

Radiology Vertical Curriculum for Medical Students: Development, Implementation and Evaluation Strategy

A.J. Chandrasekhar

Introduction: The AAMC has recommended that medical schools develop a curriculum to teach topics that have been found to be deficient in their current curricula. Genetics, End of Life, Nutrition, Musculoskeletal System, Prevention and Screening and Radiology are the topics recommended by the AAMC to be incorporated in the Stritch School of Medicine curriculum. This communication provides the strategy we used in developing, implementing and evaluating the Radiology Curriculum for medical students.

Method of delivery of content: Time constraints do not permit implementation of a separate Radiology course. Wake Forest University School of Medicine has added a radiology clerkship, consisting of ten independent half-day teaching sessions, to the required clinical clerkships ⁽¹⁾. Our approach was to incorporate the radiology curriculum within the existing courses (basic science courses and clinical clerkships) across four-years, a vertical curriculum. Many schools have a similar integration of radiology curriculum extending across the four-year curriculum. Concepts of imaging and principles of radiology are introduced in the context of learning diseases and case management sessions. Thus, the teaching of radiology is shared by the radiology faculty and other clinical faculty.

Determining the curriculum: Our schools' Central Curricular Authority has established a committee for each vertical curriculum. The committees' intent was to develop curricular content and identify the courses where it could be best imparted. Radiology Curriculum for students was developed similar to the Alliance of Medical Student Educators in Radiology ⁽¹¹⁾. The committee tailored the curriculum to suit the needs of our courses while incorporating the newly established

competencies (knowledge, professionalism, communication, life long learning, clinical skills and social and community context). A Course Director established for the Radiology Vertical Curriculum, worked with each Course Director to integrate the content within their course. When necessary, new lectures were established. Content also had to be integrated with small group sessions.

Implementation: Implementation of the Radiology Vertical Curriculum began in July, 2006. Table 1 shows the curricular objectives for courses and the methods used to accomplish these objectives. Twenty six lectures on the topic of radiology will be given over a four-year period throughout various courses. In the initial phase, selection of lecture topics was left up to the Directors. We are now in the process of determining the appropriateness of topics in order to cover the objectives set for the course. Radiological images are included in case studies presented to students in small group sessions.

Self-study (E-Learning): A website for e-learning was established. It provides resources for students and faculty. The site provides course based radiology content and objectives, including self-study material. All lectures related to the radiology curriculum are listed and many PowerPoint presentations are accessible. This is a self-study supplement to material presented in lectures and small groups. The address is:

http://www.meddean.luc.edu/lumen/MedEd/Radio/curriculum/radiology-curric1_f.htm

Evaluations: The vertical curriculum creates difficulty in evaluating the effectiveness of the course and assessing student performance specific to the radiology course ⁽ⁱⁱⁱ⁾. Content is delivered in thirteen different courses over a four-year period. We had to develop a different strategy to evaluate the course and students. We have developed electronic applications to create a calendar for teaching events, to collect course evaluations and to administer on-line

examinations. Keywords are tagged for radiology lectures, questions and evaluation questions. We are then able to extract radiology specific lectures from the calendar, student performances from on-line examinations, and radiology specific evaluations from clerkship evaluations over the entire four-year vertical curriculum.

Method of evaluating students: A comprehensive radiology examination is ready to be implemented at the end of the students' third year. However, scheduling is difficult since students are in various locations and clerkships. Third year examinations for other vertical courses add to the complexity of scheduling. An alternate method had to be developed to evaluate students' knowledge in radiology. Our school has implemented an on-line examination for all courses and most clerkships. Three clerkships use shelf examinations and could not be included for evaluation. The online examinations provided a way to test and evaluate students' radiology knowledge. Radiology faculty submitted 3-4 questions, per lecture, for inclusion in each course examination. Each question is tagged with radiology keywords. One hundred and four questions have been tagged to the Radiology Curriculum. As each question is tagged as belonging to one of the vertical courses, it is possible to track a student's performance in a vertical course. We plan to generate a report (Table 2) for each student at the end of their third year. If a student doesn't obtain a satisfactory aggregate score, they will be required to take a Radiology elective in their fourth year to acquire the necessary competency. Reports can be generated at the end of 2009, once the current freshman have finished three years of school and completed their required courses.

