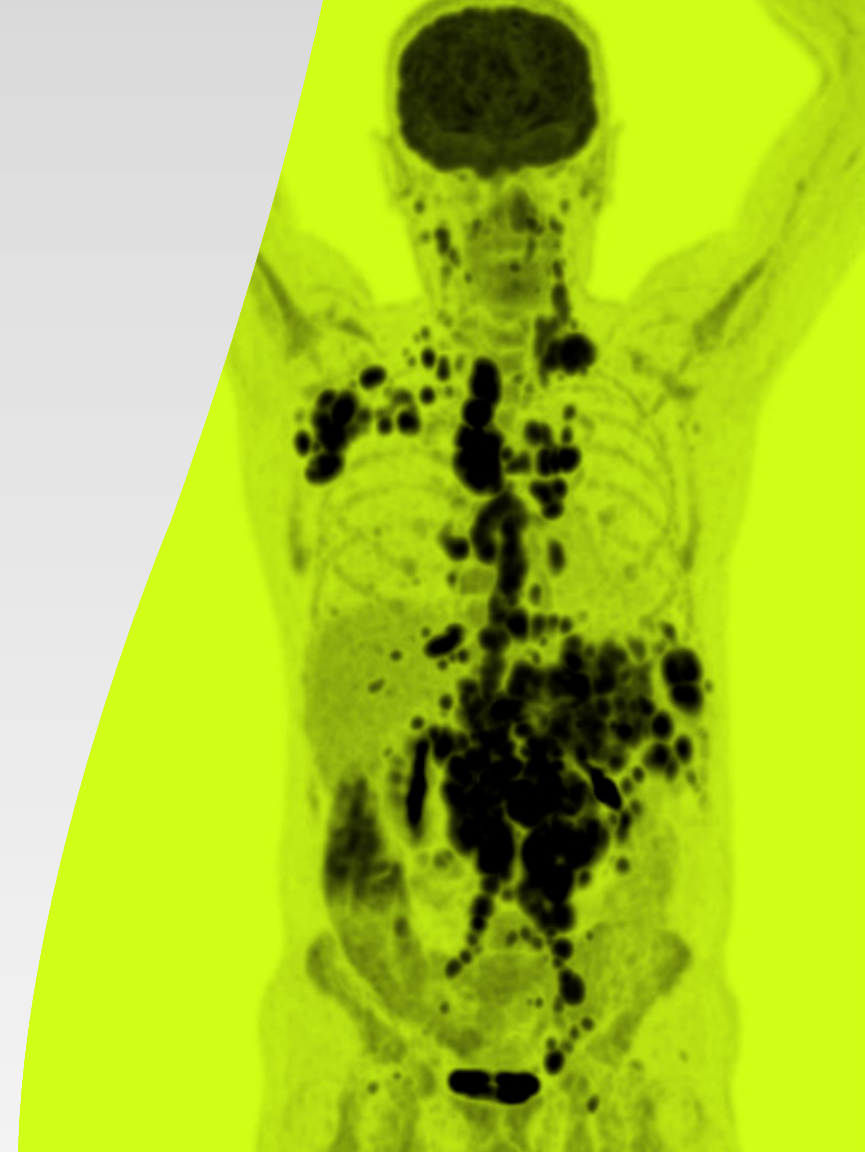


MODERN
RADIOLOGY
eBook

Nuclear Medicine

ESR EUROPEAN SOCIETY
OF RADIOLOGY

核
医学



/ Preface

Modern Radiology is a free educational resource for radiology published online by the European Society of Radiology (ESR). The title of this second, rebranded version reflects the novel didactic concept of the *ESR eBook* with its unique blend of text, images, and schematics in the form of succinct pages, supplemented by clinical imaging cases, Q&A sections and hyperlinks allowing to switch quickly between the different sections of organ-based and more technical chapters, summaries and references.

Its chapters are based on the contributions of over 100 recognised European experts, referring to both general technical and organ-based clinical imaging topics. The new graphical look showing Asklepios with fashionable glasses, symbolises the combination of classical medical teaching with contemporary style education.

Although the initial version of the *ESR eBook* was created to provide basic knowledge for medical students and teachers of undergraduate courses, it has gradually expanded its scope to include more advanced knowledge for readers who wish to ‘dig deeper’. As a result, *Modern*

Radiology covers also topics of the postgraduate levels of the *European Training Curriculum for Radiology*, thus addressing postgraduate educational needs of residents. In addition, it reflects feedback from medical professionals worldwide who wish to update their knowledge in specific areas of medical imaging and who have already appreciated the depth and clarity of the *ESR eBook* across the basic and more advanced educational levels.

I would like to express my heartfelt thanks to all authors who contributed their time and expertise to this voluntary, non-profit endeavour as well as Carlo Catalano, Andrea Laghi and András Palkó, who had the initial idea to create an *ESR eBook*, and - finally - to the ESR Office for their technical and administrative support.

Modern Radiology embodies a collaborative spirit and unwavering commitment to this fascinating medical discipline which is indispensable for modern patient care. I hope that this *educational* tool may encourage curiosity and critical thinking, contributing to the appreciation of the art and science of radiology across Europe and beyond.

Minerva Becker, Editor
Professor of Radiology, University of Geneva, Switzerland

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 前言

《现代放射学》是由欧洲放射学协会 (European Society of Radiology, ESR) 在线发布的免费放射学教育资源。第二版 (更名版) 标题反映了 *ESR 电子书* 新颖的教学概念, 它以简洁页面的形式巧妙地融合文本、图像和示意图, 并辅以临床影像学案例、问答部分和内容超链接, 使读者能够在各基于器官的部分、更具技术性的章节、摘要以及参考文献之间快速切换浏览。

其章节以 100 多名公认欧洲专家的优秀稿件为根基, 涉及各类一般技术和基于器官的临床影像学主题。同时采用了全新的图形外观, 展示了佩戴时尚眼镜的 Asklepios, 象征着传统医学教学与现代风格教育的结合。

虽然初版 *ESR 电子书* 旨在为医学生和本科生教师提供医学基础知识, 但现已逐渐扩充其知识领域, 为希望“深入挖掘”的读者提供了更多高阶技术知识。因此, 《现代放射学》还涵盖了 *欧洲放射学培训课程* 研究生水平的各类主题, 旨在解决住院医师的研究生教育需求。此外, 书中还囊括了全球医疗专业人士的反馈, 他们希望更新自己在医学影像特定领域的知识, 并对 *ESR 电子书* 在基础和高等教育水平上的深度和清晰度表示高度赞赏。

我要衷心感谢所有为这项非营利活动自愿贡献时间和专业知识的作者, 以及最初提出创作 *ESR 电子书* 的 Carlo Catalano、Andrea Laghi 和 András Palkó, 最后还要感谢 ESR 办公室所提供的技术和行政支持。

《现代放射学》充分体现了医者的协作精神和对这门热门医学学科坚定不移的承诺, 这是现代患者护理必须具备的优秀精神品质。我希望这款 *教育* 工具能够激励各位始终保持好奇心和批判性思维, 从而促进整个欧洲乃至欧洲以外地区对放射学艺术和科学的认识。

Minerva Becker, 编辑
瑞士日内瓦大学放射学教授

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/ **Nuclear Medicine.**
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CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

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/ Translation Credits

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ENDORSED BY:
Chinese Society of Radiology

NOTE FROM THE COORDINATORS:
Thank you to Chinese radiology experts for bridging languages and open the world-class English resource by ESR to every Mandarin-speaking student, fueling global radiology talent with a single click

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/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ 翻译致谢

本章节为《现代放射学电子书》的部分译文。

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中华医学会放射学分会

译者寄语:
感谢中国放射学专家们的倾力奉献! 你们跨越了语言的鸿沟, 将欧洲放射学会 (ESR) 的世界级学术宝库呈献给广大中文学子。如今, 前沿智慧一键即达, 为全球放射学人才的蓬勃发展注入了强劲动力。

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>■< FURTHER KNOWLEDGE

>|< COMPARE

<∞> REFERENCES

<?> QUESTIONS

MODERN RADIOLOGY

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核 医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 导示

<=> 核心知识

<!=> 注意

<↑> 超链接

>■< 进阶知识

>|< 比较

<∞> 参考文献

<?> 问题

Nuclear Medicine

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CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

基于 ESR 课程的放射学教育

核医学

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/ Chapter Outline

/ Introduction

- / Terminology
- / Radiopharmaceuticals

/ Nuclear Medicine Imaging Principles

- / Gamma Camera
- / Planar Imaging
- / SPECT Imaging
- / PET Imaging
- / Nuclear Medicine Applications

/ Planar and SPECT Studies

- / Bone Scan
- / Thyroid Scan
- / Ventilation/Perfusion Scan
- / Renal: DMSA
- / Renal: Renogram
- / Myocardial Perfusion Imaging
- / Metaiodobenzylguanidine (MIBG)
- / DAT Scan

/ PET Studies

- / FDG
- / PSMA
- / DOTATATE

/ Take-Home Messages

/ References

/ Test Your Knowledge

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 章节大纲

/ 简介

- / 术语
- / 放射性药物

/ 核医学成像原理

- / 伽马相机
- / 平面显像
- / SPECT 成像
- / PET 成像
- / 核医学应用

/ 平面和 SPECT 检查

- / 骨扫描
- / 甲状腺扫描
- / 通气/灌注扫描
- / 肾脏: DMSA
- / 肾脏: 肾图
- / 心肌灌注显像
- / 间碘苄胍 (MIBG)
- / DAT 扫描

/ PET 检查

- / FDG
- / PSMA
- / DOTATATE

/ 核心要点

/ 参考文献

/ 知识测试

/ Introduction

MODERN RADIOLOGY

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核 医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 简介

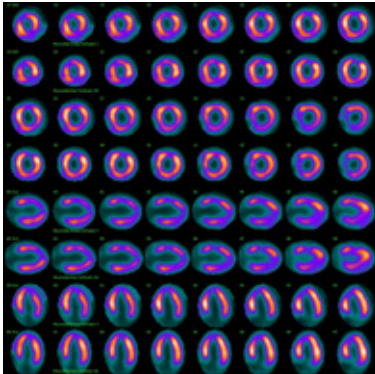
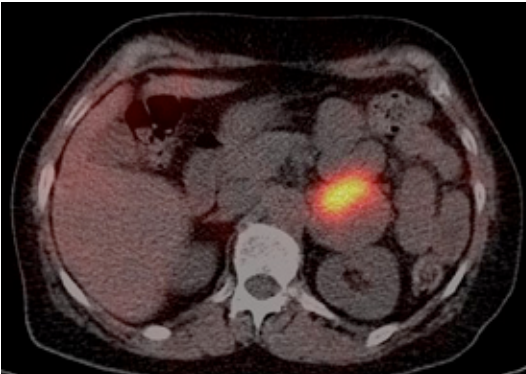
/ Introduction

What is Nuclear Medicine

Nuclear Medicine is the practice of using small quantity of unsealed radioactive sources to diagnose, monitor disease and provide targeted therapy.

Most imaging modalities, such as computed tomography (CT) or magnetic resonance imaging (MRI)

demonstrate body anatomy. Nuclear medicine is one of the few imaging modalities that demonstrate body physiology, so called 'functional' imaging. For example, a whole-body bone scan shows bone turnover. This allows nuclear medicine to have a wide range of applications across many body systems, and pathologies.



/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 简介

什么是核医学

核医学是利用少量未密封的放射源进行诊断、监测疾病并提供靶向治疗的医学实践。

大多数影像学检查方式，如计算机断层扫描 (CT) 或磁共振成像 (MRI)，主要显示人体的解剖结构。核医学是少数能显示人体生理功能的影像学检查方式之一，即所谓的“功能性”成像。例如，全身骨扫描可显示骨骼的代谢活性。这使得核医学在许多器官系统和病理状态中具有广泛的应用。

/ Terminology

- / A radiopharmaceutical combines a **radio-nuclide** and **pharmaceutical**.
- / A **radionuclide** is an unstable form of an element that emits radiation from its nucleus as it decays to a more stable form. The emitted radiation from the patient is used to create the image in nuclear medicine. Elements used for diagnostic imaging usually either emit beta particles (positrons or electrons) or gamma rays.

Technetium-99m
钼-99m
+
Hydroxy
diphosphonate (HDP)
羟基二膦酸盐 (HDP)



FIGURE 1
[^{99m}Tc]Tc- HDP whole
body bone scan

- / **Pharmaceuticals** have properties that help to target specific organs/tissues or molecular pathways.
- / Technetium-99m is the most used radionuclide in nuclear medicine and can be combined with a wide range of pharmaceuticals which enables targeting of different organs and physiological processes.

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

/ Terminology

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核 医学

章节大纲:

简介

/ 术语

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 术语

- / 放射性药物由放射性核素和药物组合而成。
- / 放射性核素是元素的不稳定形式，在其衰变为更稳定的形式时，其原子核会发射辐射。核医学通过患者体内发出的辐射信号创建图像。用于诊断成像的元素通常发射 β 粒子（正电子或电子）或 γ 射线。
- / 药物具有帮助靶向作用于特定器官/组织或分子通路的特性。
- / 钼-99m 是核医学中最常用的放射性核素，可与多种药物结合使用，从而靶向作用于不同的器官和生理过程。

图 1

[^{99m}Tc]Tc-HDP 全身骨扫描

/ Radiopharmaceuticals

RADIONUCLIDE	HALF-LIFE	PHARMACEUTICAL	CLINICAL INDICATION
Technetium-99m ([^{99m} Tc]Tc)	6 hours	Pertechnetate	Thyroid imaging, Meckel scan
		Methyl diphosphonate (MDP) or hydroxydiphosphonate (HDP)	Bone scan for cancer staging, arthropathy
		Diethylene-triamine-pentaacetate (DTPA)	Renal imaging, lung ventilation imaging (aerosol)
		Sestamibi	Cardiac, parathyroid
		Macroaggregated albumin (MAA)	Lung perfusion imaging
		Technegas	Lung ventilation imaging
		Mercaptoacetyltriglycine (MAG 3)	Renal
		2,3 dimercaptosuccinic acid (DMSA)	Renal

TABLE 1
Commonly used radiopharmaceuticals

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

/ Radiopharmaceutical

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

/ 放射性药物

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 放射性药物

放射性核素	半衰期	药物	临床适应证
锝-99m ([^{99m} Tc]Tc)	6 h	高锝酸盐	甲状腺显像，Meckel 扫描
		亚甲基二膦酸盐 (MDP) 或羟基二膦酸盐 (HDP)	肿瘤分期、关节病骨扫描
		二乙三胺五乙酸 (DTPA)	肾显像、肺通气显像（气溶胶）
		甲氧异腈	心脏、甲状旁腺
		大颗粒聚合白蛋白 (MAA)	肺灌注显像
		锝气体	肺通气显像
		巯基乙酰基三甘氨酸 (MAG 3)	肾脏
		2,3-二巯基丁二酸 (DMSA)	肾脏

表 1
常用放射性药物

RADIONUCLIDE	HALF-LIFE	PHARMACEUTICAL	CLINICAL INDICATION
Iodine-123 ([¹²³ I])	13.2 hours	-	Thyroid imaging
		Ioflupane	Brain-parkinsonian syndromes
		Metaiodobenzylguanidine (MIBG)	Neuroectodermal tumour imaging
Iodine-131 ([¹³¹ I])	8 hours	-	Thyroid imaging and treatment
Indium-111 ([¹¹¹ In])	2.8 days	Octreotide, Pentetreotide	Neuroendocrine tumour
Krypton-81m ([⁸¹ Kr])	13 seconds	-	Lung ventilation imaging

CONTINUATION OF TABLE 1

Commonly used radiopharmaceuticals

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

/ Radiopharmaceutical

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

/ 放射性药物

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

放射性核素	半衰期	药物	临床适应证
碘-123 ([¹²³ I])	13.2 h	-	甲状腺显像
		碘氟潘	脑-帕金森综合征
		间碘苄胍 (MIBG)	神经外胚层肿瘤显像
碘-131 ([¹³¹ I])	8 h	-	甲状腺显像和治疗
铟-111 ([¹¹¹ In])	2.8 天	奥曲肽、喷曲肽	神经内分泌肿瘤
氪-81m ([⁸¹ Kr])	13 s	-	肺通气显像

续表 1

常用放射性药物

/ Nuclear Medicine Imaging Principles

MODERN RADIOLOGY

/ **Nuclear
Medicine**

CHAPTER OUTLINE:

Introduction

**Nuclear Medicine
Imaging Principles**

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ **核
医学**

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 核医学 成像 原理

Nuclear Medicine (NM) Imaging

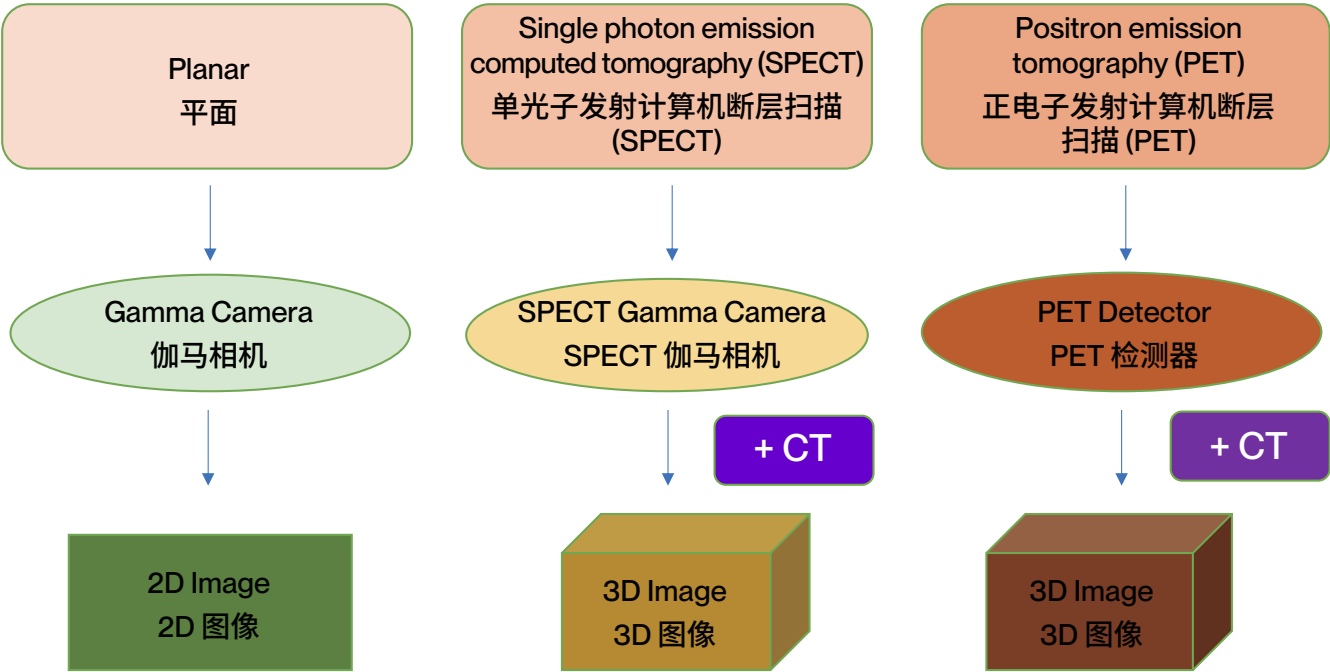


FIGURE 2
NM Imaging Modalities

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles**
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

核医学 (NM) 成像

/ 核
医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

图 2
NM 成像方法

/ Gamma Camera

- 1. Radionuclides decay releasing gamma photons.
- 2. Collimators are made of lead with holes. These only accept gamma photons that travel parallel to the collimator holes.
- 3. A scintillation crystal is fluorescent; i.e., when a gamma photon interacts, it releases light photons. The amount of light is proportional to the deposited energy of the gamma photons.
- 4. Photomultiplier tubes detect the light photons from the crystal and convert these into an electrical signal.
- 5. A computer processes the electrical signal to calculate the energy of the received photons and their x, y coordinates within the patient to form the final images.

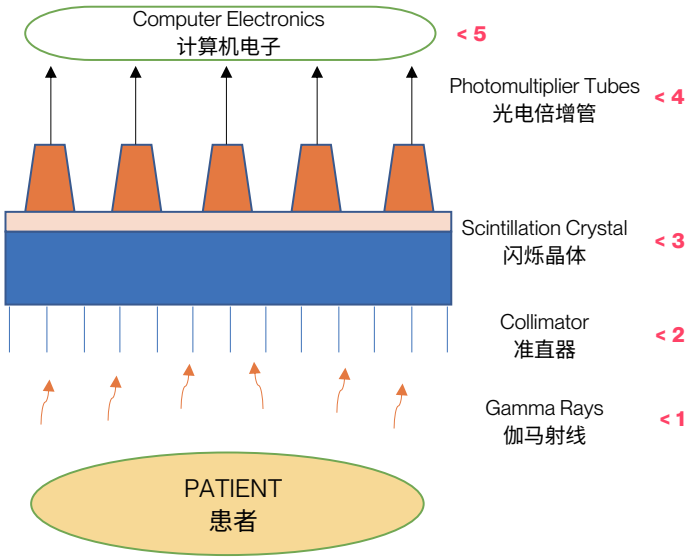


FIGURE 3
Gamma Camera Flowchart

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

/ Gamma Camera

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

/ 伽马相机

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 伽马相机

- 1. 放射性核素衰变时会释放伽马光子。
- 2. 准直器由带孔的铅制成。这些只能接受与准直孔呈平行方向移动的伽马光子。
- 3. 闪烁晶体具有荧光性；即当伽马光子相互作用时，会释放可见光光子。光量与伽马光子的沉积能量成正比。
- 4. 光电倍增管能够探测到晶体发出的可见光光子，并将其转换为电信号。
- 5. 计算机处理电信号，以计算接收到的光子的能量及其在患者体内的 x、y 坐标，从而生成最终图像。

图 3
伽马相机流程图

/ Planar Imaging

- / 2D imaging technique.
- / Typically, anterior and posterior views.
- / Oblique views - depend-
ing on clinical indication.
- / Commonly used applications include
bone, kidneys, thyroid, hepatobiliary
and gastrointestinal tract imaging.

Static

- / Radiopharmaceutical is injected
intravenously/ingested, and images
are acquired after a certain time
period delay called ‘uptake time’.
- / The uptake time and scan dura-
tion is dependent upon the half life
of the radionuclide and the study
being performed. E.g., 2-3 hours for
a Technetium-99m labelled DMSA

renal scan compared to 4-6 hours for
an Iodine-123 thyroid uptake scan.

- / Static imaging is used to gain informa-
tion about the organ of interest based
on size, morphology, intensity and
position of radiopharmaceutical uptake.

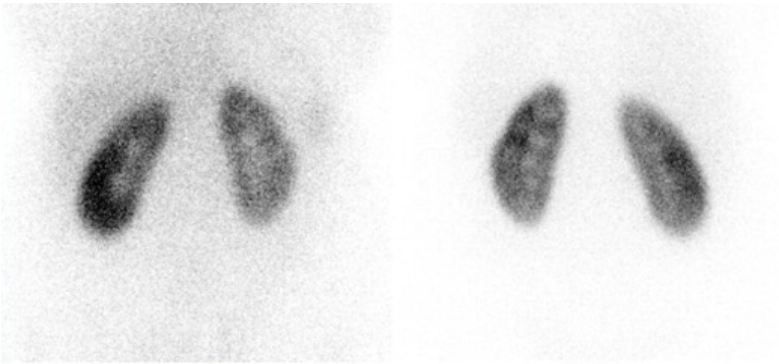


FIGURE 4
[^{99m}Tc]Tc- DMSA renal scan anterior and posterior views

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

/ Planar Imaging

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核 医学

章节大纲:

简介

核医学成像原理

/ 平面显像

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 平面显像

- / 2D 成像技术。
- / 通常显示前位和后位视图。
- / 斜位视图 - 取决于临床适应证。
- / 常见应用包括骨、肾脏、甲状腺、肝胆和胃肠道显像。

静态

- / 静脉注射/口服放射性药物，在经过一定时间的延迟（称为“摄取时间”）后采集图像。
- / 摄取时间和扫描持续时间取决于放射性核素的半衰期和所进行的检查。例如，锝-99m 标记的 DMSA 肾扫描需要 2~3 h，而碘-123 甲状腺摄取扫描需要 4~6 h。
- / 静态显像技术用于根据放射性药物摄取的分布强度、器官大小、形态和位置，来获取有关目标器官的信息。

图 4
[^{99m}Tc]Tc-DMSA 肾扫描前位相和后位相

Dynamic

- / Distribution of radiopharmaceuticals change with time due to their inherent properties.
- / Images are usually acquired immediately post injection with series of frames over time.
- / Time interval between frames varies between different studies.
- / Functional assessment of a system is provided based on radiopharmaceutical distribution over time.

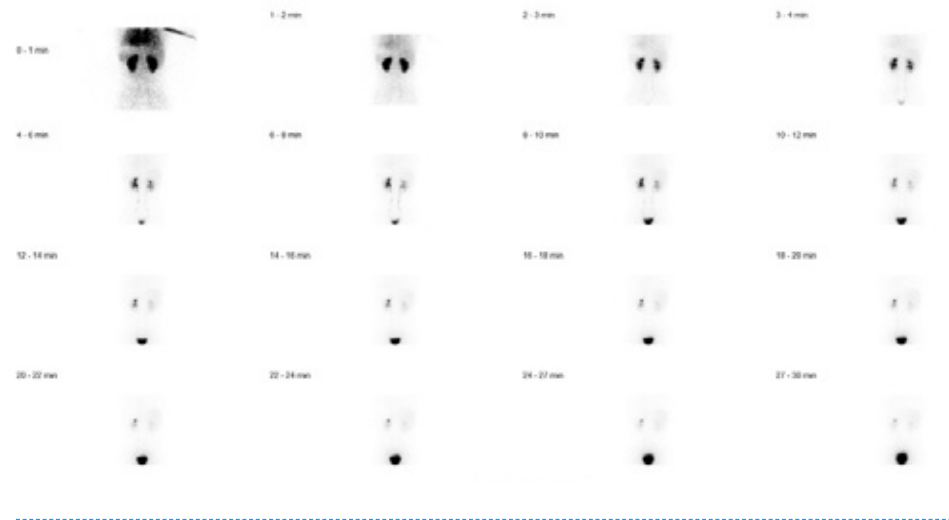


FIGURE 5
[^{99m}Tc]Tc-MAG3 Renogram

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
 - / Planar Imaging
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

核医学

可动态观察

- / 放射性药物因其固有特性，其分布会随时间而变化。
- / 通常会在注射后立即采集图像，并随时间推移获取多帧图像。
- / 不同检查中帧之间的时间间隔不同。
- / 系统的功能性评估基于放射性药物随时间的分布情况。

章节大纲：

- 简介
- 核医学成像原理
 - / 平面显像
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

图 5
[^{99m}Tc]Tc-MAG3 肾图

/ SPECT and SPECT/CT Imaging

Single photon emission computed tomography (SPECT) is an extension of conventional gamma camera imaging.

