### Preparing for Part 2 of the ABR Diagnostic Physics Exam

Timothy P. Szczykutowicz Ph.D., DABR University of Wisconsin Madison Departments of Radiology, Medical Physics and Biomedical Engineering

### Disclosures

 TPS Equipment Grant and Consultant GE HealthCare; supplies CT protocols to GE HealthCare under a licensing agreement; the founder of protocolshare.org

### Formula for success

- Read "The Essential Physics of Medical Imaging" by Bushberg, Seibert, Leidholdt, and Boone
  - Memorize and understand EVERY equation shown in this book (you can skip the Nuc. Med. Chapters in memorization, but we need to understand that material to be competent professionals)
  - Understand every plot shown in this book (650 total images in the 3<sup>rd</sup> edition) (you can skip the Nuc. Med. Chapters in memorization, but we need to understand that material to be competent professionals)
  - Scan the text for definitions and memorize them (for example, the relationship between Mechanical index/peak rarefactional pressure/frequency is given in words, not a formula...but you should memorize it)

If you do this, I can guarantee you will pass\*

\*Not Really

## **Eligibility Requirements**

- If you haven't checked out the ABR website, you need to
  - <u>www.theabr.org/ic-rp-req</u>
  - These are not very complicated, but you need to see where you fit into the eligibility pathways.
  - I contacted the ABR staff, they were helpful and re-assuring.
  - Note 
     → You need to register in a window from Dec. 1 Jan 31<sup>st</sup> for the August Exam

### **Test Format**

- Test administered at Pearson Vue Test Centers
  - (same place you took part 1)
- All done via computer interface
- 80 questions total (not sure if this is official ABR information, but the breakdown between simple/complex questions is 53/27)
- 5 hours given
- Expect a 30 minute "check in time"
  - Pearson will tell you how early to arrive
- A list of constants will be provided! So don't study them... <u>http://www.theabr.org/ic-rp-calc</u>

Practice using the calculator so you don't have to worry about it

#### Exercises for use with the TI-30XS calculator

The following exercises are not indicative of actual questions on the ABR exam. They are intended to help you practice with the calculator. You are encouraged to try other examples of calculations that would arise as a routine part of your daily work.

Use of In function:

Calculate the decay constant of 99m-Tc from its half-life of 6.02 hr.

Use of Sin function:

What is the value of the first spherical Bessel function (sin(x)/x) at 0.25 radians? This is also sometimes called the sinc function.

Use of Hyperbolic functions:

The Gateway Arch in St. Louis is famous as an inverted catenary that is given by y=693.9 - 68.8 cosh (0.01x). When x=100 ft., what is the value of y?

Finding cube roots:

The sensitivity of a photomultiplier tube is often approximated as a  $\cos^3 \theta$  function. If the relative sensitivity of the tube is 0.90, what is the effective angle  $\theta$  in radians?

Exponential function:

An 86-MBq source of  $^{99m}\mbox{-Tc}$  is allowed to decay for 14.6 hrs. At the end of that period, what will its activity be?

Exponential function and use of memory:

A <sup>99</sup> Mo/ <sup>99m-</sup>Tc generator is eluted at time zero. This reduces the activity of <sup>99m-</sup>Tc in the generator to zero. If the activity of <sup>99</sup> Mo in the generator at time zero is 861 MBq, what will the activity of <sup>99m-</sup>Tc be at 4 hrs? (The half-life of <sup>99-</sup>Mo is 67 hrs. Use the Bateman equations.)

- The ABR provides
  - Sample questions (simple and complex questions)
  - A list of topics for part 2
  - A detailed list of topics for part 3
    - This list is more detailed than the part 2 list and I suggest using it to study for part 2, which is really just prep for part 3
  - A MOC exam study guide
    - Includes a list of relevant AAPM TG reports, NCRP reports, ICRP reports, ACR references, Journal references, and some books

- Simple questions
  - Recall a fact
  - Recall a relationship
  - Perform a 1 step calculation

#### PART 2: Diagnostic Medical Physics

#### SIMPLE QUESTIONS

1. For a phototimed radiograph, an increase in which of the following factors will increase patient skin dose?

- A. Milliampere
- B. Kilovolt
- C. Patient thickness
- D. Focal spot size
- E. Source-to-image distance

2. A region of interest (ROI) in a CT image has an intensity of -30 HU. What is the ratio of the linear attenuation coefficient for the ROI to that of water?

