Resident Core Curriculum
Neuroradiology

General Goals: The goals include objectives required for every level of training with graduated levels of supervision and responsibility. All aspects of neuroradiology are incorporated into the residency, including five clinical rotations through CT, MRI, and myelography during the four year residency program. During every training rotation, the resident is expected to read the required literature and study the teaching files in neuroradiology. Over time, the resident will become progressively more knowledgeable about normal radiographic neuroanatomy, physiology of the neurological systems, and the radiological appearances of neurological diseases. In addition, the resident will demonstrate a progressively increasingly understanding of disease entities, their clinical presentations, and current modes of treatment. At the end of rotations, the resident will demonstrate knowledge and interpretive skills, technical skills, decision-making skills and judgment as outlined for each rotation. Reading assignments will be designated for each rotation to provide a comprehensive survey of neuroradiology. The progress of the resident will be evaluated at the end of each clinical rotation.

Resident Daily Work Responsibilities (OVERALL BENCHMARKS/OBJECTIVES for Self-Evaluation)

1. Residents assigned to neuroradiology are expected to be available for consultations by technologists, clinicians, and other health care providers, except during conference times, when the attending faculty will cover.
2. Resident questions will be referred to the supervising faculty and fellows covering neuroradiology.
3. Resident review of cases with the supervising faculty will be conducted as many times in the day as necessary to keep an efficient workflow.
4. All resident examinations will be dictated by the end of every working day.
5. Residents will check and sign each report prior to final verification by supervising faculty.
6. Residents must be familiar with the operation of all neuroradiological equipment including, but not limited to, processing workstation for advanced neuroradiology imaging techniques.
7. Residents must acquire knowledge of radiation protection and ways to reduce radiation exposure to both patients and hospital personnel. The resident will be supervised to assure that safe practices are followed.
8. Residents will learn the techniques for performing high quality, state-of-the art diagnostic examinations of the brain, face, neck and spine. Examinations will be checked before the patient leaves the department if requested to do so by the supervising faculty.
9. Residents must become proficient at detecting abnormalities demonstrated by plain films, CT and MRI examinations as well as be able to generate meaningful differential diagnosis.
10. Residents will become knowledgeable about the use of different radiographic contrast agents (including their indications, contraindications, dosages, and side effects).
11. Residents will acquire an understanding of the proper preparation of patients for examinations and appropriate follow-up afterward. At the start of every working day, the resident will be familiar with the patient schedule and anticipate need for protocoling. The resident will check requisitions to evaluate for appropriateness of the requested study or if additional

exams/protocols need to be performed. Absent clinical indication or seemingly inappropriate requests will be clarified and discussed with the referring physician.

12. Residents will do in-depth reading and study, along with a review of teaching file cases, to become knowledgeable about the normal anatomy and physiology of the neurological system and the radiologic appearances of neurological diseases, and gain a general understanding of the disease entities, their clinical presentations, and certain modes of treatment.
13. Residents will serve as a secondary consultant to referring physicians regarding neuroradiology. This will strengthen the confidence of the resident in the very important role every radiologist must perform throughout his/her career as a consultant to clinicians.
14. Residents will become prepared to pass the certifying examination of the American Board of Radiology.
15. Residents will teach and share knowledge to medical students, radiologic technologist students, and junior residents.
16. Residents will participate in the preparation and presentation of imaging studies at the weekly Interesting Case Conference.

Faculty:
Diagnostic Neuroradiology attendings are: Dr. David Abdullah, Dr. Joseph Donahue, Dr. Jason Druzgal, Dr. Julie Matsumoto, Dr. Sugoto Mukherjee (Division Chief), Dr. Sohil Patel.

Interventional Neuroradiology attendings are: Dr. Avery Evans, Dr. Lee Jensen, and Dr. Kenneth Liu.

Supervising Faculty Responsibilities:

1. Supervising faculty will be available at all times for any questions or consultations needed by the resident.
2. Supervising faculty will review all cases with the residents before the end of the day.
3. Supervising faculty will provide the resident with constructive feedback in any problem areas encountered during the rotation.
4. Supervising faculty will verify resident-generated reports in a timely manner and inform the resident of any major changes made.

General Rotation Organization:

There will be at least 3 residents on rotation in diagnostic neuroradiology at any time point:

- 1 myelography resident (shift: 8:00am until the last myelogram is completed, but at least 5:00pm)
- 1 late neuro resident with hours from (10:00am – 7:00pm, who will interpret CT and MR examinations that will assigned based on level of experience
- 1 resident from 8:00-5:00 who will interpret CT and MR examinations that will assigned based on level of experience

The two swing shift residents will cover ED and inpatient Neuro studies from 5:00pm – 8:00pm and will check out studies done from 5:00pm – 7:00pm with the late neuro attending. During even numbered months, the lower level swing shift resident will be assigned to the neuro division between 10:00am – 5:00pm. Studies read by the lower level swing shift resident at all times of the year after 7:00pm till the end of their shift will be transferred to the queue of the 1404 resident and will be checked out by the latter the next day with the early attending.

Schedule Expectations and Vacations:

1. All residents are expected to show up ON TIME at the beginning of their shift. If they foresee that they are going to be late, for whatever reason, they have to call the early attending to explain the reason of their being late.

2. Also, the residents cannot leave the reading-room before the official end of their shift without the permission of the late attending. All resident examinations must be dictated by the end of every working day.

3. Among the residents rotating through neuroradiology, there can be only one resident on vacation at a given time based on the residency program vacation policy.

Distribution of the Work:

1. The myelography rotation always comes first. (Please refer to Appendix – Myelography Manual) If the myelography resident is absent, then another advanced resident on rotation in neuroradiology is pulled to perform the myelograms.
2. The first-year resident is reading simple cases and has a slightly lower workload compared to the more advanced residents (see Appendix 1, including categorization of the studies according to their degree of difficulty).

3. The other residents and the neuroradiology fellows share the remaining cases; both in terms of numbers and degree of difficulty (see Appendix 1, including categorization of the studies according to their degree of difficulty).

4. Forth-year residents will have an opportunity of doing "focused time" in neuroradiology. If there are 5 residents in the reading-room, the "focused time" resident will have a dedicated curriculum. If there are less than 5 residents in the reading-room, the "focused time" resident will work similarly to the other residents in the reading-room. The “focused time” resident will not be assigned to cover the myelography service.
   Focus time is requested per the residency program policy.

Educational Goals and Objectives (First Year Resident):

This initial rotation is intended to prepare the resident for on-call responsibilities which will involve emergency CT scans of the brain, face, and spine.

Patient Care:

PC1: Reporting; **PC2:**Clinical Consulting; **PC3:**Image Interpretation; **PC4**:Competence in procedures

- Demonstrate knowledge of the ACR practice guidelines and technical standards for diagnostic neuroradiology
- Familiarity with the operation of CT equipment
- Supervise conscious sedation of patients for CT studies
- Develop a knowledge of the preparation and aftercare required for the common examinations
- Observe and learn the techniques to achieve high-quality diagnostic examinations

Medical Knowledge
MK1: Diagnostic Knowledge; **MK2:**Physics; **MK3:**Protocol selection and contrast agent selecting/dosing; **MK3**:Imaging technology and Image acquisition

- Demonstrate the ability to recommend additional imaging studies as appropriate to better assess findings on abdominal imaging studies
- Understand CT imaging protocols and the appropriate design of studies for addressing clinical questions
- Supervise, interpret, consult, screen, and protocol routine neuro CT studies daily and in a timely manner. Contact referring physicians when questions exist concerning these studies
- Explain the impact of the radiology findings on patient care, including what imaging studies may/may not be appropriate
- Learn the basic principles of CT physics and their application to neuroimaging
- Become proficient in on-call responsibilities for emergency CT scans of the brain, face, neck, and spine
- Understand normal CT anatomy of the brain, skull base, face, neck and spine
- Develop a knowledge of normal and abnormal anatomy of the brain, skull base, face, neck and spine as demonstrated on radiographic plain films and CT contrast studies
- Recognize basic neuropathology and develop a knowledge of the differential diagnoses of the more commonly encountered abnormalities
- Demonstrate the ability to recognize and describe common medical conditions depicted on CT imaging studies

Systems-based Practice
SBP1: Patient Safety; **SBP2:** Quality Improvement; **SBP3**: System navigation for patient-centered care; **SBP4:** Physician role in health care systems; **SBP5:** Contrast agent safety; **SBP6**: Radiation Safety; **SBP7:** Magnetic resonance (MR) safety; **SBP8:** Informatics

- Demonstrate knowledge of the ACR practice guidelines and technical standards for CT imaging studies
- Attend weekly division quality and safety conference
- Able and willing to participate in clinical conferences in which imaging studies are used to guide patient care/evaluations and be able to demonstrate understanding of how imaging relates to the clinical care of the patient
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging evaluation of common disorders

- Show ability to interact with clinicians regarding cost effective and streamlined evaluation for differing clinical entities

Practice-based Learning and Improvement
PBLI1: Evidence-based and informed practice; **PBLI2:** Reflective practice and commitment to professional growth

- Aware of the basic principles of radiation protection in order to reduce as much as possible the radiation dose to the patient and reduce exposure to healthcare providers
- Understand the indications for and contraindications to use of intravenous radiographic contrast, and be able to monitor its administration
- Recognize and treat reactions to intravenous contrast
- Understand the indications and contraindications to the different types of contrast, dosages, side effects, and the differences and relative merits of single and double contrast studies
- Become knowledgeable about the different contrast agents available and begin to recognize abnormalities that are demonstrated on abdominal plain radiographs and CT studies
- List the risk factors for allergic reaction to intravascular contrast media
- State the proper assessment and treatment for allergic reactions to contrast media
- Show evidence of independent study using textbooks from reading list
- Demonstrate appropriate follow up of interesting cases
- Research interesting cases as directed by faculty
- Identify, rectify, and learn from personal errors
- Incorporate feedback into improved performance
- Efficiently use electronic and print sources to access information

Professionalism
P1: Professional behavior and ethical principles; **P2:** Accountability/Conscientiousness; **P3:** Self-awareness and help seeking

- Demonstrate respect for patients, families, and all members of the healthcare team and be able to discuss significant radiology findings
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic with regard to work assignments

Interpersonal and Communication skills
ICS1: Patient and family-centered communication; **ICS2:** Interpersonal and team communication, **ICS3:** Communication within health care systems

- Adequately explain each examination to the patient in order to ensure that the patient feels comfortable and to provide patient care that is compassionate, appropriate, and effective
- Communicate with the patient at all times during the examination to ensure that patient remains comfortable

- Use the PACS, voice recognition systems, and hospital information systems to become proficient in dictating reports of significant radiographic and CT findings in a concise, timely, and clear manner; dictate studies after review with an attending neuroradiologist
- Communicate effectively with all members of the health care team (technologists, medical students, fellows, residents, allied health providers, support staff, and attending physicians/radiologists)
- Call results to the referring physicians and show ability to interact with referring physicians
- Interact with clinicians when reviewing cases involving radiographs and CT imaging studies and show ability to provide preliminary readings, follow up with attending radiologists, formulate a plan of complex cases, and communicate any changes to referring clinicians

Monitoring and Assessment of Resident Performance:

The resident's progress will be monitored by the faculty on the service. At the end of each rotation, the resident will receive a consensus evaluation of performance from faculty on service. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as determined by the program.

Educational Goals and Objectives (Second Rotation):

This second rotation is intended to increase the knowledge base and clinical skills of the resident and to assure competency for supervision and interpretation of emergency studies of the head and neck.

The objectives are as above as well as the following:

Patient Care:
PC1: Reporting; **PC2:**Clinical Consulting; **PC3:**Image Interpretation; **PC4**:Competence in procedures

- Demonstrate knowledge of the ACR practice guidelines and technical standards for diagnostic neuroradiology
- Familiarity with available medical records and how to access them for the purposes of patient care
- Obtain consent for more complex procedures and answer all questions the patient may have
- Supervise conscious sedation of patients for CT studies
- Develop a knowledge of the preparation and aftercare required for more complex procedures
- Continue to improve skills for performing CT and MRI examinations, and tailor examinations to answer all questions being asked by the clinician; anticipate those questions that should have been asked but were not

Medical Knowledge
MK1: Diagnostic Knowledge; **MK2:**Physics; **MK3:**Protocol selection and contrast agent selecting/dosing; **MK3**:Imaging technology and Image acquisition

- Understand the physics of radiation protection and how to apply it to routine studies
- Protocol cases, in consultation with the attending, to assure that the CT examination is appropriate and of sufficient quality to address the clinical concerns of the patient and referring physician
- Assume more responsibility for screening and protocoling neuro CT and MRI studies. Contact referring physicians when questions exist concerning these studies.
- Recommend the appropriate study based on the clinical scenario and understand the relative strengths of each modality
- Develop the knowledge base and clinical skills to assure competency for supervision and interpretation of emergency studies of the head and neck
- Familiarity with the anatomy of the organs examined in every case
- Familiarity with imaging findings of common acute and chronic neurological diseases evaluated with CT and MRI
- Identify neuropathology in order to interpret CT and MRI studies with accuracy appropriateness to the level of training when presenting to the attending
- Distinguish between normal and abnormal CT and MRI anatomy of the head, neck, and temporal bone to level of training when presenting to the attending
- Demonstrate increased ability to identify and evaluate basic neuropathology and to develop meaningful differential diagnoses
- Utilize workstation to create multiplanar and three dimensional reconstructions of spine and vascular CT and MRI studies
- Review all studies with the supervisor faculty attending

Systems-based Practice
SBP1: Patient Safety; **SBP2:** Quality Improvement; **SBP3**: System navigation for patient-centered care; **SBP4:** Physician role in health care systems; **SBP5:** Contrast agent safety; **SBP6**: Radiation Safety; **SBP7:** Magnetic resonance (MR) safety; **SBP8:** Informatics

- Demonstrate knowledge of ACR practice guidelines and technical standards for CT and MRI studies
- Become familiar with departmental procedures, contrast safety, and sedation required in the performance of examinations
- Make suggestions to improve methods and systems utilized in radiology whenever appropriate
- Demonstrate knowledge of ACR appropriateness criteria and cost-effective imaging evaluation of neuropathology

Practice-based Learning and Improvement
PBLI1: Evidence-based and informed practice; **PBLI2:** Reflective practice and commitment to

professional growth

- Evaluate and treat patients who develop contrast reactions
- Identify, rectify and learn from personal errors
- Incorporate feedback into improved performance
- Demonstrate evidence of independent reading and learning through use of printed and electronic resources
- Follow up on abnormal or interesting cases through personal communication with the referring physician or patient medical records

Professionalism
P1: Professional behavior and ethical principles; **P2:** Accountability/Conscientiousness; **P3:** Self-awareness and help seeking

- Demonstrate respect for patients and all members of the healthcare team (technologists, nurses, and other healthcare workers)
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic in regard to work assignments
- Observe ethical principles when recommending further work-up
- Promptness and availability at work are required of every resident
- Dress appropriately for work

Interpersonal and Communication skills
ICS1: Patient and family-centered communication; **ICS2:** Interpersonal and team communication, **ICS3:** Communication within health care systems

- Appropriately obtain informed consent
- Explain the nature of the examination or findings in an examination to patients and their families when needed
- Use appropriate language in communicating to clinicians through reports or consultations so proper management decisions can be made
- Thorough dictations will be made with indications, techniques, findings, and conclusions
- Dictate and correct reports in a timely fashion to avoid delay in patient disposition
- Demonstrate knowledge of indications for the examinations requested (when the reason for the examination is not clear, the resident will effectively communicate with the patient and referring physician until clarified)
- Provide preliminary reports to all referring clinicians if needed before the final review of cases (when there is a significant discrepancy between the preliminary reading and final reading, the resident will notify the referring clinician immediately)
- Produce concise reports that include all relevant information
- Communicate effectively with all members of the healthcare team
- Communicate effectively the results of studies to referring clinicians whenever needed (for emergent studies, this will be accomplished in a timely manner)

- Effectively convey the findings of examinations through accurate dictation of reports
- Competent in using PACS, voice recognition systems, and the hospital patient information systems in the daily accomplishment of the workload and instruct others in their use; dictate studies after review with an attending neuroradiologist
- Review, edit, and transcribe reports in a timely manner

Monitoring and Assessment of Resident Performance

The resident's progress will be monitored by the faculty on the service. At the end of each rotation, the resident will receive a consensus evaluation of performance from faculty on service. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as determined by the program.