Typically, two gamma camera heads rotate around the patient on a gantry acquiring a series of planar images which are reconstructed into 3D images.

Computed Tomography (CT) images may be acquired alongside SPECT. These permit attenuation correction and localisation of sites of radiotracer uptake in the body.

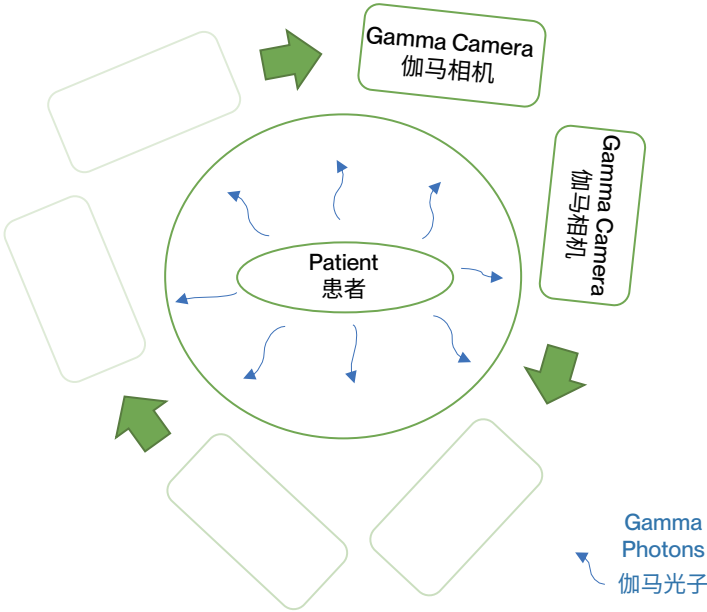


FIGURE 6
Schematic diagram of SPECT scanner

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles**
 - / SPECT and SPECT/CT Imaging
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理**
 - / SPECT 和 SPECT/CT 成像
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ SPECT 和 SPECT/CT 成像

单光子发射计算机断层扫描 (SPECT) 是传统伽马相机成像技术的扩展。

通常，两个伽马相机镜头在机架上围绕患者旋转，获取一系列平面图像，然后重构为三维图像。

计算机断层扫描 (CT) 图像可以在进行 SPECT 时同时采集。这些图像能够进行衰减校正，并能定位体内放射性示踪剂摄取的部位。

图 6
SPECT 扫描仪示意图

SPECT Applications

Commonly used applications include cardiac, bone, parathyroid, pulmonary, and brain imaging.

Figure 7 demonstrates normal radiopharmaceutical distribution in a V/Q SPECT scan.

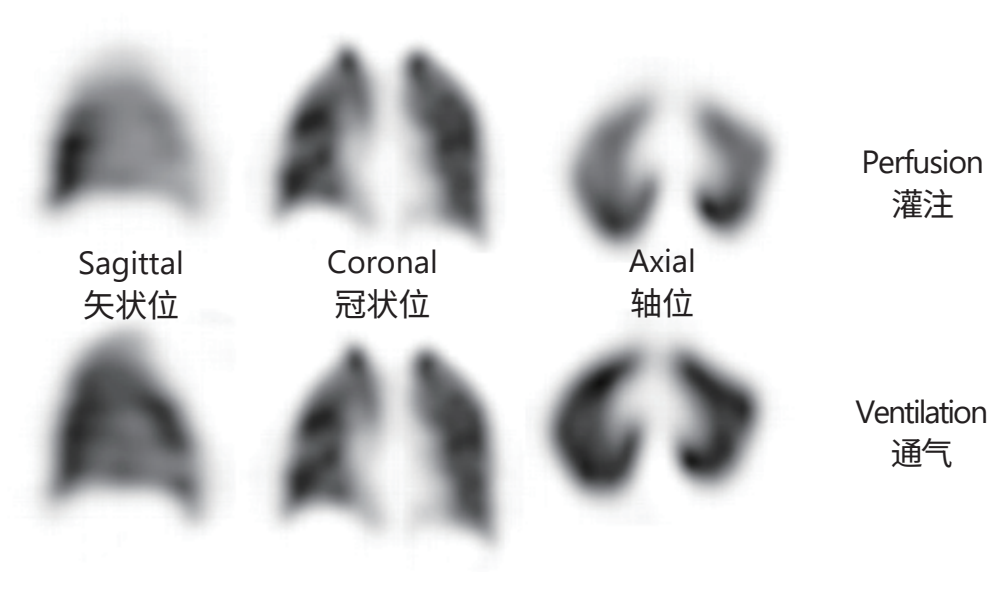


FIGURE 7
Ventilation/Perfusion (V/Q) SPECT

Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine
Imaging Principles

/ SPECT and SPECT/CT
Imaging

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

核
医学

章节大纲:

简介

核医学成像原理

/ SPECT 和
SPECT/CT 成像

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

SPECT 应用

常见应用包括心脏、骨、甲状旁腺、肺和脑显像。

图 7 显示了 V/Q SPECT 扫描中正常的放射性药物分布情况。

图 7
通气/灌注 (V/Q) SPECT

Comparison of SPECT and Planar Imaging

PLANAR	SPECT
Poorer contrast and spatial resolution compared to SPECT	Better contrast and spatial resolution compared to planar
Use gamma emitting radionuclide	Use gamma emitting radionuclide
Generally shorter image acquisition times depending on study type	Longer image acquisition times
Poorer localisation compared to SPECT(2D)	Localisation at depth as a tomographic technique (3D)

TABLE 2
Comparison of SPECT and Planar Imaging



CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
 - / SPECT and SPECT/CT Imaging
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge



章节大纲:

- 简介
- 核医学成像原理
 - / SPECT 和 SPECT/CT 成像
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

SPECT 与平面显像的比较

平面	SPECT
与 SPECT 相比，对比度和空间分辨率较差	与平面图像相比，对比度和空间分辨率更佳
使用伽马放射性核素	使用伽马放射性核素
图像采集时间通常更短，具体取决于检查类型	图像采集时间更长
与 SPECT (2D) 相比，定位较差	利用断层成像技术进行深度定位 (3D)

表 2
SPECT 与平面显像的比较

/ Positron Emission Tomography (PET) Imaging

PET imaging uses radionuclides that are proton rich (nucleus contains a relatively large number of protons compared to neutrons) and decay by positron emission.

The positron-emitting radionuclide undergoes β^+ decay with a proton converted to a neutron, a positron and a neutrino. The positron (e^+) is the antiparticle of the electron (e^-) with the same mass and electrical charge as the electron. However, the charge is positive.

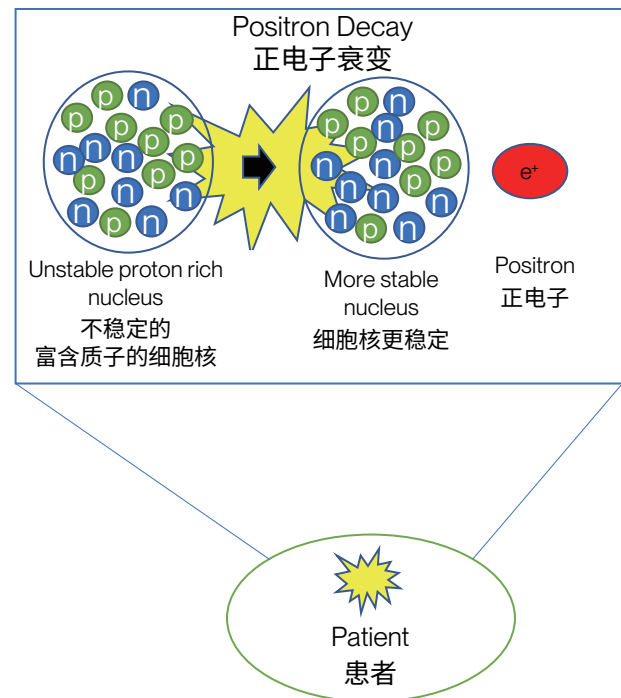


FIGURE 8
PET scanner

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

/ PET Imaging

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

/ PET 成像

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 正电子发射断层扫描 (PET) 成像

PET 成像使用的放射性核素富含质子（原子核中质子的数量相对多于中子的数量），并通过正电子发射衰变。

发射正电子的放射性核素发生 β^+ 衰变，质子转化为中子、正电子和中微子。正电子 (e^+) 是电子 (e^-) 的反粒子，质量和电荷与电子相同。但电荷为正电荷。

图 8
PET 扫描仪

Positrons travel a short distance through tissue and annihilate with electrons (see Figure 8, page 20).

This annihilation process, produces two photons of 511 kiloelectron volts (keV) energy which travel in opposite directions (at 180° to each other) and are detected by opposed radiation detectors.

The near simultaneous detection of the two photons allows the localisation of their origin to a line joining the detectors which is called annihilation coincidence detection.

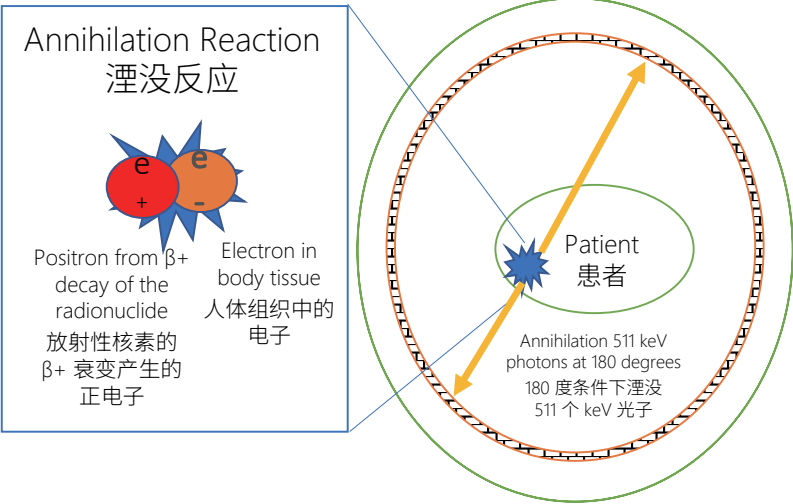


FIGURE 9
PET scanner

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine
Imaging Principles

/ PET Imaging

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

/ PET 成像

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

正电子在组织内移动一小段距离后会与电子发生湮灭（见第 20 页图 8）。

这一湮灭过程会产生两个能量为 511 千电子伏特 (keV) 的光子，沿相反方向（彼此呈 180°）移动，并被相对放置的辐射探测器探测到。

由于两个光子几乎同时被探测到，可以将其起源定位在连接探测器的一条线上，这被称为湮灭符合探测。

图 9
PET 扫描仪

/ PET is combined with CT for attenuation correction and anatomical localisation.

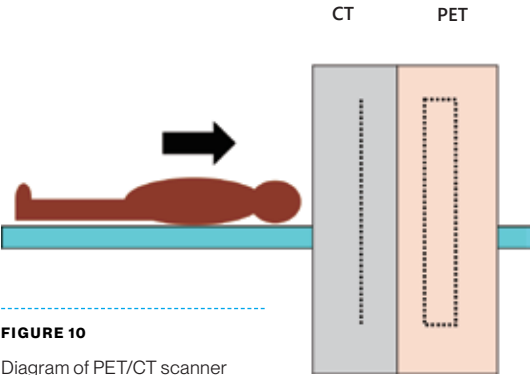


FIGURE 10
Diagram of PET/CT scanner

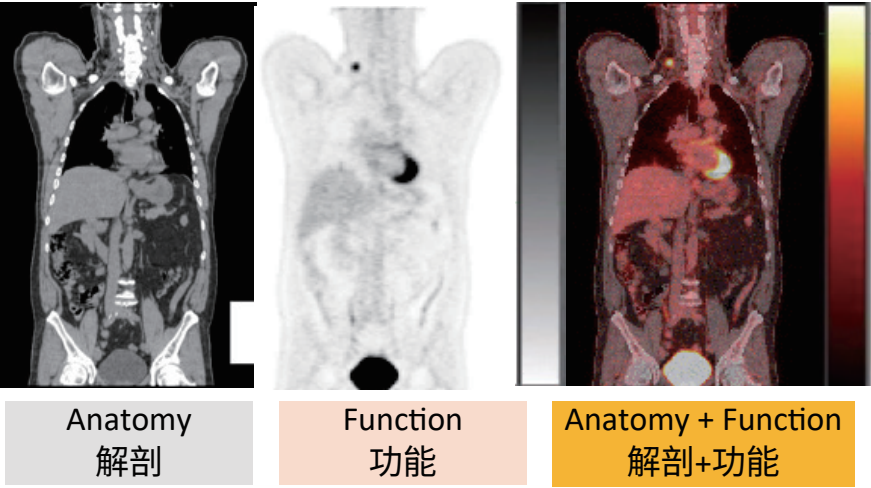


FIGURE 11
[¹⁸F]FDG PET/CT, Coronal CT, PET and fused

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

/ PET Imaging

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

/ PET 成像

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ PET 结合 CT，进行衰减校正和解剖学定位。

图 11
[¹⁸F]FDG PET/CT、冠状位 CT、PET 和融合

图 10
PET/CT 扫描仪示意图

Positron Emitting Tracers-Common Clinical Examples

RADIONUCLIDE	PHYSICAL HALF-LIFE (MINS)	PRODUCTION METHOD	PHARMACEUTICAL	PHYSIOLOGICAL PROCESS	CLINICAL APPLICATION
Fluorine-18 ([¹⁸ F]F)	110	Cyclotron	Fludeoxyglucose (FDG)	Glucose metabolism	Oncology, infection
			Fluorocholine	Cell membrane metabolism	Prostate cancer Parathyroid imaging
			Prostate-specific membrane antigen (PSMA-1007) DcF-PyL	PSMA expression	Prostate cancer
Gallium-68 ([⁶⁸ Ga]Ga)	68	Generator	Dotatate	Somatostatin receptor expression	Neuroendocrine tumour
			PSMA-11	PSMA expression	Prostate cancer

TABLE 3
Commonly used positron emitting tracers

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
 - / PET Imaging
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

核医学

章节大纲:

- 简介
- 核医学成像原理
 - / PET 成像
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

正电子发射示踪剂 - 常见临床实例

放射性核素	物理半衰期 (MIN)	生产方法	药物	生理过程	临床应用
氟-18 ([¹⁸ F]F)	110	回旋加速器	氟代脱氧葡萄糖 (FDG)	葡萄糖代谢	肿瘤学、感染
			氟代胆碱	细胞膜代谢	前列腺癌 甲状旁腺显像
			前列腺特异性膜抗原 (PSMA-1007) DcF-PyL	PSMA 表达	前列腺癌
镓-68 ([⁶⁸ Ga]Ga)	68	发生器	Dotatate	生长抑素受体表达	神经内分泌肿瘤
			PSMA-11	PSMA 表达	前列腺癌

表 3
常用正电子发射示踪剂

Comparison of SPECT and PET Imaging

SPECT	PET
Lower cost compared to PET	More expensive compared to SPECT
Use gamma emitting radionuclide	Use positron emitting radionuclide
1-3 large detectors	Ring of multiple detectors
Poorer spatial resolution 10-15 mm	Higher spatial resolution 5-8 mm
Can be combined with CT for attenuation correction and anatomical localisation	Can be combined with CT for attenuation correction and anatomical localisation

TABLE 4
Comparison of SPECT and PET Imaging

Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine
Imaging Principles

/ SPECT and SPECT/CT
Imaging

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

核
医学

章节大纲:

简介

核医学成像原理

/ SPECT 和
SPECT/CT 成像

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

SPECT 和 PET 成像的比较

SPECT	PET
与 PET 相比成本更低	比 SPECT 更昂贵
使用伽马放射性核素	使用正电子放射性核素
1~3 个大型探测器	多探测器环
空间分辨率较差，10~15 mm	更高的空间分辨率，5~8 mm
可结合 CT，进行衰减校正和解剖学定位	可结合 CT，进行衰减校正和解剖学定位

表 4
SPECT 和 PET 成像的比较

/ Applications of Planar, SPECT and PET

Bone

- / Metabolic disease
- / Rheumatology
- / Infection
- / Trauma

Cardiac

- / Ventricular function
- / Perfusion
- / Infarct

Blood

- / Inflammation
- / Infection
- / Red cell mass

Brain

- / Dementia
- / Movement disorder
- / Seizure
- / Tumour

Liver/Spleen

- / Function
- / Blood volume

Lungs

- / Perfusion
- / Ventilation

Thyroid

- / Function
- / Metastatic disease

Oncology

- / Sentinel lymph node
- / Solid organ tumours
- / Prostate cancer: PSMA receptor
- / Neuroendocrine tumours: somatostatin receptor
- / Therapy

Renal

- / Function
- / Morphology/Scarring
- / Obstruction/Blood flow

GI

- / Transit
- / Bleeding

FIGURE 12
Nuclear Medicine Applications

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

/ Nuclear Medicine Applications

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

/ 核医学应用

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 平面、SPECT 和 PET 成像的应用

骨

- / 代谢性疾病
- / 风湿病
- / 感染
- / 外伤

心脏

- / 心室功能
- / 灌注
- / 梗死

血液

- / 炎症
- / 感染
- / 红细胞总量

脑

- / 痴呆
- / 运动障碍
- / 惊厥发作
- / 肿瘤

肝脏/脾脏

- / 功能
- / 血容量

肺

- / 灌注
- / 通气

甲状腺

- / 功能
- / 转移性疾病

肿瘤

- / 前哨淋巴结
- / 实体器官肿瘤
- / 前列腺癌: PSMA 受体
- / 神经内分泌肿瘤: 生长抑素受体
- / 治疗

肾脏

- / 功能
- / 形态/瘢痕
- / 阻塞/血流

胃肠道 (Gastrointestinal, GI)

- / 转运
- / 出血

图 12

核医学应用

/ Planar and SPECT Studies

MODERN RADIOLOGY

/ **Nuclear
Medicine**

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

**Planar and SPECT
Studies**

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ **核
医学**

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 平面和 SPECT 检查

/ Bone Scan

Indications:

Oncology (particularly prostate and breast cancer), rheumatology, bone and joint infections, painful joint prosthesis, metabolic bone disease

Route: Administered intravenously

Radiopharmaceutical:

Technetium-99m (^{99m}Tc)Tc labelled bisphosphonates such as [^{99m}Tc]Tc -HDP (hydroxyethylene diphosphonate) or MDP (methylene diphosphonate) which bind to calcium and hydroxyapatite crystals in bone in proportion to local vascularity and osteoblastic activity

Image acquisition:

- / **Anterior and posterior whole body planar:** Acquired 3-4 hours post-injection for optimal concentration of radiopharmaceutical by osteoblasts and clearance from tissues
- / **Dynamic: 3 phases:** selected cases, e.g., infected prosthesis
 - / **Flow phase** (2-to-5 second images obtained for 60 seconds immediately after injection)
 - / **Blood pool phase** (5 minutes after injection)
 - / **Delayed phase** (3-4 hours after injection)

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

/ 骨扫描

适应证:

肿瘤（尤其是前列腺癌和乳腺癌）、风湿病、骨和关节感染、关节假体疼痛、代谢性骨病

途径：静脉给药

放射性药物:

锝-99m (^{99m}Tc)Tc 标记的双膦酸盐，如 [^{99m}Tc]Tc -HDP（羟乙基二膦酸盐）或 MDP（亚甲基二膦酸盐），它们与骨中的钙和羟基磷灰石晶体结合，与局部血流量和成骨细胞活性成正比。

图像采集:

- / **前、后全身平面：**注射后 3~4 h 采集，使放射性药物在成骨细胞中达到最佳放射性浓度并从组织中清除
- / **动态：3 个阶段：**特定病例，如假体感染
 - / **血流期**（注射后 60 s 内获得 2~5 s 的图像）
 - / **血池期**（注射后 5 min）
 - / **延迟期**（注射后 3~4 h）

Planar Normal Case example

Biodistribution in the skeleton should be homogenous and almost symmetrical for left and right sides.

Excretion route is renal so there is visualisation of kidneys and bladder.

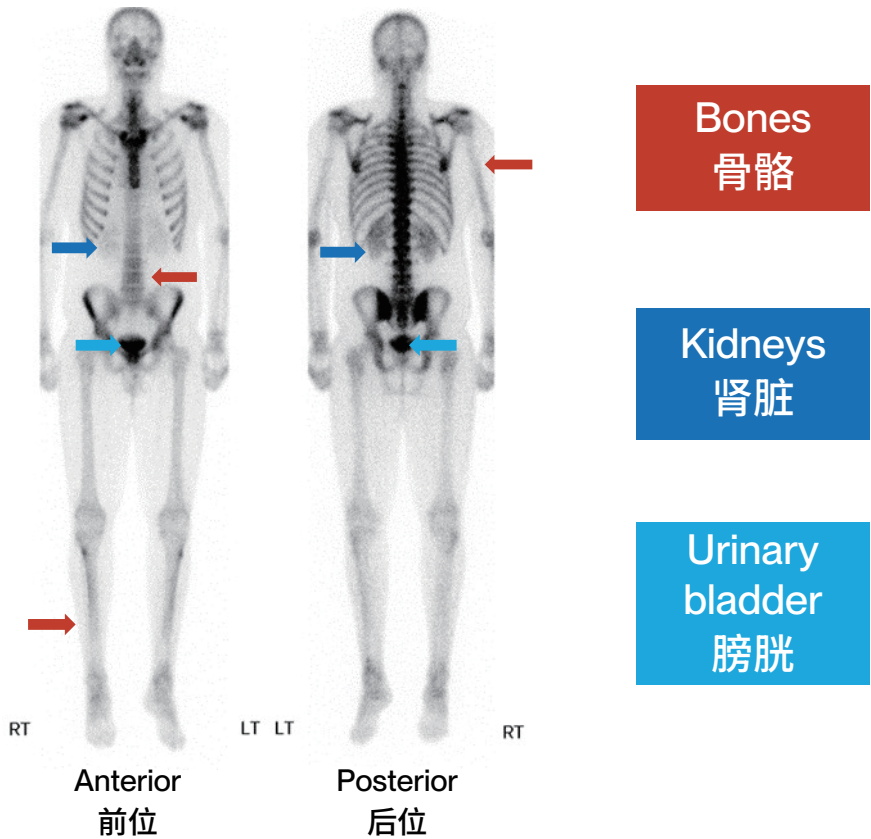


FIGURE 13
Normal ^{99m}Tc]-HDP whole body bone scan

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / Bone Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

核医学

- 章节大纲:
- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / 骨扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

平面显像正常情况示例

骨骼中的生物分布应均匀，且左右两侧几乎对称。

排泄途径为肾脏，因此可以看到肾脏和膀胱。

图 13
正常 ^{99m}Tc]-HDP 全身骨扫描

Dynamic: Normal Case example

1st phase (Flow phase)

Dynamic study to demonstrate the presence of blood flow in the affected area (e.g., inflammation/infection of a joint replacement). 2-to-5 second images are obtained for 60 seconds after injection of radiopharmaceutical. Focused on region of interest/clinical concern, e.g., hip.

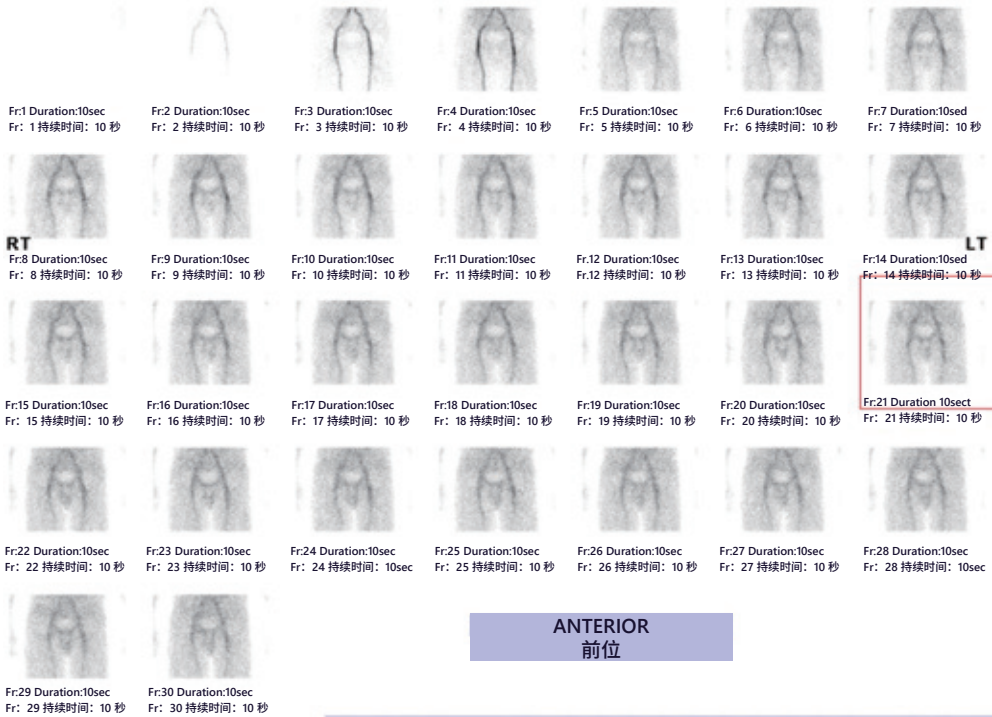


FIGURE 14

Normal perfusion phase of dynamic bone scan of the hip area

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

动态：正常情况示例

第1阶段（血流相）

动态检查，证明受累部位存在血流（例如，关节置换术的炎症/感染）。在注射放射性药物后 60 s 内获得 2~5 s 的图像。重点关注目标部位/临床关注部位，例如髋关节。

图 14

髋关节部位动态骨扫描正常灌注相

Dynamic: Normal Case example

2nd phase (Blood phase)

Early static views to visualise the distribution of radiopharmaceutical into the extra-cellular space. Focused on region of interest/clinical concern.