A. 0.70 B. 0.97 C. 1.00 D. 1.03 E. 1.30

3. As a potential contrast agent for ultrasound, which of the following materials is expected to be the strongest reflector for a fixed concentration of small (<5 nm) particles?

- A. Encapsulated polymer
- B. Encapsulated lipid
- C. Encapsulated gas

4. In a spinecho MRI pulse sequence with TR = 2000 ms and TE = 100 ms, which anatomy feature has the highest signal intensity in a brain image?

- A. Gray matter
- B. White matter
- C. Lens of the eye
- D. Cerebrospinal fluid

- Complex question
  - Perform a >1 step calculation
  - Perform a calculation and apply some kind of fact
  - Some of these may involve many steps (there are shielding questions)

#### COMPLEX QUESTIONS

1. For the series of repeat measurements of the output of an x-ray tube and generator for an 80-kV beam, 10 mAs at 1 m, what is the coefficient of variation?

<u>Measurement#</u>	<u>Output (mR)</u>
1	71.3
2	70.9
3	72.2
4	71.8
5	71.5
A. 70	

- B. 7.0 C 07 D 0.07
- E 0.007

2. A 5-MHz ultrasound beam is incident on a blood vessel at an angle of 45 degrees. If the blood is moving toward the transducer, and the mean velocity is 30 cm/s, what is the mean frequency shift of the reflected beam?

- 0.7 kHz 14 kHz 2.8 kHz 5.6 kHz
- E. 11.2 kHz

• The ABR supplies a list of topics for Part 2, I recommend ignoring this list and focusing on the list for part 3

### PART 2: Diagnostic Medical Physics

Diagnostic generating equipment and sources Clinical diagnostic medical physics Geometric considerations Recording media and their applications Information transfer theory Sensitometry Technology of medical imaging Ultrasound Magnetic resonance imaging (MRI) Computed tomography (CT) Informatics Digital techniques and image processing Picture archiving and communication systems Dosimetry Calibration of diagnostic equipment Quality assurance Radiation protection (including survey techniques and installation design) lonizing radiation safety Ultrasound safety MRI safetv

See sample questions.

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Computed tomography	CT system design and principles of operation; image- acquisition protocols, including helical acquisition and tube current modulation techniques; cone beam geometry; post-processing protocols, multi-planar and volumetric reconstruction; quantitative CT; image noise assessment, statistics, dose metrics (CTDI, DLP, SSDE), and effective dose estimation; common CT artifacts, quality assurance, and CT accreditation program
MRI and ultrasound	MR equipment, principles of magnetization, resonance, and excitation; MR pulse sequences, localization, acquisition, and processing; ultrasound (US) principles, beam properties, acquisition methods, signal processing, and image display; Doppler US and color flow imaging principles and operation; common artifacts for MRI and US, siting requirements for MRI, quality assurance, and accreditation for MRI and US
Informatics, image display, and image fundamentals	Informatics infrastructure, standards, and patient security; PACS-modality connectivity, workflow, display, and archive functions; image display requirements, characteristics, and calibration procedures; image processing techniques and qualitative data extraction; image fundamentals, sampling theory, and ROC analysis
Radiation, dosimetry, protection, and safety	Radiation biology, radiation effects, and age/gender-specific risks; radiation protection principles, guidelines, and regulations; radiation dosimetry, detectors, standards, and units; radiation shielding design factors, barrier requirements, surveys, and reports; patient safety and error-prevention issues, including dose reduction, sentinel events, and MR- and US-specific safety issues



### Maintenance of Certification Diagnostic Medical Physics 2015 Cognitive Exam Study Guide Updated 4/2016

The following is a general overview of the cognitive exam:

#### **General Information**

Approximately 30% of the material on the examination is core diagnostic medical physics, technology, and safety. The remaining 70% is taken from recent advances in the field.

