Fundamentals of Medical Imaging

郑锐 Zheng Rui （助理教授/研究员）
上海科技大学信息科学与技术学院
E-mail: zhengrui@shanghaitech.edu.cn
地址：信息学院大楼2号楼302.G

Information

Time： Tuesday & Thursday， 1:00-2:40 pm，
Week 1-16，

Location: 信息学院1D-108

Teacher: 郑锐

Email: zhengrui@shanghaitech.edu.cn

Office： 信息学院2号楼302.G

Tel: 20684452

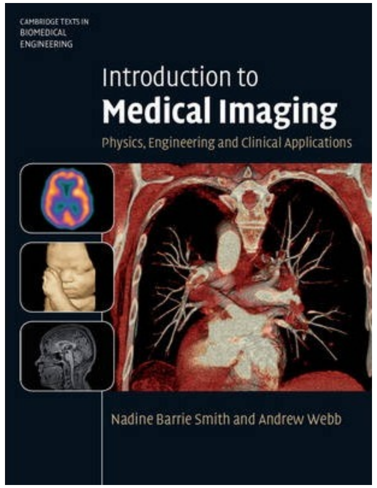
TA : 曾宏业

Email： zenghy@shanghaitech.edu.cn

医学影像学

扫一扫二维码，加入该群。

Textbook

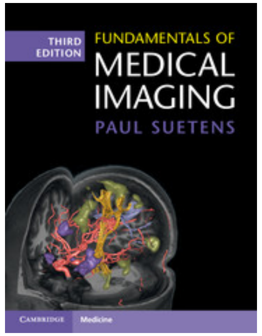


Introduction to Medical Imaging: Physics, Engineering and Clinical Applications

AUTHOR: Nadine Barrie Smith & Andrew Webb

PUBLISHER: Cambridge University Press (2010)

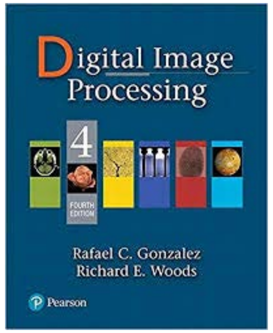
Reference book



Fundamentals of Medical Imaging, 3rd Edition

AUTHOR: Paul Suetens

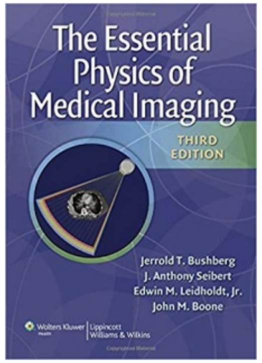
PUBLISHER: Cambridge University Press (2017).



Digital Image Processing, 4th edition

AUTHORS： Rafael C. Gonzalez & Richard E. Woods

PUBLISHER： Pearson (2017)



The Essential Physics of Medical Imaging, 3rd Edition

AUTHORS： Bushberg J. T., Seibert J. A., Leidholdt E. M. Jr., Boone J. M

PUBLISHER： Lippincott Williams & Wilkins (2011)

医学影像成像理论（第二版）

作者: 李月卿

出版社: 人民卫生出版社 (2010)