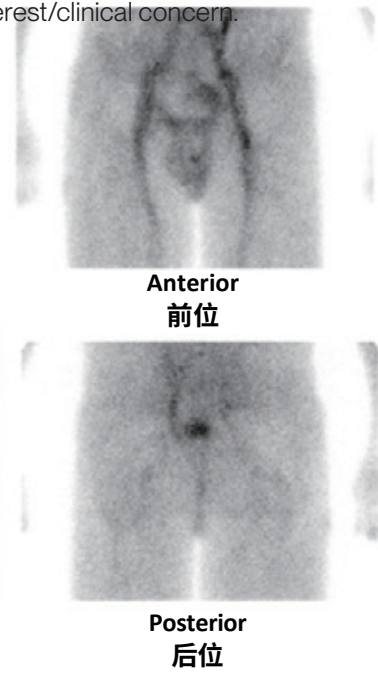
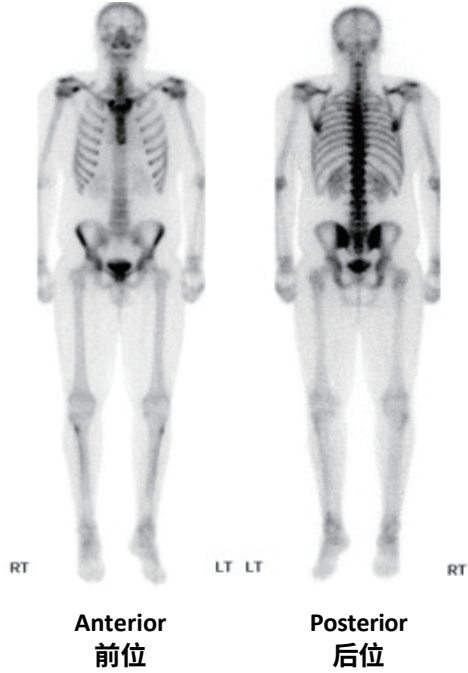


FIGURE 15
Normal blood pool phase of the hip area and whole body bone scan

3rd phase (Delayed phase)

2-4 hours later, static view-vertex to toes.



/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / Bone Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / 骨扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

动态：正常情况示例

第 2 阶段（血池期）

早期静态显像，可视化放射性药物进入细胞外间隙的分布情况。重点关注目标部位/临床关注部位。

第 3 阶段（延迟期）

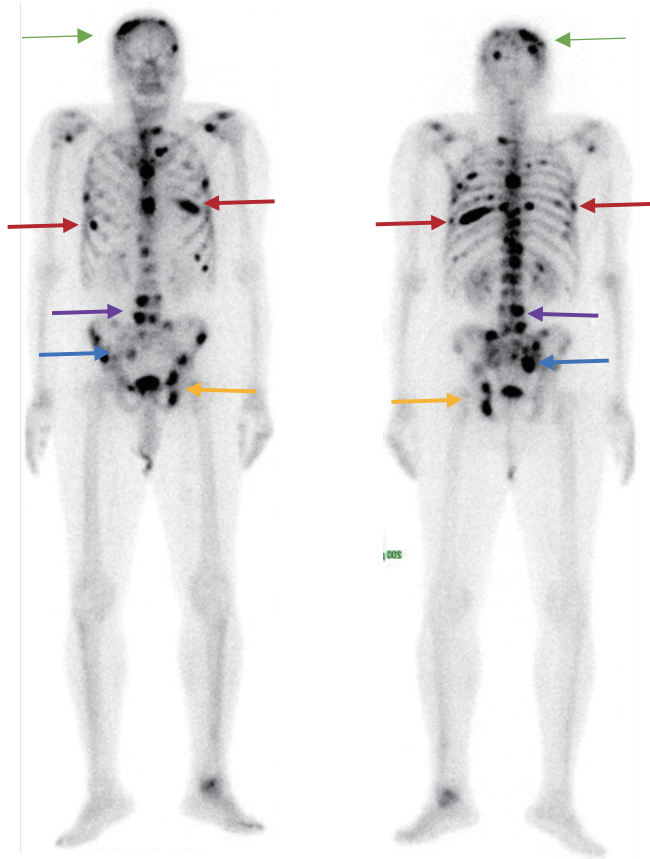
2~4 h 后从头到脚静态显像。

图 15
髋关节部位正常血池相和全身骨扫描

Case: Metastatic disease

63 years old male with prostate cancer.

There is intense radiopharmaceutical uptake within axial and appendicular skeleton, including the right sacrum (blue arrows), left acetabulum (yellow arrows), and vertebral bodies (purple arrows), and ribs (red arrows), skull (green arrows) in keeping with osteoblastic metastatic disease.



Anterior
前位

Posterior
后位

FIGURE 16
[^{99m}Tc]Tc- HDP whole body bone scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

病例：转移性疾病

63 岁男性前列腺癌患者。

中轴骨和附肢骨呈放射性高度摄取，包括右侧骶骨（蓝色箭头）、左侧髋臼（黄色箭头）、椎体（紫色箭头）以及肋骨（红色箭头）和颅骨（绿色箭头），与成骨性转移性疾病相符。

图 16

[^{99m}Tc]Tc- HDP 全身骨扫描

Case: “Superscan”

74 years old male. Known history of prostate malignancy.

Diffuse slightly hetero-
geneous increased
radiopharmaceutical
uptake throughout
the imaged skeleton,
including the skull and
long bones. Although
there is some activity
in the urinary bladder,
there is only very faint
activity in the kidneys.

The overall appear-
ances would be in
keeping with a super-
scan, indicating diffuse
metastatic bone involve-
ment, given the history
of prostate malignancy.

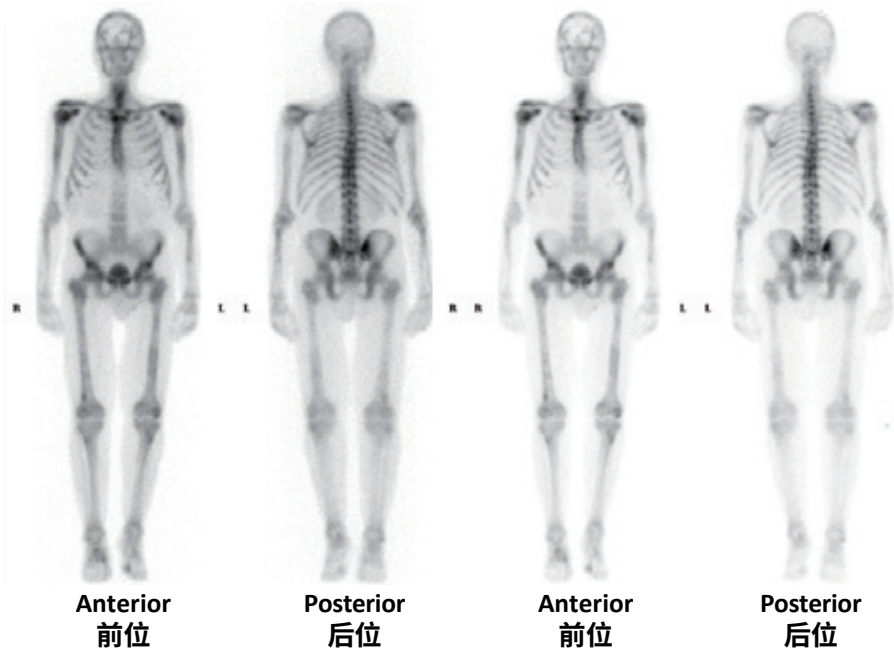


FIGURE 17
[^{99m}Tc]Tc- HDP whole body bone scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

病例：“超级影像”

74 岁男性。既往前列腺恶性肿瘤病史。

在全身骨骼（包括颅骨和长骨）中，放射性药物摄取呈弥漫性轻度异常增加。膀胱内可见显影，肾脏呈淡影。

结合前列腺恶性肿瘤病史，整体表现符合超级影像，提示弥漫性骨转移。

图 17

[^{99m}Tc]Tc-HDP 全身骨扫描

Case: Paget's disease

84 years old male, raised ALP.

Patchy increased uptake within the skull (blue arrow), intense uptake within the entire mandible (yellow arrow), L3 vertebral body pedicles and spinous process (purple arrow), and also within the right hemipelvis (red arrow). There is associated expansion of the right hemipelvis. The appearances are in keeping with polyostotic Paget's.



FIGURE 18
[^{99m}Tc]Tc- HDP whole body bone scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

病例：佩吉特骨病

84 岁男性，ALP 升高。

颅骨内摄取呈片状增加（蓝色箭头），整个下颌骨（黄色箭头）、L3 椎体椎弓根和棘突（紫色箭头）以及右半骨盆（红色箭头）内摄取强烈。伴有右半骨盆膨胀。这些表现与多骨性佩吉特骨病相符。

图 18

[^{99m}Tc]Tc-HDP 全身骨扫描

Case: breast cancer vertebral metastasis

54 years old female. Known breast cancer. Mid thoracic back pain

Increased uptake within the T9 vertebral body demonstrated on the posterior view of the whole body bone scan is subtle (blue arrow). The subsequent SPECT/CT allows better localisation to the T9 vertebral body as well demonstrating the vertebral body height loss/collapse (yellow arrow).



FIGURE 19
[^{99m}Tc]Tc- HDP whole body bone scan

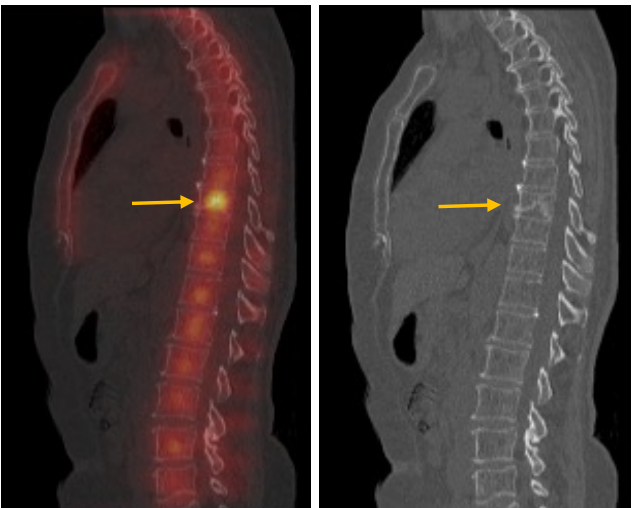


FIGURE 20
Sagittal SPECT/CT fused
矢状位 SPECT/CT 融合
Sagittal CT bone window
矢状位 CT 骨窗

FIGURE 20
[^{99m}Tc]Tc- HDP SPECT/CT

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

病例：乳腺癌椎体转移

54 岁女性。患有乳腺癌。胸背部疼痛

全身骨扫描的后位视图显示，T9 椎体内的摄取增加不明显（蓝色箭头）。SPECT/CT 检查后可更好地定位 T9 椎体，并证实椎体压缩/塌陷（黄色箭头）。

图 19

[^{99m}Tc]Tc-HDP 全身骨扫描

图 20

[^{99m}Tc]Tc-HDP SPECT/CT

Case: Bone SPECT/CT for pain generators

32 years old female. Lower back pain.

No significant uptake demonstrated on whole body scan to explain the patient’s symptoms. The subsequent SPECT/CT demonstrates increased uptake at the L3/L4 disc space (blue arrow) and right L2/L3 facet joint (yellow arrow) which are likely to be the main osseous pain generators.

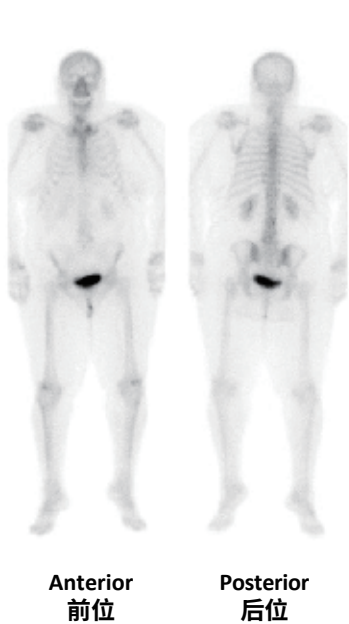
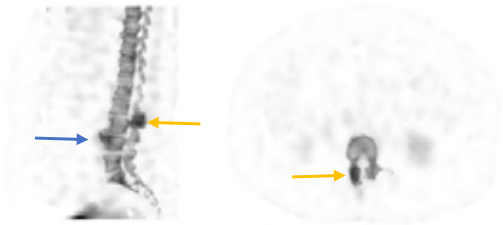
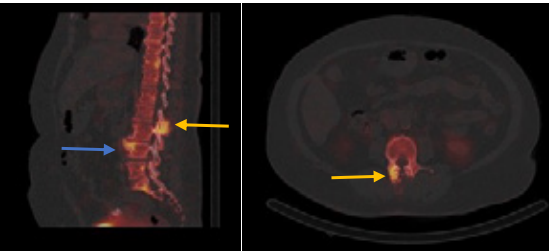


FIGURE 21
[^{99m}Tc]Tc- HDP whole body bone scan



Sagittal and axial SPECT MIP
矢状位和轴位 SPECT MIP



Sagittal and axial SPECT/CT fused
矢状位和轴位 SPECT/CT 融合

FIGURE 22
[^{99m}Tc]Tc- HDP SPECT/CT

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

病例：骨 SPECT/CT 定位疼痛部位

32 岁女性。腰痛。

全身扫描未发现明显摄取，无法解释患者的症状。随后进行 SPECT/CT，显示 L3/L4 椎间隙（蓝色箭头）和右侧 L2/L3 小关节（黄色箭头）摄取增加，这可能是主要的致痛原因。

图 21
[^{99m}Tc]Tc-HDP 全身骨扫描

图 22
[^{99m}Tc]Tc-HDP SPECT/CT

Case: Lytic metastatic disease from breast cancer

62 years old female. Breast cancer 10 years. Presenting with bilateral hip pain.

No significant uptake demonstrated on whole body scan to explain the patient's symptoms. The subsequent SPECT/CT demonstrates lucent lesions within bilateral acetabuli which do not demonstrate increased uptake, in keeping with osteoclastic metastatic disease.

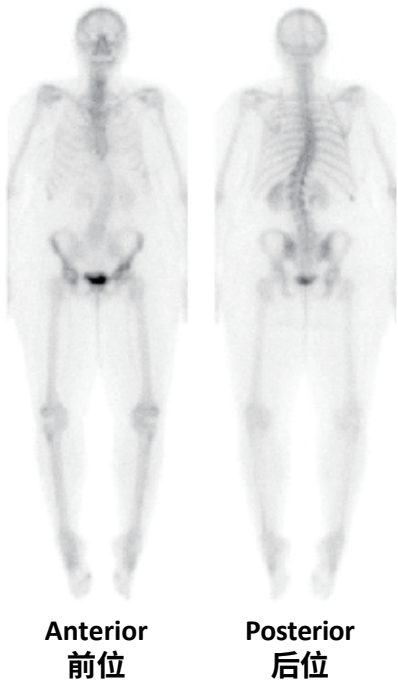
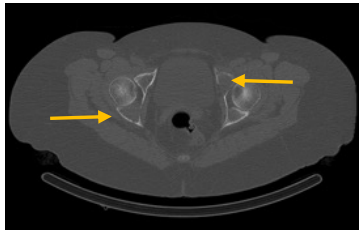


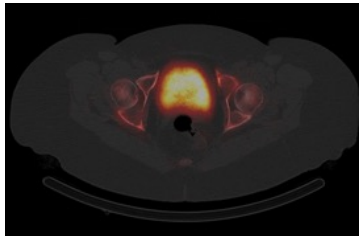
FIGURE 23
[^{99m}Tc]Tc- HDP whole body bone scan



Axial SPECT MIP
轴位 SPECT MIP



Axial CT Bone window
轴位 CT 骨窗



Axial SPECT/CT Fused
轴位 SPECT/CT 融合

FIGURE 24
[^{99m}Tc]Tc- HDP SPECT/CT

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Bone Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 骨扫描

PET 检查

核心要点

参考文献

知识测试

病例：乳腺癌溶骨性转移性疾病

62 岁女性。乳腺癌 10 年。表现为双侧髋关节疼痛。

全身扫描未发现明显摄取，无法解释患者的症状。随后进行 SPECT/CT，显示双侧髋臼内有透亮病变，但无摄取增加，与破骨细胞转移性疾病相符。

图 23
[^{99m}Tc]Tc-HDP 全身骨扫描

图 24
[^{99m}Tc]Tc-HDP SPECT/CT

>|< COMPARE

Strengths and limitations:

- / Uptake of Technetium-99m is based on vascularity and osteoblastic activity. Other bone lesions such as infection and trauma can also demonstrate high uptake. Therefore, bone scans are sensitive but nonspecific so correlation with other modalities may be needed.
- / Lytic lesions (e.g., myeloma and certain tumour metastases, e.g., renal cell) may not be visible on bone scintigraphy as bone scans assess osteoblastic activity and these are typically osteoclastic.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- / Bone Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

>|< 比较

优势和局限性:

- / 锝-99m 的摄取取决于血管分布情况和成骨细胞活性。其他骨病变（如感染和创伤）也会表现出高摄取。因此，骨扫描敏感但不具特异性，可能需要结合其他检查方法。
- / 溶骨性病变（例如骨髓瘤和某些肿瘤转移，肾细胞癌）可能在骨扫描中不显示，因为骨扫描评估的是成骨细胞活性，而这些病变通常以破骨为主。

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- / 骨扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ Thyroid Scintigraphy

RADIOPHARMACEUTICAL	PRODUCTION	EMISSION AND HALF LIFE	MECHANISM	USES	PROS/CONS
[^{99m} Tc]Tc-pertechnetate	Generator	Gamma rays, 6 hours	trapped by normal follicular cells	Thyroid uptake and imaging	Rapid examination, poor image quality when low uptake
Iodine-123 ([¹²³ I]I)	Cyclotron	Gamma rays, 13 hours	trapped by normal follicular cells, organified and stored in colloid space	Thyroid uptake and imaging Thyroid cancer metastases	Relatively expensive and unavailable as cyclotron, better image quality when uptake is low
Iodine-131 ([¹³¹ I]I)	Reactor	Beta and gamma rays, 8.06 days	trapped by normal follicular cells, organified and stored in colloid space	Hyperthyroidism / thyroid cancer treatment	

TABLE 5
Radiopharmaceuticals used in thyroid scintigraphy

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Thyroid Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 甲状腺显像

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 甲状腺扫描

PET 检查

核心要点

参考文献

知识测试

放射性药物	生产	发射和半衰期	机制	用途	优缺点
[^{99m} Tc] Tc-高锝酸盐	发生器	γ 射线，6 h	被正常滤泡细胞捕获	甲状腺摄取和显像	检查快速，摄取低时图像质量差
碘-123 ([¹²³ I]I)	回旋加速器	γ 射线，13 h	被正常滤泡细胞捕获、有机化并储存在胶体腔	甲状腺摄取和显像 甲状腺癌转移	价格相对较高，获取不便，摄取量低时图像质量更好
碘-131 ([¹³¹ I]I)	反应堆	β 射线和 γ 射线，8.06 天	被正常滤泡细胞捕获、有机化并储存在胶体腔	甲状腺功能亢进症 / 甲状腺癌治疗	

表 5
甲状腺显像中使用的放射性药物

Route: Administered intravenously
(Both [¹²³I]I and [^{99m}Tc]Tc- pertechnetate)

- Image acquisition:**
- / Anterior, left anterior oblique and right anterior oblique views
 - / [¹²³I]I: Either at 4-6 or 24 hours after administration
 - / [^{99m}Tc]Tc-pertechnetate): 20 minutes after administration

<=> ATTENTION

Certain medications can interfere with thyroid uptake of the radiopharmaceutical

No iodine-containing contrast for 6 weeks prior

No iodine-containing medications for 4 weeks prior

No amiodarone for 3-6 months prior

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies**
 - / Thyroid Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / 甲状腺扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

途径: 静脉给药
([¹²³I]I 和 [^{99m}Tc]Tc-高锝酸盐)

- 图像采集:**
- / 前位、左前斜位和右前斜位视图
 - / [¹²³I]I: 给药后 4~6 h 或 24 h
 - / [^{99m}Tc]Tc-高锝酸盐: 给药后 20 min

<=> 注意

某些药物会干扰甲状腺摄取放射性药物

检查前 6 周内不得使用含碘对比剂

检查前 4 周内不得使用含碘药物

检查前 3~6 个月内不得使用胺碘酮

Normal Case

Tc99m thyroid scan.

Diffuse homogenous uptake within both lobes of the thyroid gland.

Mild homogenous uptake noted within the salivary glands.

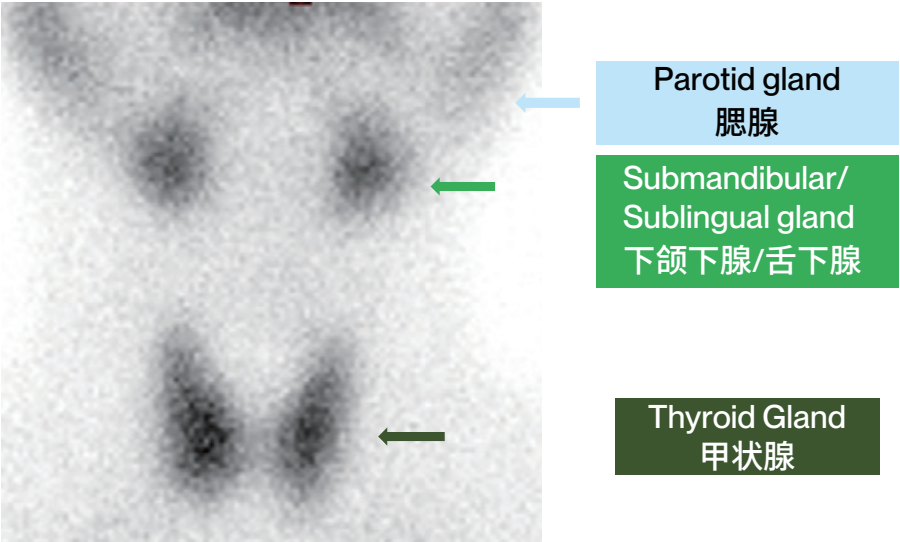


FIGURE 25
Normal [^{99m}Tc]Tc Thyroid scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Thyroid Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 甲状腺扫描

PET 检查

核心要点

参考文献

知识测试

正常情况

99mTc 甲状腺扫描。

甲状腺双叶弥漫性均匀摄取。

唾液腺轻度均匀摄取。

图 25
正常 [^{99m}Tc]Tc 甲状腺扫描

Case: Graves' Disease

Tc99m thyroid scan.

Diffuse and relatively uniform uptake by the entire enlarged thyroid gland.

Background salivary activity is suppressed.
The percentage uptake is 25.9% (normal range 0.45-3.5%).

Chin and suprasternal (SSN) markers for anatomical localisation.

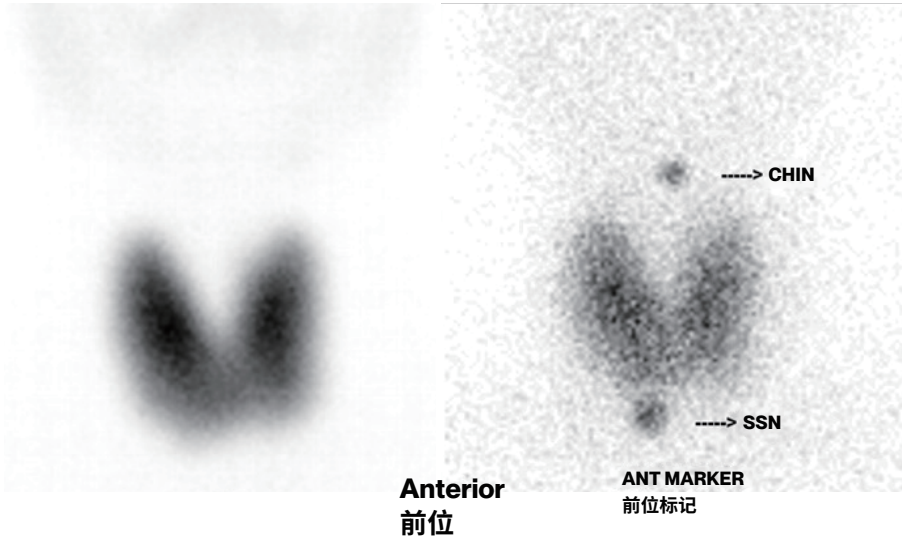


FIGURE 26
[^{99m}Tc]Tc Thyroid scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Thyroid Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

SPECT

/ 甲状腺扫描

PET 检查

核心要点

参考文献

知识测试

病例：格雷夫斯病

99mTc 甲状腺扫描。

甲状腺呈弥漫性肿大、均匀性摄取。

唾液分泌受到抑制，摄取百分比为 25.9%
(正常范围为 0.45%~3.5%)。

颈下和胸骨上 (SSN) 标记用于解剖学定位。

图 26
[^{99m}Tc]Tc 甲状腺扫描

Differential Diagnosis of Hyperthyroidism

Thyroid Scintigraphy is the key test for differentiating causes of hyperthyroidism due to different patterns of uptake:

- A. Graves' disease – homogenous increased uptake
- B. Toxic multinodular goitre – multifocal uptake, often heterogenous
- C. Autonomous toxic nodule – uptake in a single, often enlarged, nodule
- D. Subacute thyroiditis – no uptake

A 'cold' focal area with reduced uptake is concerning for a malignant nodule. In these cases, ultrasound is needed to better characterise the nodule and determine whether biopsy is required.