#### Length and Structure

The exam is approximately 150 questions in length. All questions are multiple-choice, and most have three to five possible answers. A standard calculator is available, but no complex calculations are required.



Reports from the American Association of Physicists in Medicine (AAPM):

AAPM Report OR-03, Task Group #18: Assessment of Display Performance for Medical Imaging Systems (2005)

AAPM Report 93, Task Group #10: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems (2006)

AAPM Report 96, Task Group #23: The Measurement, Reporting, and Management of Radiation Dose in CT (2008)

AAPM Report 100, Task Group #1: Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities (2010)

AAPM Report 108, Task Group #108: PET and PET/CT Shielding Requirements (2006)

AAPM Report 116, Task Group #116: An exposure indicator for digital radiography (2009) (See also IEC report 62494-1)

AAPM Report 118, Task Group #118: Parallel Imaging in MRI, Technology, Applications and Quality Control

AAPM Report 125, Task Group #125: Functionality and Operation of Fluoroscopic Automatic Brightness Control/Automatic Dose Rate Control Logic in Modern Cardiovascular and Interventional Angiography Systems (2012) Not a comprehensive list, there is more in the actual document

### Journal articles:

E Kanal, et al., ACR Guidance Document on MR Safe Practices: 2013. Journal of Magnetic Resonance Imaging 2013; 37:501-530.

EL Nickoloff, AAPM/RSNA Physics Tutorial for Residents: Physics of Flat-Panel Fluoroscopy Systems. *RadioGraphics* 2011; 31:591-602

N Hangiandreou, AAPM/RSNA Physics Tutorial for Residents: Topics in US. *RadioGraphics* 2003;23(4).

JL Gennisson, Ultrasound elastography: principles and techniques. *Diagn Interv Imaging* 2013; 94(5)

V Kapoor, et al., An introduction to PET-CT imaging. *RadioGraphics* 2004;24(2):523-43.

JN Morelli, et al., An Image-based Approach to Understanding the Physics of MR Artifacts. *RadioGraphics* 2011; 31:849-866.

F Mettler, et al., Effective doses in radiology and diagnostic nuclear medicine: a catalog. *Radiology* 2008;248(1):254-63.

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## Putting all of this together

- I recommend forming your own study guide based on the Part 3 topic list (which is very detailed) and the MOC reading list (which is pretty comprehensive)
- On the next few pages, I will list all of the detailed Part 3 topics and what references I think you need to know.
- My own personal ABR parts 2/3 study guide is formatted like this, but it includes explanations/figures/equations and is 100 pages long. Constructing that guide made studying structured and will serve as my reference for future MOC exams...if we actually will have them...
- I have bolded references I found particularly useful

#### Pixel wdith = 1/(2\*kmax) ¶



 $\Delta k = 1/FOV$   $\Delta w = 1/k_{FOV}$ 

Chemical-shift-artifact¶

- 1.→ Lamonfreq. of fat and water different by 3.5ppm (water is faster than fat, water "moves" towards higher B)¶
- 2.→ Lamor freq. is used to localize in space¶
- $\label{eq:software} 3. { \rightarrow } Software water get mapped to different locations even when they are in the same woxel \P$
- 4.→ As·B·goes·up, CSA·gets·worse as freq. separation increases¶
- $\label{eq:sector} \begin{array}{l} \text{5.} \rightarrow \text{If we increase} r\text{BW}, \text{we increase} \text{the range of freq. getting mapped to a given voxel location, so if we increase r\text{BW} higher than freq. separation between fat and water, we map fat and water to the same pixel! \P \end{array}$

6.→ happens in FEG direction¤

Diff. between fat and wateris:3.5 ppm, at:1.5 T what is diff in Hz?¶ 42.6 MHz/T\*1.5T\*3.5/1E6 =:

224Hz¶

ö

MR·QA¶

$$\label{eq:max-min} \begin{split} \mathsf{MRI}\cdot\mathsf{PIU} = & 100^*(1 - (\max-\min)/(\max-\min)) \\ \mathsf{Needstobe-greaterthan} & 87.5\% \cdot \mathsf{under} \cdot \mathsf{3T} \\ \end{split}$$





Min-ROI-left, max-ROI-right¶

To-set-ww/wl/for-measurements, set-level-to-where-water-is-"half-gone"-(<u>a.k.a</u>-mediansignal-value), then-set-window-to-equal-this-value.-¶ **Distance-measurements-must-be-w/I-2mm**¶



The spatial resolution holes are shown here, the black line in the middle shown the ramps used to measure slice thickness, the rectangle at ACR-quality-manualand-ACR-othersupportingdocuments×

- 6.→ Dopplergain → set as high as possible so long as noise is low¶
- 7.→ Color-flow-8-cycles-per-scan-line, spectral-flow-256-cycles-per-scan-line¶
- 8.→ Duplex-is-acquiring-Doppler-and-b-mode-at-thesame-time¶
- 9.→ Doppler angle should be 45-60 degrees (linear part of cosine curve)¶
- 10.+Usually,flow-towards-transducer-is-red¶
- 11.+Wall-filter-"eats"-bottom-of-spectral-waveform-(filters-out-low-(reg))-need-to-be-careful-not-to-setwall-filter-too-high-if-you-want-to-see-low-velocityflow¶
- 12.+Changing angle of insonation can reduce aliasing (make angle less head on to flow...)¶
- 13.+Color-priority-is-kind-of-like-www/wlof-color-overb-mode-image,-or-like-%-transparency-of-colorinformation-over-image-פ



changing-spectral-baseline-to-avoid-aliasing¶

#### Changing-wall-filter-values¶

¶.



#### Too-much-spectral gain-on-right¶





¶.

#### ACR for MRI and CT¶

- 1.→ Measure-max-and-min-luminance-(measure-onmonitors-brightness-setto-maximum,-also-do-whenmonitor-is-set-at-darkest-level)-(max-luminance-s,b,>-90-cd/m^2,-minimum-<-1.2-Cd/m^2¶
- 2.→ Measure-luminance-in-center-and-at-4-corners-¶
- 3.→ 0-5% pattern s.b. visible¶
- 4.→ 95-100 pattern s.b. visible¶
- 5.→ Each-step from 0%-100% s.b. visible¶
- $6. { \rightarrow } \mathsf{Borders} \mathsf{and} \mathsf{lines} \mathsf{on} \mathsf{SMPTE} \mathsf{should} \mathsf{be} \mathsf{straight} \P$
- $7. \rightarrow No \cdot distortion \cdot or \cdot m is a lignment \cdot using the girds \cdot across the screen \P$
- $8. { \rightarrow } Alphanum eric characters sharp \P}$
- 9.→ High-contrast-line-pairs-distinct-w/o-magnification¶
- 10.+No-streaking-around-white-and-black-rectangles×

This-should-be-less than-30%-for-CRT- and-15%-for-flatpanel

% difference = 
$$200 \times \frac{L_{max} - L_m}{L_{max} + L_m}$$

min·brightness<1.2·cd/cm^2¶ Max·brightness>·90·cd/cm^2¶ Check·response-curve·year-to-year-for-large-changes¤



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Radiation, dosimetry, protection, and safety	Radiation biology, radiation effects, and age/gender-specific risks; radiation protection principles, guidelines, and regulations; radiation dosimetry, detectors, standards, and units; radiation shielding design factors, barrier requirements, surveys, and reports; patient safety and error-prevention issues, including dose reduction, sentinel events, and MR- and US- specific safety issues

