Improving ED and Radiology Interdepartmental Communications Through the Application of Mobile Computing Technologies

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Background

- Communication of urgent exam results to the Emergency Dept. (ED) was identified as a process that might benefit from the application of information technologies
- Began a multi-stage project to completely replace original fax based procedure where wet-reads were written on requisitions and faxed to the ED

Old Process

1. Radiologist receives paper exam requisition as cue to review exam
2. Radiologists writes findings on requisition
3. Requisition with findings faxed to Emergency Dept. (ED)
4. ED clerk places requisition in patient's chart for ED physician to review

EXAMINATION FORM

[redacted]
Name: [redacted] M-43Y DOB: 11/08/1959
Trans: G (w/Chart) Patient Loc: L1B

Exam: ANKLE,3 VIEWS LEFT
Date: [redacted] Rm: E01 Dur: 25
Stat reading: Y Phone/Beeper: (415) 353-1238

PRECAUTION:

Attend MD: WHETSTONE, WILLIAM D
Ph: (415) 353-1238

Req.MD: WHETSTONE, WILLIAM D
Ph: (415) 353-1238

Handwritten Wet-Read

Copy to:

Hx: ANKLE PAIN

Comments: FRONT HALLWAY 1

Previous exam today:
Next exam today:DTIBF/L 8:40 PM E01

[redacted]

WET READING:

Widening of ankle mortise c lat sublux of talus w/ respect to tibia

lose body distal to medial malleolus

[redacted] (avulsion (age indeterminate avulsion)

Problems with Old Process

- Wet-reads stored in hardcopy form only
  - Cannot be recovered if lost
  - Makes Q/A more difficult since statistics must be extracted manually
- Handwritten text more likely to be misinterpreted
- Faxes sent out in batches leading to delays
- No mechanism for ED physicians to record their findings (if they happen to see the exam first)

New Process

1. Radiologists use “active” worklists to determine which cases are urgent
   - Paper requisitions still used (and preferred) by some
2. Radiologist enters wet-read using an embedded web form on the PACS display station
   - If an ED physician reviews an exam BEFORE the radiologist they are permitted to enter their findings
   - The radiologist will notify the ED via phone if there is a discrepancy between the two interpretations

New Process (cont'd)

3. Wet-read available via:
   - Printouts
   - PACS Display Stations
   - PDA
4. If wet-read was entered by radiology resident or fellow, then radiology attending reviews it. Pertinent feedback for resident or fellow sent via email and recorded for Q/A purposes

Methods: Stage 1

- Built the “wet-read module” to electronically capture, deliver and track wet-readings:
  - Wet-reads entered from PACS displays and printed out in the ED
  - Enables the capture of Q/A data
  - Provides educational feedback to radiology residents and fellows
- This module has completely replaced fax based process

Methods: Stage 2

- Explored the use of mobile computing technologies to facilitate the communication of urgent care exam results
- PDAs used to:
  1) Provide notification of results availability
  2) Provide access to full text of wet-reads and reports
- Expected to reduce the delay between when results are available and when they are first viewed

System Components

- All pieces were written in Java
- PostgreSQL used for database
  - Open source, freely available
  - Used to store wet-reads and timing metrics for system evaluation
- Web-based user interface on PACS displays
  - Used Java Server Pages (JSP) technology
  - Tomcat used as “JSP container” and web server

System Components (cont'd)

- PACS Workstation Integration
  - AGFA IMPAX R4.1 PACS
  - Clinical context captured using vendor's "context server" application
    - The context server "sends" events to registered applications
  - Buttons added to display station GUI using vendor's "script button" scripting language
    - Can access context server
    - Can launch embedded web browser