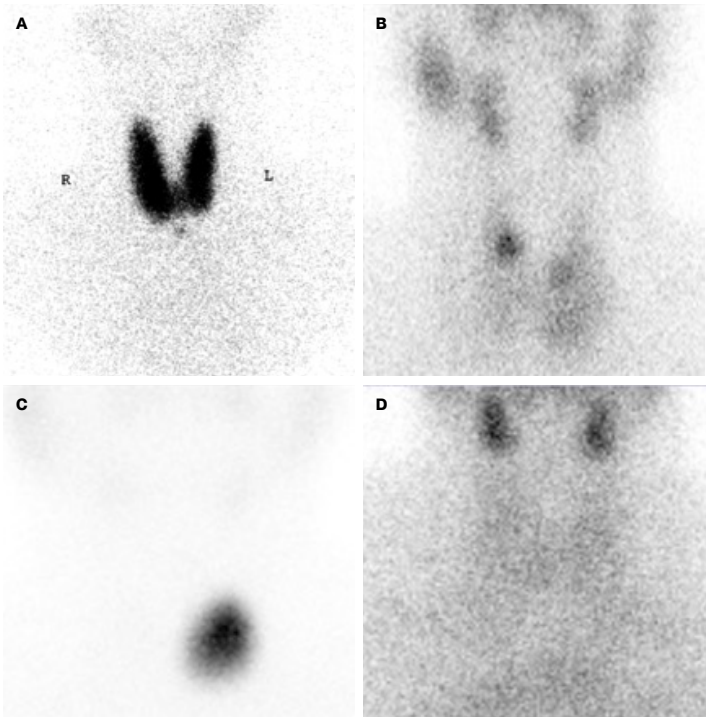


FIGURE 27
[99mTc]Tc Thyroid scan

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - Thyroid Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - 甲状腺扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

甲状腺功能亢进的鉴别诊断

由于摄取表现不同，甲状腺显像是鉴别甲状腺功能亢进病因的关键检查：

- A. 格雷夫斯病 - 摄取均匀增加
- B. 毒性多结节性甲状腺肿 - 多灶性摄取增加，通常不均匀
- C. 自主性毒性结节 - 单个结节摄取增加，通常为较大结节
- D. 亚急性甲状腺炎 - 无摄取

摄取减少的“冷”灶区可能提示恶性结节。在这类情况下，需要进行超声检查，以更好地确定结节的特征，并确定是否需要活检。

图 27
[99mTc]Tc 甲状腺扫描

/ Ventilation/Perfusion (V/Q) Scan

Indications:

Diagnosis of acute pulmonary embolism with normal chest radiograph.

Work-up of patients with pulmonary hypertension to determine whether the cause is due to chronic thromboembolic disease.

Quantification of differential lung function preoperatively (for example prior to pneumonectomy in lung cancer patients).

>=< FURTHER KNOWLEDGE

Pregnant patient should be counselled regarding radiation doses. Typically, radiation dose to maternal breast tissue is greater for CTPA compared to V/Q scan; doses to fetus are equivalent.

<!=> ATTENTION

If performing V/Q scan for acute pulmonary embolism, make sure chest radiograph has been performed and reviewed within 12 to 24 hours prior to lung scintigraphy. This is because there are other causes of perfusion defects which can be excluded on chest radiograph such as atelectasis, pneumonia, etc.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / V/Q Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / V/Q 扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ 通气/灌注 (V/Q) 扫描

适应证:

诊断为急性肺栓塞且胸片正常。

对肺动脉高压患者进行诊断检查，以确定病因是否为慢性血栓栓塞性疾病。

术前进行肺功能差异定量（例如，肺癌患者在肺切除术前进行）。

>=< 进阶知识

应告知妊娠患者辐射剂量相关事宜。CTPA 对母体乳腺组织的辐射剂量通常大于 V/Q 扫描，而对胎儿的辐射剂量相当。

<!=> 注意

如果对急性肺栓塞进行 V/Q 扫描，请确保在肺扫描前 12~24 h 内已拍摄胸片并复查。这是因为灌注缺损还有其他原因，可通过胸片排除，如肺不张、肺炎等。

Radiopharmaceutical and Route:

Perfusion:

Technetium-99m labelled human albumin (MAA) administered intravenously: These lodge in patent precapillary arterioles and capillaries and occlude the arteries temporarily reflecting regional perfusion.

Ventilation:

Krypton-81 gas administered as an aerosol for ventilation. This is inhaled until it reaches a steady state in the alveoli and then continuously during the scan. It reflects regional ventilation.

[^{99m}Tc]Tc labelled aerosols, DTPA or Technegas accumulate in bronchiole and alveoli.



FIGURE 28

Planar images from a Normal V/Q scan

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ V/Q Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ V/Q 扫描

PET 检查

核心要点

参考文献

知识测试

放射性药物和给药途径:

灌注:

锝-99m 标记的人血白蛋白 (MAA) 静脉给药: 药物滞留在患者的毛细血管前微动脉和毛细血管中, 暂时阻塞动脉, 反映局部灌注情况。

通气:

用氙-81 气体作气溶胶进行通气。将其吸入, 直到在肺泡中达到稳定状态, 并且在扫描过程中需持续吸入。此方法可以反映局部通气情况。

[^{99m}Tc]Tc 标记的气溶胶、DTPA 或锝气体会积聚在细支气管和肺泡中。

图 28

正常 V/Q 扫描的平面图像

Image acquisition:

- / Imaging starts with the ventilation scan, immediately followed by the perfusion scan.
- / Perfusion imaging and ventilation using [⁸¹Kr]Kr gas can be imaged at the same time as the perfusion study due to different energy windows of [⁸¹Kr]Kr (190 keV) and [^{99m}Tc]Tc (140 keV)
- / If DTPA or Technegas are used, the ventilation and perfusion will need to be acquired separately due to the same radionuclide being used
- / SPECT imaging with additional CT component (Planar if SPECT not available)

EANM guideline for ventilation/perfusion single-photon emission computed tomography (SPECT) for diagnosis of pulmonary embolism and beyond, 2019

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ V/Q Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ V/Q 扫描

PET 检查

核心要点

参考文献

知识测试

图像采集:

- / 首先进行通气扫描，然后立即进行灌注扫描。
- / 由于 [⁸¹Kr]Kr (190 keV) 和 [^{99m}Tc]Tc (140 keV) 的能量窗口不同，[⁸¹Kr] 因此可与灌注检查同时进行
- / 如果使用 DTPA 或锝气体，由于使用的放射性核素相同，通气和灌注显像需要分别采集
- / 带 CT 组件的 SPECT 进行额外成像（如果不带 CT，则进行平面扫描）

EANM guideline for ventilation/perfusion single-photon emission computed tomography (SPECT) for diagnosis of pulmonary embolism and beyond, 2019

Normal Case

Diffuse homogenous uptake within both lungs.

No mismatch between perfusion and ventilation imaging.

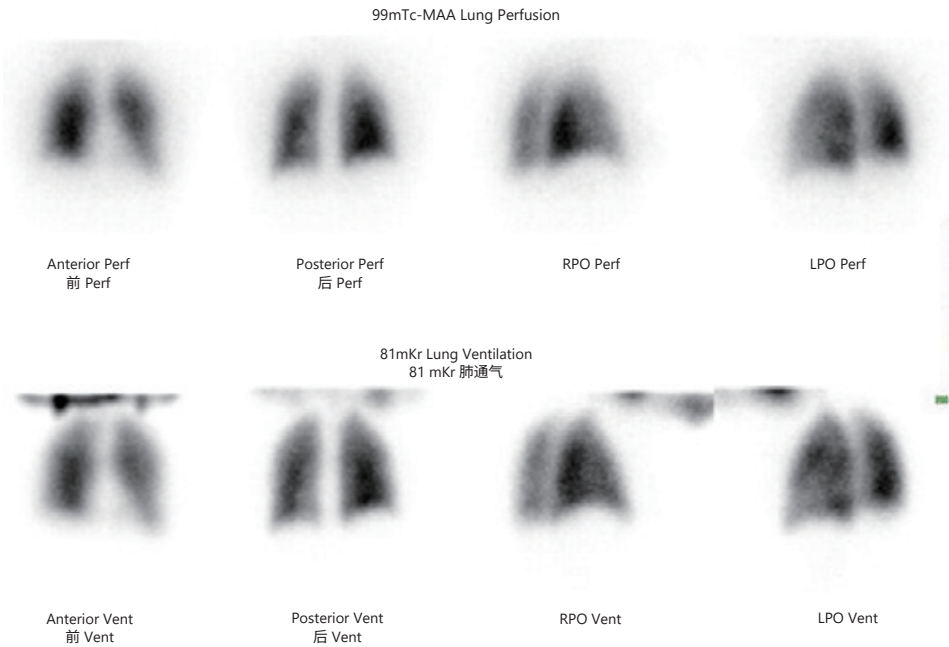


FIGURE 29
Planar images from a Normal V/Q scan

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ V/Q Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ V/Q 扫描

PET 检查

核心要点

参考文献

知识测试

正常情况

双肺内弥漫性均匀摄取。

灌注显像和通气显像不匹配。

图 29
正常 V/Q 扫描的平面图像

Case: Bilateral subsegmental pulmonary emboli

24 years old female. Focal segmental glomerulosclerosis with nephrotic syndrome. Previous pulmonary embolism. Similar pain and worsening shortness of breath whilst on apixaban.

On the SPECT/CT, there are bilateral subsegmental wedge shaped perfusion defects in the lateral segments of both lower lobes and posterior segment of the right lower lobe (blue arrows), which are mismatched and with no corresponding CT abnormality.

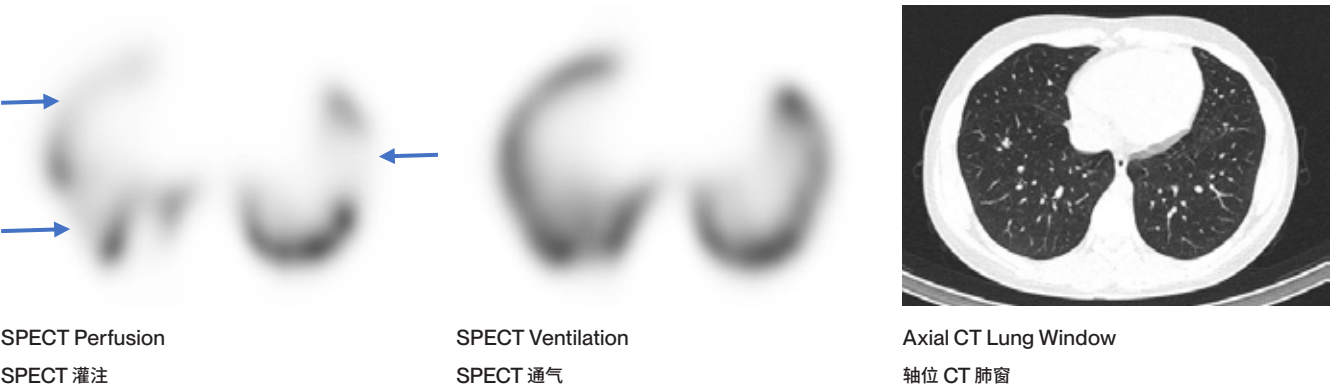


FIGURE 30
V/Q SPECT/CT

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ V/Q Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ V/Q 扫描

PET 检查

核心要点

参考文献

知识测试

病例：双侧亚段肺栓塞

24 岁女性。局灶节段性肾小球硬化伴肾病综合征。既往肺栓塞。接受阿哌沙班治疗时出现胸痛，气短加重。

SPECT/CT 显示双肺下叶外侧段及右肺下叶后段楔形灌注缺损（蓝色箭头），相应部位 CT 无异常，呈灌注/通气不匹配。

图 30
V/Q SPECT/CT

Comparison of V/Q Scan and CTPA

V/Q SCAN	CTPA
Can be used in patients with contrast nephropathy and renal impairment	Quicker, Readily available
Reduced radiation burden to radiosensitive breast tissue in pregnant women	Alternative explanations for the patient's symptoms, e.g., pneumothorax
Diagnosis of chronic thromboembolic pulmonary hypertension	If there is PE, can demonstrate findings of right heart strain

TABLE 6
Comparison of V/Q scan and CTPA
Abbreviations: CT pulmonary angiogram (CTPA); pulmonary embolism (PE)

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- V/Q Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- V/Q 扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

V/Q 扫描和 CTPA 的比较

V/Q 扫描	CTPA
可用于对比剂肾病和肾功能损害患者	更快、更方便
减轻孕妇辐射敏感乳腺组织的辐射负担	为患者症状提供其他解释，如气胸
慢性血栓栓塞性肺动脉高压的诊断	如果有 PE，可提示右心功能不全

表 6
V/Q 扫描和 CTPA 的比较
缩略语：CT 肺动脉造影 (CTPA)；肺栓塞 (PE)

/ Dimercapto Succinic Acid (DMSA) Renal Scan

Indications:

- / Detection of focal renal parenchymal abnormalities including assessment of renal scarring
- / Differential renal function estimation
- / Assessment of horseshoe, solitary or ectopic kidney

Radiopharmaceutical:

- / Technetium-99m labelled-DMSA (2, 3-dimercapto-succinic acid) is protein-bound and removed from plasma, and concentrates in the proximal tubules of the renal cortex

Route: Administered intravenously

Image acquisition:

- / Static planar 2-3 hours post-injection
- / Views: anterior, posterior and 45 degree left and right posterior oblique

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ DMSA Renal Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ DMSA 肾脏扫描

PET 检查

核心要点

参考文献

知识测试

/ 二巯基丁二酸 (DMSA) 肾静态显像

适应证:

- / 检测局灶性肾实质异常, 包括肾瘢痕评估
- / 分肾功能评估
- / 评估马蹄肾、孤立肾或异位肾

放射性药物:

- / 锝-99m 标记的 DMSA (2,3-二巯基丁二酸) 与蛋白质结合后被清除, 聚集在肾皮质的近端小管

途径: 静脉给药

图像采集:

- / 注射后 2~3 h 静态平面扫描
- / 视图: 前位、后位、左右后斜位 (45°)

Normal Case

Relative higher radiopharmaceutical uptake within the right kidney (yellow arrow) compared to the left kidney (blue arrow) due its superficial position, i.e., closer to the gamma camera. Otherwise,

both kidneys have a normal contour and exhibit homogenous radiopharmaceutical uptake. No photopenic defects to suggest cortical scarring.

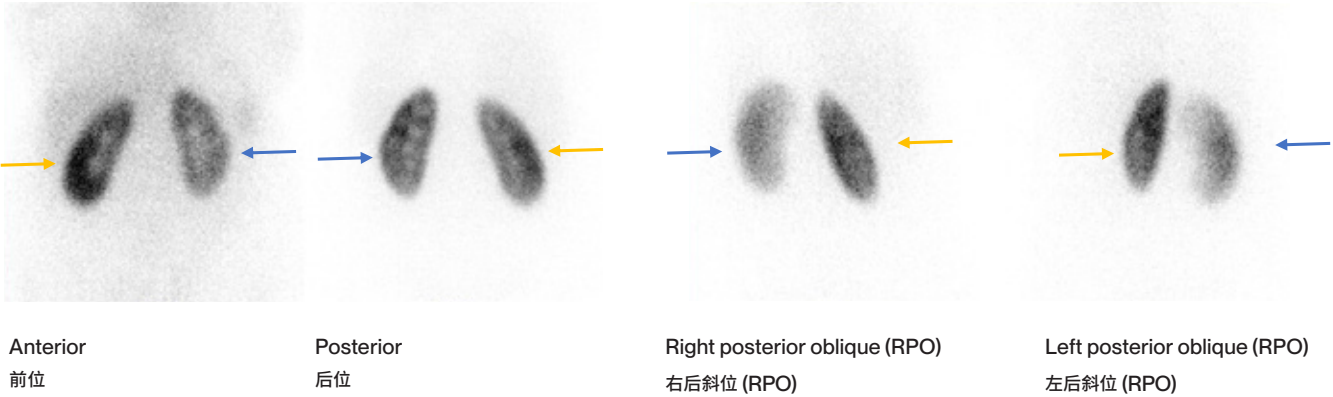


FIGURE 31
Normal [^{99m}Tc]Tc- DMSA

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / DMSA Renal Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

正常情况

由于右肾（黄色箭头）位置较浅（更接近伽马相机），其放射性摄取相对高于左肾（蓝色箭头）。另外，双肾轮廓正常，放射性药物摄取分布均匀。未见提示皮质瘢痕的放射性缺损区。

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / DMSA 肾脏扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

图 31
[^{99m}Tc]Tc-DMSA 正常显像

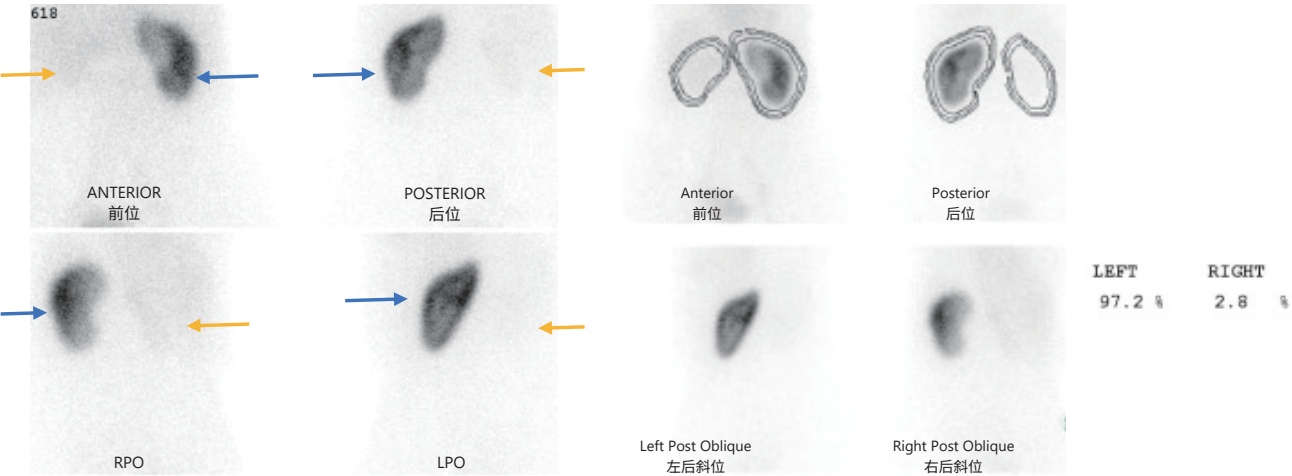
Case: Non-functioning right kidney with a likely hypertrophied left kidney

59 years old female. Severe right hydronephrosis with 1.3 cm stone. DMSA to assess renal function.

The right kidney is barely visible above background (yellow arrow) and the faint outline is smaller than the left (yellow arrow)

kidney. The left kidney is large (blue arrows) likely due to compensatory hypertrophy, with a regular contour and no regions of photopenia to indicate scarring.

Split function = right kidney 2.8%, left kidney 97.2%.



Standard views of DMSA
DMSA 标准视图

Standard views of DMSA with region of interest marked and split function
标记感兴趣区及分肾功能的 DMSA 标准视图

FIGURE 32
[^{99m}Tc]Tc- DMSA

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / DMSA Renal Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核
医学

- 章节大纲:
- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / DMSA 肾脏扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

病例：右肾无功能伴左肾代偿性肥大

59 岁女性。重度右侧肾盂积水伴 1.3 cm 结石。DMSA 评估肾功能。

右肾几乎不可见（黄色箭头），轮廓且模糊小于左肾。左肾增大（蓝色箭头），考虑代偿性肥大所致，轮廓规整，未提示瘢痕的放射性减低区。分肾功能：右肾 2.8%，左肾 97.2%。

图 32
[^{99m}Tc]Tc-DMSA

Case: Horseshoe Kidney

Horseshoe kidney configuration with no evidence of scarring.

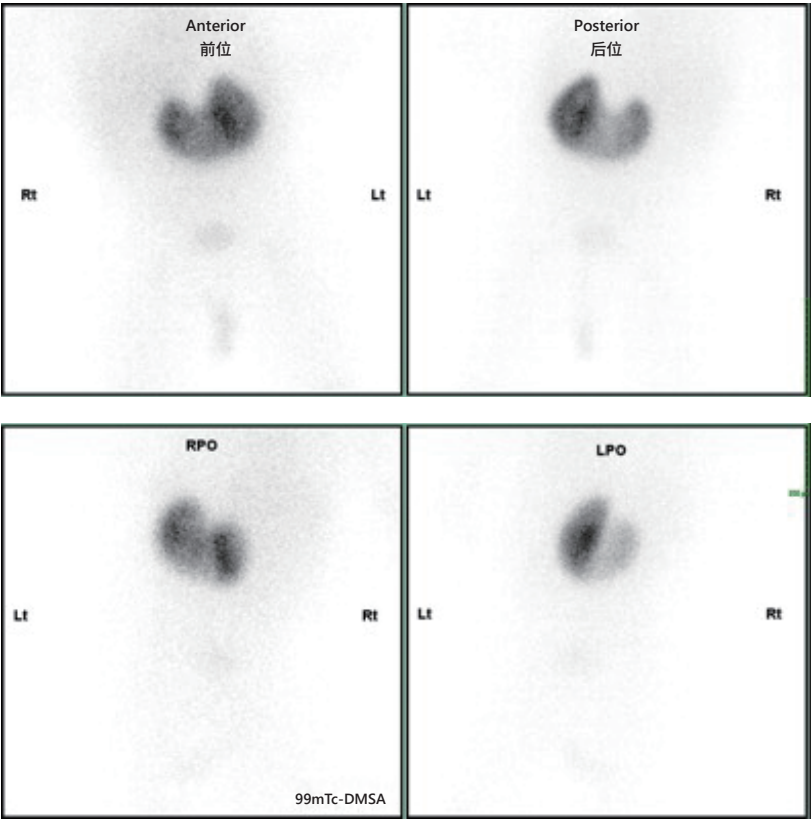


FIGURE 33
[^{99m}Tc]Tc- DMSA

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
 - / DMSA Renal Scan
- Planar and SPECT Studies
 - / DMSA 肾脏扫描
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

病例：马蹄肾

肾脏呈马蹄形结构，无瘢痕形成。

/ 核
医学

章节大纲：

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / DMSA 肾脏扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

图 33
[^{99m}Tc]Tc-DMSA

Usefulness of the test compared with other imaging modalities:

- / More accurate assessment of divided renal function compared to a renogram (see next section).
- / Pyelonephritis may also be identified as defects and mimic scars.
- / Other imaging modalities such as ultrasound and CT can assess renal size but cannot quantitatively assess function.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / DMSA Renal Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ Nuclear Medicine

章节大纲:

与其他影像学检查方法相比的优势:

- 简介
 - / 与肾图相比，可更准确地评估分肾功能（见下一节）。
- 核医学成像原理
 - / 超声和 CT 等其他影像学检查方法可以评估肾脏大小，但无法定量评估肾功能。
- 平面和 SPECT 检查
 - / DMSA 肾脏扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ Renal: Renogram

Indications:

- / Assessment of renal perfusion
- / Evaluation of divided renal function
- / Possible obstruction
- / Assessment of the urinary tract post-surgery, e.g., post pyeloplasty for pelviureteric junction (PUJ) obstruction

Radiopharmaceutical:

- / [^{99m}Tc]-Tc- Mercaptoacetyl triglycine (MAG3):
- / Undergoes both glomerular filtration and tubular excretion
- / [^{99m}Tc]-Tc- Diethylene-triamine-pentaacetate (DTPA):
- / Alternative but less used in clinical practice, undergoes glomerular filtration only

Route: Administered intravenously

Image acquisition:

- / Dynamic planar imaging for 30 minutes
- / Then static images acquired pre-micturition, post-micturition and delayed 2-hours post-micturition
- / Furosemide injected to assess for obstruction – timing varies between institution
- / Computer processing of data to provide time activity curve

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

- / Renal: Renogram

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

- / 肾脏：肾图

PET 检查

核心要点

参考文献

知识测试

/ 肾脏：肾图

适应证:

- / 肾脏灌注评估
- / 分肾功能评估
- / 可疑梗阻
- / 术后尿路评估，例如，肾盂输尿管连接部 (PUJ) 梗阻肾盂成形术后的评估

放射性药物:

- / [^{99m}Tc]Tc-巯基乙酰基三甘氨酸 (MAG3):
- / 经肾小球滤过和肾小管排泄两个过程
- / [^{99m}Tc]Tc-二乙三胺五乙酸酯 (DTPA):
- / 替代药物，临床实践中使用较少，仅经肾小球滤过

途径: 静脉给药

图像采集:

- / 动态平面显像 30 min
- / 然后采集排尿前、排尿后和排尿后 2 h 的静态图像
- / 注射呋塞米评估阻塞情况，注射时间因医疗机构而异
- / 通过计算机处理数据生成时间-活动曲线

Normal Case

Time activity curve is a representation of the uptake and excretion of the radiopharmaceutical by the kidneys as a graph.

Renogram has three phases:

A - Vascular (flow phase) - shows blood flow and initial uptake of radio-pharmaceutical by the kidneys, usually lasts 30 to 60 seconds (yellow arrow)

B - Cortical transit (tissue-function phase) - radiopharmaceutical concentrates in renal tubules, peaks at 3-5 minutes (pink arrow)

C - Excretory (drainage phase) – downslope in the renogram indicating excretion of radiopharmaceutical by the kidneys. It usually starts at 4-8 minutes after radio-tracer injection (purple arrow).

Both kidneys show prompt tracer uptake, normal transit, excretion and drainage. The time activity curves are normal. Normal study with no evidence of obstruction.

