The Electronic Revolution in Radiology: A Leapfrog Opportunity for Pathology

Electronic-based Information Workflow: Analogous, Complementary, and Converging

Paul J. Chang, M.D., FSIIM

Professor & Vice-Chairman, Radiology Informatics
University of Chicago School of Medicine

Medical Director, Enterprise Imaging
Medical Director, SOA Infrastructure
University of Chicago Hospitals
Speaker Disclosure

- Co-founder – Stentor (acquired by Philips)
- Medical/Technical Advisory Boards:
  - Philips
  - Amirsys
  - M*Modal
  - Merge
  - LifeIMAGE
- Grants and contracts - NIH, RSNA
Acknowledgement and Thanks:

- **University of Chicago Medical Center**
  - Drs. Thomas Krausz, David McClintock
  - Vinay Kumar, Jonathan Miller, Aliya Husain

- **Philips**:
  - Guido du Pree, Dirk Vossen, Wil Baas, Mariel Schrijvers
"Analogous"

- Pathology and radiology both provide crucial phenotypic evidence required for patient management
- Anatomic pathology and radiology
  - Reports based on analysis and interpretation of image data
  - Narrative reports (with some structure and early ontologic underpinnings)
  - Similar workflow models
- Both disciplines undergoing transition from analog to digital based information systems, including digital image management
- Leveraging opportunities exist when analogous workflow models validated in radiology are applied to pathology, including the avoidance of errors made in radiology
- However, important differences in workflow must also be considered.
- Opportunity to avoid recapitulation of errors made in radiology
“Complementary”

- Radiology frequently used to guide the sampling of gross specimens in pathology:
  - Breast
  - Liver
- Radiology frequently used to aid in the interpretation of anatomic pathology cases:
  - Musculoskeletal
  - Neuro
  - Pulmonary
- Teaching and research
- Needs to be significantly expanded; adoption of digital based imaging with improved electronic integration will be an important enabling tool
“Converging”

- "Diagnostic Medicine" and "Integrated Diagnostics" (Bruce Friedman)
  - Molecular imaging
  - Molecular diagnostics
  - Informatics
- Convergence critical from an informatics and IT perspective
  - Infrastructure (image archive, data services)
  - Multimedia EHR
  - Decision support
  - IHE Pathology: modeled from IHE Radiology
Near Future Requirements

- Microarrays will add significant dimensionality and complexity to data management
- Requirements for powerful decision support, advanced visualization, CAD, as well as powerful infrastructure (virtualization, grid, etc) will be very significant for genomics and proteinomics
Surgical Pathology Workflow (from the perspective of a Radiologist)

- Very analogous
- Great benefit can be gained by leveraging lessons learned from radiology
- However, important differences exist
- *Do not make the same errors of early adopters…*
The “Familiar”

- Scheduling and accessioning model
- HL7
- ICD-9
- CPT
- SNOMED (Systemized Nomenclature of Human and Veterinary Medicine)
- Synoptic Reporting and Structured Reporting
- DICOM: Digital Pathology Imaging and Telepathology
- IHE
Radiology Workflow

• “Late majority / laggard” adoption of digital image management
• Good progress in getting rid of paper
• Improved integration of IT systems
• Significant reduction in FTE throughout workflow chain
• Emphasis now on leveraging electronic workflow to enhance value, efficiency, quality, and safety (not just image management).
Image Workflow Orchestration Intelligent Dashboard
Technologist Workflow: Performed Procedure with Context Specification
Integrated Dictation / Speech Recognition / Structured Reporting
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Context Specific Patient Summary

Order summary
Procedure: CT CHEST ABDOMEN PELVIS WO
Diagnosis: NEUTROPENIA, UNSPECIFIED
Diagnosis Edits:
Clinical question: 58 female with AML with neutropenic fever and abdominal pain. r/o pulmonary infiltrate vs. abdominal pathology. Avoiding IV contrast due to rise in creatinine
Signs and Symptoms: Neutropenic fever
Problems List
Protocol notes
Tech notes
Scheduler notes

[CT scan image]
# Context Specific Patient Summary

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Pathology Report Date: 2012-08-25

MOLECULAR DIAGNOSTIC REPORT

Specimen(s) Received
A: Bone Marrow Aspirate for Molecular Diagnostics-S12-16045

Procedures/Addenda
NPM Mutation Assay
Date Ordered: 7/26/2012 Status: Signed Out
Date Completed: 8/25/2012

Molecular Diagnostics Report
Sample DNA was extracted from peripheral blood or bone marrow aspirate sample. The genomic region of exon 12 of the nucleophosmin gene (NPM) was amplified by real time polymerase chain reaction (PCR) and analyzed by capillary gel electrophoresis. This assay is designed to detect the most common mutation: a four base pair insertion at a variable position within a specific 8 basepair tract of exon 12.