Method of evaluating Radiology course: We plan to evaluate each course to ensure that the radiology objectives are being fulfilled.

1. **Student performance in on-line examinations:** An electronic report will show the aggregate student performance for each question pertinent to a vertical course (Table 3). This report will provide the Course Director with specific data needed to evaluate each question with alteration, as necessary. If a significant number of students answer a given question incorrectly, this can be a guide to improving the curriculum.
2. **Student perspective:** Students complete clerkship evaluations on-line. We collect institutional objectives, course specific objectives and faculty evaluations for each course. The clerkship evaluation form includes radiology specific objectives, unique to that clerkship. Students are asked to self assess whether they acquired the desired radiology skills (Table IV). The report reflects half of the academic year and provides student perspective regarding accomplishment of radiology specific objectives. This information is used to determine if changes to the clerkship are deemed necessary.

Conclusion:

We have developed a Radiology Curriculum for medical students and integrated with each course across four-years. Teaching the Radiology Curriculum is shared by both radiology and clinical faculty. We have devised a method to electronically provide specific data that can be used to evaluate student performance for the Vertical Radiology Course. A list of all lectures and other events related to the Radiology Course are extracted from all courses. From the student performance, we can evaluate whether a clerkship is meeting the desired objectives for the Radiology Vertical Course. This electronic method also provides a way to collect student perception in regards to achieving Radiology objectives. These evaluations are necessary to provide data to improve the course, and assure acquisition of radiology knowledge by each student. We are at midpoint of the first academic year of implementation of the curriculum. We

now have the tools to evaluate the curriculum, method of delivery, student performance and clerkship performance in meeting the teaching objectives for the Radiology Curriculum.

Attached Tables

Table 1: Course Based Radiology Curriculum Implementation

Table 2: Student Performance in Radiology Questions

Table 3: Structure Course Radiology Exam Results

Table 4: Radiology Exposure Evaluation by Students

References

1. Chew, F. and Relyea-Chew, A. Distributed Web-Supported Radiology Clerkship for the Required Clinical Clerkship Year of Medical School: Development, Implementation and Evaluation. *Acad Radiol* 2002; 9(6):713-20.
2. Shaffer, K. and Lewis, P., Editors. National Medical Student Curriculum in Radiology. Alliance of Medical Student Educators in Radiology.
http://www.aur.org/amser/AMSER_national_curriculum.html.
3. Lowitt, N. Assessment of Integrated Curriculum in Radiology. *Acad Med* 2002; 77(9):933.

Table 1. Course Based Radiology Curriculum Implementation

Course Objectives	Implementation
<p>Structure of Human Body</p> <ol style="list-style-type: none"> 1. Principles of radiology and radiation 2. Normal anatomy <ol style="list-style-type: none"> a. Plain films <ul style="list-style-type: none"> ▪ chest x-ray ▪ 4 views abdomen ▪ spine ▪ long bones of <ul style="list-style-type: none"> • adults • children ▪ IVP ▪ BE ▪ UGI b. CT <ul style="list-style-type: none"> ▪ chest ▪ pelvis ▪ abdomen 3. Angiograms <ol style="list-style-type: none"> a. Great vessels and other vasculature 	<p>Lectures</p> <ol style="list-style-type: none"> 1. Introduction to Radiology 2. Radiology of Back and Upper Limb 3. Radiology of Head and Neck:1 4. Radiology of Head and Neck:2 5. Radiology of Thorax 6. Radiology of Abdomen 7. Radiology of Pelvis 8. Radiology of Lower Extremity 9. Cross-Section Case Wrap-up <p>Self-study / E-learning</p> <ol style="list-style-type: none"> 1. Cross-Sectional Anatomy Visible Human Project 2. Radiology Curriculum Site <p>Evaluation</p> <p>Examinations contain 27 radiology questions.</p>