Educational Goals and Objectives (Third Rotation):

The above objectives as well as the following:

Patient Care:
PC1: Reporting; **PC2:**Clinical Consulting; **PC3:**Image Interpretation; **PC4**:Competence in procedures

- Familiarity with available medical records and how to access them for the purposes of patient care
- Act as a consultant in neuroradiology to the clinical services
- Perfect diagnostic examination techniques and be very skilled and efficient in performing and interpreting all diagnostic procedures performed
- Know the proper preparation of patients for diagnostic procedures and the appropriate follow-up afterwards
- Understand the rationale for use of intravenous contrast in CT and MRI studies
- Supervise conscious sedation of pediatric patients and premedication of adult patients with claustrophobia.
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Medical Knowledge
MK1: Diagnostic Knowledge; **MK2:**Physics; **MK3:**Protocol selection and contrast agent selecting/dosing; **MK3**:Imaging technology and Image acquisition

- Protocol cases, in consultation with the attending, to assure that the CT and MRI examination is appropriate and of sufficient quality to address the clinical concerns of the patient and referring physician

- Be available at the commencement of the work day to screen and prescribe CT and MRI protocols as well as assuring protocols for initial studies scheduled for the next work day are prescribed
- Review, supervise, interpret and consult on all CT and MRI studies with the supervising faculty attending
- Understand the basic applications of CT and MRI in diagnosis of disorders of the brain, head and neck, spine, and spinal cord
- Relate the imaging findings to the clinical condition and its pathology
- Familiarity with the anatomy of the organs examined in every case
- Identify pathology in order to interpret CT and MRI imaging studies with accuracy appropriateness to the level of training when presenting to the attending
- Distinguish between normal anatomy and normal anatomic variant of the brain and spinal cord particularly as seen on CT and MRI images, with excellent accuracy according to the level of training when presenting to the attending and demonstrate improvement compared to the prior rotation
- Recognize common pathologic lesions of the CNS and offer an appropriate differential diagnosis
- Obtain a broad understanding of brain, head and neck, spine, and spinal cord diseases, their clinical features, radiographic manifestations, and current modes of treatment
- Demonstrate understanding of the features and imaging characteristics of commonly used MRI pulse sequences
- Familiarity with the appearances and causes of common MRI artifacts
- Understand and utilize standard MRI protocols as well as the biological and safety issues associated with MRI
- Demonstrate a working knowledge of the MRI workstation for image review and creation of angiographic and multiplanar reconstructions

Systems-based Practice
SBP1: Patient Safety; **SBP2:** Quality Improvement; **SBP3**: System navigation for patient-centered care; **SBP4:** Physician role in health care systems; **SBP5:** Contrast agent safety; **SBP6**: Radiation Safety; **SBP7:** Magnetic resonance (MR) safety; **SBP8:** Informatics

- Demonstrate knowledge of ACR practice guidelines and technical standards for neuroradiology
- Familiarity with departmental procedures, contrast safety, and sedation required in the performance of examinations
- Make suggestions to improve methods and systems utilized in radiology whenever appropriate
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging practices in neuroradiology

Practice-based Learning and Improvement
PBLI1: Evidence-based and informed practice; **PBLI2:** Reflective practice and commitment to professional growth

- Complete final preparations to pass the core examination of the American Board of Radiology
- Understand the clinical management of the conditions encountered

- Identify, rectify, and learn from personal errors
- Incorporate feedback into improve performance
- Demonstrate evidence of independent reading and learning through use of printed and electronic resources
- Follow up on abnormal or interesting cases through personal communication with the referring physician or patient medical records
- Competent in using PACS, voice recognition systems, and the hospital patient information systems in the daily accomplishment of the workload and instruct others in their use

Professionalism
P1: Professional behavior and ethical principles; **P2:** Accountability/Conscientiousness; **P3:** Self-awareness and help seeking

- Demonstrate respect for patients and all members of the healthcare team (technologists, nurses, and other healthcare workers)
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic in regard to work assignments
- Observe ethical principles when recommending further work-up for cases
- Promptness and availability at work are required of every resident
- Dress appropriately when reporting to work

Interpersonal and Communication skills
ICS1: Patient and family-centered communication; **ICS2:** Interpersonal and team communication, **ICS3:** Communication within health care systems

- Explain the nature of the examination of findings in an examination to patients and their families when needed
- Use appropriate language in communicating to clinicians through reports or consultations so proper management decisions can be made
- Produce thorough dictations with indications, techniques, findings, and conclusions
- Dictate and correct reports in a timely fashion to avoid delay in patient disposition
- Provide preliminary reports to all referring clinicians if needed before the final review of cases (when there is a significant discrepancy between the preliminary reading and final reading, the resident will notify the referring clinician immediately)
- Demonstrate knowledge of indications for the examinations requested (when the reason for the examination is not clear, the resident will effectively communicate with the patient or referring physician until clarified)
- Appropriately communicate results to patients and clinicians whenever needed (for emergent studies, this will be done in a timely manner)
- Produce concise reports that include all relevant information and be able to effectively convey the findings of examinations through accurate dictation of reports
- Communicate effectively with all members of the healthcare team
- Assist with supervision and teaching of medical and radiology technologist students

Monitoring and Assessment of Resident Performance

The resident's progress will be monitored by the faculty on the service. At the end of each rotation, the resident will receive a consensus evaluation of performance from faculty on service. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as determined by the program.

Educational Goals and Objectives (Fourth Year Residents):

The above objectives as well as the following:

Patient Care:
PC1: Reporting; **PC2:**Clinical Consulting; **PC3:**Image Interpretation; **PC4**:Competence in procedures

- Familiarity with available medical records and how to access them for the purposes of patient care
- Facilitate scheduling of emergent/urgent studies
- Act as a consultant in neuroradiology to the clinical services
- Refine diagnostic examination techniques and be very skilled and efficient in performing and interpreting all diagnostic procedures performed
- Know the proper preparation of patients for diagnostic procedures and the appropriate follow-up afterwards

Medical Knowledge
MK1: Diagnostic Knowledge; **MK2:**Physics; **MK3:**Protocol selection and contrast agent selecting/dosing; **MK3**:Imaging technology and Image acquisition

- Protocol cases, in consultation with the attending, to assure that the MRI examination is appropriate and of sufficient quality to address the clinical concerns of the patient and referring physician
- Be available at the commencement of the work day to screen and prescribe CT and MRI protocols as well as assuring protocols for initial studies scheduled for the next work day are prescribed
- Understand strategies for reducing imaging times or improving image quality
- Protocol and supervise more complicated neuro MRI studies
- Modify imaging protocols to improve image quality and assure study completeness
- Understand and utilize standard CT and MRI protocols as well as the biological and safety issues associated with CT and MRI
- Review, supervise, interpret and consult on all CT and MRI studies with the supervising faculty attending

- Advance knowledge of CT and MRI techniques and their application in neuroimaging
- Relate the imaging findings to the clinical condition and its pathology
- Understand the clinical management of the conditions encountered
- Familiarity with the anatomy of the organs examined in every case
- Identify pathology in order to interpret CT and MRI imaging studies with accuracy appropriateness to the level of training when presenting to the attending
- Distinguish between normal anatomy and normal anatomic variant of the brain, spine, spinal cord, head, and neck particularly as seen on CT and MRI images, with excellent accuracy according to the level of training when presenting to the attending and demonstrate improvement compared to the prior rotation
- Obtain a broad understanding of brain, head and neck, spine, and spinal cord diseases, their clinical features, radiographic manifestations, and current modes of treatment
- Develop a knowledge of the differential diagnoses of the more commonly encountered abnormalities as well as recommendations for additional evaluation
- Review, supervise, interpret and consult on all CT and MRI studies with the supervising faculty attending

Systems-based Practice
SBP1: Patient Safety; **SBP2:** Quality Improvement; **SBP3**: System navigation for patient-centered care; **SBP4:** Physician role in health care systems; **SBP5:** Contrast agent safety; **SBP6**: Radiation Safety; **SBP7:** Magnetic resonance (MR) safety; **SBP8:** Informatics

- Demonstrate knowledge of ACR practice guidelines and technical standards for neuroradiology
- Familiarity with departmental procedures, contrast safety, and sedation required in the performance of examinations
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging practices in neuroradiology
- Make suggestions to improve methods and systems utilized in radiology whenever appropriate

Practice-based Learning and Improvement
PBLI1: Evidence-based and informed practice; **PBLI2:** Reflective practice and commitment to professional growth

- Complete final preparations to pass the core examination of the American Board of Radiology
- Identify, rectify, and learn from personal errors
- Incorporate feedback into improve performance
- Demonstrate evidence of independent reading and learning through use of printed and electronic resources
- Follow up on abnormal or interesting cases through personal communication with the referring physician or patient medical records
- Competent in using PACS, voice recognition systems, and the hospital patient information systems in the daily accomplishment of the workload and instruct others in their use

Professionalism
P1: Professional behavior and ethical principles; **P2:** Accountability/Conscientiousness; **P3:** Self-awareness and help seeking

- Demonstrate respect for patients and all members of the healthcare team (technologists, nurses, and other healthcare workers)
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic in regard to work assignments
- Observe ethical principles when recommending further work-up for cases
- Promptness and availability at work are required of every resident
- Dress appropriately when reporting to work

Interpersonal and Communication skills
ICS1: Patient and family-centered communication; **ICS2:** Interpersonal and team communication, **ICS3:** Communication within health care systems

- Explain the nature of the examination of findings in an examination to patients and their families when needed
- Demonstrate knowledge of indications for the examinations requested (when the reason for the examination is not clear, the resident will effectively communicate with the patient or referring physician until clarified)
- Provide preliminary reports to all referring clinicians if needed before the final review of cases (when there is a significant discrepancy between the preliminary reading and final reading, the resident will notify the referring clinician immediately)
- Appropriately communicate results to patients and clinicians whenever needed (for emergent studies, this will be done in a timely manner)
- Produce concise reports that include all relevant information and be able to effectively convey the findings of examinations through accurate dictation of reports
- Communicate effectively with all members of the healthcare team
- Use appropriate language in communicating to clinicians through reports or consultations so proper management decisions can be made
- Produce thorough dictations with indications, techniques, findings, and conclusions
- Dictate and correct reports in a timely fashion to avoid delay in patient disposition
- Assist with supervision and teaching of medical and radiology technologist students

Monitoring and Assessment of Resident Performance:

The resident's progress will be monitored by the faculty on the service. At the end of each rotation, the resident will receive a consensus evaluation of performance from faculty on service. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist. Resident performance is also evaluated through direct observation, case logs, multi-source professional

evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as determined by the program.

Educational Goals and Objectives (Myelography Rotation):

The above objectives as well as the following:

Patient Care:
PC1: Reporting; **PC2:**Clinical Consulting; **PC3:**Image Interpretation; **PC4**:Competence in procedures

- Familiarity with available medical records and how to access them for the purposes of patient care
- Act as a consultant in neuroradiology to the clinical services
- Be available at the commencement of the work day to review patient evaluations and procedures; be available throughout the work day to manage patients and perform procedures
- Learn to perform lumbar spine punctures and supervise and interpret myelographic studies
- Demonstrate competency in performing lumbar spinal punctures
- Interview and obtain consent from patients referred for myelography
- Recognize appearances of improper localization of contrast during injection
- Successfully transfer contrast from the lumbar to the cervical region
- Understand basics of intrathecal contrast including appropriate dosage, clearance from the subarachnoid space, possible side effects, and relative contraindications to myelography
- Review, supervise, interpret and consult on all lumbar spine punctures and myelography studies with the supervising faculty attending
- Share responsibility with neuroradiology fellows for pre-procedure evaluation of patients scheduled for angiography and post-procedure follow-up

Medical Knowledge
MK1: Diagnostic Knowledge; **MK2:**Physics; **MK3:**Protocol selection and contrast agent selecting/dosing; **MK3**:Imaging technology and Image acquisition

- Protocol cases, in consultation with the attending, to assure that the myelography examination is appropriate and of sufficient quality to address the clinical concerns of the patient and referring physician
- Screen for appropriateness of myelographic studies and the presence of relative contraindications to myelography
- Know the proper preparation of patients for myelography and prescribe appropriate post-myelography CT studies
- Recognize the completeness and diagnostic quality of myelographic studies
- Understand indications for myelography in the evaluation of patients with spinal disorders
- Demonstrate knowledge of the radiographic and CT anatomy of the spine, nerve roots, and spinal cord
- Relate and interpret the imaging findings on plain films and CT myelograms to the clinical condition and its pathology with accuracy appropriateness to the level of training when presenting to the attending

- Obtain appropriate myelographic images of the cervical and lumbar spine

Systems-based Practice
SBP1: Patient Safety; **SBP2:** Quality Improvement; **SBP3**: System navigation for patient-centered care; **SBP4:** Physician role in health care systems; **SBP5:** Contrast agent safety; **SBP6**: Radiation Safety; **SBP7:** Magnetic resonance (MR) safety; **SBP8:** Informatics