Schedule

Week	Date	Topic	Reading Material	Homework
1	3月3日	Introduciton to Medical imaging		Release: 3/5 Due: 3/15
	3月5日	Image characteristics	CH1.1-1.9	
2	3月10日	Basics of Digital image processing	DIP CH2.4, CH2.6	
	3月12日	X-ray physics, Radioactivity	CH2.1-2.5	Release: 3/17 Due: 3/29
3	3月17日	Instrumentation and Characteristics of Radiography	CH2.6-2.8	
	3月19日	X-ray Imaging application	CH2.9-2.11	
4	3月24日	Instrumentation for CT	CH2.12-2.13	Release: 3/26 Due: 4/12
	3月26日	Image Reconstruction Algorithm	CH2.14	
5	3月31日	Image Reconstruction for CT	CH2.14-2.15	
	4月2日	Clinical application of CT	CH2.16-2.18	
6	4月7日	Introduction to Nuclear Medicine	CH3.1-3.5	Release: 4/9 Due: 4/26
	4月9日	Gamma Camera	CH3.6-3.8	
7	4月14日	SPECT/CT, PET/CT	CH3.9-3.21	
	4月16日	Radiation Biology and protection		
8	4月21日	Fundamental Theory of MRI	CH5.1-5.7	Release: 4/23 Due: 5/10
	4月23日	MRI Image Acquistion and reconstruction	CH5.8-5.13	
9	4月28日	MRI Instrumenation	CH5.14-5.16	
	4月30日	Image Characteristics and Apllication of MRI	CH5.17-5.23	
10	5月5日	Ultrasound Physics	CH4.1-4.4	Release: 5/7 Due: 5/17
	5月7日	Ultrasound Instrumentation	CH4.5-4.7	
11	5月12日	Image Characteristics and Apllication of Ultrasound	CH4.8-4.11	
	5月14日	Other Biomedical Imaging Modalities		
12	5月19日	Medical Image Computing	FMI CH7	
	5月21日	Visualization for Diagnosis and Therapy	FMI CH8	
13	5月26日	Review		
	5月28日	Midterm		
14	6月2日	**Invited talk**		
	6月4日			
15	6月9日	Project presentation		
	6月11日			
16	6月16日			
	6月18日			

Assessment

- **Homework (30%)**
  - 6 assignments;
  - Handwriting or Hard copy;
  - Only half score is counted if not submitting before deadline; No score if not submitting at all.
- **Quiz (5%):** missing twice -2%; missing more than twice : -5%
- **Midterm Exam (30%)**
- **Project (35%)**
  - Content: Literature review on a specific subject;
  - Group of maximum 2 persons
  - Presentation: PPT in English, present in Chinese or English.
  - Project report (English) : in the format of IEEE transaction, minimum 3000 words and 20 references.
  - Score requirement (以100分计)
    - ✓ Presentation (30分)：思路清晰，重点明确，按时完成；
    - ✓ Q&A（10分）：正确回答问题，条理清楚；
    - ✓ Report（60分）：问题阐述明确，内容完整，逻辑通顺，格式正确；
    - ✓ Submission package：Abstract, PPT and Report;
    - ✓ 截止时间：Abstract (before midterm), Final package (6月21日)。无特殊情况逾期，24小时内扣20分，24小时以外扣除50分，未交则该project计0分。

COVID-19

2月12日，湖北新增确诊14840例，激增背后的原因是什么？

“尽管其他的病毒性或细菌性肺炎的CT 影像与新型冠状病
尽早隔离治疗也是首选”，张玉蛟说，“如果怀疑并发细菌感染
的抗生素。CT 检测的优势是立竿见影，马上可以做出判断。对
直观的影像资料。”

最后，张玉蛟也提醒CT存在的三点局限性：一是与其它肺部
期感染可能没有明显的肺部影像改变；三是影像诊断标准有待进
何诊断手段是完美无缺的。” 她表示。

新增确诊病例对比 | 现有确诊病例对比 | 病死率对比 | 治愈率对比

最新《新型冠状病毒肺炎诊疗方案》出炉，为何增加的湖北临床诊断病例又取消了

2020-02-20 13:32:02

长江日报-长江网2月19日讯（记者刘睿彻　通讯员冯霞）19日，国家卫健委发布了最新的《新型冠状病毒肺炎诊疗方案（试行第六版）》，和湖北相关的一项重要变化是，原本在第五版中增加的湖北临床诊断病例又被取消了。原因何在？

华中科技大学同济医学院医药卫生管理学院院长冯占春教授表示，这与临床遵循直接证据作为金标准，核酸检测能力提升，原有病人存量消化等几方面原因有关。

据悉，在第五版的诊疗方案中，湖北以外其他省份仍然分为“疑似病例”和“确诊病例”两类，湖北省增加“临床诊断”分类。湖北的疑似病例只要具有肺炎影像学特征者，就为临床诊断病例。也就是说，疑似病例的CT显示符合新冠肺炎的表现，在没有核酸检测的情况下，就是临床诊断病例。