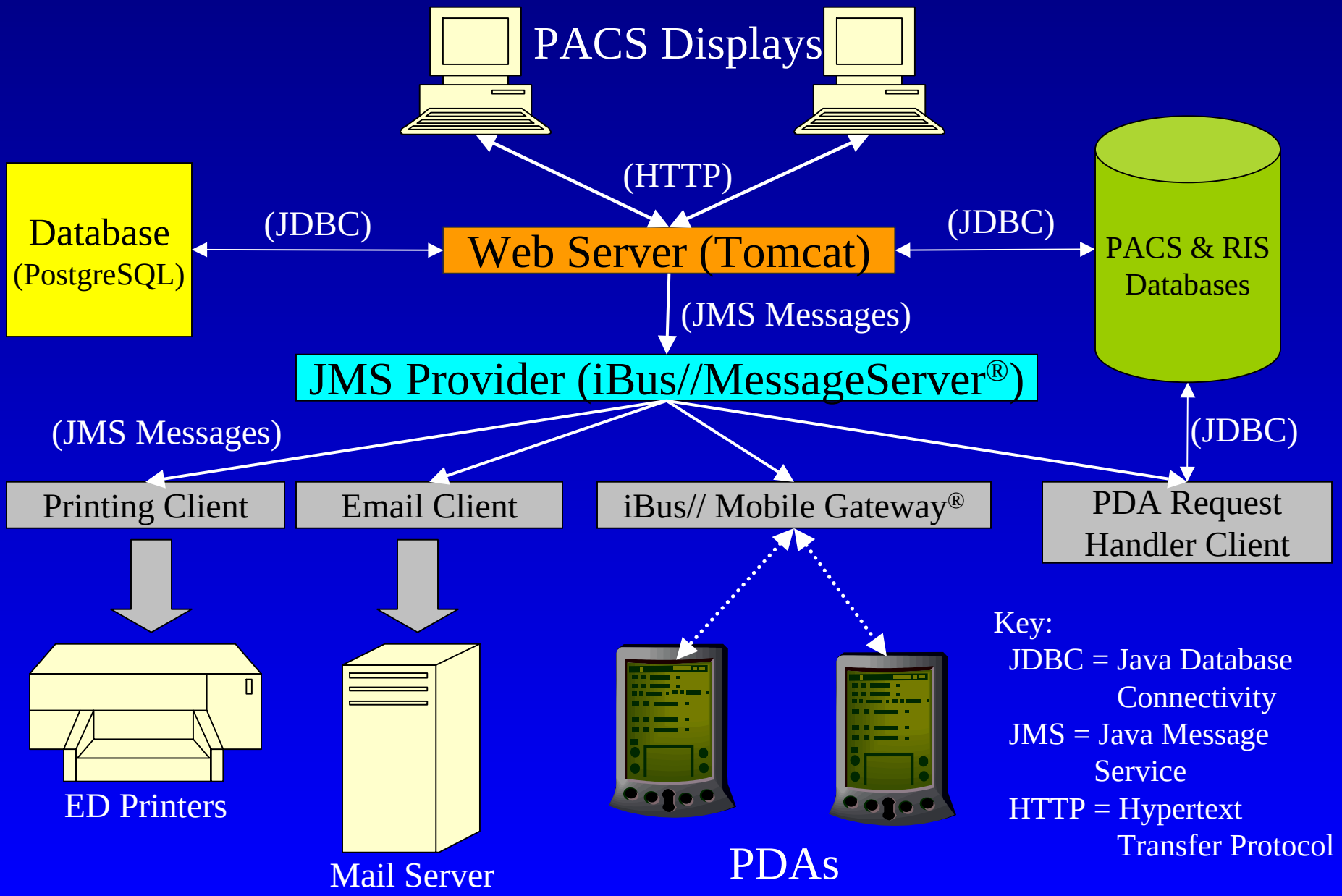
System Components (cont'd)

- Java Messaging Service (JMS)
  - Provides robust architecture for transferring messages among applications ("enterprise messaging")
  - Consists of central JMS "provider" with multiple JMS "clients" which can both send and receive messages
  - Messaging models:
    - "queues" for point to point communication
    - "topics" for broadcasting messages (publish/subscribe)
  - No restrictions on the structure of messages.
    - Messages can be all text, combination of text and other data types, or even a sequence of bytes.
  - JMS clients used to route results to appropriate destinations

System Components (cont'd)

- iBus Mobile Gateway®
  - Softwired (http://www.softwired.ch/)
  - The gateway is a proxy between mobile JMS clients (running on the PDAs) and the JMS provider
  - Automatically handles connection failures and bandwidth fluctuations
  - Provides extra layer of robustness for handling the volatile nature of mobile device connections
    - These type of client failures are not adequately addressed in most JMS implementations
  - Supports multiple PDA platforms including PocketPC® and the Sharp Zaurus® (Linux)