- Demonstrate knowledge of ACR practice guidelines and technical standards for neuroradiology
- Familiarity with departmental procedures, contrast safety, and sedation required in the performance of examinations
- Make suggestions to improve methods and systems utilized in radiology whenever appropriate
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging practices in neuroradiology

Practice-based Learning and Improvement
PBLI1: Evidence-based and informed practice; **PBLI2:** Reflective practice and commitment to professional growth

- Understand the clinical management of the conditions encountered
- Complete final preparations to pass the core examination of the American Board of Radiology
- Identify, rectify, and learn from personal errors
- Incorporate feedback into improve performance
- Demonstrate evidence of independent reading and learning through use of printed and electronic resources
- Follow up on abnormal or interesting cases through personal communication with the referring physician or patient medical records
- Competent in using PACS, voice recognition systems, and the hospital patient information systems in the daily accomplishment of the workload and instruct others in their use

Professionalism
P1: Professional behavior and ethical principles; **P2:** Accountability/Conscientiousness; **P3:** Self-awareness and help seeking

- Demonstrate respect for patients and all members of the healthcare team (technologists, nurses, and other healthcare workers)
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic in regard to work assignments
- Observe ethical principles when recommending further work-up for cases
- Promptness and availability at work are required of every resident
- Dress appropriately when reporting to work

Interpersonal and Communication skills
ICS1: Patient and family-centered communication; **ICS2:** Interpersonal and team communication, **ICS3:** Communication within health care systems

- Be able to explain the nature of the examination of findings in an examination to patients and their families when needed
- Use appropriate language in communicating to clinicians through reports or consultations so proper management decisions can be made
- Produce thorough dictations with indications, techniques, findings, and conclusions
- Dictate and correct reports in a timely fashion to avoid delay in patient disposition
- Demonstrate knowledge of indications for the examinations requested (when the reason for the examination is not clear, the resident will effectively communicate with the patient or referring physician until clarified)
- Provide preliminary reports to all referring clinicians if needed before the final review of cases (when there is a significant discrepancy between the preliminary reading and final reading, the resident will notify the referring clinician immediately)
- Appropriately communicate results to patients and clinicians whenever needed (for emergent studies, this will be done in a timely manner)
- Produce concise reports that include all relevant information and be able to effectively convey the findings of examinations through accurate dictation of reports
- Communicate effectively with all members of the healthcare team
- Assist with supervision and teaching of medical and radiology technologist students

Monitoring and Assessment of Resident Performance

The resident's progress will be monitored by the faculty on the service. At the end of each rotation, the resident will receive a consensus evaluation of performance from faculty on service. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as determined by the program.

Reading List for Each Year and Rotation

On the first day of a neuro rotation, the residents will meet with the respective attending on service. Books which are required readings will be made available for the duration of the rotation together with any required assignments.

First Year

Mauricio Castillo. *The Core Curriculum: Neuroradiology*. Lippincott Williams & Wilkins; 1st Edition, 2002.

Second Year

Laurie A. Loevner. *Brain Imaging: Case Review Series*. Mosby, 2nd Edition, 2008.

Third Year

David M. Yousem, Nafi Aygun, Ana Carolina B.S. da Motta. *Head and Neck Imaging: Case Review Series*. Mosby, 2nd Edition, 2005.

Fourth Year

Ann G. Osborn. *Diagnostic Cerebral Angiography*.Lippincott Williams & Wilkins; Second Edition, 1999).

Myelography Rotation

Brian C. Bowen, Alfonso Rivera, Efrat Saraf-Lavi. *Spine Imaging: Case Review Series*. Mosby, 2nd Edition, 2007.

Other Requirements/Expectations

Focused Time in Neuroradiology:
Focus time is for senior residents. The resident can spend between 3-6 months in the division.

During his/her "focused time" in neuroradiology, the resident:

- Assists the academic fellow in protocoling all the cases – by the end of the rotation, the academic resident will be expected to understand rationale for protocoling neuro cases
- Attends ALL the conferences indicated on the neuroradiology conference schedule.
- Prepares at least 1 case, ideally two cases, for the cookie conference, under the supervision of the academic fellow. The case presented should convey a teaching point learnt by the academic resident during one of the conferences he/she attended during the week. The case presented should be accompanied by a short blurb/power A list of topics to be covered is available at: http://theabr.org/ic/ic_neuro/ic_neuro_study.html

  These PowerPoint's will be stored on the neuroradiology intramural website and available for review.
- In between conferences, volunteer to read and dictate studies by the reading-room coordinator.

Note on Protocoling:
Protocols: I:\Shared\CT Protocols\Neuro CT Protocols.xls – online resource describing the protocols.

Throughout the day, the CT techs will call the reading-room and tell you about a patient and what study was ordered. Generally you will just agree to the study but occasionally you will question the necessity of the study and have to call the ordering physician, or you will change the study to be done because there are other studies that are better at evaluating the ordering physician's concern. During the

day one of the CT techs will usually come by with a folder of protocols to be performed at the hospital. These are completed on the forms, rather than on PACS. You don't have to look up patient labs to make sure their renal function is good enough, the techs will do that. For contrast policy, see APPENDIX about.

Protocoling Tips:

1. Very few reasons to do a CT head with and without. Usually MRI is a better study in this case but occasionally CT must be done if the patient gets an MRI. These studies are done looking for abscess or enhancing mass, mets. Note that a negative CT with and without does not rule out mets.
2. Spines: Usually these are done without contrast. Occasionally will do with contrast if looking for a postoperative collection.
3. CT Head without – most common study. Great first line study for stroke, trauma, altered mental status.
4. Sinus CT – if looking for sinusitis then do without contrast. If looking for sinonasal tumor than may have to use contrast.
5. CTA – Typically just protocol as ordered

Contrast in Renal Insufficiency

SEE APPENDIX

Expectations of the Swing shift and on-call residents:

- interpret and pre-dictate all neuro studies from the emergency room,
- interpret and pre-dictate all neuro studies obtained in inpatients,
- interpret and pre-dictate all neuro studies obtained in outpatients if an early read is requested,
- participate in the reading of neuro CTAs, which includes collecting all the clinical information for the neuro fellow, looking at the images, discussing the interpretation with the fellow, dictating an accurate impression for the study and placing this pre-dictation in the queue of the early neuro fellow and early neuro attending. THIS IS DESCRIBED IN GREAT DETAIL IN THE CTA READING POLICY (SEE APPENDIX).

Interpretation and Other Tips:

CT Head WO – Work "out to in"

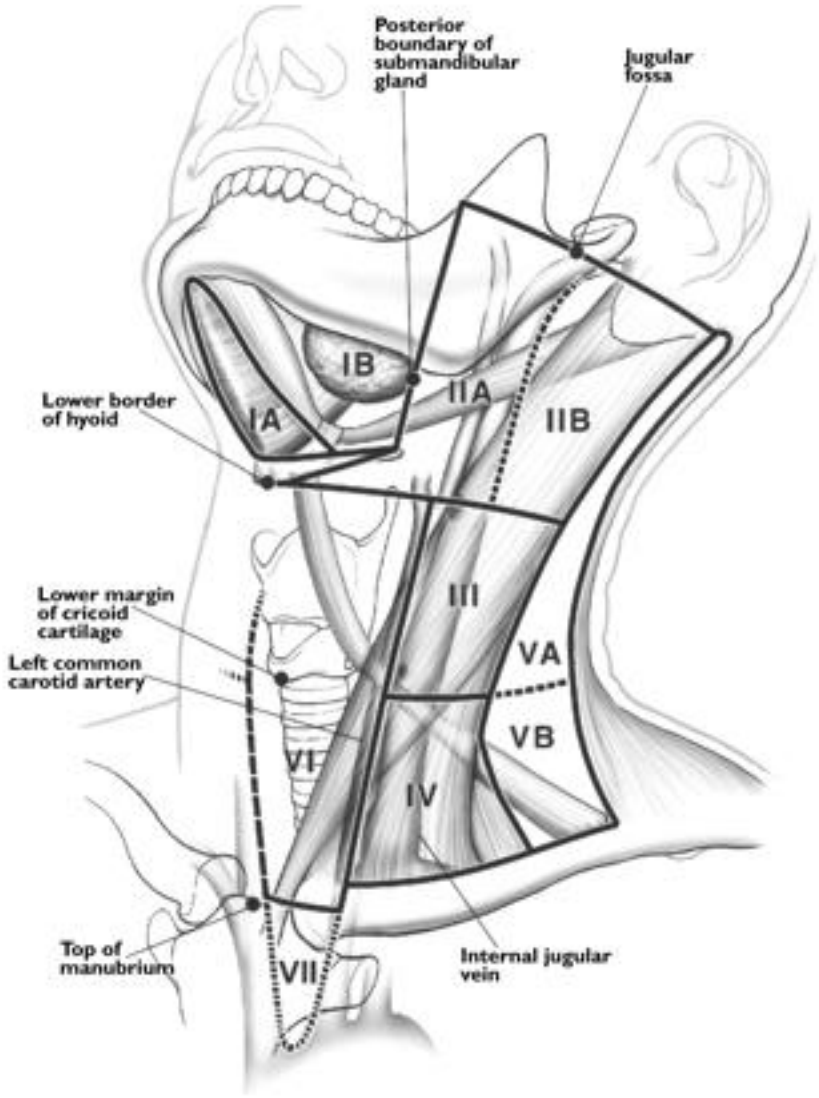
1. Set to soft tissues windows, F7, look at the scalp soft tissues for hematoma, laceration etc. Check the orbits. Look at the soft tissues in the upper neck both anteriorly and posteriorly.
2. Set to bone windows, F5. Start at the bottom and go cephalad looking for fractures. Fluid in the mastoids can be a hint of a basilar skull/temporal fracture. Blood in the sinuses usually indicates a sinus fracture. Note all skull fractures. Make note of any depressed skull fractures. Also a good window for looking for paranasal sinus inflammation.
3. Set to blood window, F8. Look for extra-axial blood and inraparenchymal blood.

4. Set to brain window, F2. Look for extra axial blood, parenchymal blood, grey white differentiation, infarcts, masses, ventricle size, and basal cisterns. Re-check blind areas like posterior cranial fossa and anterior temporal lobes.
5. Set up a "stroke window" something like C35, W35 to look for subtle infarcts.

Trauma Spine:

1. You need to look at the axial, coronal and sagittal images. And you need to look at each plane with bone windows, soft tissue windows, and sometimes lung windows. Set up reference lines and label the vertebral bodies on the sagittal view. This can help keep you oriented.
2. Everyone looks at these differently; here is how I do it:
3. I pull out the sagittal, coronal, soft tissue axial and bone ALGORITHM axials. I set up reference lines and I label the vertebral bodies on the sagittal view.
4. Start with Sagittal on bone windows. Look for overall alignment of vertebral bodies and facets. This includes curvature, retro or anterolisthesis and symmetry of disc spaces. Then scroll back and forth through each vertebral body looking for fracture.
5. Next do Sagittal soft tissue. Look for spinal hematoma and disc bulges. Look at paravertebral soft tissues (don't miss a large pneumothorax or liver laceration even though the CT abd/pelvis will call it)
6. Next do coronal on bone windows. Look at C1-C2 alignment. Look at remainder of alignment. Look at each vertebral body for fracture.
7. Next do coronal soft tissues.
8. Finally do the axials. I do the axial bone algorithm first looking for fracture. Then I do the axial soft tissue looking for central canal compression from disc or hematoma. Also look for paravertebral soft tissues as discussed above. If patient has very kyphotic or lordotic can reformat the bone algorithm axials into MPR. This will allow you to look at a true axial for each vertebral body. (ask an upper level for help on how to do this the first time).
9. Don't worry. These studies take a long time when you are starting out. You will get faster at them. Don't rush a trauma c-spine.

Cervical Lymph Node Levels (Naming Conventions)



Research:

All residents are invited to participate in the ongoing neuroradiology research programs.

Appendix 1
Distribution of the Cases in the Neuro Reading-Room:
Between 7:30am and 8:00am
Workforce:
Reading-room coordinator
Early fellow
Early attending (also checking out the overnight resident)
Cases to be read:
ALL pending emergency and inpatient studies, mainly CTAs and MRIs

Distribution:

- the early fellow reads the emergency and inpatient CTAs and MRIs
- the early attending checks out the overnight CTs with the overnight resident
- on spine trauma months (odd numbered months for neuro), the early attending checks out spine plain films with the 1404 overnight resident

(PS: neuro reads ALL pediatric ED and trauma spines, regardless of the month)

Between 8:00am and 10:00am
Workforce:
Reading-room coordinator
Early fellow, academic fellow, 4 or 5 residents (total of 6 or 7)
Early attending and procedure attending (and back-up attending)

Cases to be read:

- Emergency and inpatient studies (to be continuously distributed as they come in and to be read in priority)
- 8:30am: first check of the studies that slipped through (not in the unread queue, but no report)
- ALL pending outpatient studies

Distribution:

- studies to be split between early fellow, academic fellow, first-year resident and more advanced residents
- equal number of simple cases, intermediate cases and hard cases for the early fellow, academic fellow and for the 2 more advanced residents, notably equal number of CTAs
- for the first-year resident, only simple cases (+ a few intermediate cases a day), but overall same number of studies as the other residents and fellows

- for the myelogram resident, only simple cases and a lower number of studies read by the other residents and fellows – THIS IS IN ADDITION TO THE MEYLOGRAMS WHICH ARE ALL READ BY THE PROCEDURE RESIDENT

Between 10:00am and 3:30pm
Workforce:
Reading-room coordinator
Early fellow, late fellow, 4 or 5 residents (total of 6 or 7)
Early attending, procedure attending, and late attending

Cases to be read:

- Emergency and inpatient studies (to be continuously distributed as they come in and to be read in priority)
- 2pm: second check of the studies that slipped through (not in the unread queue, but no report)
- Outpatient studies (to be continuously distributed as they come in)

Distribution:

- the late fellow receives all the new studies until the number of studies assigned to him becomes equal to the number of cases remaining in the queue of the others in the reading-room

then

- studies to be split between early fellow, late fellow, first-year resident and more advanced residents
- equal number of simple cases, intermediate cases and hard cases for the fellows and for the more advanced residents, notably equal number of CTAs
- for the first-year resident, only simple cases (+ a few intermediate cases a day), but overall same number of studies as the other residents and fellows
- for the myelogram resident, only simple cases and a quarter of the number of studies read by the other residents and fellows – THIS IS IN ADDITION TO THE MEYLOGRAMS WHICH ARE ALL READ BY THE PROCEDURE RESIDENT

Between 3:30pm and 7:00pm
Workforce:
Reading-room coordinator
Late fellow, 1 resident (total of 2)
Late attending

Cases to be read:

- Emergency and inpatient studies (to be continuously distributed as they come in and to be read in priority)
- 5pm: second check of the studies that slipped through (not in the unread queue, but no report)
- Outpatient studies **with a request for an early read** (to be continuously distributed as they come in), **including plain films**
- The routine outpatient studies are typically not read until the next day.