而临床诊断病例参照确诊病例治疗。12日，湖北省首次公布临床诊断病例，1天之后，就将临床诊断病例纳入确诊病例统计，截至12日，武汉新增确诊病例一天陡增了1.3万人。

冯占春教授介绍，从目前诊断来说，病原学的核酸检测或者基因测序，仍然是诊断病毒感染的金标准，是最直接的证据；而影像学是根据影像如拍CT片做出的临床判断，严格来说，还不是确诊标准。

钟南山院士团队对1099例确诊患者回溯研究发现，仅靠肺部CT确诊新型冠状病毒感染准确率只有76.4%，可见也不能完全迷信CT。如果把CT检查、核酸试剂盒和临床症状结合在一起，确诊的准确率能达到97%。

王嘉兴/中国青

有检测资质的机
影响防控大局。

准”。仅仅靠CT
紧，“宁可错杀
方法去救治。

们检查的目的是
？还是为了确定

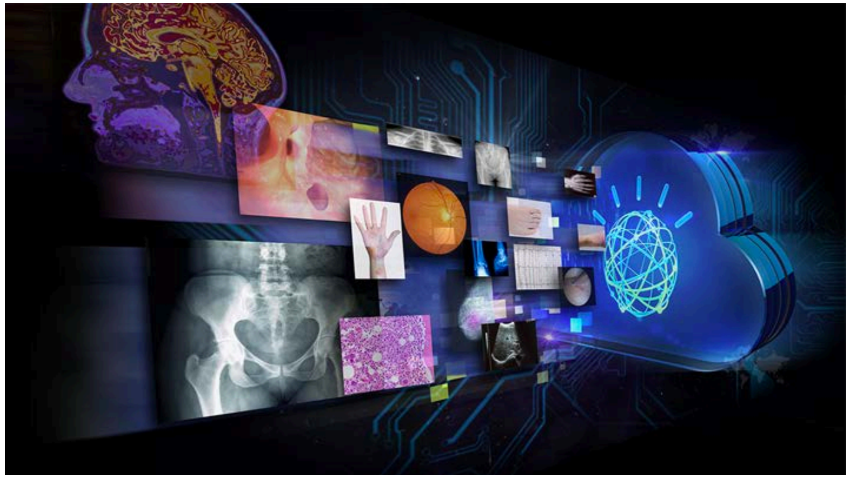
Lecture 1 - Introduction

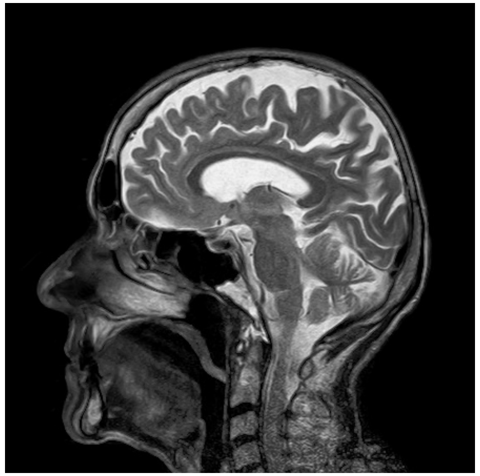
This lecture will cover:

- – What is Medical Imaging?
- – History of Medical Imaging
- – Medical Imaging Modalities
- – Contents of the course
- – Fundamentals of medical diagnosis