System Architecture



PDA & WLAN

- PDA
  - HP iPAQ 4150
    - CPU: 400 MHz X-Scale
    - Memory: 64 MB RAM
    - Display: 16K color, 320 by 240, 3.5” diagonal
    - Built-in wireless (801.11b) support
    - Extended battery
- Hospital-wide Wireless Network (WLAN)
  - Uses Cisco Aironet hardware
    - LEAP (Lightweight Extensible Authentication Protocol) for authentication
    - Primary reason why the iPAQ 4150 was chosen

Security Considerations

- HIPAA Compliance
  - Encryption
    - WEP (with dynamic keys) encryption for WLAN
    - DES (Data Encryption Standard) for JMS communication
  - Authentication
    - LEAP authentication for device authentication
    - User/name password for user authentication
  - Usage Tracking
    - All activity logged by wet-read application

View From PACS Display

ED Physician's Form for Entering Impressions

Name: **MRN:** **Acc #:** **Exam Date/Time:** 05-20-2003
Study: CHEST, 1 VIEW **Req. Doc.:** **Read Date/Time:** Not Interpreted
Clinical History:

PIGTAIL PLCMT

Additional Clinical History:

ED Impressions:

ED Physician: **Saved:** Not yet saved

Save Reset

Radiologist's Form for Entering Wet-Read

Name: MRN: Acc #: Exam Date/Time:

Study: **CT CHES THIN SE** Req. Doc.: **MOHLER, ANN S** Read Date/Time: **Not Interpreted**

Clinical History:

r/o cogential emphysema

Additional Clinical History:

Radiologist's Initial Impressions:

1° Reporting Rad.: **Test, Account** 2° Reporting Rad.: None

Discussed With: Doc ID: On: January 21 2003 at 13 : 43

Temp. Save | Save & Send Interpretation | Reset

RADIOLOGY WET-READING

NAME: **SEX:** M **AGE:** 87 **DOB:**
MRN:

EXAM: CT BRN UNENHANC
DATE/TIME:
ACC #:

REQ MD:

HISTORY: UCSF MEDICAL

HA'S

ADDITIONAL HISTORY:

ED IMPRESSIONS:

ED DOC:

Wet-Read Printout

INITIAL WET-READING: 4.5 cm heterogeneous mass in the midline of the posterior fossa with associated hydrocephalus and interstitial edema. Tumor, perhaps flow of CSF and diffuse effacement of sulci and basal cisterns. Tumors in this location in a patient of this age include medulloblastoma, ependymoma, astrocytoma, ATRT.

DISCUSSED WITH: Dr. [illegible] **ON**
REPORTING RAD: **DATE/TIME:** 05/25/2002 at 2:26 PM

Form for Entering Attending's Q/A Review

Name: **MRN:** **Acc #:** **Exam Date/Time:** 05-19-2003
Study: CT ABD PELV EN **Req. Doc.:** **Read Date/Time:** 05-20-2003
Clinical History:

FEVER, SEVERE BACK PAIN - BIG LIVER

Additional Clinical History:

Radiologist's Initial Impressions:

CM - reflux of contrast into dilated hepatic v. and IVC
Hepatomegaly, 9mm LAL TSTC in liver tail.
B basilar consol.
tortuous aorta
L THR
cortical disruption R fem metadiaphysis, R post iliac wing.
sacral decub->coccyx c cort irreg to suggest poss osteo
no FF/no FA
no abscesses.