Distribution:

- studies to be split between late fellow and the late resident
- equal number of simple cases, intermediate cases and hard cases for the fellow and the resident, notably equal number of CTAs

Notes:

Keep an eye out for any ED studies because they have to be turned around in less than an hour. If you get one of these while you're working on another study, you should stop and switch to the ED study. Once you look at it, let the attending know you have an ED study to read out. If you will not be able to get an attending to look at it within an hour, you can call the ordering physician and give them your impression, and let them know you will call them if there are any important changes. ED studies are denoted on PACS by "645."

Each study has an associated paper form that is organized by the reading room coordinator. You should try to find the paperwork for each study you read so others know it has been read. Also, even if you plan to do your dictations after you sign out the study, please scan in the study to CareStream when you read it so that others who are working off of the computer lists do not read the same study as you.

One first year is the early person and one is the late. The early person should arrive at 7 AM, sign in to PACS and CareStream before conference because they are responsible for any traumas that come in after 7 AM. The late person starts at 10 AM. The early person will stop looking at new studies around 3:30 PM and just read out and dictate changes until the shift ends. The early person usually leaves between 5 and 6 PM, and the late person between 7:30 and 9 PM. If there are a ton of studies to be read, the early person should be prepared to stay and help the late person out. The early person also reads out the overnight 1404 plain film studies; however ER “spine” plain films are only read-out by Neuro during Neuro spine months. Neuro and MSK rotate handling the ER spine CT’s. During odd number months Neuro reads trauma spines and on even numbered months the MSK folks read the trauma CT spines. Note however that Neuro still reads the neurosurgery postoperative spines during non NEURO spine months.

Core Knowledge Presentation Topics

Simple Cases:
Plain films
Head CT
CT of the sinuses/face/mandible
CT of the spine

Intermediate Cases:
CT temporal bone
CTAs
MRI/MRA of the brain
MRA neck
MRI of the spine

Hard Cases:
MRI of the neck
Special MRI studies (CSF flow studies, seizure, etc)

Appendix 2
ALL On-Call Neuroradiology CTAs
Procedure:

- The 1404 resident who is contacted with a request for a CTA is responsible for collecting the clinical information motivating the CTA (symptoms, symptom side, and symptom onset).
- The 1404 resident then protocols the CTA so that the technologist can perform it ASAP. If need be, and based on the degree of clinical urgency, the 1404 resident helps the technologists prioritize the pending CT cases. The 1404 resident can call the fellow if he/she needs help to prioritize a CTA case.

Resident Review of CTAs:

- As soon as the study has been completed, the 1404 Resident will review the CTA and discuss every case with the 1590 resident or the 1232 resident.
- The residents reading CTAs should pay particular attention to:
    - Clinical information motivating the CTA (symptoms, symptom side, symptom onset),
    - Presence or absence of infarct signs on NCT (hypodensity, effacement of the cortical ribbon or basal ganglia, dense artery sign) and their extent (more or less than 1/3 of the MCA territory)
    - Presence or absence of hemorrhage on NCT (especially subarachnoid and intraparenchymal)
    - Presence or absence of intracranial arterial or venous occlusion (remember to check all dural venous sinuses, internal cerebral veins, vein of Galen)
    - Presence or absence of intracranial aneurysm
    - Presence or absence of cervical arterial stenosis or dissection
    - If perfusion-CT is obtained, presence or absence of infarct/penumbra and their relative extent
    - If the study is obtained for penetrating injury (e.g. stab wound to neck), search for arterial wall irregularity, arterial or venous occlusion, or pseudoaneurysm/contrast puddling/extravasation.
    - Any incidental finding relevant to patient's symptoms or management

When to Call the Fellow:

- The 1404 resident, AFTER CONSULTING WITH THE 1590 AND 1232 RESIDENTS, should page the Diagnostic Neuroradiology Fellow in the following situations:
    - Any doubt regarding the elements listed above
    - Presence of subarachnoid hemorrhage WITH OR WITHOUT ruptured aneurysm detected
    - Any stroke patient who is within the INR treatment time window and who is seriously considered for INR therapy

These are general guidelines, and the 1404 resident should of course use common sense in applying these general guidelines, and do whatever is best for the patient.

- When the 1404 resident pages the Diagnostic Neuroradiology fellow on call, she/he should communicate the clinical indication for the CTA (symptoms, symptom side, symptom onset) as well as the interpretation by the 1404/1590/1232 residents.
    - The fellow must return the page to confirm to the 1404 resident that the call was received. If the fellow is not reachable (including attempt by direct telephone call), the 1404 Resident is to page the Diagnostic Neuroradiology Attending on call.
    - The fellow should call the Diagnostic Neuroradiology Attending on call for help, if needed.

Communication of Results to Ordering Physician:

- Interpretation for all CTAs should ALWAYS be communicated to the ordering physician (ED doc, stroke pager 1681, neurosurgery pager 1576) and this communication must be documented (include name of the physician spoken to and time of the phone conversation) in the report.
    - For cases not involving the fellow, the 1404 resident will communicate the results to the ordering physician.
    - For cases involving the fellow, the fellow will communicate the results to the ordering physician. The fellow will also call the 1404 resident and communicate the results of his/her interpretation.

Dictation of Reports (Summary version):

- The 1404 Resident will dictate, in CareStream, the Impression section of the report, summarizing the main findings communicated to the requesting physician.
    - This very short text will indicate the name of 1404 resident, the name of the 1590 and/or 1232 resident involved in the interpretation, the name of the neuro

diagnostic fellow (if the latter was consulted on the case), and the name of the on call attending neuroradiologist (if the latter was consulted on the case).

- The report will be dictated under the overnight CTA queue so that it can be placed in the early fellow queue by the reading-room coordinator the next morning.
- The full report will be dictated and completed the next morning by the on call diagnostic neuro fellow (or his/her replacement) and the Early attending.

Dictation of Reports (Full length version):

- The Early fellow will review these cases with Neuroradiology Attending as soon as possible in the morning.
- If the On Call fellow is not scheduled as “Early” the following morning and reviewed a CTA (or any other urgent/emergency case) over night, she/he MUST communicate (email or telephone) the findings on these cases to the Early fellow by 7:00 am, including what she/he told the referring physician.
- If there are significant changes to the interpretation the next morning, the Early fellow will communicate these to the appropriate physicians.
- The Early fellow will complete dictation of the case after review with the Attending.

To page someone from outside the hospital: 434-982-3500.
To call hospital page operator (aka “call sheet operator”) if dialing from outside the hospital: 434-924-0000.

Appendix 3

Findings that Necessitate a Phone Call to the Ordering Physician(s)

- Use your best medical judgment for individual exceptions to the situations listed. Ask your Attending if in doubt. There may be additional, unlisted instances when a phone call is indicated.
- Document your phone call in your report: person, method of communication, time, and date.
- **Text paging or e-mail is NOT sufficient for documentation**. You must verbally speak with the responsible physician, physicians' assistant, nurse practitioner, or nurse.

1. New hemorrhage (subarachnoid, epidural, subdural, parenchymal, intraventricular)
2. New infarct
3. New mass; markedly enlarging mass
4. New or substantially worsening herniation, brain swelling, or edema
5. New or substantially worsening hydrocephalus
6. Misplaced surgical catheter
7. Misplaced or broken surgical hardware (check the electronic medical record to see if the referring physician has already noted this in the notes)
8. Findings suggesting meningitis, encephalitis, empyema, or abscess
9. Findings suggesting Creutzfeldt-Jacob disease
10. Incompletely clipped aneurysm
11. Clipped normal vessel
12. New or enlarging aneurysm or vascular malformation
13. Findings of acute thrombus (arterial or venous), occlusion, dissection, or significant vasospasm
14. Findings suggesting child abuse
15. Worsening on tumor follow-up when the clinical note states otherwise (e.g. Neuro oncologist wrote "I've reviewed today's MRI and the tumor looks unchanged.")

16. Unexpected or unexplained pneumocephalus
17. New or worsening cord compression
18. New or enlarging cord mass
19. Findings suggesting acute cord infarct
20. Significant spinal ligamentous injury in a trauma patient
21. Findings of spinal instability in a trauma patient
22. Findings suggesting acute airway compromise

Appendix 4

MYELOGRAPHY PROCEDURE MANUAL

Neuroradiology

Key Points

1. Only non-ionic contrast can be injected into the thecal sac. We use Omnipaque. Injection of *ionic* contrast into the thecal sac can result in death.

2. While performing the procedure remain aware of the patient's condition. Vasovagal reactions are fairly common with myelograms, especially in young muscular males (football player types). By intervening early one can avoid a potentially life-threatening reaction. See the discussion later in this handout.

3. Proper labeling of the vertebral bodies is a critical aspect of the myelographic examination. Surgeons rely on correct labeling and communication of the lesion location.

4. When performing Cervical Myelograms, take great care when extending the patient's neck. Prolonged extension or over-extension of the neck in a patient with a high-grade cervical canal stenosis can result in permanent cord damage, even quadriplegia. Obtain and review any previous imaging studies prior to performing the procedure.

5. Avoid passing a needle through an epidural abscess into the thecal sac. This could result in meningitis. This also applies to any abscess or infected decubitus ulcer, etc.

6. During a cervical myelogram via a cervical needle placement, avoid injecting contrast directly into the cord by never injecting contrast unless there is good flow of CSF out through the needle.

General

Myelography refers to the examination of the contents of the thecal sac after administration of intrathecal radiographic contrast. The examination is done with both plain films and CT.

Keep in mind that you will be doing multiple examinations during your Neuroradiology rotation; therefore, it is important to limit your exposure to radiation during each examination. Stand away from the tube and limit your fluoroscopy time.

Basic Anatomy and Physiology

The total adult CSF volume is about 150 ml (50% intracranial, 50% spinal). About 500-750 ml of CSF is produced each day (0.4 ml/min, 20-30 ml/hr). Adult opening pressure is normally 7-15 cm fluid, >18 abnormal (although young adult can be slightly higher with normal <18-20).

According to Dr. Hodges: The AP diameter of the cord is 7 mm down to C7, 6 mm from C7 to the conus, then 7 mm at the conus. The cord size can be considered abnormal if it is over 8 mm or under 6 mm.

There are normally 7 cervical vertebral bodies, 12 thoracic vertebral bodies, 5 Lumbar vertebral bodies, the sacrum and the coccyx. There are corresponding nerve roots: *8 Cervical*, 12 Thoracic, 5 Lumbar, 5 Sacral, and the coccygeal nerve.

The position of the tip of the conus at birth is debated. By 3 months it is usually at the normal adult level of mid L1 to mid L2. It is considered abnormal if it is below the L2-L3 disk space level (ref. Barkovitch).

Indications for Myelography

This examination is usually performed to assess for HNP or spinal stenosis. Less often it is used to determine the level of spinal cord compression from metastatic disease or trauma. Myelography often yields better information about the bony structures than does MRI.

Alternative Examinations: MRI of the spine or a noncontrast CT can also yield useful information.

Steroid Premedication Regimen

Patients with a history of reaction to iodinated contrast should receive premedication with steroids and Benadryl (diphenhydramine) prior to contrast administration. However, contrast reaction is extremely rare following myelography. The usual premedication regimen (Manual on Contrast Media, 6th Ed. ACR, 2008) is: prednisone 50 mg PO 13, 7, and 1 hour before contrast administration; Benadryl 50 mg PO (or IM or IV) one hour before contrast administration. If Benadryl is given make sure someone else is available to drive the patient home. For patients who can not take oral medication, substitute hydrocortisone 200 mg IV for each prednisone dose and give diphenhydramine IV. A period of *at least 6 hours* between the onset of corticosteroid administration and the

injection of contrast medium is recommended, regardless of the route of steroid administration.

H2 blockers can be used for patients with a history of severe reaction; cimetidine (Tagamet) 300 mg PO (or IV; diluted in 20 ml or more normal saline and infused slowly over a minimum of 5 minutes) 1 hour prior to contrast administration. Cimetidine should be given only to patients also receiving diphenhydramine.

In emergency situations, intravenous medications can be administered: hydrocortisone (Solu-Cortef) 200 mg IV stat and q 4 hour until the examination is complete. Benadryl 50 mg IV 1 hour before contrast administration. Premedication with ephedrine can also be considered, but caution is advised in patients with unstable angina, arrhythmia or hypertension (Manual on Contrast Media, ACR). A period of *at least 6 hours* between the onset of corticosteroid administration and the injection of contrast medium is recommended, regardless of the route of steroid administration.
ref: Greenberger PA, et al. (Oral) J Allergy Clin Immunol 1991; 87:867-872 and (IV) J Allergy Clin Immunol 1986; 77:630-634.
Manual on Contrast Media, 6th Edition, ACR monograph, 2008.

Contraindications and Acceptable Lab Values
Lab values
INR – upper limit is 1.5
Platelets (nl 150,000-450,000) (bleeding time nl for platelets >100,000, Transfuse < 50,000)

Coagulation parameters should be within normal limits. Check PT and PTT (and platelets) if there is a clinical condition that predisposes the patient to bleeding. It is preferable to cancel or delay the examination if PT > 15.0. If possible, heparin should be held for 4 hours prior to the procedure. It can be restarted 2 hours after the procedure. Coumadin should be held for 3-4 days, until PT is normal. If platelets are below 50,000 (some prefer 70,000), a platelet transfusion can be given prior to LP (this situation occurs especially in patients in whom an LP is being performed for administration of intrathecal chemotherapy). Transfusion of one unit of platelets raises the platelet count by 10-20,000. Check the platelet count before continuing with the LP.

NEW REGULATIONS- pts are NOT to come down with platelets running, unless accompanied by a nurse from the floor. The chances of getting a nurse to come down are nearly non existent. Therefore, make sure the plts are up tp 50000 before doing the procedure.

Creatinine is usually not checked prior to the myelogram. If the patient has very poor renal function you could time the myelogram to precede dialysis, or perform an MRI.
If a normal healthy outpatient arrives without recent laboratory results it may be possible to continue the examination at the discretion of the staff. Ask the patient about history of renal disease or bleeding abnormalities before proceeding.

Medications that lower the seizure threshold should not be administered for 48 hours prior to or following the procedure. The patient should be informed during the consent procedure that their risk of seizure is higher than if they were not taking the medication. This mostly applies to tricyclic antidepressants. Check the PDR if uncertain whether the medication lowers the seizure threshold. (Many of these medications have half-lives well over 48 hours; however, usually we still hold the medication for 48 hours.)