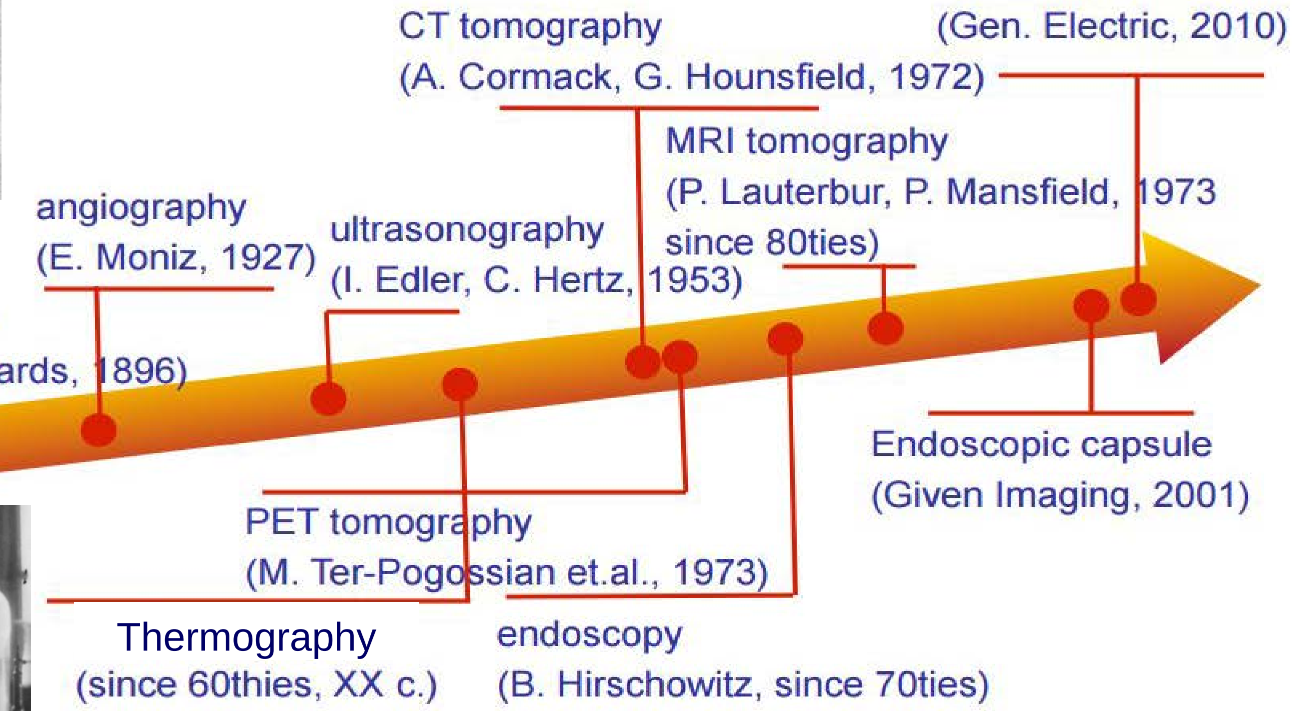
Medical Imaging

- **Medical visual representation of human in multi-modality and multi-dimension**
  - Revealing internal structures of a body (anatomy)
  - Visual representation of the function of some organs or tissues (physiology).
- **Goals**
  - Clinical analysis (Diagnosis)
  - Medical intervention (Treatment)
  - Establishing a database of normal anatomy and physiology to make it possible to identify abnormalities.





History



radiography
(J. Hall-Edwards, 1896)
angiography
(E. Moniz, 1927)
ultrasonography
(I. Edler, C. Hertz, 1953)
CT tomography
(A. Cormack, G. Hounsfield, 1972)
MRI tomography
(P. Lauterbur, P. Mansfield, 1973
since 80ties)
CT+MRI, PET+MRI
(Gen. Electric, 2010)
Endoscopic capsule
(Given Imaging, 2001)
PET tomography
(M. Ter-Pogossian et.al., 1973)
Thermography
(since 60thies, XX c.)
endoscopy
(B. Hirschowitz, since 70ties)

Categories

- **Biomedical micro-imaging**
  - Scanning Electron Microscope (SEM)
  - Optical microscope
- **Medical imaging**
  - **Radioactive:** X ray, CT, Nuclear medicine, PET, SPECT
  - **Non-radioactive:** MRI, Ultrasound, Thermography, Photoacoustic
- **Functional and Anatomical**