This assay can detect the presence of this exon 12 NPM mutation when cells containing the mutation(s) comprise as little as 5% of nucleated cells. The absolute lower limit has not been established. The result is NOT quantitative; the percent of affected cells in a given sample cannot be specified at this time. Other rarer mutations have been reported in this gene, they will not be detected.

Clinical Information: The patient has a history of treatment for multiple myeloma. Hematopathologic analysis of this marrow identified therapy related AML with a prominent monocytic component. There was NO evidence of residual myeloma.

Results-Comment
There is NO evidence of the NPM mutation at or above the 5% level.
The DNA amplified satisfactorily. All controls performed appropriately.

Loren Joseph, M.D.

This test was developed and its performance characteristics were determined by the University of Chicago Molecular Diagnostics Laboratory. It is performed pursuant to a license agreement with Roche Molecular Systems, Inc. for the use of Polymerase Chain Reaction. It has not been cleared or approved by the U.S. Food and Drug Administration (FDA). Because the reagents used in these studies

Context Specific Patient Summary
62 year-old female with lung carcinoma status post resection and adjuvant therapy. Also has ovarian cyst and must be followed. Doing well, disease evaluation ongoing compared to previous scans and common.
Early Philips – UChicago Research Prototype
Early Philips – UChicago Research Prototype
Lesion Tracker Intelligent Agent

iSite Plugin

* Early Philips – UChicago Research Prototype
* Early Philips – UChicago Research Prototype
* Early Philips – UChicago Research Prototype
### Lesion Tracker

#### Scratching

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Select/drop here to report new lesions...

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*Early Philips – UChicago Research Prototype*
Oncology Lesion Management

With permission from MEDIAN Technologies
## Radiology Review Station

### Prioritized Report List

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<th>Age/Gender</th>
<th>Procedure</th>
<th>Date</th>
<th>Status</th>
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<td>35 y/o M</td>
<td>CT Head</td>
<td>11/1/05</td>
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<td>MR Spine</td>
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### Dr. Peter Tanzer

- [schedule new study](http://128.147.146.89/preauthorization/prioritizedworklist/default.html)
- [view in PACS](http://128.147.146.89/preauthorization/prioritizedworklist/default.html)
- [view in PACS](http://128.147.146.89/preauthorization/prioritizedworklist/default.html)
- [view in PACS](http://128.147.146.89/preauthorization/prioritizedworklist/default.html)
- [view in PACS](http://128.147.146.89/preauthorization/prioritizedworklist/default.html)
- [view in PACS](http://128.147.146.89/preauthorization/prioritizedworklist/default.html)
Radiology Review Station
Prioritized Report List

Simpson, Homer  
35 y/o M  
CT Head  
MR Spine  
5454545454  
11/1/05  
11/2/05  

Kaufman, Nicole  
27 y/o F  
MR Brain  
4848484848  
11/5/05  

Lobular enhancing mass in the right jugular bulb is most consistent with recurrent schwannoma of cranial nerve 9, 10, or 11. Paraganglioma and meningioma are considered less likely.  
(view full report)

Turtle, Oliver  
18 y/o M  
CT Neck  
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11/5/05  

Grace, Jennie  
50 y/o M  
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schedule new study  
view in PACS  
view in PACS  

schedule new study  
view in PACS  

schedule new study  
view in PACS  
view in PACS
DOE, JOHN - Multimedia Report
MR OF THE HEAD [00001] 6/27/01 12:01AM

HISTORY: Sensorineural hearing loss

TECHNIQUE: Multiplanar, short and long TR images were obtained through the brain before and after the administration of intravenous contrast.