Drugs that lower seizure threshold (not an exhaustive list) – *check with SHARON/ROBIN/SUSAN* –they have a complete list.
(source: Neuroradiology, The Requisites, R.I. Grossman, D.M. Yousem):
Phenothiazines (chlorpromazine [Thorazine], prochlorperazine [Compazine], perphenazine [Etrafon, Trilafon], thioridazine [Mellaril])
Antipsychotics (thiothixene [Navane], haloperidol [Haldol], droperidol [Fentanyl])
Tricyclic antidepressants (amitriptyline [Elavil], desipramine [Norparmin], imipramine [Tofranil], nortryptyline [Pamelor], doxepin [Sinequan])
CNS stimulants (methylphenidate [Ritalin], ephedrine, pseudoephedrine)
Monoamine oxidase inhibitors (tranylcypromine [Parnate], procarbazine [Matulane])
Others (lithium, reserpine, isoniazid)

If the patient has a history of seizures or is taking seizure medications, there is no premedication for seizures. Discuss with the referring physician and the patient that there is a higher risk of the contrast inducing a seizure than in a patient without a seizure history. The patient should continue to take their usual seizure medications prior to the myelogram.

Caution must be exercised in patients taking Glucophage (metformin) because of the risk of renal failure or lactic acidosis after receiving iodinated contrast. The FDA package insert states that Glucophage should be withheld temporarily in patients undergoing radiological studies using *intravenous* iodinated contrast media. We apply this to *intrathecal* iodinated contrast media also.

NOTE: *See The Manual on Contrast Media, 6th Ed. by the ACR (2008) pp. 39-41 regarding metformin* recommendations for discontinuation before or at the time of the procedure. If applicable, be sure to call the patient's physician so that he/she can manage the patient's diabetes while off Glucophage. Call the patient's physician before the procedure to verify that the proposed plan to manage the diabetes is acceptable and discuss with the physician instructing the patient as to when to resume taking Glucophage.

Metformin containing medications: Glucophage, Fortamet, Glumetza, Riomet, Glucovance, Metaglip, ActoPlusMet, Avandamet.
Low Molecular Weight Heparin (Fragmin, Lovenox, Normiflow, Orgaran) are a contraindication to LP or Myelogram.

Of course, never pass a needle through an epidural abscess into the thecal sac. If a patient has a suspected lumbar epidural abscess, an MRI is usually the best means of

evaluation. If a myelogram must be done, introduce the contrast into the thecal sac using the cervical approach.

A complete CSF Block is a contraindication to collecting CSF below the block. Reduction in CSF volume and pressure below the block can cause downward herniation of the cord. The risk versus benefit of the procedure must be considered in each case individually.

A Complete CSF Block is also a contraindication to injecting contrast below the block (of course, it is acceptable to inject contrast above the block). This is because the block prohibits resorption of the intrathecal contrast by the arachnoid villi in the head and leaves neurotoxic contrast in contact with the spinal cord and nerve roots. Resorption through the ependyma is only minimal and will not suffice in this situation.
If a complete block is suspected, one can inject two cc of contrast below the suspected level of the block as a test. Run the contrast up into the head to assess whether a block is present at any level. If no block is present, inject the remainder of the contrast and continue with the study. If a block is present, do not inject any more contrast. The two cc of contrast already injected should be visible on the CT examination and can help define the lower extent of the block.

If the patient has immediate pain during the contrast injection it might be due to distention of the thecal sac below an unsuspected block. Stop injecting and investigate whether a block is present.

Other general contraindications include medical conditions that might lead to complications. For instance, a patient with bacteremia from a tooth abscess should not undergo myelography because of the risk of meningitis.

Possible Complications

The most common complications are due to meningeal reactions, spinal headache, vomiting, vertigo, and neck pain. This is partly the result of CSF loss due to dural injury from the puncture. This complication is minimized by using a small needle. It also helps to orient the bevel of the needle parallel to the longitudinal fibers of the thecal sac during puncture (to separate the fibers rather than cut them). The limiting factor for needle caliber is the viscosity of the injected contrast material.

The typical headache after puncture can be distinguished from migraine or other types of headache by the increased severity in the upright position and the spontaneous improvement in recumbency. It has its onset immediately after puncture or within a few hours.

Other complications include nerve root damage, meningitis, epidural abscess, contrast reaction, CSF leak, or hemorrhage,

Unlikely complications include damage to the spinal cord, such as due to a low conus or tethered cord with a lumbar approach or direct cord damage in a cervical approach. Other

complications include death or paralysis from cord damage due to injection of contrast into the cord or hemorrhage in the cord from needle damage.

If it is discovered during the injection that a large fraction of the contrast has gone into the subdural space it is usually best to discontinue the study and reschedule it for two weeks later. This is because the enlarged (contrast containing) subdural space fills the region of the canal that previously contained subarachnoid space. It is thus difficult to reposition the needle tip into the subarachnoid space.
If a small subdural injection is discovered early, it may be possible to reposition the needle and continue with the study.

Post Procedure Instructions
The routine post procedure orders are:
Strict bedrest for 4-8h with HOB elevated 30 degrees, at discretion of the physician, then bathroom privileges the rest of the day.
Light activity for 24-48 h after discharge.
Force Fluids.
No phenothiazines, tricyclic antidepressants or Tigan for 48 hours after study.
Also, the patient should be told that if there are any signs of meningitis (severe headache with stiff neck, fever) within 48 hours he or she should contact their doctor or go to the emergency room.

Post Myelogram Headache
Tylenol, horizontal position, forced fluids, and caffeine all help relieve the headache. The headache can persist up to a week after the procedure. If headache persists over 24 hours after the myelogram or if there is a fever or signs of meningitis the patient should contact his referring clinician or go to the emergency room.

It may be necessary for the patient to receive a blood patch to alleviate the headache. Blood patches are effective at stopping post myelogram headaches anytime between 24 hours and several weeks after the procedure. The first blood patch is effective in 70% of patients; a second blood patch increases the effectiveness to 95%. If a headache persists at 48 hours after the procedure a blood patch should be considered. In the case of a severe headache, a blood patch should be considered at 24 hours. This involves an injection of 10-15 cc of autologous blood into the epidural space. The Neuroradiology Service performs the blood patch procedure on our post-myelogram patients **(see pp 17-22 below).** The headache usually stops immediately after the injection of blood. This suggests that the mechanism of headache is not simply CSF leak. The procedure is effective even if the epidural blood injection is not at the same level as the original myelogram needle puncture.

Equipment
Spinal needles come in 3.5-, 4.5- and 6-inch lengths. The standard needle is 22, 25- or 26-gauge 3.5 inch. The longer needles are larger-gauge (20, 22-gauge 4.5 cm; and 18-gauge 6 cm). The use of smaller gauge needles has been shown to reduce the incidence

of spinal headaches. The flow of CSF through a 25-gauge needle is insufficient to allow for CSF collection. If a CSF sample is to be obtained, use a 22 gauge or larger needle. Try to use a 26G needle whenever possible. Use 22g needle for post-op backs and for large patients.

Before starting the procedure, estimate the necessary length of needle. It is far preferable to start with a 4.5-cm needle than to find out that you are slightly short after the attempted placement of a 3.5-cm needle.
NEVER numb up with lidocaine with a spinal needle.
Table Weight Limits: 200kgs

Iodinated Contrast
Nonionic contrast must be used for the examination. Intrathecal administration of *Ionic* iodinated contrast can cause death.

We use Omnipaque (Iohexol). It comes in 20-ml vials with concentrations of 180 mg I/ml and 240 mg I/ml. The adult dose limit for myelography is 3 g total of iodine (i.e., 17 ml of 180 mg I /ml; or 10 ml of 300 mg I/ml). Use 180 for lumbar myelograms and 240 for cervical, thoracic, or combined myelograms. (Use 180 for cervical myelograms with a cervical approach). Consult the contrast material package insert for pediatric dose limits. Before drawing the contrast into the syringe, the technologist should show you the bottle. Verify that (1) non -ionic contrast is being used (Omnipaque), (2) the expiration date has not passed (the date will appear, for example, as 07 02 indicating July 2002), and (3) the desired concentration of contrast (180 or 240 mg I/ml) is being used.

Admonition
Procedures in neuroradiology are based on finesse, not brute force. Plan what you want to do, set it up, recheck it, and then do it. Avoid multiple passes with the myelography needle by knowing ahead of time what you want to do and how to do it.

LUMBAR MYELOGRAPHY
Preliminary steps
Before beginning, talk to the patient. Obtain a history and learn what information is desired from the test. Explain the risks, benefits, and alternatives to the patient. Obtain written informed consent. The post myelogram orders should be explained to the patient. Write a short note in the chart before the procedure including: indication for examination, labs, allergies, documentation of the consent, planned procedure.

Check the lab values. Check whether the referring clinician has any special requests concerning the myelographic examination or the CSF analysis.

Obtain old MR, CT, plain films and myelograms and reports. It is important to look at the old films prior to starting the procedure. Determine the level of the suspected pathology; usually you should avoid placing the needle at this level. Exclude tethered cord or low-lying conus. Count ribs from chest x-rays and old myelograms.

Place the patient prone on the table. It is useful to have a pillow under the abdomen producing a slight flexion of the L-spine. Using fluoroscopy, carefully verify the number of ribs and the number of vertebrae. Document with plain films.

Have everything needed for the procedure set up before beginning. Have the contrast drawn up and flushed through the long connection tube. The short connection tube is used for CSF collection. The long connection tube holds 1.9 cc and the short connection tube holds just over 1.0 cc.

Locate the desired entry point with fluoroscopy and place an ink mark on the skin. Prep and drape the patient. Position the patient in true prone, such that the transverse processes project in the midline between the pedicles on fluoroscopy. Locate the desired level for needle placement. (See Figure at the end of this section.) The usual level is L2-3. Above this, at L1-2, there is a risk of damaging the conus (which normally lies at L1-2 or above). Degenerative disease is usually below this level, and the presence of a large disk herniation or bulge can make it difficult to place the needle tip in the thecal sac. The thecal sac is also smaller at the lower levels, especially if there is epidural lipomatosis. The normal lumbar lordosis makes the L2-3 spinous processes and inter laminar space relatively perpendicular to the table for easier needle placement than at other levels.

Estimate the approximate depth of the thecal sac (i.e., is it superficial in a thin patient or deep in a large patient?). Anesthetize the skin with lidocaine. Deep lidocaine may not be necessary; a single pass of a 22- or 25-gauge spinal needle is less painful than multiple passes with a 22-gauge lidocaine injection needle and lidocaine injection.
Lidocaine mixed with bicarbonate is less painful than straight lidocaine. Use a mixture of 10 cc of 1-% lidocaine and 1 cc of 8.4% sodium bicarbonate.

The attending spine neuroradiologist must be present for the surgical procedure portion of the examination, i.e. needle placement and contrast injection. This is because a procedure surgical code is used in billing in addition to the film interpretation code.
The two most common approaches for lumbar needle placement are midsagittal and parasagittal. It is useful to be proficient at both approaches because in some difficult cases one may work better than the other**. We almost never use the midsagittal approach**

In the midsagittal approach the needle is usually placed between the L2 and L3 spinous processes, through the interspinous ligament. (See Figures 1 and 2 at the end of this section.) The needle should be positioned during placement such that the fluoroscopy beam looks "down the barrel." The needle should appear to be a dense dot projected between the transverse processes on AP fluoroscopy. Hold the needle with two hands; one index finger should hold the stylet in place, the other hand should be at the skin.
AP fluoroscopy should be used periodically to verify the needle trajectory. It is often not necessary to move the fluoroscopy unit back and forth, completely out of the way; just reach under the unit to advance the needle (for large patients this may not be possible). Insert the needle to the estimated depth of the thecal sac. Check the depth on

lateral fluoroscopy. Check for CSF return by tilting the table slightly head up and removing the stylet. Move the image intensifier out of the way to remove the stylet. Check for CSF return. (Note: It is very important that the head of the table is tilted up so that the column of CSF rises above the hub of the needle before withdrawing the stylet, otherwise there will be no CSF return. This might lead you to erroneously believe that the needle tip is not in the thecal sac, leading to unnecessary repositioning.) With a 25-gauge needle the CSF return might be minimal and/or slow.

The needle can be "steered" slightly by using the bevel. The bevel side is indicated by a raised mark on the hub. By rotating the needle, the bevel can be used to deflect the needle away from obstructions.

The advantage of the mid sagittal approach is that it is less painful than the parasagittal approach because the ligament is not innervated to the same degree as the paraspinal muscles.

The disadvantage of the midsagittal approach is that in a severely degenerated back it may be difficult to place the needle between the spinal processes. The space between the processes may be diminished, and the ligament may be severely calcified. This, along with the normal caudally oriented spinous process and interspinous space, makes it difficult to access the thecal sac with a needle that is oriented perpendicular to the table. Do not negate the advantages of fluoroscopy by trying to place the needle at an angle other than parallel to the fluoroscopic x-ray beam.

The oblique parasagittal technique is performed by placing the needle on either side of the spinous process. The side with the greatest interlaminar space is chosen. The patient is positioned with the knee slightly turned outward on the side of desired needle placement. This rotates the spine a minimal amount (about 10 degrees) to demonstrate the interlaminar space just to the side of the spinous process. Proceed as in the midsagittal needle placement, being sure to use the fluoroscopy beam correctly by looking "down the barrel" of the needle and seeing that it is directly superimposed on the desired target space.

The advantage of the oblique parasagittal technique is that the needle is not forced through the interspinous ligament. It need not negotiate a narrowed obliquely oriented interspinous space.

The disadvantage of the oblique parasagittal approach is that it may be more painful than the midsagittal approach because the needle passes through muscle instead of through ligaments. However, if the needle can be placed more quickly and with fewer passes, the

overall patient discomfort is less than with the other technique.

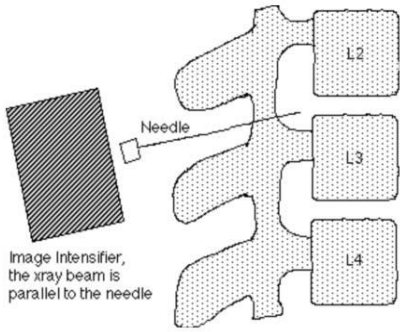


Figure. A lateral view of the lumbar spine showing the relationship between the osseous structures, the needle and the image intensifier. The x-ray beam is parallel to the path of the needle. The image intensifier is angled to optimally demonstrate the space between the spinous processes and laminae of L2 and L3.