Comparison of Imaging modalities

Imaging modalities	**2D**	**3D**	**Other technology**
X-ray	Planar radiography	CT	Angiography, fluoroscopy,
Nuclear medicine	Gamma camera	SPECT, PET/TOF PET	
MRI		MRI	fMRI
Ultrasound	B-mode, M-mode,	Multi-dimension arrays	Doppler ultrasound

Knowledge & Requirement

Involved knowledge

- Physics
- Mathematics
- System and signals analysis
- Anatomy and Physiology

Learning outcome

- Understanding the principles of various medical imaging techniques.
- Computing parameters for each imaging modality such as resolution, signal to noise ratio.
- Evaluating data sets from different devices
- Evaluating and analyzing image properties
- Discussing how a specific imaging modality can relate to an imaging scenario in the body.
- Quality control and Health protection

Fundamentals

- **Diagnostic Test** (*Reference: CH1.2*)
  - Binary Classification
  - Sensitivity and Specificity
  - ROC Curve
- **Anatomical Planes**

Binary Classification (二元分类)

		True Condition (真实值)	
		Positive (阳性)	**Negative** (阴性)
Predicted Condition (预测值)	**Positive** (阳性)	**True Positive** (TP) 真阳性	**False Positive** (FP) 伪阳性
	Negative (阴性)	**False Negative** (FN) 伪阴性	**True Negative** (TN) 真阴性

Contingency Table (列联表)

<table>
<tr><td colspan="2"></td><td colspan="2">True condition</td><td colspan="3"></td></tr>
<tr><td></td><td>Total population</td><td>Condition positive</td><td>Condition negative</td><td>Prevalence = $\frac{\Sigma \text{ Condition positive}}{\Sigma \text{ Total population}}$</td><td colspan="2">Accuracy (ACC) = $\frac{\Sigma \text{ True positive} + \Sigma \text{ True negative}}{\Sigma \text{ Total population}}$</td></tr>
<tr><td rowspan="2">Predicted condition</td><td>Predicted condition positive</td><td>True positive, Power</td><td>False positive, Type I error</td><td>Positive predictive value (PPV), Precision = $\frac{\Sigma \text{ True positive}}{\Sigma \text{ Predicted condition positive}}$</td><td colspan="2">False discovery rate (FDR) = $\frac{\Sigma \text{ False positive}}{\Sigma \text{ Predicted condition positive}}$</td></tr>
<tr><td>Predicted condition negative</td><td>False negative, Type II error</td><td>True negative</td><td>False omission rate (FOR) = $\frac{\Sigma \text{ False negative}}{\Sigma \text{ Predicted condition negative}}$</td><td colspan="2">Negative predictive value (NPV) = $\frac{\Sigma \text{ True negative}}{\Sigma \text{ Predicted condition negative}}$</td></tr>
<tr><td colspan="2"></td><td>True positive rate (TPR), Recall, Sensitivity, probability of detection $= \frac{\Sigma \text{ True positive}}{\Sigma \text{ Condition positive}}$</td><td>False positive rate (FPR), Fall-out, probability of false alarm $= \frac{\Sigma \text{ False positive}}{\Sigma \text{ Condition negative}}$</td><td>Positive likelihood ratio (LR+) $= \frac{\text{TPR}}{\text{FPR}}$</td><td rowspan="2">Diagnostic odds ratio (DOR) $= \frac{\text{LR+}}{\text{LR−}}$</td><td rowspan="2">$F_1$ score = $\frac{1}{\frac{\frac{1}{\text{Recall}} + \frac{1}{\text{Precision}}}{2}}$</td></tr>
<tr><td colspan="2"></td><td>False negative rate (FNR), Miss rate $= \frac{\Sigma \text{ False negative}}{\Sigma \text{ Condition positive}}$</td><td>Specificity (SPC), Selectivity, True negative rate (TNR) $= \frac{\Sigma \text{ True negative}}{\Sigma \text{ Condition negative}}$</td><td>Negative likelihood ratio (LR−) $= \frac{\text{FNR}}{\text{TNR}}$</td></tr>
</table>