COMPARISON: NONE.

FINDINGS: There is a 6 cm mass in the left cerebellopontine angle. It has uniform low T1 signal, and moderately increased T2 signal. The edges of the mass are well-defined, but it infiltrates around the brainstem and extends through the foramen magnum. The mass is heterogeneous on FLAIR images, and demonstrates restricted diffusion. Only minimal peripheral enhancement is seen. The brainstem is displaced and compressed. The internal auditory canals are normal. The remainder of the brain is unremarkable.

---------------------------------------------

IMPRESSION:

Large epidermoid tumor of the left cerebellopontine angle.
M24

My signature below is attestation that I have interpreted this/these examination(s) and agree with the findings as noted above.

Radiologist 1: Barton F. Branstetter
DOE, JOHN - Multimedia Report
MR OF THE HEAD [00001] 6/27/01 12:01AM

HISTORY: Sensorineural hearing loss
DOE, JOHN - Multimedia Report
MR OF THE HEAD [00001] 6/27/01 12:01AM

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Radiologist 1: Barton F. Branstetter
Current Surgical Pathology Workflow

Specimen acquisition → Specimen accessioning → Specimen grossing

Specimen cutting → Specimen embedding → Specimen processing

Staining, coverslipping, & labeling → Microscopic analysis → Case post-processing and archival
Dominant Anatomic Pathology Workflow

- “Innovator-early adopter” phase with respect to digital image management
- Significant reliance on paper and people
- Significant FTE requirements (minimum of eight hand-offs between different users from receipt of specimen to final reporting)
- Suboptimal efficiency
- Safety issues
Anatomic Pathology Workflow

- Workflow as a spectrum – heavy on the pre-analytic, lighter on the analytic and post-analytic phases
The Need for Change

- Lengthy and labor intensive
  - Routine workflow with at least 20 steps (22 – 30 at UCMC)
- Dozens of opportunities for error
  - Risk of error increases with every step in process
- Patients expectations – actively involved with all stages of their disease management
- Medical liability
- Technology available
Errors and Patient Safety

- Pathology labs not immune to patient safety improvements

- Critical review of lab practices has led to new accreditation standards

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<td><strong>CAP Laboratory Patient Safety Goals (April 2006)</strong></td>
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<td>Goal 4</td>
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*JCAHO indicates Joint Commission on Accreditation of Healthcare Organizations; CAP, College of American Pathologists.
Adverse Outcomes

- **2005** – Histotechnologist mixes up two breast core biopsy cases during microtomy
  - Result – unnecessary mastectomy for one patient and delay in treatment for another patient
  - Effect on medical center – negative press, pending $15-20 million lawsuit

- **2000** – Slide contaminant between two colon biopsy cases
  - Result – unnecessary hemi-colectomy
  - Effect on medical center - $3.5 million settlement
Lessons from the Radiology Experience

- *It’s not about the PACS, it’s about the WORKFLOW*
- Integration of IT systems is key
- *You need a RIS before you get a PACS*
- Teleradiology is “easy”, PACS is “hard”
- How images are consumed is important
Workflow: Gross Room

Gross Room Workflow – Detailed (October 2007)

- OR/Clinic
  - Collect Specimen
  - Delivered to J601 (via dumbwaiter, tube, or courier)
  - Container(s) & rec filled out

- J601 Front Desk
  - Double check rec/container
  - Look for RUSH, frozen, tissue bank, etc

- Accession into CoPath by Gross Room Technician

- Specimen triaged for routine grossing

- Tissue Banking
  - Specimen given to PA

- Case grossed using Dictaphone dictation, manual photography

- Wet tissue/empty container filed on cart in bags

- Stored in J601 for 24 hours

- Container placed on cart

- Cassettes transferred to formalin/ethanol baths

- Cassettes taken to Histology

- Dicotation sent after gross

- Paperwork to transcription

- Sections taken/cassettes added to case

- Container pulled from morgue

- Paperwork given to AP tech

- Paperwork for request completed in J601

- Frozen section slides taken to Histology

- Frozen section slides stored in J601 until end of day

- Resident/Attending requests more sections (cassettes) from specimen

- Pathologist makes frozen section diagnosis ⇒ calls OR

- Stain and coverslip of frozen section

- Cryotomy

- Frozen section blocks/slides printed
Workflow: Interpretation and Analysis

Microscopy / Analytic Workflow – Detailed (October 2007)

1. Outside slides received for consult. Requisition included.
   - Accession into CoPath by Clerical staff, E-603.
     - Slides uniquely identified with UCH labels. Clinical history transcribed.
       - Working draft printed out by clerical staff.

