artifact



擺位傾斜：橫切無法同時呈現所有球的最大徑



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致謝

GMS 贊助提升影像品質討論會與假體使用

核研所 NL 1040368 影像品質提升計畫

Thank you for your attention!