Sensitivity and Specificity

- **Sensitivity (敏感性) or True Positive Rate**

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

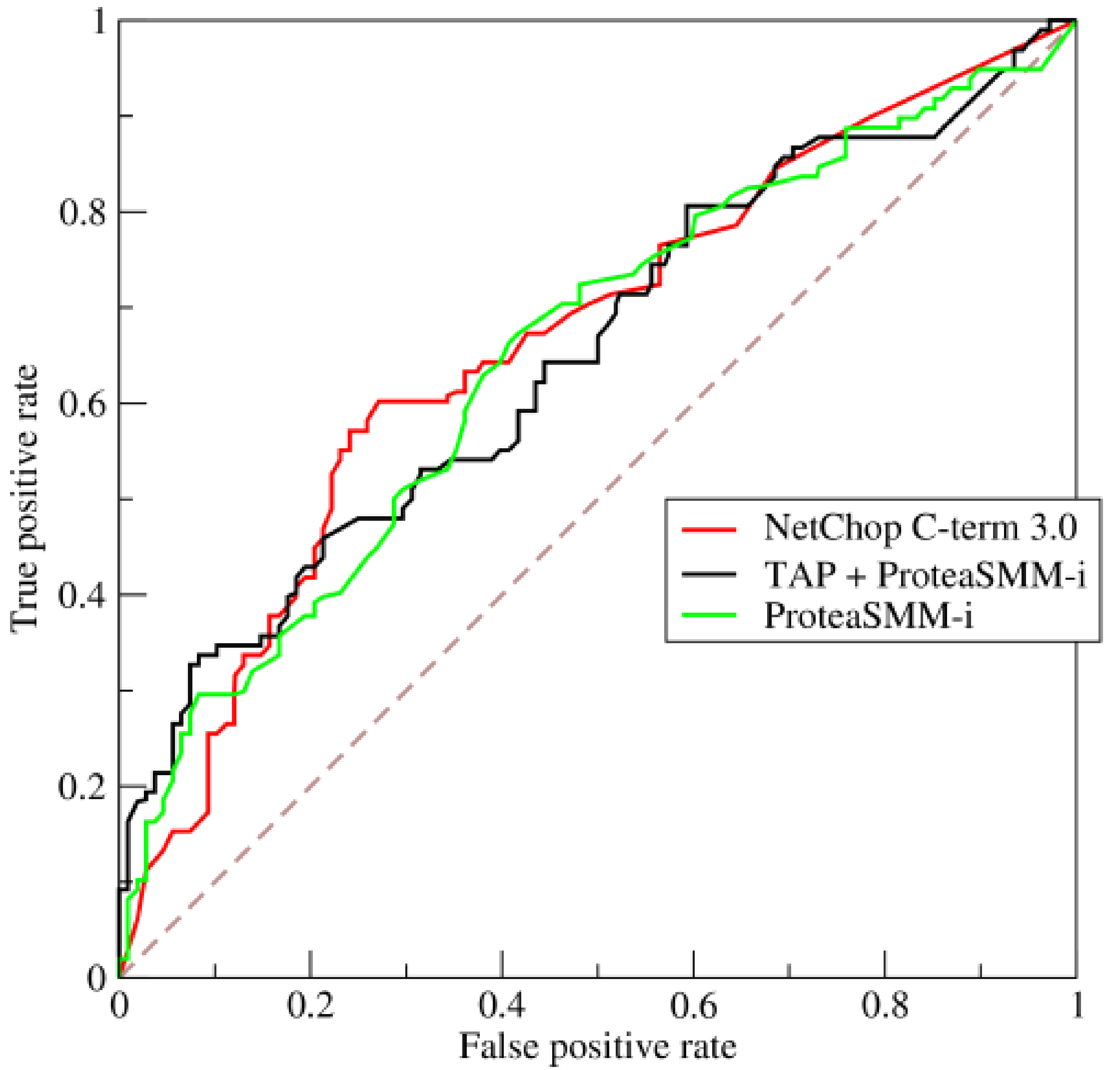
- **Specificity (特异性) or True Negative Rate**