2. Slides / paperwork placed in Resident / Attending box S-653.
   - Slides picked up by Resident / Fellow Pathologist.
     - Slides previewed. Preliminary diagnosis hand-written on working draft.
   - Case discussed with Attending Pathologist.

3. Completed special stains.
   - IHC / special stains, additional cuts requested (see histology detail).
   - Slides previewed. Preliminary diagnosis dictated.

4. Slides filed in E-603 by clerical staff.
   - Slides to filing cart S-653.

5. Final diagnosis (dictated or hand-written) to transcription with paperwork.
   - Final diagnosis transcribed.

6. Final complete report sent to Pathologist queue.
   - Final hard copy in Pathologist box.

   - Final report sent to EMR, ordering physicians, outside consulting physicians.

8. Slides from routine cases and frozen sections, from Histology.
   - Finished paperwork filed in E-603 by clerical staff.
Digital Pathology Imaging

- Still very immature, especially with respect to workflow
- Telepathology
  - Increasingly prevalent
- Whole slide imaging
  - 9-15 gigabytes/slide (single focal plane)
  - Typical anatomic pathology department > 10 terabytes/day
  - Rigorous validation lacking
  - Business model difficult to justify if persistent storage is required
Can a Permanent Persistence Digital Pathology Archive be Justified?

- Dave McClintock, University of Chicago (*Preliminary Results*):
  - 5 residents and 2 fellows recorded the prevalence of prior studies/slides viewed over 13 work days
  - Out of 791 cases, prior archival material was “pulled” 13 times (1.6%)
  - Of the 13 times prior archival material was “pulled,” an average of 1.8 slides were actually viewed

- It is hard to justified a “write once, read rarely” archive.

- Consider a limited persistence “cache” model (with permanent storage of “key images”)

The Fundamental Difference:

“Radiology is digital at the beginning; Pathology is digital at the end”
The most important requirement:

Reliable specimen tracking, starting at specimen acquisition
Specimen Acquisition and Tracking

- Pending lists
- Courier/transport barcode specimen
Specimen Accessioning

- LIS populated from the EMR through CPOE
  - Efficient
  - Minimizes redundancy
  - Minimizes human error transferring data
- Specimens barcoded to continue the positive patient identification process
Tissue Grossing

- Patient safety – cassettes printed on demand
- Specimen management
- Decision support & standardization
- Image correlation with radiology
Tissue Embedding

Decision support: the technician scans the barcoded cassette – verification and identifies special instructions
Microtomy

- Eliminate hand labeled slides and pre-labeling errors
- Cassette barcode drives slide printing interfacing with the information system
Staining

- Automated H&E stainer and glass coverslipper
- Barcode finished product for verification
Tissue Processing Throughput

Standard workflow: large batch slide distribution

Time Slides Given to Pathologist

From: David McClintock, M.D., University of Chicago Dept of Pathology
From Batch to Inline Tissue Processing

Time Slides Given to Pathologist

From: David McClintock, M.D., University of Chicago Dept of Pathology
Transition from Batch to Inline Tissue Processing

From: David McClintock, M.D., University of Chicago Dept of Pathology
Case Collation, Retrieval and Distribution
Slide review should incorporate all imaging and clinical data available from EMR, integrated workflow / PACS solution, including radiology studies.

Additional studies will benefit from real-time decision support.

Final report, diagnosis and case sign out all electronic, paperless.
Pathologist Workstation ("Cockpit")
Integrated and Comprehensive Presentation of Patient Data

Integrated viewer with access to all patient imaging studies
“Just in Time” Decision Support

With permission from Amirsys, Inc
## Just in Time Decision Support

With permission from Amirsys, Inc

### Suggested Panel

### Comprehensive Panel

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**Differentiation**
- Differentiates
- Does not differentiate
- Neutral
"Just in Time" Decision Support

With permission from Amirsys, Inc
Opportunities

- The REAL need: reliable specimen tracking in anatomic pathology
- “Present opportunistic” use of digital imaging
  - Telepathology
  - Documentation of gross specimen sampling
  - More efficient access to *relevant* priors ("key image approach")
- Interoperability with existing radiology / enterprise PACS
- Exploiting enterprise interoperability infrastructure
Do we have to “give up” on “best of breed?”