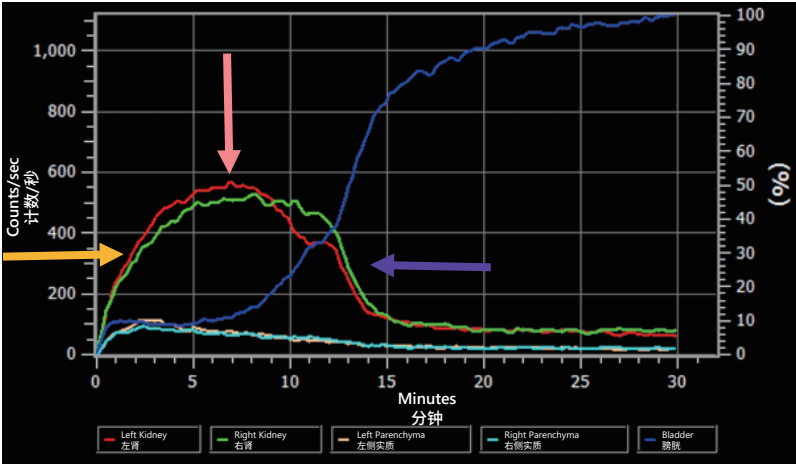


FIGURE 34
Normal [99mTc]Tc- MAG3 Renogram Time Activity Curve

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Renal: Renogram

PET Studies

Take-Home Messages

References

Test Your Knowledge

核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 肾脏: 肾图

PET 检查

核心要点

参考文献

知识测试

正常情况

时间-活动曲线反映肾脏摄取和排泄放射性药物的过程。

肾图分 3 个阶段:

A - 血管 (血流相) - 显示血流和肾脏对放射性药物的初始摄取, 通常持续 30~60 s (黄色箭头)

B - 皮质转运 (组织功能相) - 放射性药物在肾小管中聚集, 3~5 min 达峰 (粉色箭头)

C - 排泄 (引流相) - 肾图曲线向下倾斜, 表明放射性药物经肾脏排泄。通常在放射性示踪剂注射后 4~8 min 开始 (紫色箭头)。

双肾示踪剂摄取迅速, 转运、排泄和引流正常。肾图曲线正常。检查结果正常, 无梗阻迹象。

图 34

正常 [99mTc]Tc-MAG3 肾图时间-活动曲线

Case: Right kidney pelviureteric junction obstruction

CT abdomen and pelvis demonstrated right sided hydronephrosis (yellow arrow). Normal appearance of left kidney (green arrow).

On the renogram there is delayed uptake, cortical transit, excretion and limited drainage of the right kidney demonstrated by the flattened amplitude of

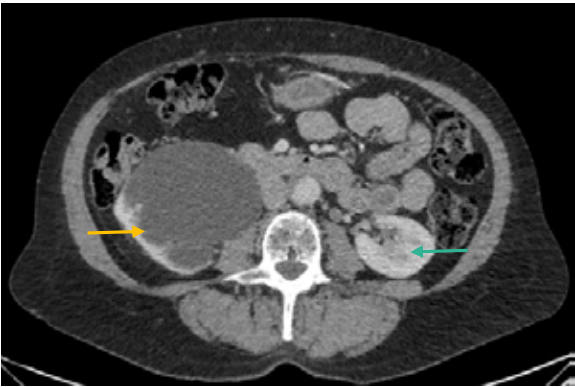


FIGURE 35
Axial Post Contrast CT

the time-activity curve (green curve, pink arrow). Appearances are in keeping with a very high-grade/ near complete obstruction. The left kidney shows prompt tracer uptake, normal transit, excretion and drainage (red curve, purple arrow). The blue curve represents tracer within the urinary bladder.

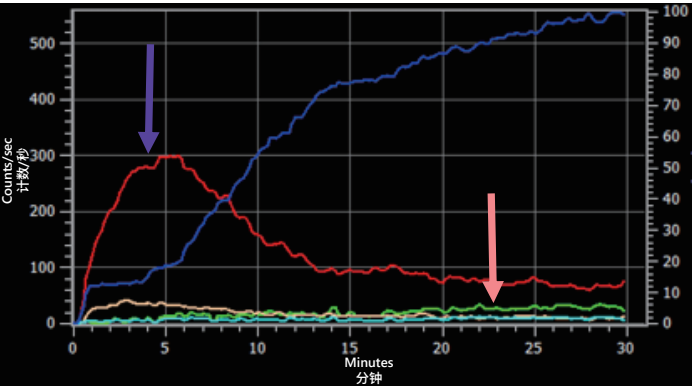


FIGURE 36
[^{99m}Tc]Tc- MAG3 Renogram Time Activity Curve

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Renal: Renogram

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 肾脏: 肾图

PET 检查

核心要点

参考文献

知识测试

病例: 右肾肾盂输尿管连接部梗阻

腹部和盆腔 CT 显示右侧肾盂积水 (黄色箭头)。左肾外观正常 (绿色箭头)。

肾图显示右肾摄取延迟、皮质功能受限、排泄和尿路引流差, 肾图曲线低平 (绿色曲线, 粉色箭头), 这些表现符合极重度/近乎完全性梗阻。左肾示踪剂摄取迅速、转运、排泄和引流正常 (红色曲线, 紫色箭头)。蓝色曲线代表膀胱内的示踪剂。

图 35
增强 CT 轴位图像

图 36
[^{99m}Tc]Tc-MAG3 肾图时间-活动曲线

Case: Right kidney pelviureteric junction obstruction

- A) In the initial vascular (flow) phase - radiopharmaceutical within the abdominal aorta (red arrow) and left kidney (yellow arrow). No activity demonstrated in the right kidney (green arrow).
- B) Cortical transit (tissue-function) phase - radiopharmaceutical concentrates in renal tubules of the left kidney (yellow arrow). Faint rim of cortical uptake around the grossly distended pelvis of the right kidney (green arrow).
- C) Excretory (drainage) phase - radiopharmaceutical demonstrated within the left renal pelvis (yellow arrow), ureter (yellow arrow) and bladder (purple arrow) in keeping with excretion of radiopharmaceutical by the left kidneys. Increasing activity within the right kidney cortex (green arrow) but no radiopharmaceutical within the renal pelvis or ureter.
- D) Low level activity within the dilated right pelvicalyceal system (green arrow) on the post micturition.

Appearances are in keeping with a very high-grade/near complete obstruction.

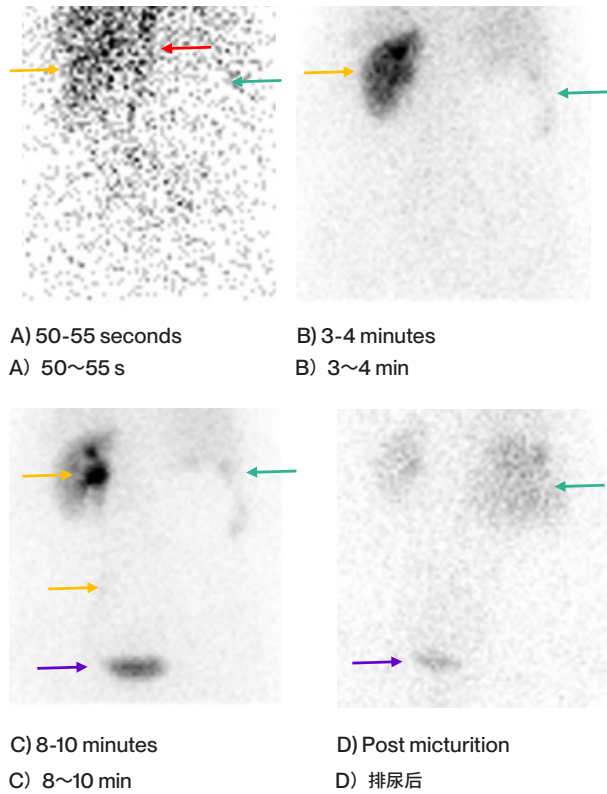


FIGURE 37
[^{99m}Tc]Tc- MAG3 Renogram Dynamic Study, abdominal aorta (red arrow), left kidney (yellow arrow), right kidney (green arrow), bladder (purple arrow)

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Renal: Renogram

PET Studies

Take-Home Messages

References

Test Your Knowledge

核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 肾脏: 肾图

PET 检查

核心要点

参考文献

知识测试

病例: 右肾肾盂输尿管连接部梗阻

- A) 初期血管 (血流相): 腹主动脉 (红色箭头) 和左肾 (黄色箭头) 内出现放射性药物, 右肾 (绿色箭头) 内无显示。
- B) 皮质转运 (组织功能相) - 放射性药物聚集在左肾的肾小管中 (黄色箭头), 右肾显著扩张的肾盂周围皮质摄取边缘模糊 (绿色箭头)。
- C) 排泄 (引流相) - 左肾盂 (黄色箭头)、输尿管 (黄色箭头) 和膀胱 (紫色箭头) 内可见放射性药物, 与左肾排泄放射性药物相符。右肾皮质摄取增加 (绿色箭头), 但肾盂或输尿管内无放射性药物。
- D) 排尿后扩张的右侧肾盂肾盏系统 (绿色箭头) 内可见轻度放射性摄取。
- 这些表现符合极重度/近乎完全性梗阻。

图 37
[^{99m}Tc]Tc-MAG3 肾图动态检查, 腹主动脉 (红色箭头)、左肾 (黄色箭头)、右肾 (绿色箭头)、膀胱 (紫色箭头)

Usefulness of the test compared with other imaging modalities:

- / Dynamic test hence useful for assessment of urine passage and check for high-grade obstruction which can lead to obstructive uropathy and nephropathy.
- / CT and MR urogram demonstrate anatomical abnormality but renogram provides functional assessment helping to determine degree of impaired drainage and split function.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- / Renal: Renogram
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- / 肾脏: 肾图
- PET 检查
- 核心要点
- 参考文献
- 知识测试

与其他影像学检查方法相比的优势:

- / 动态检查可用于评估尿液通过情况, 检查是否存在可导致尿路梗阻性疾病和梗阻性肾病。
- / CT 和 MR 尿路造影可显示解剖结构异常, 但肾图能进行功能评估, 有助于确定引流和分肾功能受损的程度。

/ Myocardial Perfusion Imaging

Indications:

- / To identify the presence, site and grade the severity of coronary artery disease
- / Select patients who will benefit from revascularisation, e.g., PCI/CABG
- / Assess response post revascularisation or medical treatment

Radiopharmaceutical:

- / Technetium-99m labelled Tetrofosmin (Myoview) or Sestamibi - lipophilic cationic agents which passively diffuse and accumulate in the mitochondria of viable myocardial tissue

Route: Administered intravenously

Image acquisition:

- / Two components: stress and rest. Depending on institutions performed on same day or separate days
- / Rest: Imaging 45-60 minutes post radiopharmaceutical injection
- / Stress: Exercise test or pharmaceutical stress agents given prior to radiopharmaceutical. Either adenosine, regadenoson, or dobutamine are used depending on their background medical history and medications.
- / SPECT Imaging
- / Additional CT component acquired for attenuation correction

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

- / Myocardial Perfusion Imaging

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

- / 心肌灌注显像

PET 检查

核心要点

参考文献

知识测试

/ 心肌灌注显像

适应证:

- / 确定是否存在冠状动脉疾病以及发病的部位和严重程度分级
- / 选择能从血运重建中获益的患者，如冠脉搭桥/经皮冠脉介入 (CABG/PCI)
- / 评估血运重建或药物治疗后的反应

放射性药物:

- / 锝-99m 标记的替曲膦 (Myoview) 或甲氧异腈 (亲脂性阳离子药物)，可被动扩散并在活心肌组织的线粒体中蓄积

途径: 静脉给药

图像采集:

- / 两个部分: 负荷和静息。视医疗机构而定，在同一天或不同天进行
- / 静息: 放射性药物注射后 45~60 min 显像
- / 负荷: 在注射放射性药物之前进行运动试验或负荷药物试验。根据患者的背景病史和用药情况，可使用腺苷、瑞加诺生或多巴酚丁胺。
- / SPECT 成像
- / CT 部分用于衰减校正

Pharmaceutical stress agent:

A stress myocardial perfusion scan assesses blood flow to the myocardium under stress.	stress agents that increases heart rate or dilate coronary arteries like physical exercise.
Stress test can use exercise (e.g., bicycle or treadmill). If patients are unable to exercise, the heart can be stressed by taking a pharmaceutical	The table lists the main pharmaceutical stress agents and mechanism of action.

PHARMACEUTICAL STRESS AGENT	MECHANISM OF ACTION
Regadenoson	Specific A2A adenosine receptor agonist Vasodilator (direct)
Adenosine	Nonspecific adenosine receptor agonist Vasodilator (direct)
Dipyridamole	Prevent the intracellular reuptake and deamination of adenosine Vasodilator (indirect)
Dobutamine	β1- and β2-receptor agonist Vasodilator (indirect)

TABLE 7
Pharmaceutical stress agents for cardiac imaging

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / Myocardial Perfusion Imaging
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / 心肌灌注显像
- PET 检查
- 核心要点
- 参考文献
- 知识测试

药物负荷:

负荷心肌灌注扫描可评估负荷状态下心肌的血流情况。

负荷试验可通过运动进行（如踏车运动或平板运动）。如果患者无法运动，可以服用增加心率或扩张冠状动脉的药物来达到运动的效果，增加心脏负荷。

下表列出了主要的负荷药物及其作用机制。

负荷药物	作用机制
瑞加诺生	特异性 A2A 腺苷受体激动剂 血管扩张剂（直接作用）
腺苷	非特异性腺苷受体激动剂 血管扩张剂（直接作用）
双嘧达莫	防止腺苷的细胞内再摄取和脱氨 血管扩张剂（间接作用）
多巴酚丁胺	β1 和 β2 受体激动剂 血管扩张剂（间接作用）

表 7
心脏影像学检查用负荷药物

Normal Case Example

Both stress and rest images demonstrate normal radiopharmaceutical distribution. Short, horizontal long and vertical long axis represent the different reconstructed SPECT views of the myocardium.

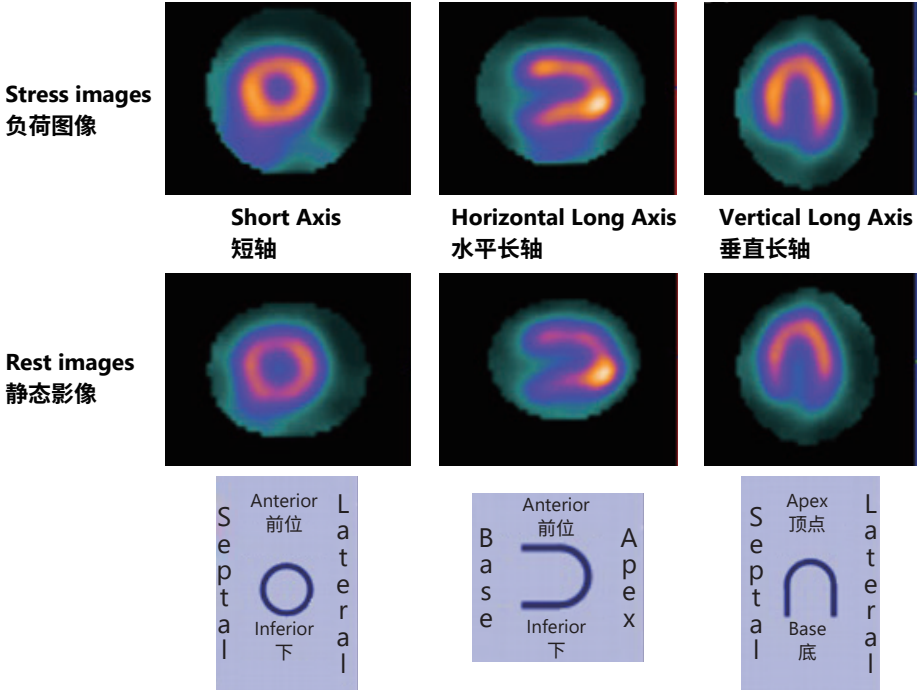


FIGURE 38
Normal [^{99m}Tc]Tc Myocardial Perfusion Imaging

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / Myocardial Perfusion Imaging
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核
医学

正常情况示例

负荷和静息图像均显示放射性药物分布正常。短轴、水平长轴和垂直长轴代表心肌的不同重建 SPECT 视图。

- 章节大纲:
- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / 心肌灌注显像
- PET 检查
- 核心要点
- 参考文献
- 知识测试

图 38
正常 [^{99m}Tc]Tc 心肌灌注显像

Case:

68 years old male. Assessment of coronary artery disease.

On the stress component, there is severe reduction of tracer uptake at the apex (red arrows) with the rest component demonstrating that this is largely fixed in keeping with an distal left anterior descending infarct.

Stress images
负荷图像

Rest images
静态影像

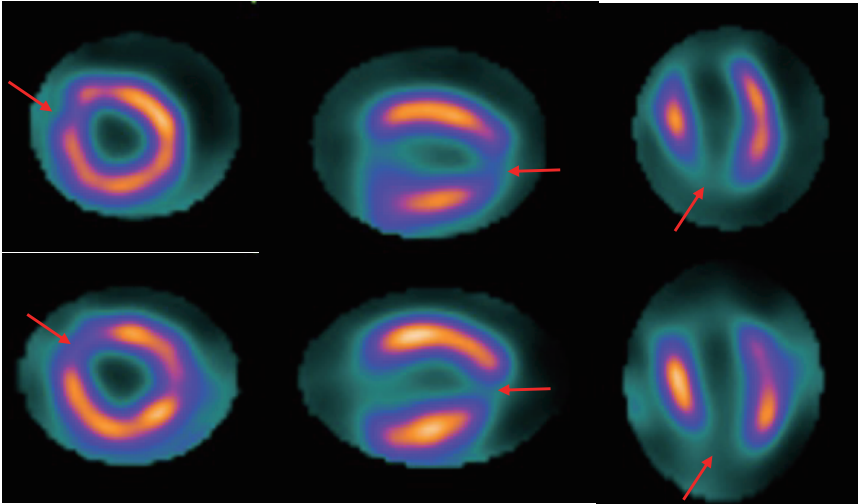


FIGURE 39
[^{99m}Tc]Tc Myocardial Perfusion Imaging

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Myocardial Perfusion
Imaging

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 心肌灌注显像

PET 检查

核心要点

参考文献

知识测试

病例:

68 岁男性。评估冠状动脉疾病。

负荷显像显示心尖部示踪剂摄取严重减低（红色箭头），静息显像显示该区域示踪剂摄取基本固定，符合左前降支远端梗死。

图 39

[^{99m}Tc]Tc 心肌灌注显像

STUDIES	USEFULNESS OF THE TEST COMPARED WITH OTHER IMAGING MODALITIES
Myocardial Perfusion Imaging (MPI)	Functional assessment compared to anatomical information gained from coronary angiogram or CT coronary angiogram MPI provides limited quantification of perfusion and limited spatial resolution
PET perfusion imaging (Rubidium-82 or Nitrogen-13)	Better spatial resolution and decreased noise compared to SPECT but not widely available
Cardiac MRI	High spatial resolution, can perform quantification of perfusion, and avoids ionising radiation. Detailed characterisation of myocardial tissue can be performed but expensive and limited availability
CT coronary angiogram	Provides anatomical information by visualising the coronary artery lumen and assessing coronary artery stenosis but does not provide functional information
Stress echocardiogram	Widely available, bedside test, inexpensive, however operator dependent, lack of reproducibility

TABLE 8
Comparison of different cardiac imaging modalities

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Myocardial Perfusion
Imaging

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 心肌灌注显像

PET 检查

核心要点

参考文献

知识测试

检查	与其他影像学检查方法相比的优势
心肌灌注显像 (MPI)	与冠状动脉造影或 CT 冠状动脉造影所获得的解剖信息相比，可进行功能评估MPI 提供的灌注定量和空间分辨率有限
PET 灌注成像 (铷-82 或氮-13)	与 SPECT 相比，空间分辨率更高，噪音更低，但尚未普及
心脏 MRI	空间分辨率高，可定量灌注，避免电离辐射。可对心肌组织进行详细鉴定，但价格昂贵且普及程度有限
CT 冠状动脉造影	能够可视化冠状动脉管腔和评估冠状动脉狭窄，从而显示解剖信息，但无法给出功能信息
负荷超声心动图	广泛普及，床旁检测，价格低廉，但依赖于操作者，缺乏重复性

表 8
不同心脏影像学检查方法的比较

/ Metaiodobenzylguanidine (MIBG)

Indications:

- / Detection, localisation, staging and follow-up of neuroendocrine tumours: Phaeochromocytomas, Neuroblastomas, Carcinoid tumours, etc.
- / Iodine-131 labelled MIBG is used for treatment of certain neuroendocrine tumours

Route: IV slowly over 4 minutes

Radiopharmaceutical:

- / Iodine-123 labelled with MIBG (meta-iodobenzyl-guanidine)
- / MIBG is an analogue of noradrenaline and guanethidine and enters neuroendocrine cells by an active uptake mechanism via the adrenergic transporters and stored in neurosecretory granules

Image acquisition:

- / Early planar 4 hours post injection
- / Delayed planar 24 hours post injection
- / +/- SPECT/CT at 24 hours

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ MIBG Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ MIBG 扫描

PET 检查

核心要点

参考文献

知识测试

/ 间碘苄胍 (MIBG)

适应证:

- / 神经内分泌肿瘤的检测、定位、分期和随访：嗜铬细胞瘤、神经母细胞瘤、类癌等
- / 碘-131 标记的 MIBG 用于治疗某些神经内分泌肿瘤

途径：IV 缓慢注射 4 min

放射性药物:

- / 碘-123 标记的 MIBG (间碘苄胍)
- / MIBG 是去甲肾上腺素和胍乙啶的类似物，通过肾上腺素能转运蛋白的主动摄取机制进入神经内分泌细胞，并储存在神经分泌颗粒中

图像采集:

- / 注射后 4 h 早期平面扫描
- / 注射后 24 h 延迟平面扫描
- / 24 h 后 ± SPECT/CT 显像

Normal Case

[¹²³I]I-MIBG scan.

Diffuse homogenous uptake within liver and urinary bladder.

Mild homogenous uptake within the salivary glands.

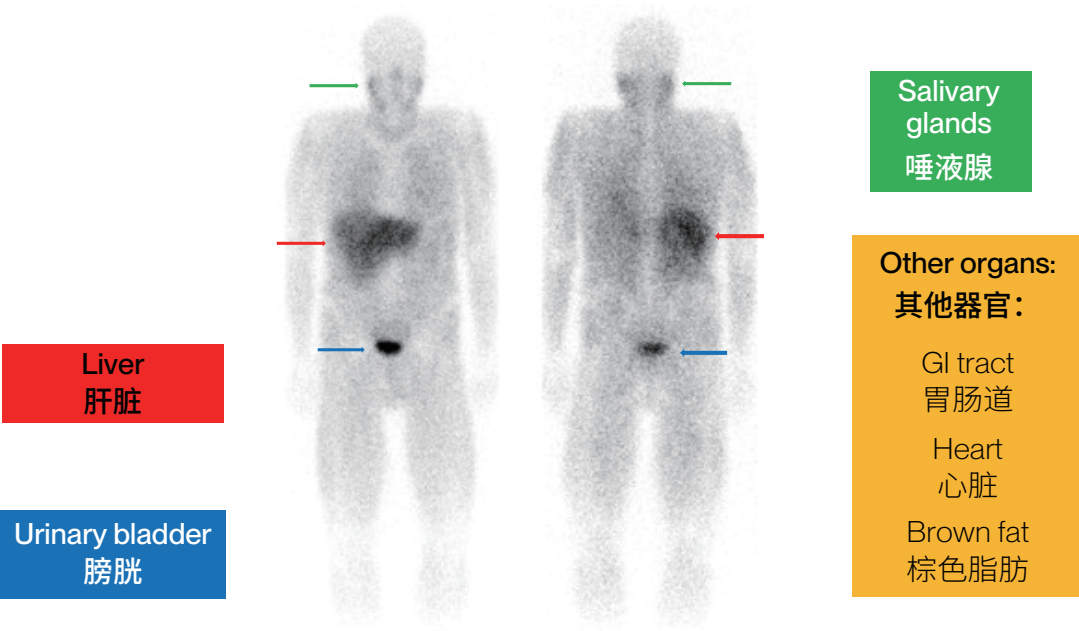


FIGURE 40
Normal [¹²³I]I-MIBG Scan

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

/ Metaiodobenzylguanidine (MIBG)

PET Studies

Take-Home Messages

References

Test Your Knowledge

正常情况

[¹²³I]I-MIBG 扫描。

肝脏和膀胱内弥漫性均匀摄取。

唾液腺内轻度均匀摄取。

章节大纲：

简介

核医学成像原理

平面和 SPECT 检查

/ 间碘苄胍 (MIBG)

PET 检查

核心要点

参考文献

知识测试

图 40
正常 [¹²³I]I-MIBG 扫描

MIBG SPECT/CT

Case: Left phaeochromocytoma

61 years old female. Left suprarenal mass measuring 5 cm. Indeterminate on CT with no arterial enhancement but functional studies suggest phaeochromocytoma.

On the whole-body planar imaging, there is intense asymmetric increased MIBG uptake

localising to the left adrenal gland persisting on the 24-hour imaging (yellow arrow).

On the SPECT/CT, there is intense radio-pharmaceutical activity anteromedially within a 5 cm left adrenal mass (blue arrows).