<p>Mechanisms of Human Disease</p> <p>Recognize the following abnormalities on</p> <ol style="list-style-type: none"> 1. Chest x-ray <ol style="list-style-type: none"> a. Pleural effusion b. CHF c. Pneumonia d. Lobe location e. COPD f. Atelectasis g. Pulmonary nodule 2. CT chest <ol style="list-style-type: none"> a. Pulmonary nodule 3. CT abdomen/pelvis <ol style="list-style-type: none"> a. Diverticular disease b. Appendicitis c. Bowel obstruction d. Abdominal aortic aneurysm e. Pancreatitis f. Intra-abdominal abscess g. Hepatic mass h. Renal mass i. Pancreatic mass 	<p>Lectures</p> <p>Most lectures covering clinical topics show radiological images.</p> <ol style="list-style-type: none"> 1. CXR Clinicopathological Correlation 2. Radiology and Oncology <p>Path Lab Sessions (17)</p> <p>Radiological images are included with presentation.</p> <p>Small Group Sessions (30 sessions)</p> <p>Radiological images are presented when appropriate.</p> <p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p> <p>Evaluation</p> <p>Fourteen questions to cover the principles of radiology, including images.</p>
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<p>Neuroscience</p> <ol style="list-style-type: none"> 1. Utility of MRI versus CT for head imaging 2. Utility of MRI versus CT for spine imaging 3. Normal anatomy on <ol style="list-style-type: none"> a. CT Head b. CT Spine c. MRI head d. MRI spine 4. Recognize the following abnormalities on <ol style="list-style-type: none"> a. CT head <ul style="list-style-type: none"> • hemorrhage • subarachnoid • subdural • parenchymal • infarcts • edema • mass effect • hydrocephalus b. CT spine <ul style="list-style-type: none"> • metastatic disease • DJD • disc disease c. MRI head/spine <ul style="list-style-type: none"> • CNS infection • masses • infarcts • multiple sclerosis • disc disease • metastatic disease • cord compression 	<p>Lectures</p> <p>Most clinically oriented lectures have radiological images.</p> <ol style="list-style-type: none"> 1. Brain imaging (1) 2. Brain imaging (2) <p>Self-study / E-learning</p> <ol style="list-style-type: none"> 1. Neuroblast 2. Neurovascular Tutorial 3. Lab MRI Scans 4. Cross-sectional Tutorial 5. Radiology Curriculum <p>Evaluation</p> <p>Nine test questions to cover the brain imaging lectures.</p>
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<p>Patient Centered Medicine II</p> <ol style="list-style-type: none"> 1. Demonstrate a systematic approach to interpretation of CXR and abdominal radiographs. 2. Correlate radiographic findings on CXR, chest CT, and abdominal CT with normal anatomy. 3. Describe the physical exam findings that correlate with the radiographic findings of: consolidation, pleural effusion, congestive heart failure, pulmonary edema, pneumothorax, pulmonary masses and intestinal obstruction. 	<p>Lectures</p> <ol style="list-style-type: none"> 1. Chest and Abdominal Radiography 2. Introduction to Abdominal CT and Body <p>Small Group Sessions (2)</p> <p>Students are expected to review films prior to session, commit to a diagnosis, and come prepared to discuss the films with the facilitator.</p> <ol style="list-style-type: none"> 1. Session 1 2. Session 2 <p>Self-study / E-learning</p> <p style="text-align: center;">Radiology Curriculum Site</p> <p>Evaluation:</p> <p>Exam consists of ten questions with radiological images.</p>
<p>Introduction to Third and Fourth Years</p> <ol style="list-style-type: none"> 1. Role of Radiologist as specialist and consultant 2. Basic concepts of risk management, malpractice, confidentiality, as they relate to radiology 3. Contrast allergy 4. Differences, utility and use of CT versus MRI 5. General principles of ultrasound including doppler flow 6. General principles of nuclear medicine 7. General principles of angiography including indications, utility and diagnostic/therapeutic use 8. Selection and use of information technology in radiology, including PACS 	<p>Lectures</p> <ol style="list-style-type: none"> 1. Radiology Introduction to Clerkships: Chest 2. Imaging 5.0: Our Newest Operating System 3. Radiology Review 4. Radiology Basics <p>Introduction to IV Year Lecture</p> <ol style="list-style-type: none"> 1. Nuclear and Radiation Exposure