Торіс	Reference
X-ray production	"Bushberg" (first few chapters and chapter 6), Handbook of Medical Physics (chapter 1 by Boone)
Beam characteristics	"Bushberg" (first few chapters and chapter 6), Handbook of Medical Physics (chapter 1 by Boone)
Interactions	"Bushberg" (first few chapters), Handbook of Medical Physics (chapter 1 by Boone)
Image formation process	"Bushberg" (chapter 7)
Types of detectors	"Bushberg" (chapter 7, 8, 9) CMOS, CCD, Flat panel TFT (how are they read out), indirect vs. direct
Clinical protocols for common exams	NCRP 149 (for Mammo) Radiation Doses in interventional radiology procedures: The rad-IR study Journal of Vascular Interventional Radiology 2003 (good for knowing what high dose exams are and what the dose level are) Get real experience in the clinic (know what commonly is multiphasic in CT, know what views are typical for mammo, know what we do to image scoliosis, know the workflow for MRI brain scans, etc.)
Fluoroscopy and interventional	"Bushberg" (chapter 9), AAPM TG 125, The AAPM/RSNA Physics Tutorial for Residents: Fluoroscopy: Optical Coupling and the Video System
Acquisition parameters	AAPM TG 116 Report 116 An exposure Indicator for Digital Radiography
Dose reduction	"Bushberg" (many tables throughout listing the effect of changing acquisition parameters)
Image noise assessment	"Bushberg", Handbook of Medical Physics (read the chapters on linear systems analysis)
Dose metrics	"Bushberg" (see each modalities section, and see the section in this guide on radiation protection)
Artifacts	Computed Radiography Image Artifacts Revisited AJR:196, January 2011 Digital radiography: CR versus DR? Sometimes recognizing the distinction in technologies makes a difference by Chuck Willis Appl Radiol. January 16, 2008 Digital Mammographic Artifacts on full-field systems: what are they and how do I fix them? Radiographics 2008
QA/QC	AAPM Report #93 Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems from TG 10 Code of Federal Regulations Title 21 Section 1020.32 (fluoroscopic equipment)
Mammo accreditation/MQSA	ACR Mammo Quality Control Manual AND a couple modern systems QA/QC manuals know category a/b/c, ACR Accreditation Program Requirements

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MRI and ultrasound	localization, acquisition, and processing; ultrasound (US) principles, beam properties, acquisition methods, signal processing, and image display; Doppler US and color flow imaging principles and operation; common artifacts for MRI and US, siting requirements for MRI, quality assurance, and accreditation for MRI and US
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Торіс	Reference
System design/operation principle	"Bushberg" (chapters 10-11) "Computed Tomography" by Jiang Hsieh or "Computed Tomography" by Willi Kalender
Image acquisition protocols	"Bushberg" (chapter 10) "Computed Tomography" by Jiang Hsieh (chapter 12) "Computed Tomography" by Willi Kalender (chapter 2)
AEC/TCM/auto kV	<ul> <li>McCollough, Cynthia H., Michael R. Bruesewitz, and James M. Kofler Jr. "CT dose reduction and dose management tools: overview of available options 1." <i>Radiographics</i> 26.2 (2006): 503-512.</li> <li>Yu, Lifeng, et al. "Automatic selection of tube potential for radiation dose reduction in CT: a general strategy." <i>Medical physics</i> 37.1 (2010): 234-243.</li> <li>Boone, John M., et al. "Dose reduction in pediatric CT: A rational approach 1." <i>Radiology</i> 228.2 (2003): 352-360.</li> </ul>
Cone beam	All diagnostic CT today is conebeam dedicated CBCT is seen in Rad Onc OBI, Dental, interventional suites,think flat panel
Post processing	"Bushberg" (chapter 5) "Computed Tomography" Jiang Hsieh
Reformats (volume render and multiplanar)	"Bushberg" (chapter 5) "Computed Tomography" Jiang Hsieh (chapter 4)
Quantitative CT	"Bushberg" (chapter 10) and "Computed Tomography" by Willi Kalendar (chapter 1 figure 1.9)
Noise	"Bushberg" (chapter 10)
Dose metrics	"Bushberg" (chapter 11)
Effective dose	"Bushberg" (chapter 11) AAPM TG 220 and Report 204
Artifacts	"Computed Tomography" Jiang Hsieh (chapter 7)
QA/QC	AAPM Task Group Report 66 (it is for Rad Onc, but it is the best for diagnostic right now as well), TG 2 from 1993 also covers CT Testing
Accreditation	ACR Quality Control Manual 2012 AND FAQ manual