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}}$$

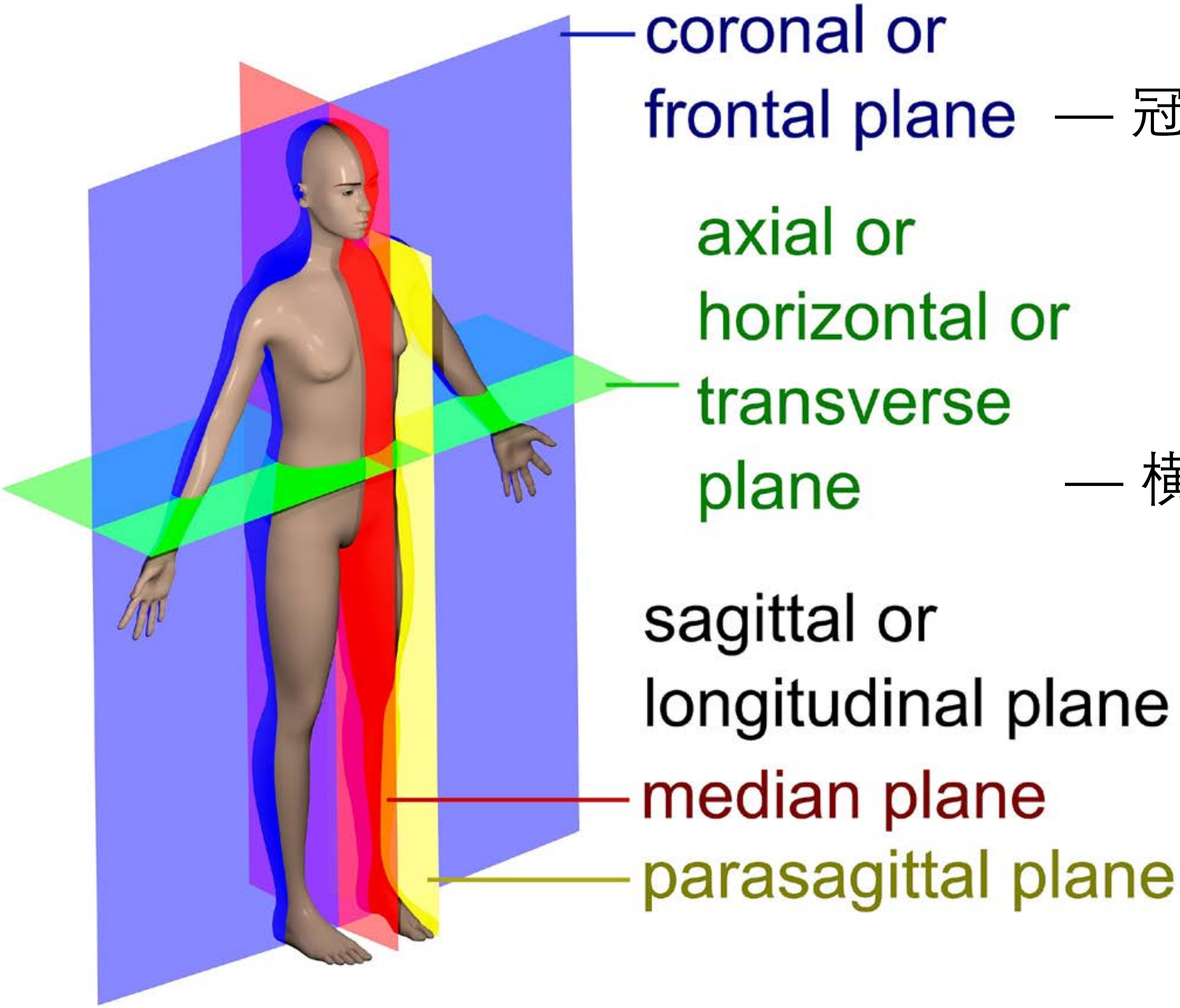
ROC Curve

Receiver Operating Characteristic (ROC) Curve

(受试者操作特性曲线)



Anatomical Planes



— 冠状面

— 横截面

— 矢状面