<p>Patient Centered Medicine III</p> <p>Utility of radiology for investigation of abnormal physical findings</p> <ol style="list-style-type: none"> 1. Ascites 2. Abnormal heart sounds 3. Prostate nodules 4. Bruits 5. Aneurysms 6. Testicular masses 7. Thyroid nodules 8. Hepatic/splenomegaly 	<p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p>
<p>Medicine Clerkship</p> <ol style="list-style-type: none"> 1. Chest x-ray <ol style="list-style-type: none"> a. Normal anatomy b. Pleural effusion c. Pneumonia d. Lobe location e. CHF f. COPD g. Atelectasis h. Pulmonary nodules 2. CT chest <ol style="list-style-type: none"> a. Normal anatomy b. Nodules/masses 3. Indications and limitations of echocardiograms – including <ol style="list-style-type: none"> a. Transthoracic versus transesophageal b. Chamber size c. Valve disease d. Pericardial effusions 4. Mechanisms, indications and limitations of certain nuclear medicine tests <ol style="list-style-type: none"> a. IDA scan b. Bone scan c. Tagged RBC scan d. Myocardial perfusion and function scans e. Bone densitometry scan f. V/Q scan 5. Utility of radiology in the work-up of <ol style="list-style-type: none"> a. Cardiac ischemia b. Common cancers c. GI bleeding d. Pulmonary emboli 	<p>Lectures</p> <ol style="list-style-type: none"> 1. Genitourinary Radiology 2. Radiology of Chest and Liver 3. Cardiac Radiology 4. Musculoskeletal Radiology <p>Small Group Case Discussions (23)</p> <p>Most sessions discuss imaging aspects of the case.</p> <p>Ward Rounds and Patient Management Sessions</p> <p>Most patient management involves imaging studies.</p> <p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p> <p>Evaluation</p> <p>Exam consists of ten questions with radiological images.</p>