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MR equipment/operation	
Principles of magnetization/resonance/ex citation	"Bushberg" Know the figures plotting signal intensity vs. time for T! and T2 decay for all the major pulse sequences
MR Localization/ acquisition /processing	"Bushberg" Google "pulse sequence design made easier"
MR artifacts	"Bushberg" (chapter 13) ACR MR Phantom guidelines, An image based approach to understanding the physics of MR artifacts Radiographics 2011
MR accreditation	ACR Quality Manual, ACR phantom test guidance, Site scanning instructions for use of the MR Phantom for the ACR MRI Accreditation Program
MR shielding/sitting	AAPM Report 100 Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities
US principles (beam forming, processing)	"Bushberg" (chapter 14) Google US probes and know what all the different ones look like and why you would use them (convex, endocavity, linear, phased array, etc)
US image display	"Bushberg" (chapter 14 know what you are looking at on A/B/m mode, Doppler image, Doppler waveform all look like)
US Doppler/Color Flow	Optimizing Doppler and color flow US: Application to hepatic sonography Radiuographics 2004
US accreditation	"Bushberg" (chapter 14) Confusingmedical physicist not actually required. See the ACR technical spec on Doppler and Accreditation Manual
US artifacts	Feldman, Myra K., Sanjeev Katyal, and Margaret S. Blackwood. "US artifacts 1." <i>Radiographics</i> 29.4 (2009): 1179-1189. Pozniak, Myron A., James A. Zagzebski, and Kathleen A. Scanlan. "Spectral and color Doppler artifacts." <i>Radiographics</i> 12.1 (1992): 35-44. "Bushberg" (chapter 14)

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Торіс	Reference
Informatics infrastructure	General guidelines for purchasing and acceptance testing of PACS equipment Radiographics 2004
Standards	Google $ ightarrow$ Know DICOM, HL7, know dose structured reporting, (spend some time on www.dclunie.com)
Patient safety/security	Google $ ightarrow$ Know HIPAA, Know the Belmont report
PACS modality connectivity	"Bushberg" (chapter 5) Read a DICOM conformance statement with your IT staff and ask questions Digital Imaging and Communications in Medicine by Oleg Pianykh (probably overkill, but good reference, if you don't have it try www.dclunie.com)
Workflow/display/archive functions	"Bushberg" (Chapter 5)
Image display requirements	ACR–AAPM–SIIM TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING AAPM TG 18 Assessment of display performance for medical imaging systems Technological and Phychophysical Considerations for digital mammographic displays Radiographics 2005
Monitor calibration requirements	"Bushberg" (chapter 5) DICOM GDSF
Image processing	http://www.optics.rochester.edu/workgroups/cml/opt307/spr05/chris/
ROC analysis	"Bushberg" (chapter 5)
Imaging fundamentals/sampling theory	"Bushberg" (chapter 4), "Handbook of Medical Imaging" (chapter 2)