Vasovagal Reaction

Occasionally a patient may have a vasovagal reaction during placement of the needle. This occurs most often in large young physically fit men (football player types). *Be aware of the patient fidgeting and sweating*. Stop the procedure, place the patient in Trendelenburg position and place a cool wet towel on the back of his or her neck and head before the reaction becomes severe. Assess their pulse rate and blood pressure. Let the patient recover for an extra few minutes after they seem to have recovered. Trendelenburg position and smelling salts are useful in moderate reactions (vials of smelling salts are taped to the image intensifier). A severe reaction (hypotension, bradycardia) may require IV Atropine and rapidly infused IV normal saline. The Atropine comes in premeasured syringes containing 1 mg. The usual Atropine dose is 0.8 - 1.0 mg IV slow push. It can be repeated in 3-5 minutes, up to 2 mg total. But the key point is to notice the early signs, attend to the patient and avoid a severe reaction. After the patient recovers from a vasovagal reaction they usually will not have another during the remainder of the procedure.

Once the needle is placed and there is CSF return, gently spin the needle around 180 degrees (with the stylet in place). This clears the needle from the dura and helps avoid subdural or epidural injections.

We will collect CSF for laboratory analysis only when it is requested by the referring clinician. If CSF is to be collected, collect at least 1 cc in each of the 4 test tubes in the order of the test-tube label (1, 2, then 3). The rate the CSF collects can be increased by having the patient periodically cough or bear down. Slightly more than 1 ml of fluid fills the short connection tube. Collect the CSF in the collection tubing when filling test-tube 3 by holding it at a downward slope and gently disconnecting the tube from the needle and allowing it to drain into the test-tube by gravity and siphon action. Tightly close the tubes and give them to the technologists for labeling. The technologists will transport them to the laboratory. The samples are analyzed for: cell count and differential, VDRL, glucose, and protein. Patients tend not to like to have CSF drip onto their backs; try to avoid it.

Sometimes there is a request to collect a large volume of CSF. This is fine as long as the request clearly STATES THAT A THERAPEUTIC HIGH VOLUME TAP IS NEEDED, such as in pseudotumor cerebri. In cases of "? Pseudotumor – need high volume tap" requests, confirm with manometry that the tap is warranted before doing so. 26 cm H2O is the cutoff for pseudotumor as per our neurology division. Some physicians will ask for a "high volume" tap just to run a number of lab tests. 15cc will usually suffice in such circumstances. If in doubt PAGE THE REFERRING PHYSICIAN. Neurosurgeons suggest that we do not collect more than 30 cc. Removal of larger volumes tends to cause subdural hematomas.

Connect the contrast syringe. Note that if 20 ml are drawn up initially, and 2 ml are flushed through the tube, there remains 18 ml contrast in the syringe. Thus the maximum allowable dose of 3 gm contrast can be administered without flushing through the contrast in the connection tube. (Note that the maximal dose of 17-cc contrast is seldom necessary, 13 to 14 cc are usually sufficient.) The goal is to administer sufficient contrast so that the thecal sac is completely filled below the level of the midbody of L3 when the patient is upright.

The contrast is injected under fluoroscopic observation to avoid subdural or epidural injections. The table should be tilted with the patient's head slightly upward. Lateral fluoroscopy should be used initially to clearly see the first puff of contrast *freely fall away* from the needle tip to form a dense horizontal line of contrast along the ventral side of the canal. A subdural or epidural injection can be identified by accumulation of contrast at the needle tip or in the dorsal (non-dependent) part of the spinal canal.

After one or two tests puffs are injected, then a steady slow injection can be performed. During this time, periodic lateral (or AP) fluoroscopy shows filling of the caudal portion of the sac, with no accumulation of contrast near the needle tip. Fluoro periodically throughout the injection to verify that the needle tip does not migrate and cause a subdural or epidural injection. If contrast starts to accumulate near the needle tip during the injection it usually indicates that the injection has become subdural. Stop the injection and consult the staff or fellow.

Usually 13 to 14 cc of intrathecal contrast are sufficient. This dose reduces the rate of complications relative to the highest allowable dose of 17 cc. If the patient has a patulous thecal sac the highest allowable dose of 17 cc may be necessary. The tubing is then disconnected and the stylet is replaced. The needle and stylet are left in place (or withdrawn slightly so that the tip is in the soft tissues of the back) during filming to document its location and to help localize lumbar vertebral levels.

Digital plain film images are obtained. *Make sure that the entire extent of the very distal caudal thecal sac is filled with contrast before imaging*. This may require standing the patient almost completely upright (at least 45 degrees of table tilt should be done in all patients). If there is a tight stenosis that impedes passage of the contrast into the lower lumbar/sacral canal, stand the patient up and have him or her flex and extend. This usually opens the canal sufficiently to allow for some passage of contrast. It is very rare to

have such a tight stenosis that insufficient contrast passes for adequate CT evaluation, even if the plain films do not show adequate contrast.

AP, lateral, shallow oblique and steep oblique images are obtained for the lower L Spine. (The shallow and steep obliques are obtained at about 15 degrees and 25 degrees off AP, respectively.) The Tavaras View profiles the L5 and S1 nerve roots. Head of the bed is elevated 30 degrees so that the contrast accumulates in the lower thecal sac. An image is obtained with the tube angled 30 degrees relative to the patient (so that it is perpendicular to the floor).

The patient is then positioned to move the contrast column higher and the same images are obtained for the upper L spine. *The lower images should include the sacrum and the upper images should include the lowest rib* to provide unequivocal landmarks for localization of levels (this is a good habit to adopt even though the needle is also in place for localization.)

Supine and weight-bearing flexion and extension lateral views are obtained.

Finally, a conus view is obtained with the patient supine so that the contrast accumulates near the thoraco-lumbar junction.

During the plain film examination, note levels of pathology so that these can be included in the CT examination. This is especially true for pathology that is outside of the usual limits of the CT examination (i.e., low thoracic or sacral).

A short note is left in the chart documenting the procedure, and describing any preliminary fluoroscopic findings.

THE LEVELS FOR CT ARE TO BE INDICATED ON THE MYELO REQUEST FORM. UNLESS OTHERWISE SPECIFIED, IT IS OCCIPUT-T1 FOR CERVICAL MYELOS AND T12-S1 FOR LUMBAR MYELOGRAMS. ALWAYS LOOK AT THE ORDER FOR SPECIAL REQUESTS FROM PHYSICIANS

The patient is transferred off of the myelogram table onto a gurney and transported to the CT scanner. While waiting for the CT scan, the patient should remain basically in the prone position so that the contrast stays dependent in the lumbar lordosis (unless he or she is unable to tolerate this position). The patient is then turned supine for the CT scan. If there is a long delay before the CT scan (10 minutes or more), the contrast might settle too much in the spinal canal causing layering. If the delay between the myelogram and the CT is longer than 10 minutes, the CT technologist should tell the patient to alternately roll gently and slowly toward one side, then toward the other side, etc. This mixes the contrast and helps avoid layering. (You can have the patient wait for the CT in the prone position; this ensures that he or she will turn over at least once into the supine position for the CT. Also, in the prone position, the contrast collects in the lumbar lordosis--where you want it--rather than pooling in the sacrum.)

The technologists should also check the scanogram at the beginning of the CT scan. If the contrast is seen layering in the lumbar or sacral regions, the patient should be rolled from side to side or completely around to mix the contrast before proceeding with the CT scan.

For suspected pathology outside of the usual levels, instruct the technologists to obtain images at additional levels.

CT images are photographed at a "myelographic window" between usual CT bone and soft tissue windows (W 2000/C 0). This window is optimal for viewing the contrast in the thecal sac.
THE REQUESTS FOR THE MYELOGRAMS ARE FOUND IN THE BIN NEXT TO THE ANGIO WORK STATION IN THE ANGIO ROOM.

The examination must be read and dictated on the day of the procedure since many patients will have surgery the following morning. **The dictation must include A SLOT AT**

THE END FOR ATTENDING PRESENCE.
The findings portion of the report is best organized level by level, i.e. all of the findings at L12 are described, then L23, etc.

Lumbar Myelogram with Congenital Lumbar Anomaly
These patients should usually be evaluated by MRI before the myelogram in order to delineate the exact nature of their anomaly. Often a lumbar myelogram is obtained by injecting the contrast in the cervical region and running it down to the lumbar region. This approach avoids placing the needle through a region of anomaly. However, many of these patients have associated cervical anomalies such as low lying cerebellar tonsils. Before placing a needle into the cervical region you must be sure that there is no accompanying cervical lesion. A cervical MRI is the best and most positive proof. If you are sure that the patient's particular lumbar anomaly is not associated with a cervical anomaly you might proceed without an MRI.

Cervical Approach for Lumbar Myelogram
Occasionally it is necessary to do a cervical approach for lumbar myelogram. Perform the puncture as described below. It is usually best to use 300 mg I/ml contrast so that adequate opacification will be obtained after the contrast dilutes on its way down to the lumbar region. Inject the contrast with the head of the bed up and allow the contrast to flow into the lumbar region (and not into the head).

Note that only Neuroradiology Fellows and Staff are allowed to perform C1-2 punctures and injections.

CERVICAL MYELOGRAPHY
Cervical Myelography--Lumbar Approach
The history, consent, and old films are as described above.

Using the lumbar approach for cervical myelography, the contrast is administered in the lumbar region and manipulated under gravity to the cervical region. The patient can be positioned either prone or in the lateral decubitus position while the contrast flows to the cervical region.

Beware, spinal cord damage can result if a patient with severe cervical canal stenosis is over extended. Look at previous imaging studies before positioning the patient to assess for cervical spinal canal stenosis. If there is severe stenosis consider either a cervical approach for introduction of contrast or use the lateral decubitus position for running the contrast up from a lumbar introduction. Note that a severe stenosis will impede passage of the contrast so there is no need to extend the neck to create a lordotic depression to trap the contrast.

Patient in Prone Position: Pillow supports are placed around the head to gently extend the neck and produce a lordotic cervical curvature. The contrast will collect in this lordotic depression rather than running into the head.

Access to the thecal sac is as was described above for the lumbar myelogram. 10 cc of 240-mg I/ml contrast are administered. During administration the table is tipped with the patient's head slightly downward. Care is taken to avoid too steep of an angle, which would send the contrast beyond the cervical lordosis and into the head. However, the angle must be steep enough to allow the contrast to flow over the normal thoracic kyphosis. The contrast can be observed either with lateral or AP fluoro. First verify the subarachnoid injection in the lumber region, and then move to the cervical region to monitor the contrast accumulation. Proceed with imaging as below.

Patient in Lateral Decubitus Position: By having the spine horizontal, this position avoids the problem of getting the contrast over the thoracic kyphosis without having it flow into the head. This method is most useful in patients with an exaggerated thoracic kyphosis and least useful in patients with scoliosis. Access the lumbar thecal sac. With the table level, administer the contrast. Adjust the angle of the table to avoid having the contrast flow into either the sacral or thoracic region.

Position the patient in the lateral decubitus position facing away from you. Have the patient turn his/her face toward the ceiling and tip their upper ear toward the upper shoulder to create a cervical depression. Using LATERAL fluoro observe the contrast as it flows cephalad while tilting the table. Once the contrast is in the cervico-thoracic region have the patient turn prone with his/her head extended. Adjust the table tilt to maximize the contrast in the cervical region.

Images are obtained: AP, lateral, steep and shallow obliques. A swimmer's view of the cervical-thoracic junction is obtained. The plain film images should be acquired expeditiously while the contrast is well concentrated in the cervical region.
CT of the cervical spine is obtained from the skull base to T1. Additional levels can be obtained if necessary.

Cervical Myelography--Cervical Approach

The cervical approach should **be *performed only by Neuroradiology Staff or Fellows AND ONLY IF ABSOLUTELY INDICATED, AFTER CLEARANCE FROM AN ATTENDING PHYSICIAN*.** Residents are encouraged to observe.

The cervical approach shares the same risks and complications as the lumbar approach. In addition, there is also the risk of direct trauma to the cord by the needle. Contraindications to the procedure include Chiari malformation with low-lying cerebellar tonsils or a low course of the posterior inferior cerebellar artery (PICA). If the CSF cistern posterior to the cord at C1-2 is too small for safe puncture, a lumbar approach should be used. If previous MR or myelograms are available they should be studied to exclude the presence of these entities. When filling out the consent form, remember to include the risks that are unique to cervical myelography.

Ankle braces or a body harness should be used to avoid the patient slipping off the table. There are two approaches for cervical puncture, the horizontal needle approach and the vertical needle approach. In the horizontal needle approach the patient is positioned prone on the table, whereas for the vertical needle approach the patient is positioned in the lateral decubitus position. Both involve placement of the needle at the C1-C2 level. **WE ALWAYS USE THE HORIZONTAL APPROACH.**

In the horizontal needle approach, the patient is placed in the prone position with the neck positioned such that the contrast introduced into the C1-C2 area will pool in the cervical region (i.e. so that it will not run into the head or down into the thoracic spine). This does NOT usually require extending the neck, the normal lordosis of the neck in neutral position usually suffices. The important aspect is to tilt the table so that the cervical spine is overall horizontal (between C1 and C7) with the lowest point in the mid-cervical region.

Use of a head-extending device is usually NOT necessary (and not desirable). When the neck is extended the cord is moved into the dorsal spinal canal where the needle will be placed. The extended neck position also closes the C1-C2 interlamina space where the needle is to be placed. Finally, extending the neck accentuates stenosis; this could potentially injure the cord in a patient with severe stenosis or a large disk herniation. Care is taken to position the patient such that horizontal fluoroscopy views the spine in a true lateral projection. Line up the right and left external auditory canals in the head and the right and left sides of the arch of C1 in the cervical spine.

The horizontal needle is placed between the pedicles of C1 and C2 at the junction of the ventral 2/3 and the dorsal 1/3 of the spinal canal. Lateral fluoroscopy is used. The needle is positioned so that a "down the barrel" view is projected directly over the target point. Estimate the depth from skin to thecal sac (the needle can be placed over the patient's neck for direct estimation). Insert the needle. Check the depth of the needle tip by AP fluoroscopy. A characteristic "pop" is felt when entering the dura. Do not rotate the needle to clear it from the dura, as is commonly done in the lumbar region. If the needle happens to be in the cord this maneuver would increase the damage.

Common mistakes include: Placing the needle too far posteriorly; this can cause one to pass posterior to the thecal sac. Another common mistake is to not advance the needle slightly after the dura is entered; this may lead to a mixed epidural/subdural/subarachnoid injection because the needle does not completely clear the dura.

Either 10 cc of 240 (or 15 cc of 180 contrast) can be used. **Verify the location of the needle in the thecal sac by fluoroscopy and by ample CSF return before injecting contrast.** ***Do not inject contrast if there is any chance of the needle being in the cord.*** The first injection should be a small puff viewed under lateral fluoroscopy. The contrast should be seen to cascade down away from the needle tip, over and around the cord, and into the ventral side of the thecal sac. Epidural and subdural injections are identified by contrast pooling around the tip of the needle. During the injection, care is taken to avoid contrast running into the head (which may cause a seizure). Periodically fluoroscopic observation is used throughout the injection to verify that the needle tip does not migrate and cause a subdural or epidural injection.