<p>Surgery Clerkship</p> <ol style="list-style-type: none"> 1. 4-view abdomen <ol style="list-style-type: none"> a. Normal anatomy 2. CT abdomen/pelvis <ol style="list-style-type: none"> a. Normal anatomy b. Diverticular disease c. Appendicitis d. Bowel obstruction e. Abdominal aorta aneurysm f. Pancreatitis g. Intra-abdominal abscess h. Ascites i. Hepatic mass j. Pancreatic mass k. Renal mass 3. 4-views abdomen <ol style="list-style-type: none"> a. Ileus b. Small bowel obstruction c. Large bowel obstruction d. Free air e. Calcifications (including aneurysm) 4. Bone x-rays <ol style="list-style-type: none"> a. Fracture b. DJD c. Osteoporosis (with vertebral collapse) d. Primary and secondary bone tumors 5. Utility of vascular doppler ultrasound for <ol style="list-style-type: none"> a. Aneurysm b. DVT c. Carotid artery disease d. Peripheral vascular disease 6. Utility of ultrasound for <ol style="list-style-type: none"> a. Bile duct obstruction b. Liver imaging c. Kidney cysts d. Kidney tumors e. Prostate evaluation f. Blunt trauma 7. Basics of normal and abnormal mammography 8. Utility of radiology in the work-up of <ol style="list-style-type: none"> a. Acute abdomen b. Bone/joint pain c. Hematuria and flank pain d. Aortic aneurysms e. Suspected aortic dissections f. Trauma 	<p>Small Group Sessions (30)</p> <p>Case management discussions include imaging principles.</p> <p>Ward Rounds and Patient Management</p> <p>Includes review of radiological images</p> <p>Weekly Radiology Conference by the Course Director</p> <p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p> <p>Evaluation</p> <p>Examination to include 16 clinical questions which incorporates imaging principles.</p>
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<p>Pediatric Clerkship</p> <ol style="list-style-type: none"> 1. Recognize on chest x-ray <ol style="list-style-type: none"> a. Pneumothorax b. Hyaline membrane disease 2. Utility of radiology in the work-up of suspected child abuse 	<p>Imaging studies are discussed in the lecture series.</p> <p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p>
<p>Family Medicine Clerkship</p> <ol style="list-style-type: none"> 1. Utility of radiology in the work-up of <ol style="list-style-type: none"> a. Neck pain b. Back pain 2. Preventive medicine <ol style="list-style-type: none"> a. Spinal CT for lung nodules b. Bone densitometry scans for osteoporosis c. Screening mammograms for breast cancer d. Prostate ultrasounds for elevated PSA e. Cancer screening f. Coronary artery disease screenings 	<p>During Ward Rounds and Clinic Encounters</p> <p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p> <p>Evaluations</p> <p>Final shelf examination includes 5-10 questions.</p>
<p>OB/GYNE Clerkship</p> <ol style="list-style-type: none"> 1. Indications and limitations of ultrasound for <ol style="list-style-type: none"> a. Molar pregnancy b. Anencephalic pregnancy c. Placenta previa d. Fetal age e. Ectopic pregnancy 2. Utility of radiology in the work-up of <ol style="list-style-type: none"> a. Normal b. Abnormal pregnancy 	<p>Ward Rounds and Clinic Encounters</p> <p>Small Group Sessions (19)</p> <p>Problem Based Learning Sessions include Imaging Aspects.</p> <p>Self-study / E-learning</p> <p>Radiology Curriculum Site</p> <p>Evaluation</p> <p>Final shelf exam includes radiology questions.</p>

<p>Neurology Clerkship</p> <ol style="list-style-type: none"> 1. CT head <ol style="list-style-type: none"> a. Normal anatomy b. Hemorrhage c. Infarct d. Edema e. Mass effect f. Hydrocephalus 2. CT spine <ol style="list-style-type: none"> a. Metastatic disease b. DJD c. Disc disease 3. MRI head/spine <ol style="list-style-type: none"> a. Normal anatomy b. CNS infection c. Masses d. Infarcts e. Multiple sclerosis f. Miscellaneous disease g. Metastatic disease 4. Utility of radiology in the work-up of <ol style="list-style-type: none"> a. Cord compression b. Seizures c. Cerebrovascular accidents d. Headaches e. Focal neurological findings f. Mental status changes g. Head trauma 	<p>During Patient Rounds, Clinic Encounters and Conferences</p> <p>Lectures</p> <ol style="list-style-type: none"> 1. Neurological emergencies 2. Neurodiagnostic testing <p>Self-study / E-learning</p> <ol style="list-style-type: none"> 1. Practical Neurology Cases DVD Review 2. Radiology Curriculum Site <p>Evaluation</p> <p>Final exam consists of thirteen questions with images.</p>
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Table 2. Student Performance in Radiology Questions

Radiology Knowledge Competency Report
John Doe
Class of 2010

Responses to radiology questions from on-line exams

Course Name	Year	Correct	# of Questions	% Correct
SHB	Freshman	20	27	74%
Neuroscience	Sophomore	7	9	78%
MHD 1	Sophomore	3	4	75%
MHD 2	Sophomore	7	10	70%
PCM 2	Sophomore	6	10	60%
Medicine	Junior	6	10	60%
Surgery	Junior	12	16	75%
Neurology	Senior	9	13	69%
ICU	Senior	2	3	66%
Pediatrics	Junior			
OBGyn	Junior			
Family Med	Junior			
Total		72	102	71%

Family Medicine, Obstetrics/Gynecology and Pediatric clerkships administer shelf examinations. Hence, those numbers could not be included in this report.