EARLY 4HR WB MIBG 23/06/2022
早期 4HR WB MIBG, 2022 年 6 月 23 日

EARLY 4HR WB MIBG 23/06/2022
早期 4HR WB MIBG, 2022 年 6 月 23 日

24HR WB MIBG 24/06/2022
24HR WB MIBG, 2022 年 6 月 24 日

24HR WB MIBG 24/06/2022
24HR WB MIBG, 2022 年 6 月 24 日

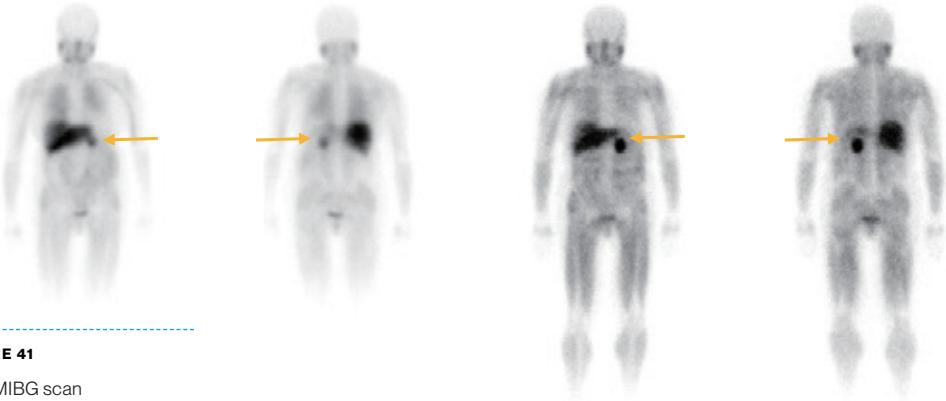
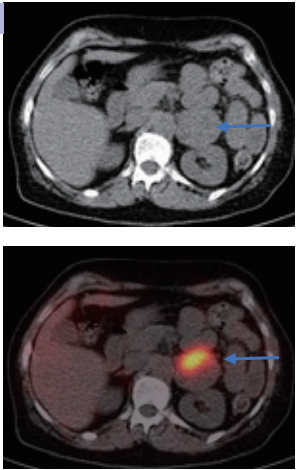


FIGURE 41
[¹²³I]-MIBG scan
with SPECT/CT



SPECT/CT

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ Metaiodobenzylguanidine (MIBG)

PET Studies

Take-Home Messages

References

Test Your Knowledge

核 医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ 间碘苄胍 (MIBG)

PET 检查

核心要点

参考文献

知识测试

MIBG SPECT/CT

病例：左侧嗜铬细胞瘤

61 岁女性。左肾上腺区 5 cm 肿块。CT 表现不典型，无动脉期强化，但功能学检查提示嗜铬细胞瘤。

在全身平面显像中，左肾上腺存在明显的不对称 MIBG 摄取增加，且在 24 h 显像中持续存在（黄色箭头）。

在 SPECT/CT 检查中，左肾上腺 5 cm 肿块的前内侧区域存在显著放射性摄取（蓝色箭头）。

图 41

[¹²³I]-MIBG SPECT/CT 扫描

Usefulness of the test compared with other imaging modalities:

- / Generally considered an accurate test for visualisation of neuroendocrine tumours
- / Important functional study when findings are suspected on conventional anatomic imaging (CT/MRI)
- / MIBG is useful for suspected adrenal and abdominal tumours versus [⁶⁸Ga]Ga-DOTA peptide PET/CT for extra abdominal neuroendocrine tumours (see PET study section)

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / Metaiodobenzylguanidine (MIBG)
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
 - / 通常认为是神经内分泌肿瘤可视化的准确检测方法
- 核医学成像原理
 - / 是常规解剖成像 (CT/MRI) 结果可疑时应进行的一项重要功能检查
 - / MIBG 可用于疑似肾上腺和腹部肿瘤的检查，而 [⁶⁸Ga]Ga-DOTA 肽 PET/CT 可用于腹部以外的神经内分泌肿瘤（参见 PET 检查部分）
- 平面和 SPECT 检查
 - / 间碘苄胍 (MIBG)
- PET 检查
- 核心要点
- 参考文献
- 知识测试

与其他影像学检查方法相比的优势:

/ DaT Scan

Indications:

- / Diagnosis of Parkinson’s disease and other neurodegenerative parkinsonian syndromes (e.g., dementia with Lewy bodies, progressive supranuclear palsy, and multiple system atrophy)
- / Differentiating between dementia with Lewy bodies and other dementias
- / Differentiating between parkinsonism due to presynaptic degenerative dopamine deficiency and other forms of parkinsonism, e.g., drug induced, psychogenic or vascular

Route: Administered intravenously

Radiopharmaceutical:

- / Iodine-123 DaTSCAN (loflupane or FP-CIT) administered intravenously
- / Bind to presynaptic dopamine active transporters within the nigrostriatal pathway
- / Loss of nigrostriatal dopaminergic nerve terminals in patients with parkinsonian syndromes. Uptake of the radiopharmaceutical corresponds to the integrity of these transporters

Image acquisition:

- / Imaging is performed 3-6 hours post-injection
- / Patient positioned supine in a headrest
- / Trans axial tomographic slices acquired

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / DaT Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / DaT 扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ DaT 扫描

适应证:

- / 帕金森病和其他神经退行性帕金森综合征（例如，路易体痴呆、进行性核上性麻痹和多系统萎缩）的诊断
- / 鉴别路易体痴呆和其他类型痴呆
- / 鉴别突触前多巴胺神经元缺失引起的帕金森综合征与其他类型的帕金森综合征，例如药物引起、心源性或血管性帕金森综合征

途径：静脉给药

放射性药物:

- / 静脉注射碘-123 DaTSCAN（碘氟潘或 FP-CIT）
- / 与黑质纹状体通路内的突触前多巴胺活性转运蛋白结合
- / 帕金森综合征患者黑质纹状体多巴胺能神经末梢缺失。放射性药物的摄取反映转运蛋白的完整性。

图像采集:

- / 注射后 3~6 h 显像
- / 患者仰卧位，头部固定于头枕
- / 采集横轴断层扫描图像

Normal Case

Normal radiopharmaceutical uptake within bilateral caudate and putamina; the basal ganglia nuclei have a normal 'comma' morphology (blue circle).

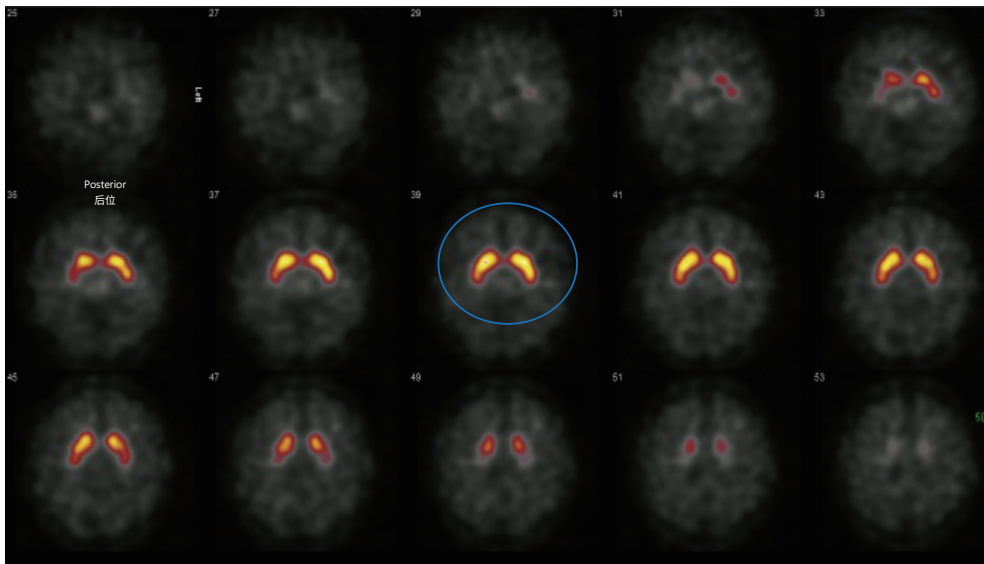


FIGURE 42
Axial SPECT images from DaT Scan

Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / DaT Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

正常情况

双侧尾状核和壳核内放射性药物摄取正常；基底节核呈正常的“逗号”形态（蓝色圆圈）。

核
医学

- 章节大纲：
- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / DaT 扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

图 42
DaT 扫描的轴位 SPECT 图像

Case: Parkinson’s disease or a parkinsonian syndrome

72 years old male. Left hand tremor predominantly at rest, then began to involve right hand more recently.

Significantly reduced uptake of radiopharmaceutical in the bilateral putamina (blue arrow), worse on the right, with some reduction in uptake in the right caudate head (green arrow). Both basal ganglia are shaped like a dot rather than a comma; the “dot sign”.

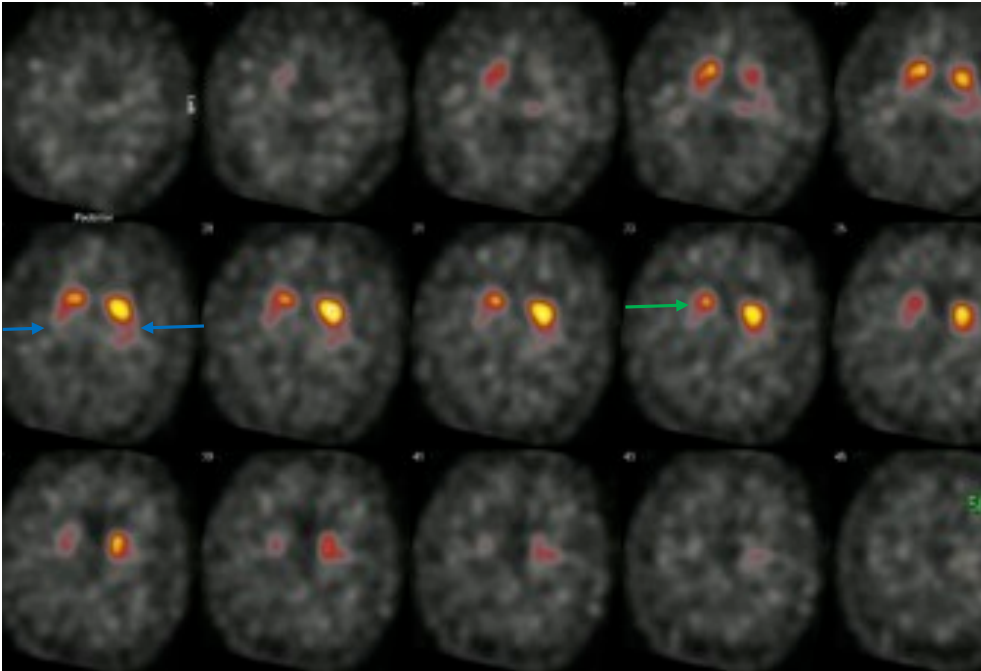


FIGURE 43
Axial SPECT images from DaT Scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT
Studies

/ DaT Scan

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

/ DaT 扫描

PET 检查

核心要点

参考文献

知识测试

病例：帕金森病或帕金森综合征

72 岁男性。静止时左手震颤为主，近期逐渐累及右手。

双侧壳核放射性药物摄取显著减少（蓝色箭头），右侧为著，右侧尾状核头部摄取部分减少（绿色箭头）。双侧基底节的形状呈点状而非逗号状，即“点征”。

图 43
DaT 扫描的轴位 SPECT 图像

Usefulness of the test compared with other imaging modalities:

- / Used synergistically with other tests depending on clinical indication, e.g., MRI brain or FDG PET/CT.
- / Only readily available test to assess for pre-synaptic dopaminergic neuronal loss making it useful for its primary indication.
- / If there is concern over vascular parkinsonism (especially if there are clinical risk factors or unilateral abnormal findings on a DaT scan), an MRI would be helpful to assess for an ipsilateral infarct.
- / MRI or perhaps even FDG PET/CT may be used together with DaT scan when trying to discriminate causes of dementia.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
 - / DaT Scan
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
 - / DaT 扫描
- PET 检查
- 核心要点
- 参考文献
- 知识测试

与其他影像学检查方法相比的优势:

- / 根据临床适应证与其他检查联合使用，例如，脑部 MRI 或 FDG PET/CT。
- / 是评估突触前多巴胺能神经元缺失的唯一检测方法。
- / 若怀疑血管性帕金森综合征，尤其是存在临床危险因素或 DaT 扫描单侧异常时，MRI 有助于评估同侧梗死情况。
- / 在鉴别痴呆原因时，可在 DaT 扫描的同时进行 MRI 或者 FDG PET/CT 检查。

/ PET Studies

MODERN RADIOLOGY

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核 医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ PET 检查

/ FDG PET Scan

Indications:

- / Provides a measure of glucose consumption and mainly used to detect malignancies
- / Oncology - Malignancy staging and restaging, determining metabolic activity of cancer, monitoring the effects of therapy, detecting tumour recurrence, and radiation therapy planning
- / Inflammation/Infection - Fever of unknown origin and vasculitis
- / Neurology - Dementia and localisation of seizure foci
- / Cardiology – Cardiac infection and inflammation, assessment of myocardial hibernation

FDG PET/CT: EANM procedure guidelines for tumour imaging: version 2.0, 2015

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

/ FDG PET 扫描

适应证:

- / 可测定葡萄糖消耗量，主要用于检测恶性肿瘤
- / 肿瘤学 - 恶性肿瘤分期和再分期、确定癌症的代谢活性、监测治疗效果、检测肿瘤复发和制定放疗计划
- / 炎症/感染 - 不明原因发热和血管炎
- / 神经病学 - 痴呆和癫痫病灶定位
- / 心脏病学 - 心脏感染和炎症，心肌冬眠评估

FDG PET/CT: DG PET/CT: 氟脱氧葡萄糖正电子发射断层成像/计算机断层扫描
EANM procedure guidelines for tumour imaging: version 2.0, 2015 欧洲核医学协会 (EANM) 肿瘤成像操作指南 (2015 年第 2.0 版)

Radiopharmaceutical:

- / Fluorine-18 labelled fluorodeoxyglucose (FDG), Glucose analogue
- / Cyclotron produced
- / Half-life 110 minutes
- / FDG is metabolised to FDG-6-Phosphate. FDG enters cells via GLUT transporters similar to glucose but accumulates intracellularly after initial phosphorylation as it cannot undergo further metabolism. The higher the metabolic activity of the cells, the higher the FDG uptake. Malignant cells increase GLUT and hexokinase activity

Route: Administered intravenously

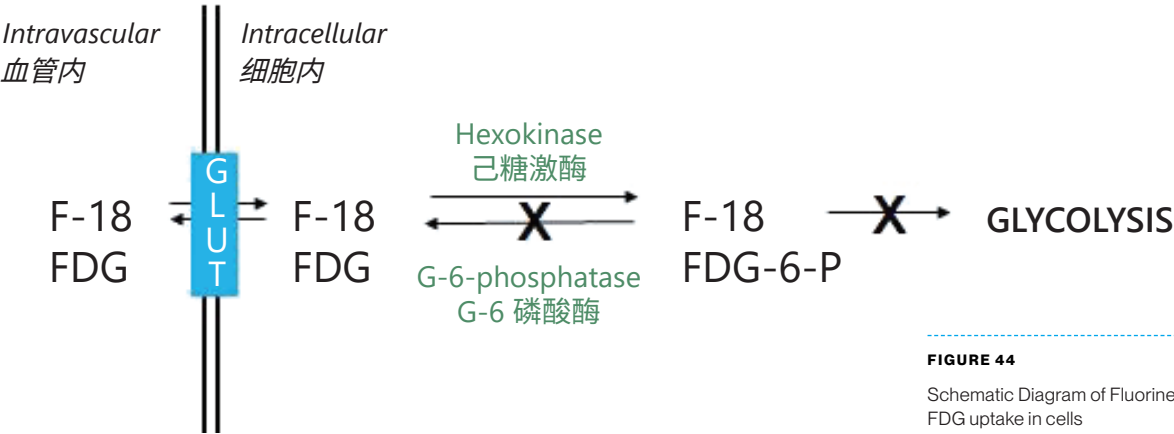


FIGURE 44
Schematic Diagram of Fluorine-18
FDG uptake in cells

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

放射性药物:

- / 氟-18 标记的脱氧葡萄糖 (FDG), 葡萄糖类似物
- / 回旋加速器生产
- / 半衰期 110 min
- / FDG 代谢为 FDG-6 磷酸盐。FDG 通过与葡萄糖类似的 GLUT 转运蛋白进入细胞, 但由于无法进一步代谢, 在初始磷酸化后会在细胞内积聚。细胞的代谢活性越高, FDG 摄取就越高。恶性细胞会增强 GLUT 和己糖激酶的活性

途径: 静脉给药

图 44

细胞中氟-18 FDG 摄取示意图

Image acquisition:

- / Fast 4-6 hours prior to scan - optimise glucose and insulin levels
- / No intense physical exercise 24 prior to scan - reduce muscle FDG uptake
- / Patient should rest in a room for a period of 30 min to 1 hour - reduce muscle FDG uptake
- / Patient should void before start of images - reduced FDG concentration in urinary bladder
- / Imaging is performed 60 minutes post-injection
- / Images acquired depending on protocols; either whole body (From the top of the head through the feet), torso imaging (from the top of the head/base of skull to mid-thigh)
- / Combined with low dose CT for attenuation correction and localisation

FDG PET/CT: EANM procedure guidelines for tumour imaging: version 2.0, 2015

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

图像采集:

- / 扫描前需禁食 4-6小时 - 优化葡萄糖和胰岛素水平
- / 扫描前 24 h 内避免高强度体育锻炼 - 减少肌肉对 FDG 的摄取
- / 患者应在房间内休息 30 min 至 1 h - 减少肌肉对 FDG 的摄取
- / 患者应在显像开始前排空膀胱 - 降低膀胱中 FDG 的浓度
- / 在注射后 60 min 进行显像
- / 根据扫描协议采集图像; 全身 (从头顶到足部)、躯干显像 (从头顶/颅底到大腿中段)
- / 结合低剂量 CT 进行衰减校正和定位

FDG PET/CT: DG PET/CT: 氟脱氧葡萄糖正电子发射断层成像/计算机断层扫描
EANM procedure guidelines for tumour imaging: version 2.0, 2015 欧洲核医学
协会 (EANM) 肿瘤成像操作指南 (2015 年第 2.0 版)

Blood glucose and insulin

- / Both glucose and FDG are actively transported into cells, so glucose levels in blood will affect the uptake of FDG.
- / High blood glucose levels will result in lower uptake of FDG.
- / High insulin levels would cause increased FDG uptake into muscles and sub-cutaneous tissue
- / It is important that blood glucose levels are within a normal range before [18F] FDG administration.
- / Patients must fast for 4-6 hours prior to a FDG PET scan.
- / The preparation for diabetic patients is complicated and depends on the type of medications and if on insulin.
- / A recent medical history is vital prior to imaging.

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
 - / FDG PET
- Take-Home Messages
- References
- Test Your Knowledge

核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
 - / FDG PET
- 核心要点
- 参考文献
- 知识测试

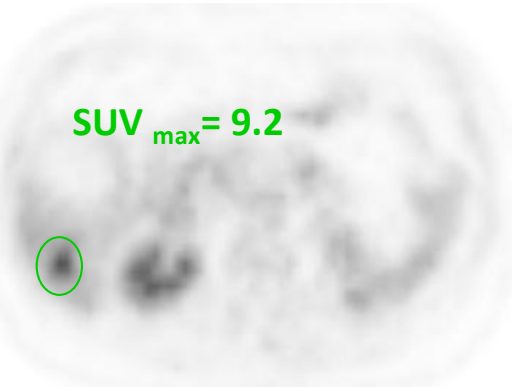
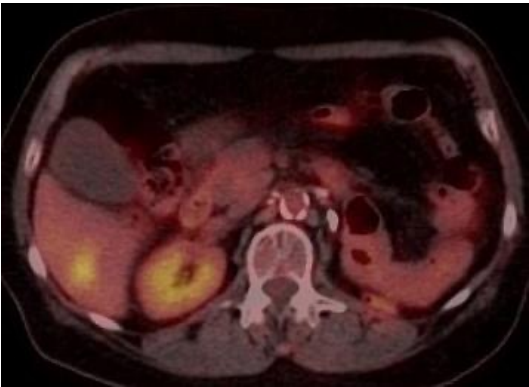
血糖和胰岛素

- / 葡萄糖和 FDG 均通过主动转运进入细胞，因此血液中的葡萄糖水平会影响 FDG 的摄取。
- / 高血糖水平会导致 FDG 摄取降低。
- / 高胰岛素水平会导致肌肉和皮下组织对 FDG 的摄取增加
- / 在注射 [18F]FDG 之前，必须确保血糖水平处于正常范围内。
- / 患者必须在FDG PET 扫描前禁食 4~6 h。
- / 糖尿病患者的准备工作较为复杂，取决于用药类型和是否使用胰岛素。
- / 在影像学检查前了解近期病史至关重要。

SUV:

- / The standardised uptake value (SUV) is a semiquantitative measure used to quantify activity on PET/CT scans.
- / Maximum SUV of a region of interest is used to assess lesions (SUVmax) which can be compared to background activity in normal tissues (e.g., liver or mediastinal blood pool).

$$SUV = \frac{\text{radiopharmaceutical concentration}}{\text{injected activity/patient weight} \times 1000}$$



The green circle demonstrates a region of interest drawn around the focus demonstrating high tracer uptake within the liver allowing for SUV measurement.

FIGURE 45
Axial fused and PET images from [18F]FDG PET/CT Scan

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
 - / FDG PET
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
 - / FDG PET
- 核心要点
- 参考文献
- 知识测试

SUV: 标准摄取值

- / 标准摄取值 (SUV) 是一个半定量指标，用于量化 PET/CT 扫描中的显像活性。
- / 感兴趣区的最大 SUV (SUVmax) 可用于评估病灶，该数值可与正常组织（例如肝脏或纵隔血池）中的本底活性进行比较。

$$SUV = \frac{\text{放射性药物浓度}}{\text{注射活性/患者体重} \times 1000}$$

绿色圆圈标识出的感兴趣区，是肝脏内示踪剂高摄取病灶，该区域可进行 SUV 的测量。

图 45
[18F]FDG PET/CT 扫描的轴位融合图像和 PET 图像

Factors affecting SUV	blood glucose insulin levels at time of injection time period between FDG administration and scanning
High SUV	most high-grade malignancies, infectious and inflammatory processes
Low SUV	specific malignancies (prostate, hepatocellular carcinoma, lung adenocarcinoma spectrum lesions, neuroendocrine tumours) and histological subtypes (low grade, mucinous/lobular tumours), smaller tumours (particularly below 6 mm)

TABLE 9
SUV

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
 - / FDG PET
- Take-Home Messages
- References
- Test Your Knowledge

/ 核
医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
 - / FDG PET
- 核心要点
- 参考文献
- 知识测试

影响 SUV 的因素	血糖 注射时的胰岛素水平 FDG 给药和扫描之间的间隔时间
高 SUV	绝大多数高级别恶性肿瘤、感染性和炎症性病变
低 SUV	特定类型恶性肿瘤（前列腺癌、肝细胞癌、肺腺癌谱系病变、神经内分泌肿瘤）和组织学亚型（低级别、粘液性/小叶性肿瘤）、较小的肿瘤（尤其是小于 6 mm 者）

表 9
SUV

Normal Case Example

Normal Physiological Uptake

- / **Brain:** Intense FDG uptake as glucose is main substrate for metabolism.
- / **Urinary tract** (kidneys, ureters and bladder): High uptake as excretion route is renal.
- / **Myocardium:** variable and dependent on insulin/glucose levels and the patient's fasting status (low post fast). Myocardium usually prefers fatty acid for its metabolism.
- / **Gastrointestinal tract:** Uptake is variable, diffuse mild to moderate uptake is normal. Metformin can increase FDG uptake.
- / **Liver:** Low/moderate, diffuse homogeneous uptake.
- / **Salivary glands, tonsils, thyroid:** Mild to moderate symmetric uptake.
- / **Muscles:** FDG uptake is usually low. FDG accumulation in muscles can be increased following exercise and with elevated insulin.
- / **Brown fat:** Metabolically active adipose tissue usually located within supraclavicular, axillary, mediastinal and paravertebral regions, observed if the patient is cold and more so in younger patients.

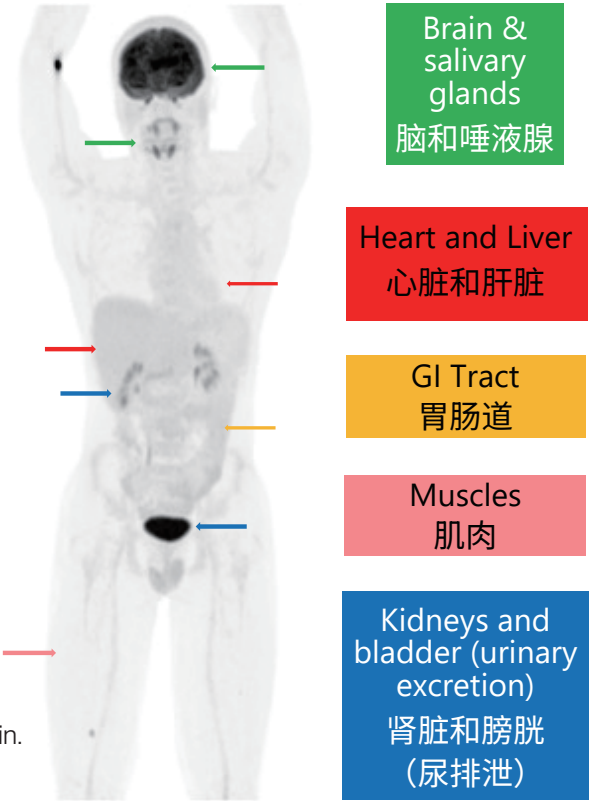


FIGURE 46
MIP image from [18F]FDG PET Scan

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
 - / FDG PET
- Take-Home Messages
- References
- Test Your Knowledge

核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
 - / FDG PET
- 核心要点
- 参考文献
- 知识测试

正常情况示例

正常生理性摄取

- / **脑:** FDG 显著摄取, 因葡萄糖是脑代谢的主要底物。
- / **尿路 (肾脏、输尿管和膀胱):** 因为主要通过肾脏排泄而呈现高摄取。
- / **心肌:** 摄取程度多变, 取决于胰岛素/葡萄糖水平和患者的空腹状态 (禁食后摄取降低)。心肌通常优先利用脂肪酸进行代谢。
- / **胃肠道:** 摄取程度不一, 弥漫性轻度至中度摄取属于正常显像。二甲双胍可增加 FDG 摄取。
- / **肝脏:** 弥漫性均匀低至中度摄取。
- / **唾液腺、扁桃体、甲状腺:** 轻度至中度对称摄取。
- / **肌肉:** 通常 FDG 摄取较低。运动后和胰岛素水平升高时, 肌肉中 FDG 的蓄积会增加。
- / **棕色脂肪:** 代谢活跃的脂肪组织, 通常位于锁骨上、腋窝、纵隔和椎旁区域, 当患者处于寒冷环境中时会明显可见, 在年轻患者中尤为常见。

图 46
[18F]FDG PET 扫描的 MIP 图像

Case: Lung cancer with osseous metastatic disease

82 years old male. CT Thorax demonstrated solitary pulmonary nodule.

A spiculated left apical nodule demonstrates (green arrow) increased metabolic activity (SUV-max 6.3). In addition, there is a metabolically active lytic lesion in the right 8th rib consistent with a bone metastasis (yellow arrow). No metabolic active lymph nodes demonstrated.