1° Reporting Rad.: **2° Reporting Rad.:**
Impressions Discussed With: wang **On:** 05-20-2003

Attending's Confidential Q/A Review:

Discrepancy found: Unspecified **which** is unspecified

Unspecified
None
Questionable
Minor
Major

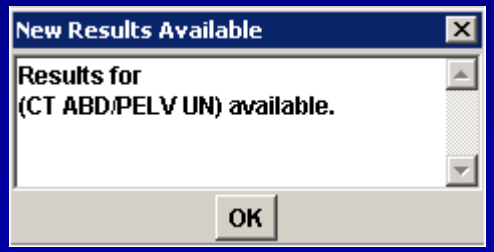
Comments:

Discussed With: **Doc ID:** **On:** May 20 2003 at 16 : 42

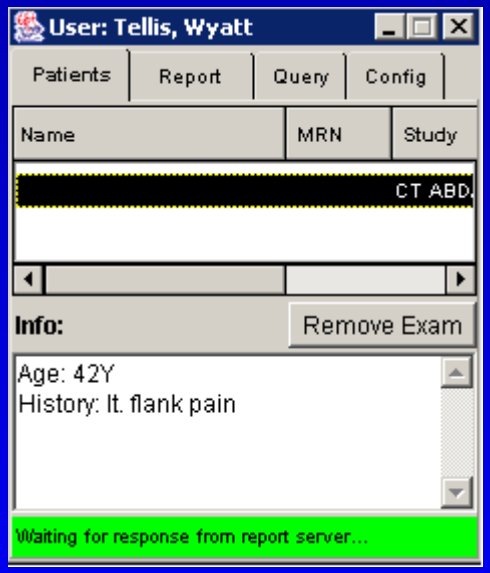
Reviewing Attending: Tellis, Wyatt M. **Reviewed On:** Not reviewed

Temp. Save | Save & Send Review | Reset

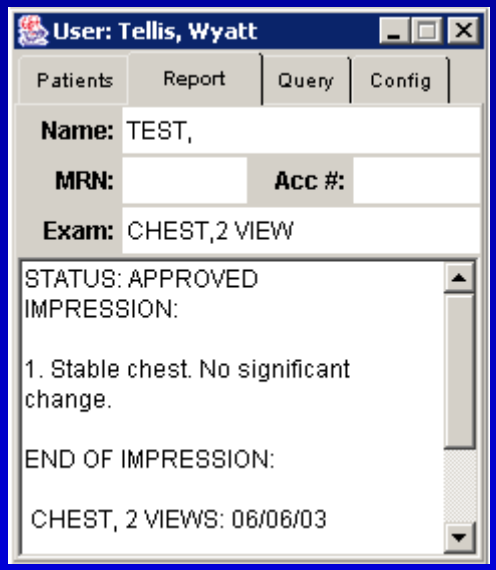
PDA GUI



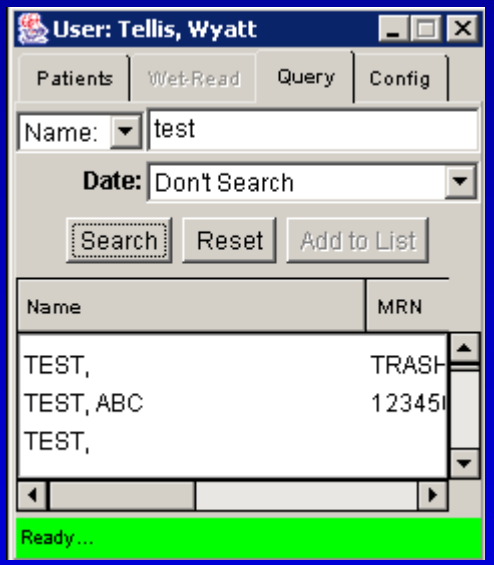
Wet-Read Alert



ED Patient List



Wet-Read & Full Report Display



RIS Query Panel

System Evaluation

- Pre/post design
  - Necessitated by need to turn on wet-read module at once for all cases (no mix of faxes & printouts)
  - Only projection radiography exams compared since faxes were only used for CRs
- Pre-implementation
  - 61 days
  - Recorded fax timestamps
  - Requested ED physicians to “sign-off” on when they viewed the wet-read fax

System Evaluation (cont'd)

- Post-implementation
  - 71 days
  - System records when radiologist enters a wet-read
  - System records when wet-read is viewed by ED physician on a PDA
  - PDAs were carried by the 4 medicine residents who rotate through ED each month