This is a **hypothetical report** of a freshman student in the Class of 2010, after completing the required clerkship in his 4th year.

Table 3. Structure of Human Body (SHB) Radiology Exam Results

Responses to radiology questions from on-line exams
Academic Year 2007, Freshman Class of 2010

Exam Number	Q Dbase Number	Difficulty Factor	Discrimination Factor
Exam 1	182	0.70	0.46
	1259	0.81	0.34
	4474	0.83	0.34
	4962	0.73	0.54
	8239	0.51	0.32
	8241	0.72	0.17
	8242	0.70	0.29
	8267	0.96	0.17
	8269	0.62	0.32
	8267	0.96	0.17
Exam 2	5001	0.68	0.38
	8258	0.54	0.36
	8264	1.0	0.02
	8265	0.71	0.41
	8345	0.63	0.38
	8348	0.48	0.35
	8349	0.24	0.27
	8355	0.89	0.05
Exam 3	236	0.62	0.23
	5049	0.98	0.21
	5050	0.91	0.28
	8711	0.88	0.30
	8712	0.87	0.44
	8713	0.98	0.19
	8714	0.85	0.35
	8719	0.80	0.51
	8721	0.96	0.23
	8722	0.58	0.56
<ul style="list-style-type: none"> ▪ Difficulty Factor: the proportion of respondents selecting the right answer to that question. ▪ Discrimination Factor: measures the extent to which item responses can discriminate between individuals who attain a high score and those who attain a low score. ▪ Question Number: Click on the number to view the question in on-line reports. 			

Twenty-seven questions in the SHB course were concerning radiology. Judging from the difficulty factor, the class performed extremely well in reference to those questions. Individual student performance can also be generated.

**Table 4. Radiology specific Objectives Evaluation by Students
Mid-point of Academic year
(07/01/2006 - 12/31/2006)**

Student's self evaluation of Radiology specific objectives in clerkships

	(1)=Strongly Disagree/Poor	(2)=	(3)=	(4)=	(5)=Strongly Agree/Excellent		
Clerkship	Specific Objective				Average Evaluation	One STD	Number of Students
Medicine	I learned to interpret ancillary tests (lab, radiology, cardio graphics, etc.).				4.5	0.6	33
	I learned to recognize common problems in CXR.				4.2	1.1	
	I understand the basic principles involved in nuclear medicine studies (V/Q scan, myoview etc).				3.6	1.0	
	I learned the use of echocardiograms.				4.2	1.0	
Family Medicine	I learned to interpret ancillary tests.				3.9	1.1	49
	I learned preventive screening strategy for breast cancer.				4.5	0.7	
	I learned preventive screening strategy for osteoporosis.				4.0	1.1	
Neurology	I enhanced my knowledge in the basic interpretation of CT and MRI scans.				4.3	0.8	51
ObGYN	I learned to interpret ancillary tests.				4.2	1.0	52
	I learned to recognize an abnormal fetal heart rate tracing.				4.7	0.6	
	I learned to diagnose pregnancy including ectopic pregnancy.				4.4	0.9	
	I learned to properly use relevant screening tests (pap, mammography, and colonoscopy).				4.6	0.6	
	I learned how to diagnose an ovarian mass.				3.9	1.1	
	I understand the use of ultrasound for evaluation of pregnancy and pelvic problems.				4.6	0.6	
Pediatrics	I learned to interpret ancillary tests.				3.9	1.1	55
	I can evaluate a child suspected to be abused with proper imaging studies.				4.0	1.1	
ICU	I learned to interpret ancillary tests.				4.7	0.5	46
	I learned to evaluate proper placement of tubes, lines, etc., on imaging studies.				4.4	0.8	
Subintern	I learned to interpret ancillary tests.				4.4	0.8	41
Surgery	I learned to interpret ancillary tests .				4.4	0.8	41