- In order to support modern healthcare workflow, information systems that do not natively “talk to each other” must interoperate to support these complex workflow models.
- “One size does not fit all:” many users are appropriately idiosyncratic.
- Advanced workflow models require the instantiation of “idiosyncratic” business logic by frequently unavailable (at least by “standard” interfaces) state change triggers (e.g. research and quality).

The Goal: True Interoperability
What is Interoperability?

- “Ability of two or more systems or components to exchange information and to use the information that has been exchanged…” *(IEEE Standard Computer Dictionary, 2006)*
- “Ability of a system or a product to work with other systems or products without special effort on the part of the customer” *(IEEE, The Role of Standards Glossary, 2005)*
- “The task of building coherent services for users from components that are technically different and independently managed” *(William Arms, Digital Libraries, MIT Press, 2000)*
- “A condition that exists when the distinctions between information systems are not a barrier to accomplishing a task that spans multiple systems” *(Glossary, Gov. Info Locator Service, 1994)*
Integration Models

- Presentation State integration/coordination ("context sharing", "single logon")
- Advanced interoperability
  - "Granular" information / object exposure and consumption
  - Instantiation and orchestration of business logic, decision support
  - Creation of optimized, customized workflow and presentation user experiences
Typical Legacy-based IT Environment: "Using humans to integrate workflow"
Integration using a “Single Vendor Solution”

Single Vendor Application “Suite”

EHR Module  RIS Module  Path Module  PACS Module
Using “Edge” Protocols (DICOM & HL7) to Choreograph Integrated Workflow: IHE PACS – RIS Integration Workflow Model

- RIS
  - Scheduled Prefetch
  - Report Prefetch
  - Demographic / ADT Update
  - Study Validation
  - Dictated Status Worklist Update
  - Performed Procedure
  - Modality Worklist
  - Modality Performed Procedure
  - Storage Commit
- PACS
  - DICOM
  - HL7
- Modality
  - DICOM
- Dictation Reporting
  - HL7
  - Performed Procedure
  - Dictated Status Update
- DICOM
  - DICOM
  - DICOM
Limitations of Choreography using “Edge Protocol” Approaches

- OK for relatively few actors
- Point-to-point messaging approach challenging to scale and manage beyond 2-4 actors
- “Everyone has to be on the same page”
- Incremental implementation difficult
- “Cookie cutter vs Optimization”
- “Autonomic nervous system:” necessary but not sufficient
- Needs more flexible and powerful workflow / business logic orchestration
XB360 Call of Duty 2

Product Description
Call of Duty 2 redefines the cinematic intensity and chaos of battle as seen through the eyes of ordinary soldiers fighting together in epic WWII conflicts. The sequel to 2003’s Call of Duty, winner of over 80 Game of the Year awards, Call of Duty 2 offers more immense, more intense, more realistic... Read more (Why was I recommended this?)

Recommended for you

- Xbox 360 Play and Charge Kit by Microsoft Software
  (Why was I recommended this?)
- Batman: The Dark Knight Returns by Frank Miller
  (Why was I recommended this?)
- XB360 Fight Night: Round 3 by Electronic Arts
  (Why was I recommended this?)
“Choreography vs. Orchestration”
Enterprise Integration Model: Towards a Service Oriented Architecture

Pathology | HIS | RIS | PACS

Middle ("Business Logic") Layer (Agents, ORBs, Web Services, etc.)
Service Oriented Architecture (SOA)

- Component based architecture that supports “composite” applications by orchestrating loosely coupled “services”
- Transition from “hard linked” data and presentation state to “loosely coupled” services:
  - Universally exposable
  - Universally self-describing
  - Universally consumable
- Services are “orchestrated” to create optimized “composite” user “experience”
SOA is not Web Services