Timing Metrics

- Time to image availability
  - Measures time from when exam is scheduled to when it is available on the PACS for interpretation
  - Captured from RIS & PACS
- Time to interpretation availability
  - Measures time from when the exam is available on PACS to when it is read by a radiologist and the results made available to the ED physician
  - Captured from fax timestamps & wet-read timestamp
- Time to results encounter
  - Measures time from when results are available to when they are first viewed by the ED physician
  - Captured from fax sign-off timestamp and PDA timestamp

Timing Metrics in Relation to Workflow

1. Scheduling
2. Imaging
3. Study transmission to PACS
4. Radiology interpretation
5. Wet-read transmission to ED
6. Initial clinical viewing

Time to image availability

+

Time to interpretation availability

+

Time to results encounter

=

Total exam time

Results

Data Properties

	Evaluation Period	# of Data Points
Fax	61 days	165
PDA	76 days	189

Pre/Post Comparison*

	Average (SD)		Median	
Metric	Fax	PDA	Fax	PDA
Image availability	34.5 (27.0)	27.0 (25.7)	29	20
Interpretation availability	54.9 (38.4)	52.0 (61.0)	42	37
Results encounter	54.2 (104.8)	39.7 (54.6)	24	18
Total exam time	143.6 (114.3)	118.8 (89.7)	120	93

*all times in minutes

Results (cont'd)

- Metric histograms have "long tails" due to outliers
  - KS-test shows results don't follow normal curve
  - U-test performed to test statistical significance

	Average (SD)		U-Test
Metric	Fax	PDA	P-Value (2 tail)
Image availability	34.5 (27.0)	27.0 (25.7)	<0.001*
Interpretation availability	54.9 (38.4)	52.0 (61.0)	0.006*
Results encounter	54.2 (104.8)	39.7 (54.6)	0.063
Total exam time	143.6 (114.3)	118.8 (89.7)	0.001*

*statistically significant differences

Discussion

- All metrics showed improvement in both mean & median times
- Time to image availability
  - 7.5 minute reduction in means ($P<0.01$)
  - Reduction, however, cannot be explained by wet-read module
- Time to interpretation availability
  - 2.9 minute reduction in means ($P<0.01$)
  - Median reduction is 5 minutes
  - Causes:
    - Use of “worklists”
    - Batch mode interpretation

Discussion (cont'd)

- Time to results encounter
  - Largest mean reduction of the three metrics (14.5 min)
  - Not statistically significant ($P>0.05$)
    - Due to high variance of the datasets (SD=104.8 and 54.6 for fax and PDA periods respectively)
  - Still suggests that PDAs may have helped
- Total time
  - 24.8 minute reduction in mean times ($P<0.01$)
  - Suggests wet-read module has improved turn around times
    - Time to image availability still a confounding factor

ED Resident Survey

- Survey evaluated use of PDAs
  - 8 out of 12 (75%) residents completed survey
- Two sections:
  - First part covered the residents' personal experiences with PDAs
  - Second part asked about their experiences using the wet-read PDA
- 6 (66%) currently have their own PDA
  - All Palm OS
  - Most common length of ownership was 1 to 3 years
- ePocrates was most common clinical application used (5, 83%)
- Battery life was most common complaint (4, 67%)

ED Resident Survey (cont'd)

- Breakdown of ED residents' access methods for wet-reads during the PDA evaluation period

	1% - 25%	26% - 50%	51% - 75%	76% - 100%
PDA	2	3	1	2
PACS		2		6
Printout	6	2		

- PACS display still most used for viewing results
  - Some felt viewing images provided an "educational opportunity"

ED Resident Survey (cont'd)

- Biggest problems:
  - Network connectivity (4 respondents, 50%)
  - Battery life (3 respondents, 38%)
- 3 (38%) felt it improved patient care
- All felt PDAs could be clinically useful
- Most requested features:
  1) Labs
  2) Order entry
  3) Radiology images

Conclusion

- Radiology feedback has been extremely positive
  - System is now used for all urgent imaging exams
  - All modalities (not just projection radiography)
  - Handles ~90 wet-reads/day
- Reduction in timing metrics suggests wet-read module helped save time with urgent care cases
  - Potential positive impact on patient care
- PDAs are a viable means for accessing clinical data

Acknowledgements

- Work supported in part by a SCAR research grant in imaging informatics