As contrast begins to accumulate in the cervical region the patients usually experience a crampy pain in the neck, across the back and down the arms. This is probably related to direct irritation from the contrast. The patient will want to move his/her neck to relieve the cramp. If you are satisfied that the pain is due to this and not some other cause, tell the patient that this is a common but transient effect. It usually lasts about 10-15 minutes. Advise that changing positions will not help and that soon the pain will lessen on its own. Ask the patient to remain still for the filming.

Filming is as described in the lumbar approach/cervical myelogram section. The plain film images should be acquired expeditiously while the contrast is concentrated in the cervical region.

The vertical needle approach for cervical myelography involves placement of the needle at C1-C2 under vertical fluoroscopy. This approach is most useful when horizontal beam fluoroscopy is not available, such as when using a "GI" x-ray table. The patient is positioned in the lateral position. The needle is again parallel to the fluoroscopy beam, but both are vertical, rather than horizontal as above. The contrast can be injected with the patient in the lateral position, and then the patient is rolled prone with head extended after the needle has been removed. Alternately, the patient can be rolled prone with the needle in place, then the contrast can be injected (care must be exercised to avoid cord damage from the needle during patient repositioning).

The dictation must include as the last line of the procedure section, "Dr. Smith, the attending neuroradiologist, was present throughout the procedure".

RELATED PROCEDURES

Lumbar Puncture under Fluoroscopy

If an LP can not be performed by the clinicians, the patient can be sent for LP under fluoroscopy. Before beginning, check whether the referring clinician has special instructions for the CSF analysis so that it is collected and handled in the proper

manner. CSF is obtained. If access is not possible in the lumbar spine, a cervical approach may be necessary.

In order to ensure that the proper laboratory tests are ordered on the CSF sample, the collected CSF is given to the referring clinician for disposition.

LP for Meningitis: It is a good idea to start with a 20-gauge needle. In frank meningitis the purulent CSF may be too viscous to flow through a 22-gauge needle.

LP for Multiple Sclerosis: When collecting CSF to examine for the diagnosis of MS (usually cell count and differential, total protein, gamma globulin, and oligoclonal bands), *a minimum of 8 cc* of CSF must be collected.

LP for cells: CSF is often collected to diagnose cells in a malignancy. If there is a large intrathecal or intramedullary mass, the removal of CSF below the mass might cause it to herniate downward. Previous images are helpful to assess for risk of herniation. One might consider a C1-2 or cisterna magna tap if there is a great risk of herniation of a spinal lesion from lumbar puncture.
The dictation needs to explicitly state the staff member's name and that he or she was present for the procedure.

CSF Opening Pressure

A true CSF opening pressure must be measured with the patient in the lateral position so that the entire CSF column is at the same horizontal level. This horizontal position of the CSF in the spine is not possible in the prone position due to the normal cervical and lumbar lordosis and thoracic kyphosis.

Set up the manometer before starting the procedure. Have the stopcock valve set to be open from the needle attachment port to the manometer.

Place the patient in the lateral position and place the spinal needle at L23 with fluoro using a midsagittal approach (to keep the needle level with the CSF). When in the thecal sac, attach the stopcock to the needle. Wait for the CSF to stop rising in the manometer. This takes a few breaths of the patient. Measure the pressure in cm of water (i.e. not mm Hg). The pressure varies with the cardiac cycle; use the maximum pressure over the cycle. Abnormal is more than 18 cm water.

If CSF is to be collected, open the stopcock to allow the CSF in the manometer to flow into the test-tube.

Include the opening and closing pressure in your dictation. The dictation needs to explicitly state the staff member's name and that he or she was present for the procedure.

CT Cisternogram

A CT cisternogram involves injection of intrathecal contrast followed by head CT. This is used for evaluation of arachnoid cysts and for investigation of CSF leaks, particularly into the nasal cavity after trauma or surgery.

In the case of CSF leak, the CT cisternogram is used to locate the source of a known CSF leak prior to surgery. A radionuclide study (below) is usually used to determine whether a leak is present. Slow leaks might not be identified on the CT study.

Contrast is administered into the lumbar spine or less often the cervical spine as described above. Because a large amount of contrast in the head may produce seizures, only 5-7 cc of 180 nonionic contrast (Omnipaque [Iohexol]) are administered.

Have the patient face down and head down for contrast to pool near the sinuses. Obtain an immediate post contrast axial CT .If this is negative, a coronal or 30 minute delayed CT may be useful. If you obtain a delayed image much later than 30 minutes the contrast will be too dilute to see well.

The dictation needs to explicitly state the staff member's name and that he or she was present for the procedure.

Radionuclide Cisternogram

This study is used to look for CSF leaks into the nasal cavity and to assess the CSF flow in normal pressure hydrocephalus.

In the case of CSF leak, the radionuclide cisternogram is used to determine whether a CSF leak is present. It is quite sensitive to slow leaks. However, it can not determine the exact location of the leak. A CT cisternogram (above) is used for preoperative planning to identify the source of a known leak.

The technologists usually order and pick up the radionuclide from Nuclear Medicine (Hot Lab 362-2799). Before starting the procedure, verify that the radionuclide is present and ready for injection.

Obtain the patient's consent for the LP. It is also a good idea to obtain consent for contrast administration. (Occasionally it is useful to inject a little contrast prior to administering the radionuclide to verify that you are indeed in the thecal sac.)

A needle is placed into the lumbar thecal sac.
In the case of R/O CSF leak, CSF is usually collected because of the risk of meningitis.
In the case of normal pressure hydrocephalus, NPH, ask the clinician ahead of time if they would like an opening pressure, or just obtain the measurement.

The radionuclide for injection (0.5 mCi of 111-indium DTPA) is sent from Nuclear Medicine in a lead container. Keep it in the lead container until you are ready to inject it. Nuclear Medicine says that you need not wear special leaded gloves while holding the syringe

during the injection, just wear the usual sterile gloves and then discard them. Note that the syringe containing the radiopharmaceutical is not sterile.

All items that touched the radiopharmaceutical need to be disposed of in a special radioactive disposal container (syringe, needle, etc).
The dictation needs to explicitly state the staff member's name and that he or she was present for the procedure.

On the rare occasion that a CT cisternogram and a radionuclide cisternogram are done simultaneously, nuclear medicine prefers that the radiopharmaceutical is injected before the iodinated contrast so that it has a little longer to circulate before scanning. After injection, obtain the post injection CT, then send the patient to Nuclear Medicine for the first scan. Then have the patient return to Radiology for a delayed CT, if necessary.

Chemotherapy Injection

Intrathecal chemotherapy is often administered, especially for intracranial lymphoma and leukemia. These patients are often thrombocytopenic, so check the coagulation factors and the platelet count before proceeding. A platelet count below 50,000 requires a platelet transfusion before LP. Check before the procedure that the technologists ordered (362-1518) and picked up the chemotherapeutic agent.

Discuss the risks of LP in addition to the risks of chemotherapy injection to the patient before the procedure. As with administration of any drug, the risk of chemotherapy reaction needs to be explained in the consent process. It is also a good idea to obtain consent for contrast administration. (Occasionally it is useful to inject a little contrast prior to administering the chemotherapeutic agent to verify that you have indeed accessed the thecal sac.)

The lumbar approach is most common. Sometimes, after many doses, there are adhesions and sclerosis in the lumbar thecal sac, making access difficult. Delivery of chemotherapy should probably not be done via a cervical approach. An Ommaya reservoir may need to be placed by Neurosurgery if there is no access to the thecal sac via LP.

Occasionally the clinician requests CSF collection for laboratory analysis. This is usually cell count (at least 1 cc in one tube) and cyto-spin (at least 4 cc in a second tube).
Wear safety goggles while handling and administering the chemotherapeutic agent. A protective gown may also be appropriate.

The outside (and inside) of the syringe containing the chemotherapeutic agent is sterile. It is delivered within a special container to maintain sterility. Inject the agent at a moderate rate; there are no special guidelines for the rate of injection. Insert the stylet before removing the needle so that no chemotherapeutic agent is deposited in the soft tissues during needle removal.

All items that touched the chemotherapeutic agent need to be disposed of in a special chemotherapy disposal container (syringe, needle, gloves, etc).
If the patient is an outpatient, he or she can leave immediately after the injection. No observation period is necessary.
The dictation needs to explicitly state the staff member's name and that he or she was present for the procedure.

MISCELLANEOUS
Residents should be maintaining a procedure book in which all procedures are logged. The entry should include: date, patient name, procedure, and staff. It is necessary to document procedures performed for future board certification and hospital accreditation. The myelogram entries should include the site of puncture (cervical or lumbar) and the region(s) imaged. Other procedures to be put in the book include angiograms, drainage procedures, biopsies, arthrograms, etc.
Fellows should maintain a procedure book until after passing the CAQ examination.
Note: Medicine is an ever-changing science. Although the author has made every effort to ensure the accuracy of the information in this article, readers are encouraged to confirm the information herein with other sources. Drug and procedural information are designed as guidelines. Nuances in performing safe procedures depend on the operator's experience and the patient's condition. Certain applications described herein may not be appropriate for a given patient situation. Moreover, readers are advised to check product information available in the package insert for specific drugs and to tailor usage for each individual patient cognizant that dosages, indications and contraindications may change.

POST DURAL PUNCTURE HEADACHES AND EPIDURAL BLOOD PATCHES *–please refer to Dr. NicolasJilwan's PowerPoint Presentation, also.*
Headaches occur in 1% to 30% of patients following dural punctures (Choi, 1996). Symptoms vary from mild to incapacitating and may persist for days or even weeks. Although this usually self-limiting complication may be considered merely an annoying nuisance to the busy physician, the post-dural-puncture headache (PDPHA) comprises a significant aspect of patient care for those neuroradiologists performing myelograms and fluoroscopically guided diagnostic lumbar punctures.

RECOGNIZING THE PDPHA – Prior to treating PDPHA, the diagnosis must be secured and differentiated from mimics such as meningitis (usually heralded by fever, stiff neck, and a nonpostural headache). Key aspects of the PDPHA include (Hardman, 1996; Leibold, 1993; Weakland, 1994);

1. Severe postural headache aggravated by Valsalva maneuver- worse when patient sitting up; better when lying down.
2. Headache affecting any part of the cranium, but typically located in the frontal or occipital region; rarely unilateral.
- pressure, pounding, worse on movement of head.
3. Onset usually within 24 hours of dural tap, but may be delayed.
- 90% of patients develop PDPHA within 3 days.
- 25% resolve within 7 days.
4. Associated findings:

Visual or auditory symptoms.
Nausea, vomiting.
Neck stiffness.
Visual symptoms such as photophobia, blurred vision, diplopia (10%).
Dizziness.
Hearing loss.
Occasionally cranial nerve palsies due to traction.

MIMICKERS OF PDPHA – The positional nature of PDPHA provides the key to diagnosis. Nevertheless, other headache syndromes can mimic PDPHA. Clinical differential diagnoses include:

1. Meningitis – fever, patient usually quite ill. Assuming sterile technique for the original spinal puncture, this complication is quite rare. Nevertheless, any patient with a question of infection should be referred to the Emergency Department immediately.
2. Pneumocephalus – not positional.
3. Cortical vein thrombosis – not positional; patient usually quite ill.
4. Migraine – not positional, may have prodrome.
5. Hypoglycemia – not positional.
6. Dehydration – not positional.
7. Fatigue – not positional.
8. Subarachnoid hemorrhage – not positional; patient usually quite ill.

MECHANISMS OF THE PDPHA – The currently held theory for the PDPHA states that the tear in the dura left by the spinal needle produces a leak of cerebrospinal fluid (CSF). The leak causes intracranial hypotension, reflex arterial dilatation, and resultant headache. Intracranial hypotension also causes loss of intracranial buoyancy and traction on pain-sensitive structures such as the basal meninges (Hardman, 1996; Weakland, 1994). In its most severe form, intracranial hypotension has been linked with development of subdural hematoma (Tekkok, 1996).

Research has revealed that younger patients are at higher risk, possibly due to differences in meningeal thickness or compliance compared to older adults (Leibold, 1993). Women are affected twice as commonly as men. Development of PDPHA is inversely related to needle size. Therefore, smaller needles, such as 25G, theoretically should be associated with fewer headaches compared to 18G or 20G needles. Special needles, such as the pencil point needle, may reduce the incidence of PDPHA; however, benefits must be weighed against added cost. Needles puncturing the dura at an oblique angle to the long axis of the spine cause almost 10% fewer headaches than punctures perpendicular to the long axis of the spine. Apparently, this approach tunnels into the dura and allows for the edges of the dural hole to close more effectively than if the dura is cleanly cut. Orienting the bevel of the needle parallel to the longitudinally arranged dural fibers may also diminish likelihood of PDPHA. Hypovolemia and dehydration prior to puncture increase likelihood of PDPHA. Interestingly, operator skill has not been shown to correlate with PDPHA (Leibold, 1993). Finally, traumatic taps seem to produce fewer PDPHAs than nontraumatic taps, possibly due to “self-administered” blood patches.

TREATMENT OF THE PDPHA – Conservative measures include:

1. Bedrest – symptoms improve with the patient in the horizontal position. This position may also relieve hydrostatic pressure around the leak.
2. Hydration.
3. Analgesics – Over-the-counter analgesics usually adequately control pain. Analgesics should not substitute bedrest and horizontal positioning.

a. Aspirin, acetaminophen (Tylenol), or ibuprofen (Advil, Motrin) following dosage recommendations on the label.

NOTE: Aspirin 650 mg po qid, acetaminophen (Tylenol) 650 mg po qid (not to exceed 3900 mg/day), or ibuprofen (Advil, Motrin) 200-300 mg po q4-6 hrs. (not to exceed 3200 mg/day) is usually adequate. Some preparations of ibuprofen offer 800 mg tablets. Cautions related to anticoagulation, gastrointestinal upset, prior allergy, and aspirin sensitivity apply.

b. Narcotics should be avoided.

4. Caffeine 300 mg po – This often-overlooked drug found in coffee and cola drinks offers excellent short-term relief by causing mild vasoconstriction. Caution with rebound phenomena pertains. Heavy coffee drinkers should be encouraged to maintain their usual intake to avoid withdrawal headache, which can exacerbate PDPHA. Caffeine can be administered as caffeine sodium benzoate 500 mg IV q8h in severe cases. Caution re: coronary status and seizures applies.

Caffeine contents of common foods	
Coffee, 5-8 oz	
Regular brewed	40 – 180 mg
Instant	30 – 120
Soft drinks	20 - 110

NOTE: Some over-the-counter preparations such as Excedrin Extra strength (Acetaminophen 250 mg, aspirin 250 mg and caffeine 65 mg per tables; average dose 2 tablets po q6h not to exceed 8 tablets in 24 hrs.) offer analgesia and caffeine

5. Epidural blood patch – See discussion below.

EPIDURAL BLOOD PATCH – Epidural blood patch (EBP) is the preferred therapy for sealing the dural leak and attacking the cause of PDPHA.