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Radiography, mammography, fluoroscopy, and interventional imaging	X-ray production, beam characteristics, interactions, and image-formation principles; types and characteristics of image detectors; clinical protocols for common imaging exams; fluoroscopy and interventional procedures, including acquisition parameters and dose- reduction strategies; image noise assessment and dose metrics for all projection imaging modalities; common artifacts, quality assurance, quality control, mammography accreditation, and MQSA standards
Computed tomography	CT system design and principles of operation; image- acquisition protocols, including helical acquisition and tube current modulation techniques; cone beam geometry; post-processing protocols, multi-planar and volumetric reconstruction; quantitative CT; image noise assessment, statistics, dose metrics (CTDI, DLP, SSDE), and effective dose estimation; common CT artifacts, quality assurance, and CT accreditation program
MRI and ultrasound	MR equipment, principles of magnetization, resonance, and excitation; MR pulse sequences, localization, acquisition, and processing; ultrasound (US) principles, beam properties, acquisition methods, signal processing, and image display; Doppler US and color flow imaging principles and operation; common artifacts for MRI and US, siting requirements for MRI, quality assurance, and accreditation for MRI and US
Informatics, image display, and image fundamentals	Informatics infrastructure, standards, and patient security; PACS-modality connectivity, workflow, display, and archive functions; image display requirements, characteristics, and calibration procedures; image processing techniques and qualitative data extraction; image fundamentals, sampling theory, and ROC analysis
Radiation, dosimetry, protection, and safety	Radiation biology, radiation effects, and age/gender-specific risks; radiation protection principles, guidelines, and regulations; radiation dosimetry, detectors, standards, and units; radiation shielding design factors, barrier requirements, surveys, and reports; patient safety and error-prevention issues, including dose reduction, sentinel events, and MR- and US- specific safety issues

Торіс	Reference
Radiation biology	"Bushberg" (chapter 20)
Radiation effects	"Bushberg" (chapter 20)
Age gender specific risks	"Bushberg" (chapter 20bigger for kidsfunction of cancer type)
Radiation protection principles	"Bushberg" (chapter 21) Radiation Management for interventions using fluoroscopic or computed tomography Journal of Interventional Radiology 2012
Guidelines and principles of radiation protection	NCRP Report No. 116 - Limitation of Exposure to Ionizing Radiation Balter, Stephen, et al. "Fluoroscopically Guided Interventional Procedures: A Review of Radiation Effects on Patients' Skin and Hair 1." <i>Radiology</i> 254.2 (2010): 326-341. NCRP 168 Radiation Dose Management for Fluoroscopically guided interventional medical procedures 2010 ACR-AAPM PRACTICE PARAMETER FOR DIAGNOSTIC REFERENCE LEVELS AND ACHIEVABLE DOSES IN MEDICAL X-RAY IMAGING
Dosimetry	Jones, A. Kyle, and Alexander S. Pasciak. "Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods." Journal of Applied Clinical Medical Physics 12.4 (2011). Landauer "Special Dose Calculations" worksheet Fetal Dose Calculations by Mark Rzeszotarski AAPM Review Course
Detectors	"Bushberg" (chapter 21) I recommend going to one of the vendors websites and reading the tech specs on all of their chambers covering solid state, ion chamber, etc. for all applications like shielding verification, CTDI, exposure, kV, etc.
Standard/units	Covered by other topics
Shielding	NCRP 147 Structural Shielding design for medical x-ray imaging facilities
Patient safety/error prevention	Covered by other topics
Sentinel event	1500 rads to a single field (defined by Joint Commission Bulletins)
MR safety	"Bushberg" (chapter 13) ACR Guidance Document on MR Safe Practices: 2013, Wikipedia article on NSF
US safety	"Bushberg" (chapter 14)

### After the exam

- I had a few issues with my exam which I emailed to the ABR
  - All related to monitor quality. There was an MR pulsatile flow artifact that was invisible to me until I bent down and viewed the monitor from a different angle...Not good. I urged them to make these artifacts higher contrast (artificially if needed). I got no response from them.
    - I do not advise arguing over test questions. If the question is bad, they will figure that out in their robust statistical analysis of the responses and throw it away.
- On August 17<sup>th</sup> (~10 days after the exam) I received an email from the ABR via survey monkey asking to complete an exit survey. Same day I emailed the ABR my monitor issues...so it could have been a coincidence or that could be their mechanism to facilitate collecting exam feedback

### Conclusion

- If you want a magic bullet for this test, study "The Essential Physics of Medical Imaging" by Bushberg, Seibert, Leidholdt, and Boone
- Part 2 should be viewed as a primer for Part 3