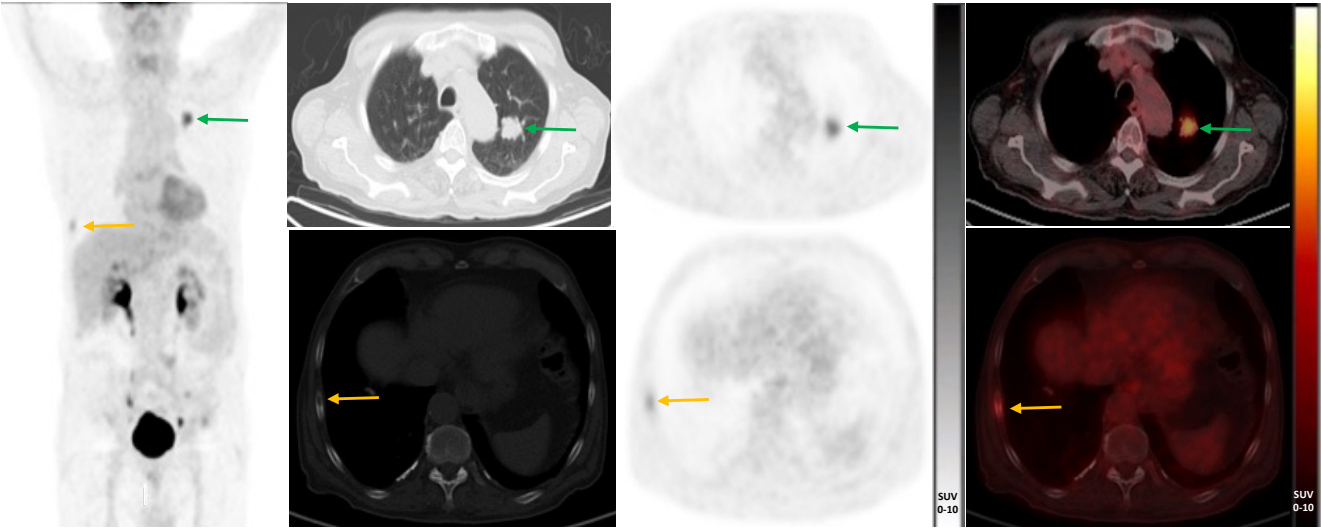


FIGURE 47
[¹⁸F]FDG PET/CT Scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

病例：肺癌伴骨转移性疾病

82 岁男性。胸部 CT 显示孤立性肺结节。

左肺尖一带毛刺结节（绿色箭头），显示代谢活性增高 (SUV-max 6.3)。此外，右侧第 8 肋骨可见一代谢活跃的溶骨性病变（黄色箭头），符合骨转移表现。未见代谢活性异常的淋巴结。

图 47
[¹⁸F]FDG PET/CT 扫描

Case: Diffuse Large B Cell Lymphoma

The MIP image demonstrates multiple metabolically active foci corresponding to multiple intensely metabolically active lymph nodes above and below the diaphragm (yellow arrow). The axial images show paratracheal (purple arrow), prevascular (green arrow), internal thoracic (red arrow), axillary (blue arrow), para-aortic (pink arrow), and mesenteric (brown arrow) nodal disease.

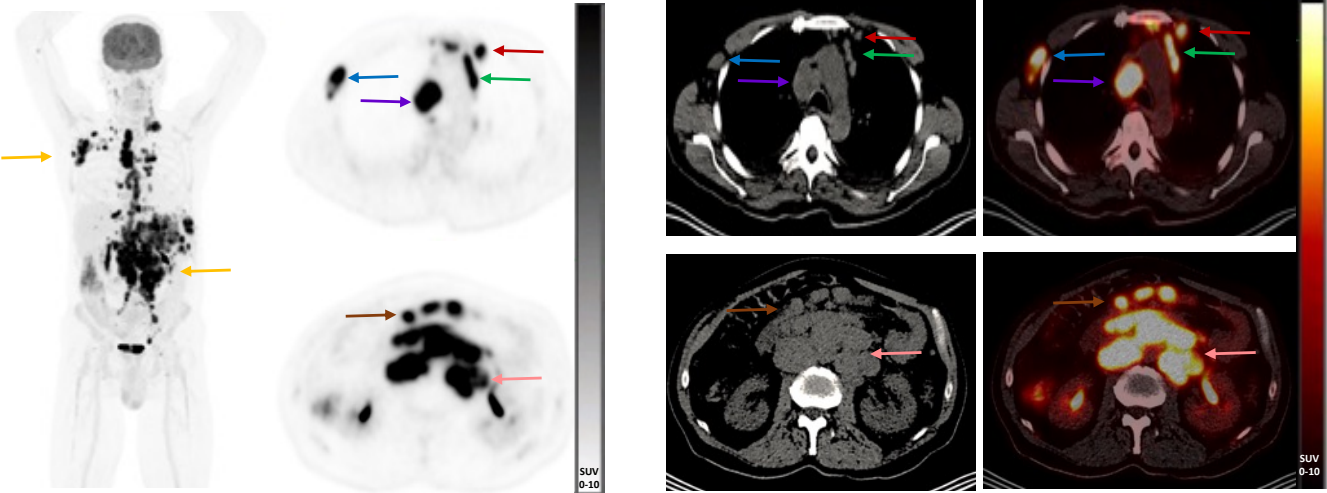


FIGURE 48
[¹⁸F]FDG PET/CT Scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

病例：弥漫性大 B 细胞淋巴瘤

最大密度投影 (MIP) 图像显示多个代谢活跃病灶，对应横膈上、下多个代谢显著活跃的淋巴结 (黄色箭头)。轴位图像显示气管旁 (紫色箭头)、血管前 (绿色箭头)、胸廓内 (红色箭头)、腋窝 (蓝色箭头)、主动脉旁 (粉红色箭头) 和肠系膜 (棕色箭头) 淋巴结病变。

图 48

[¹⁸F]FDG PET/CT 扫描

Case: Non Hodgkin Lymphoma pre and post 6 cycles of chemotherapy

The left sided images demonstrates multiple metabolically active foci corresponding to multiple intensely metabolically active lymph nodes within the left neck (red arrow) and mediastinum (green arrow) which have resolved the subsequent right sided images post 6 cycle of chemotherapy.

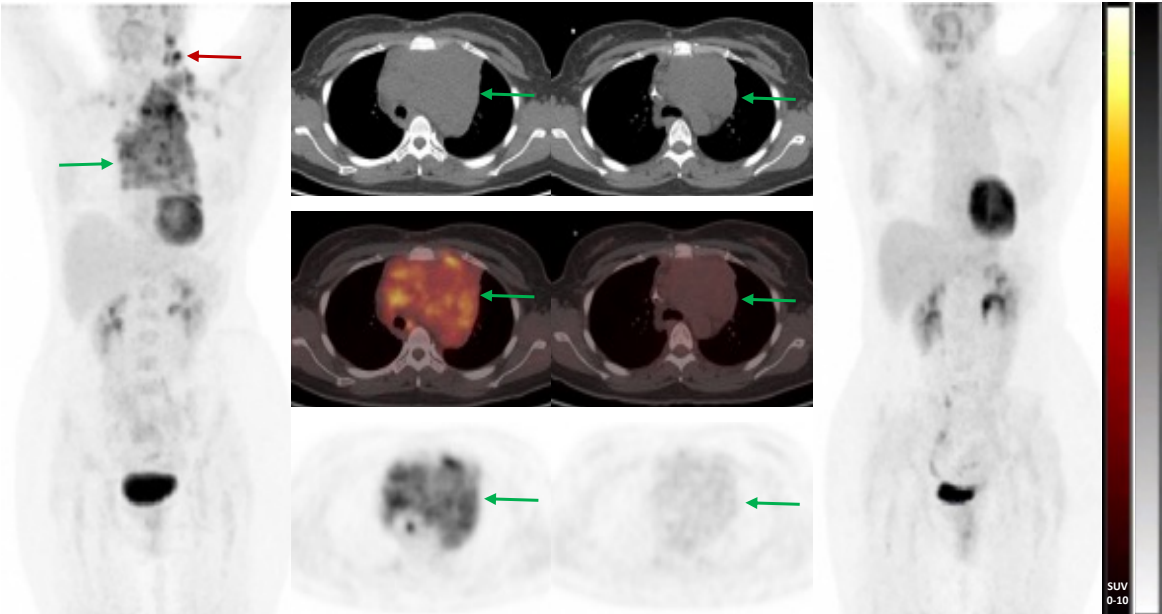


FIGURE 49
[¹⁸F]FDG PET/
CT Scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

病例：非霍奇金淋巴瘤化疗 6 个周期前后对比

左侧图像显示左颈部（红色箭头）和纵隔（绿色箭头）多个代谢活跃病灶，对应多处显著代谢活跃的淋巴结，右侧图像为化疗 6 个周期后复查，可见上述病灶已完全消退。

图 49

[¹⁸F]FDG PET/CT 扫描

Deauville scale

- / 5-point scale.
- / Grade visual assessment of [18F]FDG uptake comparing with two reference points: mediastinal blood pool and the liver.
- / Used in the initial staging and treatment response assessment of Hodgkin lymphoma and certain non-Hodgkin lymphomas including the diffuse large B cellular lymphoma.

Scale:

1	No uptake, i.e., indiscernible from background level or no residual uptake
2	Uptake ≤ mediastinal blood pool (MBP)
3	Uptake > MBP ≤ liver
4	Uptake moderately higher than liver
5	Uptake markedly greater than liver and/or new lesions

TABLE 10
Deauville scale

Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

Deauville 量表

- / 5 分量表。
- / 用于霍奇金淋巴瘤和特定非霍奇金淋巴瘤（包括弥漫性大 B 细胞淋巴瘤）的初始分期和治疗反应评估。
- / 通过对比两个参考点（纵隔血池和肝脏），对 [18F]FDG 摄取进行视觉评估分级。

量表:

1	无摄取，即与本底摄取无法区分或无残留摄取
2	摄取 ≤ 纵隔血池 (MBP)
3	摄取 > MBP ≤ 肝脏
4	摄取中度高于肝脏
5	摄取明显高于肝脏和/或出现新发病灶

表 10
Deauville 量表

PROS +

Anatomical and functional imaging on a single study (however the CT component is a low-dose study compared to standard CT imaging)

Detects metastatic disease that would have been missed on conventional CT/MRI Imaging which is crucial for management decisions

CONS -

False positives in oncology scans: infectious and inflammatory processes, and sarcoid-like reaction in malignancy, ureteric activity mimicking lymph nodes

False negatives: Histology (low grade, necrotic or mucinous tumours, certain cancers such as prostate, hepatocellular carcinoma), small tumours

TABLE 11
Pros and Cons of FDG PET/CT

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ FDG PET

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ FDG PET

核心要点

参考文献

知识测试

优势 (+)

单次显像即可实现解剖和功能成像 (但与标准 CT 成像相比, CT 部分为低剂量检查)

能检测出常规 CT/MRI 成像易遗漏的转移性疾病, 这对于治疗决策来说至关重要

劣势 (-)

肿瘤学扫描中的假阳性: 感染性和炎症性病变、恶性肿瘤中的结节病样反应、类似淋巴结表现的输尿管活性

假阴性: 特定组织学类型 (低级别、坏死性或粘液性肿瘤、特定癌症, 如前列腺癌、肝细胞癌)、微小肿瘤

表 11
FDG PET/CT 的优势和劣势

/ PSMA PET Scan

Indications:

- / Staging of high-risk primary prostate cancer prior to prostatectomy
- / Detectable PSA post-prostatectomy in the setting of persistent elevation of PSA (≥ 0.2 ng/ml) post prostatectomy, to assess for residual or otherwise occult disease, not identified pre-operatively
- / Localisation of disease in biochemical recurrence after radical prostatectomy, and radial radiotherapy if it will affect subsequent patient management decisions
- / Patient selection for Lutetium-177 labelled PSMA radionuclide therapy in metastatic castration-resistant prostate cancer

Route: Administered intravenously

Radiopharmaceutical:

- / Prostate-specific membrane antigen (PSMA) a trans-membrane glycoprotein that is expressed on the cell surface in normal prostate tissue
- / PSMA expression is increased in prostate cancer especially higher-grade tumours
- / PSMA can be labelled with Gallium-68 (Ga68), a positron emitter. There are radiotracers such as Fluorine-18 which can be labelled to PSMA with similar biodistribution but difference in binding affinities and nonspecific uptake.
- / Eluted from a Germanium-68 (68Ge)/68Ga generator
- / Half-life of 68 minutes

Image acquisition:

- / Imaging is performed approximately 45–75 minutes after radiopharmaceutical administration
- / PET images acquired from the pelvis to the head to minimise misregistration between the CT and PET components of the study due to filling of the bladder during acquisition

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ PSMA PET Scan

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ PSMA PET 扫描

核心要点

参考文献

知识测试

/ PSMA PET 扫描

适应证:

- / 前列腺切除术前高危原发性前列腺癌的分期评估
- / 在前列腺切除术后 PSA 持续升高 (≥ 0.2 ng/mL) 的情况下, 可检测前列腺切除术后 PSA, 以评估是否有术前未发现的残留或其他隐匿性疾病
- / 根治性前列腺切除术后生化复发的病灶定位, 如果会影响后续患者治疗决策, 则进行根治性放疗
- / 转移性去势抵抗性前列腺癌患者接受镥-177 标记 PSMA 放射性核素治疗的筛选评估

途径: 静脉给药

放射性药物:

- / 前列腺特异性膜抗原 (PSMA) 是一种跨膜糖蛋白, 表达于正常前列腺组织的细胞表面
- / 前列腺癌组织中 PSMA 表达增高, 特别是在高级别的肿瘤中更为显著
- / PSMA 可用正电子发射体镓-68 (Ga68) 标记。也可以用放射性示踪剂 (如氟-18) 标记 PSMA, 生物分布相似, 但结合亲和力和非特异性摄取存在差异。
- / 镓-68 (68Ge)/68Ga 发生器洗脱获得
- / 物理半衰期为 68 min

图像采集:

- / 放射性药物给药后约 45~75 min 显像
- / 采集范围自盆腔至头部的 PET 图像, 旨在通过减少膀胱充盈, 最大限度降低 CT 与 PET 图像配准误差。

68Ga PSMA PET Scan – Normal Distribution

Normal Physiological Uptake is related to PSMA expression tissues and radiotracer excretion.

- / Salivary glands: Physiological uptake related to PSMA expression
- / Liver and spleen: Moderate, diffuse homogeneous uptake
- / Pancreas and small bowel loops, particularly duodenum: Increased radiopharmaceutical uptake PSMA expression for dietary folate absorption
- / Urinary tract (kidneys, ureters and bladder): High activity as excretion route is renal

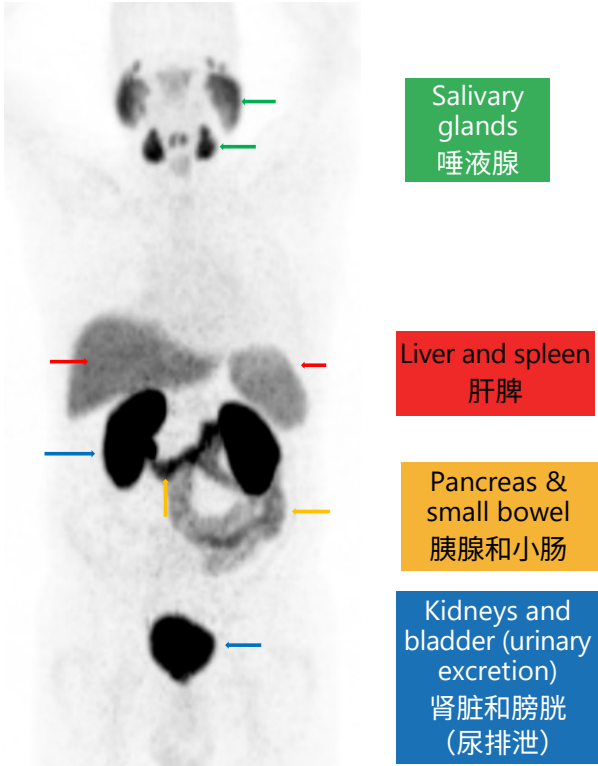


FIGURE 50
MIP image from [68Ga]Ga-PSMA-11 PET Scan

Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
 - / PSMA PET Scan
- Take-Home Messages
- References
- Test Your Knowledge

核医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
 - / PSMA PET 扫描
- 核心要点
- 参考文献
- 知识测试

68Ga PSMA PET 扫描 - 正常分布

正常生理性摄取与 PSMA 表达组织和放射性示踪剂排泄有关。

- / 唾液腺：与 PSMA 表达相关的生理性摄取
- / 肝脏和脾脏：弥漫性中度均匀摄取
- / 胰腺和小肠袢，尤其是十二指肠：放射性药物摄取增高，PSMA 表达与膳食叶酸吸收相关
- / 尿路（肾脏、输尿管和膀胱）：因经肾脏排泄途径而呈高活性

图 50
[68Ga]Ga-PSMA-11 PET 扫描的 MIP 图像

Case: Prostate cancer recurrence with lymph node and osseous metastatic disease

76 years old male. Rising PSA 129 post previous radiotherapy for prostate cancer.

PSMA avid disease in the prostate (green arrow) with small volume right inguinal and pelvic nodal disease (purple arrow), as well as multiple bone metastases (yellow arrow).

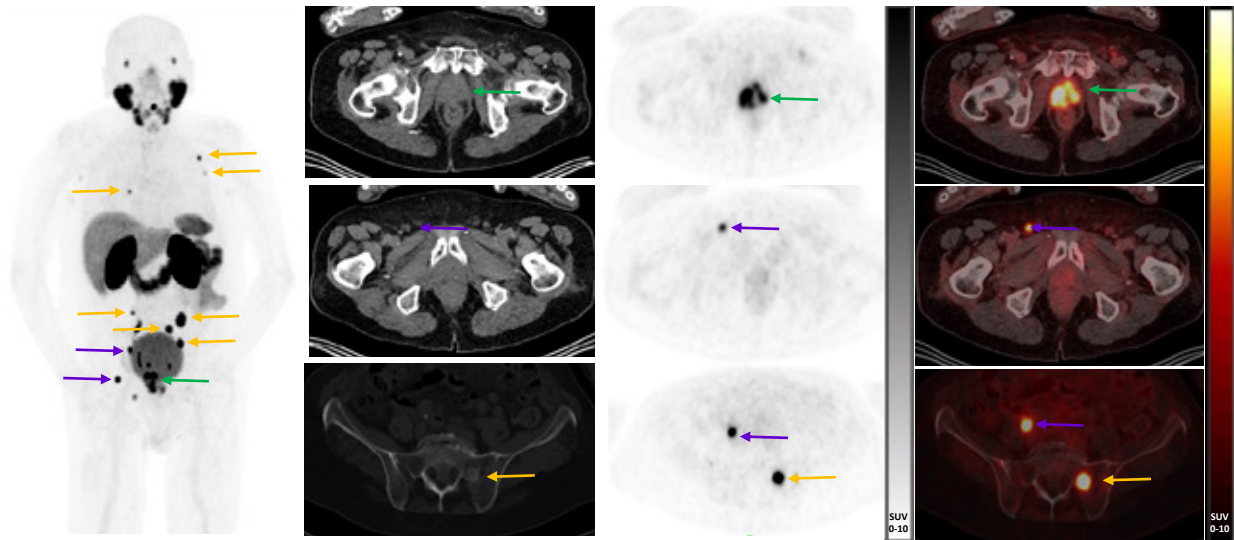


FIGURE 51
[⁶⁸Ga]Ga-PSMA-11 PET/CT Scan

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ PSMA PET Scan

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ PSMA PET 扫描

核心要点

参考文献

知识测试

病例：前列腺癌复发伴淋巴结和骨转移性疾病

76 岁男性。前列腺癌放疗后 PSA 升高至 129。

前列腺内 PSMA 高摄取病灶（绿色箭头）伴右侧腹股沟和盆腔小淋巴结转移（紫色箭头），以及多发性骨转移（黄色箭头）。

图 51
[⁶⁸Ga]Ga-PSMA-11 PET/CT 扫描

Usefulness of the test compared with other imaging modalities:

Pelvic MRI is superior to other imaging modalities for local regional staging of prostate cancer.

[68Ga]Ga- PSMA PET/CT allows comprehensive metastatic disease assessment of the prostate, lymph nodes, soft tissues and bones. High sensitivity of PSMA PET, allows identification of small-volume disease, compared with conventional imaging.

Other PET radiopharmaceuticals for Prostate cancer include Fluciclovine, and radiolabelled Choline (Fluorine-18 or Carbon-11). Evidence suggest PSMA PET has superior diagnostic performance compared to the above pharmaceuticals.

False negative - 10% prostate cancer can be PSMA negative.

False positives:

- / Infection/inflammatory process, e.g., prostatitis
- / Bone conditions, e.g., fracture, Paget's disease, fibrous dysplasia
- / Benign tumours, e.g., adrenal adenoma
- / Other malignancies expressing PSMA, e.g., breast, lung, colorectal

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ PSMA PET Scan

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ PSMA PET 扫描

核心要点

参考文献

知识测试

与其他影像学检查方法相比的优势:

盆腔 MRI 在前列腺癌局部区域分期方面优于其他影像学方法。

[68Ga]Ga-PSMA PET/CT 可实现前列腺、淋巴结、软组织及骨转移的全面评估。与常规影像相比，PSMA PET 的高灵敏度可识别小体积病灶。

其他用于前列腺癌的 PET 显像剂包括氟西洛芬 (Fluciclovine) 及放射性标记胆碱 (氟-18 或碳-11 标记)。有证据表明 PSMA PET 较上述药物具有更优的诊断效能。

假阴性 - 10% 的前列腺癌可呈 PSMA 阴性显像。

假阳性:

- / 感染/炎症性病变，例如前列腺炎
- / 骨骼疾病，例如，骨折、佩吉特病、骨纤维异常增殖症
- / 良性肿瘤，例如肾上腺腺瘤
- / 其他表达 PSMA 的恶性肿瘤，例如，乳腺癌、肺癌、结直肠癌

/ DOTATATE PET Scan

Indications:

- / Neuroendocrine tumours (NET) localisation of primary tumour and detect sites of metastatic disease (staging)
- / Follow-up imaging to detect residual, recurrent or progressive disease (restaging)
- / Selection of patients for somatostatin receptor-targeted peptide receptor radionuclide therapy
- / Also used for assessment of pheochromocytoma, paraganglioma, neuroblastoma, and meningioma

Procedure guidelines for PET/CT tumour imaging with 68Ga-DOTA-conjugated peptides: 68Ga-DOTA-TOC, 68Ga-DOTA-NOC, 68Ga-DOTA-TATE, 2010

Route: Administered intravenously

Radiopharmaceutical:

- / Somatostatin receptors (SSTRs) are present on the cell surface of neuroendocrine cells
- / DOTATATE is a somatostatin analogue, binds to SSTR type 2
- / Gallium-68 is labelled with DOTATATE. Other pharmaceutical including DOTATOC and DOTA-NOC which have affinity for different somatostatin receptors

Image acquisition:

- / Imaging is performed approximately 45–60 minutes after radiopharmaceutical injection

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ DOTATATE PET Scan

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ DOTATATE PET 扫描

核心要点

参考文献

知识测试

/ DOTATATE PET 扫描

适应证:

- / 神经内分泌肿瘤 (NET) 原发肿瘤的定位和转移灶的检测 (分期)
- / 检测残留、复发或进展性疾病的随访影像学检查 (再分期)
- / 筛选生长抑素受体靶向肽受体放射性核素治疗的患者
- / 也用于嗜铬细胞瘤、副神经节瘤、神经母细胞瘤和脑膜瘤的评估

Procedure guidelines for PET/CT tumour imaging with 68Ga-DOTA-conjugated peptides: 68Ga-DOTA-共轭肽PET/CT肿瘤成像操作指南 68Ga-DOTA-TOC, 68Ga-DOTA-NOC, 68Ga-DOTA-TATE, 2010

途径: 静脉给药

放射性药物:

- / 生长抑素受体 (SSTRs) 存在于神经内分泌细胞表面
- / DOTATATE 为生长抑素类似物, 主要与 SSTR2 型受体结合
- / 镓-68 标记 DOTATATE。其他药物如 DOTATOC、DOTANOC 对不同生长抑素受体具有亲和力

图像采集:

- / 放射性药物注射后约 45~60 min 显像

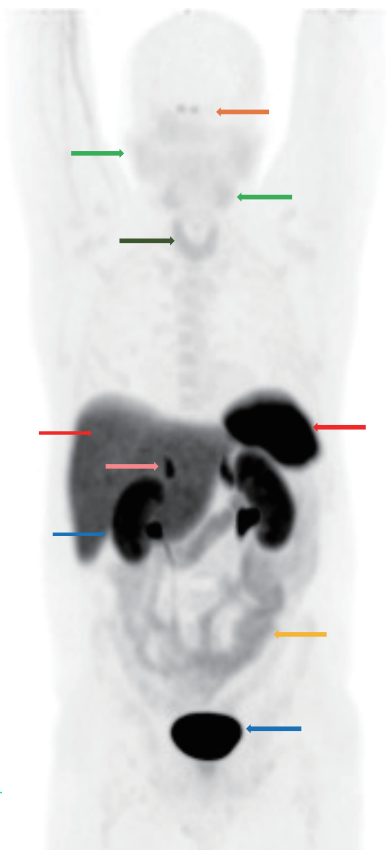
Normal Case

Normal Physiological Uptake

Related to **specific receptor binding** and **non-specific tissue handling of the peptide**.