What is EBP? – EBP consists of delivering autologous blood into the epidural space.

How successful is EBP? – EBP is typically 85%-90% effective after the first patch and 95%-98% successful after a second patch, if a second EBP is necessary (Choi, 1996; Hardman, 1996). Relief may occur instantly.

When is the best time to administer EBP? – EBP is 96% successful when administered after 24 hours following lumbar puncture (Weakland, 1994). Interestingly, EBP is only

24% successful if performed within 24 hours of puncture (Hardman, 1996). Prophylactic EBP has not been shown effective.

How does EBP work? – The short-term effect may be due to tamponade of the epidural space, which temporarily elevates intracranial pressure. This reinstates brain buoyancy and often provides instant relief (Weakland, 1994; Carrie, 1991). Magnetic resonance imaging has demonstrated the initial mass effect of the clot. Long-term relief probably occurs because the clot occludes and fibroses the hole in the dura.

How does one perform EBP? – Following the diagnosis of PDPHA, counseling and advised consent, begin an intravenous line for hydration with normal saline (20-30 ml/hr). Attach a three-way stopcock to the line.

An 18G spinal needle is introduced into the ligamentum flavum of the chosen lumbar level. Blood used for the EBP tends to track cranially, as demonstrated in tagged red cell studies; therefore, the EBP needle should be placed at the site or one interspace inferior to the original tap site (Hardman, 1996; Taivainen, 1993). If the original tap was paramedian, the needle should be placed on the same side of the midline as the tap. Fluoroscopy may be helpful for visually positioning the needle.

A 5-ml syringe is filled with approximately 2 ml of normal saline. This 5-ml syringe is then attached to the spinal needle hub. The spinal needle is gently advanced while applying gentle pressure on the syringe piston. When the epidural space is entered, resistance to the piston markedly diminishes. Withdraw the piston slightly to exclude the possibility of entering the subarachnoid space. If CSF freely flows (indicating an intrathecal needle), attempt a second tap at a lower level (Miller, 1994).

Once the epidural space has been identified, 20 ml of blood is withdrawn from the intravenous line using the three-way stopcock; care must be taken to avoid sample dilution by the normal saline. It may be necessary to discard the first few saline diluted mls. (Because withdrawing venous blood prior to the epidural tap risks having a clot clog the syringe, we recommend that the venous blood be obtained after the epidural space is identified.) Inject the blood slowly into the epidural needle. The optimal volume of blood for injection is controversial; however, based on the current literature, the recommended volume should be approximately 15 ml (Taivainen, 1993; Hardman, 1996). Volumes less than 10 ml are often ineffective and volumes greater than 15-20 ml have a higher incidence of complications such as backache (Weakland, 1994). Document the procedure in the patient's outpatient record.

Is blood the best medium? – Substitutes of normal saline, crystalloid, and dextran have not been shown to be as effective as blood and even carry a higher rate of adverse effect.

When is EBP contraindicated? – EBP is contraindicated in the following situations:

1. Coagulopathy – Risk of epidural bleeding with needle placement; lack of clot formation with instilled blood.
2. HIV positive status – Risk of epidural abscess.

3. Meningitis – Risk of epidural abscess.
4. Septicemia – Risk of epidural abscess
5. Local skin infection – Risk of epidural abscess.
6. CNS or marked nerve root dysfunction – The temporary rise in intracranial and/or epidural pressure with epidural tamponade could exacerbate intracranial or peripheral nerve root conditions. Most of the conditions for which patients are referred for myelography should be eligible for EBP; however, patients with serious motor impairment or bowel or bladder dysfunction should only be referred for EBP after consultation with the clinician.

What are the complications of EBP? Blood extravasating into the subcutaneous tissues of the back may contribute to the backache (Carrie, 1993). This mild transient complication occurs in 35% of patients and usually occurs with higher volumes of injected blood. Leg pain or paresthesia is rare (1%) and should be investigated with MR imaging. Bradycardia and mild hyperpyrexia are usually transient. Facial nerve palsy has been reported and may be due to increased intracranial pressure and compromise of blood flow to the nerve. Arachnoiditis is rare due to the small amount of blood injected (Choi, 1996; Weakland, 1994).

What if the EBP is ineffective? - A second patch may be considered. At this point, consultation with the referring clinician is advised. CT or MR imaging of the brain or spine or other evaluation may be necessary for excluding:

1. Meningitis – fever, child, stiff neck
2. Intracranial hypertension – papilledema
3. Intracranial mass lesion (hematoma, tumor) – focal signs.
4. Cortical vein thrombosis.

CHECKLIST FOR EPIDURAL BLOOD PATCH

1. Determine if the headache is truly a post dural puncture headache (PDPHA). Measure the patient's temperature and obtain the white blood cell count. Review contraindications.
2. Explain the procedure and potential complications. Obtain informed consent.
3. Begin an intravenous line for hydration with normal saline. Attach a three-way stopcock to line.
4. Position the patient and determine the desired vertebral level for puncture. Aim for the site of the original puncture or one interspace inferior to the original tap site.
5. Place an 18G needle into the ligamentum flavum. Using a 5-ml syringe containing approximately 2 ml of normal saline, advance the needle into the epidural space while applying gentle pressure on the syringe piston. Upon entering the epidural space, resistance markedly diminishes. Withdraw the piston slightly to exclude the possibility of entering the subarachnoid space. If CSF freely flows, attempt a second tap at a lower level.
6. Withdraw 20 ml of blood from the intravenous line using the three-way stopcock. Be sure to avoid dilution with the saline.
7. Inject 15 ml of blood slowly into the epidural needle.

8. Keep the patient horizontal (no bathroom privileges) for 1-2 hours while infusing normal saline (20-30 ml/hr).
9. Instruct the patient to avoid straining or lifting for 4 to 5 days and to seek medical advice if headache symptoms recur or fever or chills develop. A stool softener [i.e., Docusate sodium (COLASE) 50 mg po bid up to 200 mg/day for 5 days] is recommended.
10. Document the procedure in the patient's records

Appendix 5

DICTATING ADVICE and RADIOLOGY REPORTS

It is essential to learn to issue accurate, readable, and error free radiology reports every time. Besides the obvious issues of communicating precisely with the referring physician, good medical care and insurance reimbursement, lawyers show NO mercy and jurors and judges do not understand excuses like "But I dictate hundreds of these a month" or "Most of my reports don't contain mistakes like this," or "What I really meant to say was…"

1. Check EVERY dictation for errors, coherence, and readability. The written report is your final work product and a legal document. Make sure your sentences are understandable and not filled with gibberish that convey little meaning (ex: “there are multiple T2 hyperintensities that are T1 hypointense and are nonspecific”).

2. **DO NOT MIX UP RIGHT VS. LEFT IN YOUR REPORTS.** Always, always, always double check RIGHT vs. LEFT *throughout* the report before signing.

3. All invasive procedures (angios, myelos, bxs, etc.) need to be dictated as soon as the procedure is done (NOT the next day), including on-call studies.

4. All inpatient and ED imaging studies must be dictated and sent to the Attending’s queue prior to leaving for the day.

5. Do not put out a preliminary report with an Attending’s name in the signature section (please leave a blank set of brackets beneath your signature) unless that Attending has already sat down and reviewed the case with you.

6. Avoid radiology jargon in the Impression, esp. MRI techno lingo (“T2 hyperintensities,” “susceptibility artifact,” “lesion with T1 shortening”). You can use those terms in your description in the body of the report, but for the Impression you should aim to SUMMARIZE and give your OPINION in “plain English.”

7. Keep dictations concise but pertinent. Give a succinct statement for each conclusion. Do not repeat the body of your report.

8. Use PARAGRAPHS to logically group thoughts or anatomic areas described, instead of one long block of randomly placed sentences. Place your statements about the clear paranasal sinuses, normal orbits, etc. in a separate paragraph from your description of brain lesions.

9. When dictating comparisons, state the **type of exams** compared, not just the date of the exam you’re comparing (ex: “Comparison: Head CT 5/6/07, Brain MRI 8/3/08”)

10. If an MR is the most recent brain exam available for comparison for a current head CT you're reading, use it. Don't just look for old head CTs for comparison.

11. Specify the **indication** (or “additional clinical data”) for the examination, if it does not come up automatically when you wand it into Power Scribe. Do **NOT** use the words “history of …” Also do not use: rule-out, probable, suspected, questionable or pre-op --- these words cannot be coded.

You should include signs and/or symptoms that prompted the ordering of the test. These are needed for coders if a test does not provide a confirmatory diagnosis. Look it up in the electronic medical record if necessary.

12. If studies are done without and with contrast, first document the without findings and then additional findings on the post-contrast study. **EVERY post-contrast exam must include a statement in the body of the report regarding the findings after contrast.** Ex: “There are no areas of abnormal contrast enhancement.”

13. When unexpected, unusual or urgent findings are seen on imaging, **call** the referring physician **and document** in your report when (date and time) and with whom you communicated.

14. EVERY brain report must include a statement about a) ventricle size and b) whether ventricles are midline or shifted. Do not avoid this responsibility by saying “the ventricles are unchanged.”

15. If you are reporting the first appearance of a mass, cyst, hematoma, etc. no matter where located (i.e. brain, thyroid, spinal canal) report the **measurements** of the lesion. It is inadequate and poor practice to say "small mass in the frontal lobe" or "large hemorrhage in the cerebellum." What do "small" and "large" mean?

If you are looking at a follow up study and the size has already been reported on earlier imaging studies, you don't have to keep giving the measurements.

16. “Prior" and Priors" are not nouns, unless you're referring to monks of some religious orders. Example: don't say "Comparison: No priors"

17. Subarachnoid hemorrhage IS an extra axial fluid collection, so don't describe SAH and then go on to say "no extra axial fluid collections."

18. No need to say this long string of words: "...is unchanged *compared to prior CT exam of 5/12/08*." Simply say "...*is unchanged."* You've already put at the top of the report what exam you are comparing. If you are comparing to more than one old exam, in the body of the report you can say *“…is unchanged compared to the May 2007 MRI”*

19. For that matter, the use of "PRIOR" is hardly every needed. It is almost ALWAYS redundant, as in "prior comparison."

20. "There has been an interval increase..." is better simply said as "There has been an increase..." Likewise, what's the difference between "no interval change" and "no change?" Brevity is GOOD.

21. Shunt catheters RARELY "change position" spontaneously. You don't need to mention again in the impression that the shunt is unchanged if you've made a brief statement in the body.

22. Do not waste your time describing every location of post-op pneumocephalus; it will be in a different location by the time the patient gets back upstairs. Just comment on the overall general amount and say something if there's mass effect (tension).

23. Foramen of Monro. NOT MONROE.

24. If there's a bur hole, then the calvarium is NOT "intact."

25. Don't let embarrassing typos or voice recognition errors go through. Watch out for common Power Scribe errors, such as: "restrictive effusion" which should be, correctly, "restricted diffusion."

26. An answer to the arguments over what the plural form is for globus pallidus: use "pallidal nuclei" or "globi pallidi."

27. Do not overuse "significantly." If there is no edema, say so, rather than "no significant edema." It is fun to be definite, so take advantage of those opportunities.

28. Do not waste your breath on "…unchanged in size and imaging characteristics." Simply say "is unchanged." Says it all.

29. Do not say "posterior fossa mass" if you can narrow it down to "inferior vermian mass" or "right cerebellar mass" etc.

30. "High" and "upper" are not brain anatomic descriptors. Use "superior" or "cephalad" or "at the vertex."

If an Attending expresses some unique preference for how dictations should be done, try to remember and do it that way for that attending

APPENDIX 6

CONTRAST POLICY FOR NEURORADIOLOGY

	CT	MRI
when to check creatinine	renal insufficiency and/or disease (including solitary kidney, renal transplant, renal tumor)	
	age > 60	
	history of hypertension	
	history of diabetes	
	history of vascular disease (CAD, MI, carotid disease, PVD, or known visceral artery disease)	
	history of severe hepatic disease liver transplant/pending liver transplant	
	history of collagen vascular disease	
	history of paraproteinemia syndromes such as multiple myeloma	
definition of what is sufficiently current lab	within 30 days of imaging study	
	needs to be more recent if history of recent illness	
	patients from the ED should have labs drawn the same day	
in the setting of acute stroke patients	need for a creatinine check prior to a stroke CT can be waived by the ED or neurology attending if obtaining a creatinine value would delay acute stroke treatment (IV or IA thrombolysis)	for a stroke MRI/MRA, a creatinine value should ALWAYS be obtained first; if there is no time to wait for a creatinine value, then MRI without contrast and TOF MRA techniques ONLY should be used; NO gadolinium contrast should be administered
how to handle creatinine values	estimated GFR (eGFR) should always be calculated	
	eGFR > 45 ml/min: administer contrast as prescribed (this includes single kidney with normal eGFR)	*eGFR > 60 ml/min:* administer contrast as prescribed (this includes single kidney with normal eGFR)
	eGFR < 45 ml/min: **the technologist will double check with the protocling radiologist that iodinated contrast is needed** if contrast must be administered (in exceptional circumstances):	*eGFR 30-60 ml/min:* - try to reduce the dose of Multihance - do not use Omniscan, Optimark and Magnevist

	- pre and post hydratation (oral or IV) 250 cc of normal saline solution, with special consideration for patients with a history of congestive heart failure - try to reduce the dose of Omnipaque - use Visipaque in diabetic patients at least 24 hours gap between repeat high volume contrast injections (CTA, head/neck and rest of the body, etc) in patients with renal issues	
	eGFR < 30 ml/min: iodinated contrast will usually not be administered iodinated contrast should NEVER be used if the patient is still making urine and is on intermittent dialysis neuroradiologist will suggest alternative options if contrast must absolutely be administered: - patient needs to be consented - use Visipaque - dialysis should be arranged within 24-36 hours post injection	*eGFR < 30 ml/min:* **gadolinium can be prescribed only by the neuroradiology attending** CT (possibly with contrast if absolutely needed) should always be considered as an alternative if contrast must be administered (in exceptional circumstances): - study must be performed at the medical center - patient needs to be consented for the risk of nephrogenic systemic fibrosis - try to reduce the dose of Multihance - do not use Omniscan, Optimark Magnevist - dialysis should be arranged immediately post injection
pregnant women	Try to avoid CT and iodinated contrast in pregnant women	No gadolinium contrast in pregnant women
breastfeeding mothers	encourage to discontinue breast feeding for 24 hours, and pump and discard breast milk for that 24-hour period	discontinue breast feeding for 24 hours, and pump and discard breast milk for that 24-hour period

Refer to special policy for metformin