- SOA is an architecture
  - Disciplined governance
  - Security
  - Semantics
  - QOS
- Web Service is an *implementation technology*
  - Interface that exploits HTTP to achieve interoperability
  - XML, SOAP, REST, WDSL
The need for semantic normalization

Electronic health records raise doubt

Google service's inaccuracies may hold wide lesson

Boston Globe

By Lisa Wangsness
Globe Staff / April 13, 2009

WASHINGTON - When Dave deBronkart, a tech-savvy kidney cancer survivor, tried to transfer his medical records from Beth Israel Deaconess Medical Center to Google Health, a new free service that lets patients keep all their health records in one place and easily share them with new doctors, he was stunned at what he found.

Google said his cancer had spread to either his brain or spine - a frightening diagnosis deBronkart had never gotten from his doctors - and listed an array of other conditions that he never had, as far as he knew, like chronic lung disease and aortic aneurysm. A warning announced his blood pressure medication required "immediate attention."

"I wondered, 'What are they talking about?'" said deBronkart, who is 59 and lives in Nashua.
Normalization of HL7 to XML

XML Translation for TRIDOM:

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  xmlns:enc="http://schemas.xmlsoap.org/soap/encoding/"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
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Governance and Security
SOA: High-Level Architecture

Governance

Access Layer

Process Layer

Service Layer

Resource Layer

EPIC (HIS)

Patient Data, Logs, Policies, Identity

ANCILLARIES

PACS

STORAGE, VIRTUALIZATION and DR

Patients

Clinicians (e.g. VIB)

Researcher

Partners/Vendors

Devices

ETL

HL7

DICOM

Patients, Clinicians (e.g. VIB), Researcher, Partners/Vendors, Devices

Governance

Access Layer

Process Layer

Service Layer

Resource Layer

EPIC (HIS)

Patient Data, Logs, Policies, Identity

ANCILLARIES

PACS

STORAGE, VIRTUALIZATION and DR

ETL

HL7

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Context Specific Patient Summary

**Pathology Report Date:** 2012-08-25

**MOLECULAR DIAGNOSTIC REPORT**

**Specimen(s) Received:**
- Bone Marrow Aspirate for Molecular Diagnostics-S12-16045

**Procedures/Addenda:**
- NPM Mutation Assay

**Date Ordered:** 7/26/2012  
**Status:** Signed Out  
**Date Completed:** 8/25/2012

**Molecular Diagnostics Report:**

Sample DNA was extracted from peripheral blood or bone marrow aspirate sample. The genomic region of exon 12 of the nucleophosmin gene (NPM) was amplified by real time polymerase chain reaction (PCR) and analyzed by capillary gel electrophoresis. This assay is designed to detect the most common mutation: a four base pair insertion at a variable position within a specific 8 basepair tract of exon 12.

This assay can detect the presence of this exon 12 NPM mutation when cells containing the mutation(s) comprise as little as 5% of nucleated cells. The absolute lower limit has not been established. The result is NOT quantitative; the percent of affected cells in a given sample cannot be specified at this time. Other rarer mutations have been reported in this gene, they will not be detected.

**Clinical Information:** The patient has a history of treatment for multiple myeloma. Hematopathologic analysis of this marrow identified therapy related AML with a prominent monocytic component. There was NO evidence of residual myeloma.

**Results-Comment:**

There is NO evidence of the NPM mutation at or above the 5% level. The DNA amplified satisfactorily. All controls performed appropriately.

Loren Joseph, M.D.

This test was developed and its performance characteristics were determined by the University of Chicago Molecular Diagnostics Laboratory. It is performed pursuant to a license agreement with Roche Molecular Systems, Inc. for the use of Polymerase Chain Reaction. It has not been cleared or approved by the U.S. Food and Drug Administration (FDA). Because the reagents used in these studies
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**Patient History Timeline**

**Acute Indicator**
- MALIGNANT NEOPLASM
- CHEST:

**Prior recommendations**
- Note: Patient with lung carcinoma status post resection and chest cyst and must be followed.
- CT scans showing compared to previous scans and common.

**Referring Physician:**
- Reason for Study: Patient with lung carcinoma status post chemo, resection, and ovarian cysts.

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**Image:**
- Histological images showing tissue samples.