- / **Spleen:** Highest intensity physiologic uptake, SSTR expression
- / **Kidneys:** Glomerular filtration, partially reabsorption in the proximal convoluted tubule, resulting in high activity in the collecting system and bladder, retained activity in the renal parenchyma
- / **Pituitary, thyroid and adrenal glands:** SSTR expression
- / **Liver:** Moderate, diffuse homogeneous uptake
- / **Salivary glands:** SSTR expression
- / **GI Tract:** Variable physiologic radiopharmaceutical uptake

FIGURE 52
MIP image from ⁶⁸Ga]Ga-DOTATATE PET Scan



- Salivary glands
唾液腺
- Pituitary Gland
垂体
- Thyroid Gland
甲状腺
- Spleen and Liver
脾脏和肝脏
- Bowel
肠道
- Adrenal Gland
肾上腺
- Kidneys and bladder
肾脏和膀胱

Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

/ DOTATATE PET Scan

Take-Home Messages

References

Test Your Knowledge

核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

/ DOTATATE PET 扫描

核心要点

参考文献

知识测试

正常情况

正常生理性摄取

与肽的特异性受体结合和非特异性组织处理有关。

- / **脾脏:** 生理摄取强度最高 (SSTR 表达所致)
- / **肾脏:** 经肾小球滤过, 部分在近曲小管重吸收, 导致集合系统与膀胱呈高活性, 肾实质内可见残留活性
- / **垂体、甲状腺和肾上腺:** SSTR 表达相关摄取
- / **肝脏:** 弥漫性中度均匀摄取
- / **唾液腺:** SSTR 表达相关摄取
- / **胃肠道:** 放射性药物生理性摄取程度不一

图 52

[⁶⁸Ga]Ga-DOTATATE PET 扫描的 MIP 图像

Case: Pancreatic neuroendocrine tumour

42 years old male. Lesion within the pancreas on CT and MRI.

A lesion at the neck of the pancreas demonstrating peripheral arterial enhancement with a small low density/cystic focus posteriorly (yellow arrow). The lesion demonstrates diffuse intense increased DOTATATE uptake in keeping with a neuroendocrine tumour (green arrow).

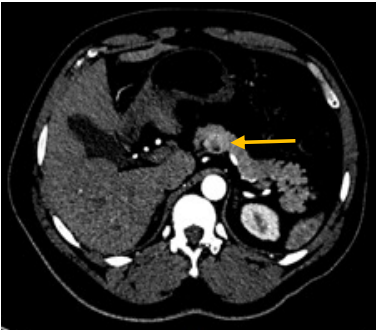


FIGURE 53
Axial image from Post Contrast CT

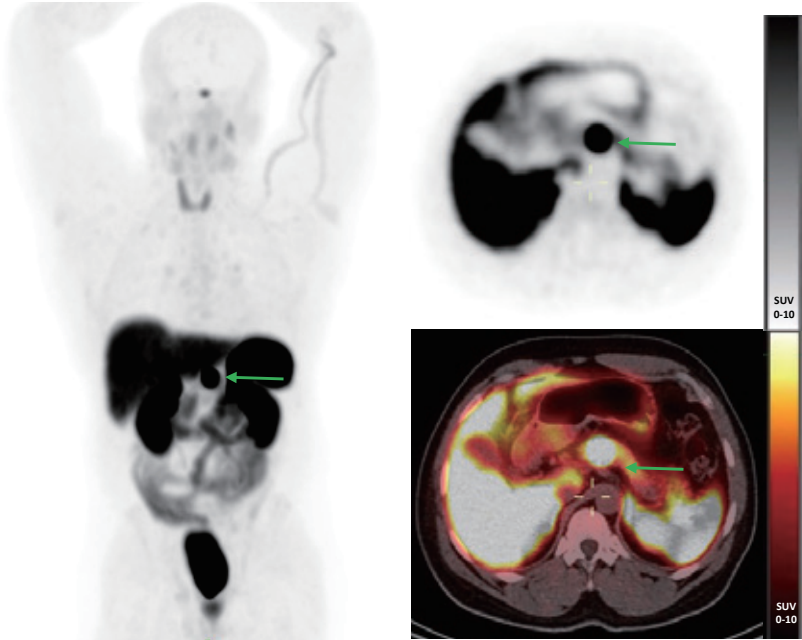


FIGURE 54
[⁶⁸Ga]Ga- DOTATATE PET Scan

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

/ DOTATATE PET Scan

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET

/ DOTATATE PET
扫描

核心要点

参考文献

知识测试

病例：胰腺神经内分泌肿瘤

42 岁男性。CT 和 MRI 发现胰腺内病变。

胰颈部病变显示动脉期周边强化，后方见一个小低密度/囊性病灶（黄色箭头）。该病灶表现为弥漫性显著 DOTATATE 摄取增高（绿色箭头），符合神经内分泌肿瘤特征。

图 53

轴位 CT 增强图像

图 54

[⁶⁸Ga]Ga-DOTATATE PET 扫描

Usefulness of the test compared with other imaging modalities:

- / Multiple studies have shown [⁶⁸Ga]Ga- DOTATATE PET/CT to be more accurate than conventional imaging, including octreotide SPECT/CT and contrast material–enhanced CT, in the diagnosis of low- and intermediate-grade NETs.
- / Most NETs have low uptake on [¹⁸F]FDG PET/CT scan. It is used in the staging or restaging (including pre-operative assessments) of selected patients with poorly differentiated high-grade NETs.

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
 - / DOTATATE PET Scan
- Take-Home Messages
- References
- Test Your Knowledge

/ 核
医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
 - / DOTATATE PET 扫描
- 核心要点
- 参考文献
- 知识测试

与其他影像学检查方法相比的优势:

- / 多项研究证实, [⁶⁸Ga]Ga-DOTATATE PET/CT 在诊断低、中 级别神经内分泌肿瘤 (NET) 时, 较常规影像学检查 (包括奥曲肽 SPECT/CT 和对比剂增强 CT) 具有更高准确性。
- / 大多数 NET 在 [¹⁸F]FDG PET/CT 扫描中呈现低摄取。该检查 主要用于某些低分化高级别 NET 患者的分期或再分期 (包括术 前评估)。

/ Take-Home Messages

- / Nuclear Medicine is a specialty allowing functional assessment beyond anatomical information provided by other imaging modalities.
- / A radiopharmaceutical combines a radionuclide and pharmaceutical, enabling targeting of different organs and physiological processes.
- / Three major imaging modalities used in nuclear medicine are planar, SPECT and PET.
- / SPECT and PET imaging can be combined with CT/MRI for attenuation correction and anatomical localisation.
- / Technetium-99m is the most commonly used radiopharmaceutical in planar and SPECT imaging.
- / Fluorine-18 FDG is the most commonly used radiopharmaceutical in PET imaging.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

/ 核心要点

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

- / 核医学是一门能够实现功能评估的专业学科，其价值超越其他影像学检查所提供的解剖学信息。
- / 放射性药物由放射性核素和药物分子结合而成，能够靶向不同的器官及其生理过程。
- / 核医学三大主要成像技术：平面显像、SPECT 与 PET
- / SPECT 和 PET 成像可与 CT/MRI 融合，实现衰减校正和解剖定位。
- / 锝-99m 是平面显像和 SPECT 成像中最常用的放射性药物。
- / 氟-18 FDG 是 PET 显像中最常用的放射性药物。

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/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 参考文献

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/ Test Your Knowledge

MODERN RADIOLOGY

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识 测试

/ Test Your Knowledge

<?> QUESTION

1

What type of radiation is used in Planar and SPECT imaging?

- ☐ Alpha radiation
- ☐ X-ray
- ☐ Ultraviolet
- ☐ Gamma radiation

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

/ 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 问题

1

平面显像和 SPECT 成像是使用哪种类型的辐射?

- ☐ α 辐射
- ☐ X 线
- ☐ 紫外线
- ☐ 伽马辐射

/ Test Your Knowledge

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<?> ANSWER

1

What type of radiation is used in Planar and SPECT imaging?

- ☐ Alpha radiation
- ☐ X-ray
- ☐ Ultraviolet
- ☒ Gamma radiation

Planar and SPECT imaging uses gamma radiation. Alpha radiation is used in radiotherapy and certain radionuclide therapies. X-ray is used for conventional radiology imaging techniques including plain film radiography, fluoroscopy and computed tomography. Ultraviolet has no role in imaging studies.

<?> 回答

1

平面显像和 SPECT 成像是使用的是哪种类型的辐射?

- ☐ α辐射
- ☐ X 线
- ☐ 紫外线
- ☒ 伽马辐射

平面显像和 SPECT 成像采用伽马辐射。α辐射用于放射治疗和特定放射性核素治疗。X 线用于常规放射成像技术，包括 X 线平片、荧光透视检查和计算机断层扫描。紫外线在影像学检查中无应用价值。

/ Test Your Knowledge

<?> QUESTION

2 What is the half-life of Technetium-99m?

- ☐ 110 minutes
- ☐ 6 hours
- ☐ 68 minutes
- ☐ 8 days

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<?> 问题

2 锝-99m 的半衰期是多长?

- ☐ 110 min
- ☐ 6 h
- ☐ 68 min
- ☐ 8 天

/ Test Your Knowledge

<?> ANSWER

2 What is the half-life of Technetium-99m?

- ☐ 110 minutes
- ☒ 6 hours
- ☐ 68 minutes
- ☐ 8 days

The half-life of Technetium-99m is 6 hours. This makes for a good radiopharmaceutical because it is long enough to be able to transport but not too long that the patient is radioactive for an extended period of time.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References

Test Your Knowledge

/ 核医学

/ 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献

知识测试

<?> 回答

2 锝-99m 的半衰期是多长?

- ☐ 110 min
- ☒ 6 h
- ☐ 68 min
- ☐ 8 天

锝-99m 的半衰期为 6 h。这一特性使其成为理想的放射性药物，因其半衰期既足以保证运输所需时间，又不会导致患者体内放射性持续过久。

/ Test Your Knowledge

<=> QUESTION

3 Technetium-99m is used in the assessment of bone metastasis. Which of the following cancers is [^{99m}Tc]Tc- HDP used in the assessment of bone metastasis?

- ☐ Prostate
- ☐ Lung
- ☐ Renal
- ☐ Thyroid

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<=> 问题

3 锝-99m 用于评估骨转移。下列哪种癌症的骨转移评估会使用 [^{99m}Tc]Tc-HDP?

- ☐ 前列腺
- ☐ 肺
- ☐ 肾脏
- ☐ 甲状腺

/ Test Your Knowledge

<?> ANSWER

3 Technetium-99m is used in the assessment of bone metastasis. Which of the following cancers is [^{99m}Tc]Tc- HDP used in the assessment of bone metastasis?

- ☒ Prostate
- ☒ Lung
- ☐ Renal
- ☐ Thyroid

[^{99m}Tc]Tc- HDP is useful for osteoblastic metastasis such as prostate and breast (can be mixed). Lytic/osteoclastic bone metastases are not evident and may even appear as photopenic regions.

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<?> 回答

3 锝-99m 用于评估骨转移。下列哪种癌症的骨转移评估会使用 [^{99m}Tc]Tc-HDP?

- ☒ 前列腺
- ☒ 肺
- ☐ 肾脏
- ☐ 甲状腺

[^{99m}Tc]Tc-HDP 可用于成骨性转移评估，如前列腺癌和乳腺癌（可混合存在）。溶骨性/破骨细胞性骨转移并不明显，甚至可能呈现为放射性稀疏区。

/ Test Your Knowledge

<=> QUESTION

4

36 years old female patient presents with clinical and biochemical symptoms of hyperthyroidism. As part of the investigation, she had a [⁹⁹mTc]Tc-pertechnetate thyroid scan (see Figure 55). What diagnosis is demonstrated in the study?

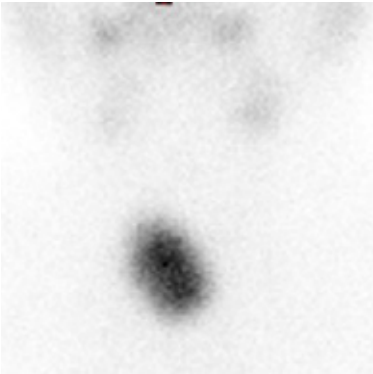


FIGURE 55
[⁹⁹mTc]Tc Thyroid scan

- ☐ Graves' disease
- ☐ Toxic multinodular goitre
- ☐ Autonomous toxic nodule
- ☐ Subacute thyroiditis

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References

Test Your Knowledge

/ 核
医学

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

/ 知识测试

<=> 问题

4

36 岁女性患者出现甲状腺功能亢进的临床和生化症状。作为检查的一部分，她接受了 [⁹⁹mTc]Tc-高锝酸盐甲状腺显像（见图 55）。检查显示何种诊断？

- ☐ 格雷夫斯病
- ☐ 毒性多结节性甲状腺肿
- ☐ 自主性毒性结节
- ☐ 亚急性甲状腺炎

图 55
[⁹⁹mTc]Tc 甲状腺扫描

/ Test Your Knowledge

<?> ANSWER

4

36 years old female patient presents with clinical and biochemical symptoms of hyperthyroidism. As part of the investigation, she had a [⁹⁹mTc]Tc-pertechnetate thyroid scan (see Figure 55). What diagnosis is demonstrated in the study?

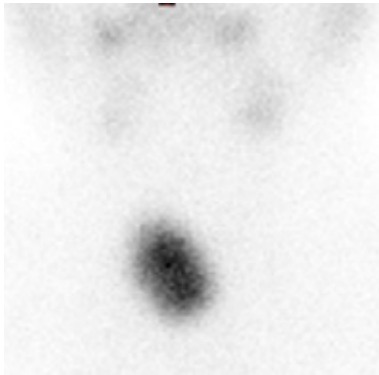


FIGURE 56
[⁹⁹mTc]Tc Thyroid scan

- ☐ Graves' disease
- ☐ Toxic multinodular goitre
- ☒ Autonomous toxic nodule
- ☐ Subacute thyroiditis

There is a rounded, focal tracer activity centred on the mid right lobe of the thyroid. Appearances are keeping with autonomous nodule in the right lobe of the thyroid.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References

Test Your Knowledge

/ 核医学

/ 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 回答

4

36 岁女性患者出现甲状腺功能亢进的临床和生化症状。作为检查的一部分，她接受了 [⁹⁹mTc]Tc-高锝酸盐甲状腺显像（见图 55）。检查显示何种诊断？

- ☐ 格雷夫斯病
- ☐ 毒性多结节性甲状腺肿
- ☒ 自主性毒性结节
- ☐ 亚急性甲状腺炎

图 56
[⁹⁹mTc]Tc 甲状腺扫描

甲状腺右叶中部可见局灶性类圆形示踪剂浓聚灶。影像学表现符合右叶自主性功能结节特征。

/ Test Your Knowledge

<?> QUESTION

5

Which of the following is an indication for renal DMSA?

- ☐ Assessment of renal scarring
- ☐ Calculation of e-GFR
- ☐ Identify renal obstruction
- ☐ Corticomedullary differentiation

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

/ 知识测试

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

<?> 问题

5

下列哪一项是
肾静态显像
(DMSA) 的
适应证?

- ☐ 肾瘢痕评估
- ☐ 估算肾小球
滤过率 (e-GFR)
- ☐ 识别肾梗阻
- ☐ 皮髓质分界

/ Test Your Knowledge

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<?> ANSWER

5

Which of the following is an indication for renal DMSA?

- ☒ Assessment of renal scarring
- ☐ Calculation of e-GFR
- ☐ Identify renal obstruction
- ☐ Corticomedullary differentiation

DMSA scans allow detection of focal renal parenchymal abnormalities including assessment of renal scarring. [99mTc]-DTPA is used for eGFR calculation. MAG3 renogram plays crucial role in confirming renal obstruction alongside other imaging modalities such as US and CT. US, CT, and MRI demonstrate the anatomy including corticomedullary differentiation of the kidneys.

<?> 回答

5

下列哪一项是肾静态显像 (DMSA) 的适应证?

- ☒ 肾瘢痕评估
- ☐ 估算肾小球滤过率 (e-GFR)
- ☐ 识别肾梗阻
- ☐ 皮髓质分界

DMSA 显像可用于检测局灶性肾实质异常, 包括肾瘢痕评估。[99mTc]-DTPA 用于估算肾小球滤过率 (eGFR)。MAG3 肾图在确认肾梗阻方面起关键作用, 常与超声 (US) 和 CT 等影像学检查联合应用。US、CT 和 MRI 可显示肾脏的解剖结构, 包括皮髓质分界。

/ Test Your Knowledge

<?> QUESTION

6

Radiation dose to maternal breast tissue is greater for CTPA compared to V/Q scan.

- ☐ True
- ☐ False

/ Nuclear
Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核
医学

/ 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 问题

6

与 V/Q 显像相比，CTPA 对母体乳腺组织的辐射剂量更高。

- ☐ 对
- ☐ 错

/ Test Your Knowledge

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

/ 知识测试

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

<?> ANSWER

6

Radiation dose to maternal breast tissue is greater for CTPA compared to V/Q scan.

☒ True

☐ False

Typically, radiation dose to maternal breast tissue is greater for CTPA compared to V/Q scan; doses to foetus are equivalent.

<?> 回答

6

与 V/Q 显像相比，CTPA 对母体乳腺组织的辐射剂量更高。

☒ 对

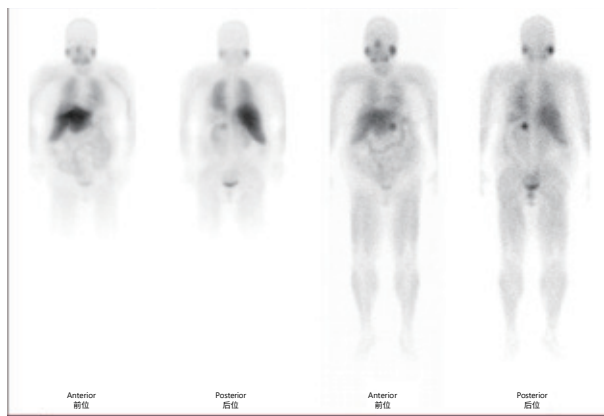
☐ 错

通常而言，CT 肺动脉造影 (CTPA) 对母体乳腺组织的辐射剂量高于通气/灌注显像 (V/Q 显像)；而对胎儿的辐射剂量两者相当。

/ Test Your Knowledge

<=> QUESTION

7 Figure 56 demonstrates a left pheochromocytoma. What nuclear medicine study do these images represent?



- ☐ $[^{68}\text{Ga}]\text{Ga}$ - PSMA
- ☐ $[^{18}\text{F}]\text{FDG}$
- ☐ $[^{123}\text{I}]\text{I}$ - MIBG
- ☐ $[^{99\text{m}}\text{Tc}]\text{Tc}$ - pertechnetate

FIGURE 57

NM Study

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<=> 问题

7 图 56 所示为左侧嗜铬细胞瘤。这些图像代表哪种核医学显像?

- ☐ $[^{68}\text{Ga}]\text{Ga}$ -PSMA
- ☐ $[^{18}\text{F}]\text{FDG}$
- ☐ $[^{123}\text{I}]\text{I}$ -MIBG
- ☐ $[^{99\text{m}}\text{Tc}]$
Tc-高锝酸盐

/ Test Your Knowledge

<=> ANSWER

7 Figure 56 demonstrates a left pheochromocytoma. What nuclear medicine study do these images represent?

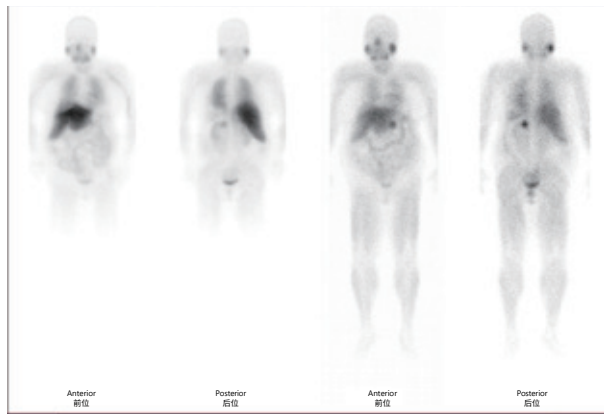


FIGURE 56

NM Study

- ☐ $[^{68}\text{Ga}]\text{Ga}$ - PSMA
- ☐ $[^{18}\text{F}]\text{FDG}$
- ☒ $[^{123}\text{I}]\text{I}$ - MIBG
- ☐ $[^{99\text{m}}\text{Tc}]\text{Tc}$ - pertechnetate

Figure 53 corresponds to images from $[^{123}\text{I}]\text{I}$ - MIBG study. $[^{68}\text{Ga}]\text{Ga}$ - PSMA is used for metastatic prostate cancer assessment. $[^{18}\text{F}]\text{FDG}$ is widely used in oncology, neuroradiology and cardiology. $[^{99\text{m}}\text{Tc}]\text{Tc}$ - pertechnetate is used for thyroid scans.

/ Nuclear
Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging
Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核
医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<=> 回答

7 图 56 所示为左侧嗜铬细胞瘤。这些图像代表哪种核医学显像?

- ☐ $[^{68}\text{Ga}]\text{Ga}$ -PSMA
- ☐ $[^{18}\text{F}]\text{FDG}$
- ☒ $[^{123}\text{I}]\text{I}$ -MIBG
- ☐ $[^{99\text{m}}\text{Tc}]\text{Tc}$ -高锝酸盐

图 53 对应 $[^{123}\text{I}]\text{I}$ -MIBG (间碘苄胍) 显像图像。 $[^{68}\text{Ga}]\text{Ga}$ -PSMA 用于转移性前列腺癌评估。 $[^{18}\text{F}]\text{FDG}$ 广泛应用于肿瘤学、神经放射学和心脏病学领域。 $[^{99\text{m}}\text{Tc}]\text{Tc}$ -高锝酸盐用于甲状腺显像。

图 56

NM 检查

/ Test Your Knowledge

<=> QUESTION

8 Which of the images represents an FDG PET study?



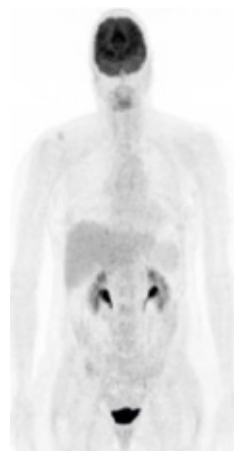
☐ A



☐ B



☐ C



☐ D

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

/ 知识测试

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

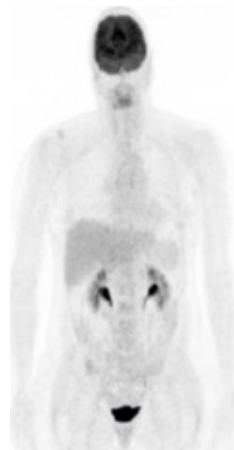
<=> 问题

8 哪些图像代表 FDG PET 检查?

/ Test Your Knowledge

<=> ANSWER

8 Which of the images represents an FDG PET study?

☐ [68Ga]Ga-DOTATATE PET scan☐ [99mTc]Tc-HDP whole body bone scan☐ [123I]I-MIBG scan☒ [18F]FDG-PET scan

/ Nuclear Medicine

CHAPTER OUTLINE:

Introduction

Nuclear Medicine Imaging Principles

Planar and SPECT Studies

PET Studies

Take-Home Messages

References

Test Your Knowledge

/ 核医学

章节大纲:

简介

核医学成像原理

平面和 SPECT 检查

PET 检查

核心要点

参考文献

知识测试

/ 知识测试

<=> 回答

8 哪些图像代表 FDG PET 检查?

☐ [68Ga]Ga-DOTATATE PET 扫描☐ [99mTc]Tc-HDP 全身骨扫描☐ [123I]I-MIBG 扫描☒ [18F]FDG-PET 扫描

/ Test Your Knowledge

<?> QUESTION

9

Which radionuclide is PSMA labelled for the detection of metastatic disease in prostate cancer

- ☐ Gallium-68
- ☐ Rubidium- 82
- ☐ Iodine-123
- ☐ Technetium-99m

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

/ 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 问题

9

哪种放射性核素经 PSMA 标记后用于检测前列腺癌的转移性疾病

- ☐ 镓-68
- ☐ 铷-82
- ☐ 碘-123
- ☐ 锝-99m

/ Test Your Knowledge

<?> ANSWER

9 Which radionuclide is PSMA labelled for the detection of metastatic disease in prostate cancer

- ☒ Gallium-68
- ☐ Rubidium- 82
- ☐ Iodine-123
- ☐ Technetium-99m

Rubidium-82 is used in myocardial perfusion imaging. Iodine-123 is the commonly used in thyroid imaging. Technetium-99m is the most widely used radionuclide in planar and SPECT imaging.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References

Test Your Knowledge

/ 核医学 / 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 回答

9 哪种放射性核素经 PSMA 标记后用于检测前列腺癌的转移性疾病

- ☒ 镓-68
- ☐ 铊-82
- ☐ 碘-123
- ☐ 锝-99m

铊-82 用于心肌灌注显像。碘-123 常用于甲状腺显像。锝-99m 是平面显像和 SPECT 成像中使用最广泛的放射性核素。

/ Test Your Knowledge

<?> QUESTION

10 Which of the following organs demonstrate normal physiological uptake in DOTATATE PET imaging?

- ☐ Brain
- ☐ Heart
- ☐ Spleen
- ☐ Pancreas

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References
- Test Your Knowledge

/ 核医学

/ 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 问题

10 下列哪些器官在 DOTATATE PET 显像中表现为正常生理性摄取?

- ☐ 脑
- ☐ 心脏
- ☐ 脾脏
- ☐ 胰腺

/ Test Your Knowledge

<?> ANSWER

10 Which of the following organs demonstrate normal physiological uptake in DOTATATE PET imaging?

- ☐ Brain
- ☐ Heart
- ☒ Spleen
- ☐ Pancreas

Normal physiological uptake in DOTATATE PET scan is related to specific receptor binding and nonspecific tissue handling of the peptide. Spleen demonstrates highest intensity physiologic uptake due to SSTR expression. Other organs with normal physiological uptake include kidneys, pituitary, thyroid, adrenal glands, liver, salivary glands and GI tract.

/ Nuclear Medicine

CHAPTER OUTLINE:

- Introduction
- Nuclear Medicine Imaging Principles
- Planar and SPECT Studies
- PET Studies
- Take-Home Messages
- References

Test Your Knowledge

/ 核医学 / 知识测试

章节大纲:

- 简介
- 核医学成像原理
- 平面和 SPECT 检查
- PET 检查
- 核心要点
- 参考文献
- 知识测试

<?> 回答

10 下列哪些器官在 DOTATATE PET 显像中表现为正常生理性摄取?

- ☐ 脑
- ☐ 心脏
- ☒ 脾脏
- ☐ 胰腺

DOTATATE PET 扫描中的正常生理性摄取与肽类的特异性受体结合和非特异性组织处理有关。脾脏因 SSTR 表达呈现最高强度的生理性摄取。其他生理性摄取正常的器官包括肾脏、垂体、甲状腺、肾上腺、肝脏、唾液腺和胃肠道。

