

Award Number: W81XWH-04-2-0050

TITLE: NMMC Picture Archiving and Communication Systems (PACS)

PRINCIPAL INVESTIGATOR: Robert C. Becker, M.D.

CONTRACTING ORGANIZATION: North Mississippi Medical Center Inc.  
Tupelo, MS 38801-4996

REPORT DATE: July 2008

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;  
Distribution Unlimited

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

# REPORT DOCUMENTATION PAGE

*Form Approved*  
*OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

<b>1. REPORT DATE (DD-MM-YYYY)</b> 01-07-2008		<b>2. REPORT TYPE</b> Final		<b>3. DATES COVERED (From - To)</b> 29 Sep 2004 – 14 Jun 2008	
<b>4. TITLE AND SUBTITLE</b>  NMMC Picture Archiving and Communication Systems (PACS)				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b> W81XWH-04-2-0050	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  Robert C. Becker, M.D.  E-Mail: <a href="mailto:rbecker@nmhs.net">rbecker@nmhs.net</a>				<b>5d. PROJECT NUMBER</b>	
				<b>5e. TASK NUMBER</b>	
				<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  North Mississippi Medical Center Inc. Tuppelo, MS 38801-4996				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland 21702-5012				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b> Approved for Public Release; Distribution Unlimited					
<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b> This final report summarizes project activity from October 1, 2004 through June 30, 2008. All deliverables for this project were met: <ul style="list-style-type: none"> <li>• PACS equipment became fully operational at the NMMC-Tupleo campus, all five community hospitals (Eupora, Pontotoc, West Point, luka and Hamilton sites), and at 15 primary care clinics in rural Mississippi</li> <li>• Radiology staff at all sites were thoroughly training</li> <li>• Data collection and analysis continued with results reported</li> <li>• Network vulnerability assessment and penetration tests were completed with results reported; Network vulnerability recommendations were installed and assessment and penetration tests were completed with results reported.</li> </ul>					
<b>15. SUBJECT TERMS</b> PACS, ARSAM, clinical outcomes					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>
<b>a. REPORT</b>	<b>b. ABSTRACT</b>	<b>c. THIS PAGE</b>			<b>19b. TELEPHONE NUMBER (include area code)</b>
U	U	U	UU	27	USAMRMC

## Table of Contents

<b>Introduction.....</b>	<b>4</b>
<b>Body.....</b>	<b>4</b>
<b>Project Period Deliverables.....</b>	<b>5</b>
<b>Key Research Accomplishments.....</b>	<b>6</b>
<b>Efficiency.....</b>	<b>6</b>
<b>Cost.....</b>	<b>9</b>
<b>Satisfaction.....</b>	<b>10</b>
<b>Clinical Outcomes.....</b>	<b>12</b>
<b>Security Architecture.....</b>	<b>20</b>
<b>Project Deviations.....</b>	<b>23</b>
<b>Conclusions.....</b>	<b>24</b>

## **Introduction**

This project report is the summary of a three-phase initiative to install Picture Archiving and Communication Systems (PACS) and Teleradiology at North Mississippi Medical Center's (NMMC) main hospital campus in Tupelo, four community hospitals in northeastern Mississippi and one community hospital in northwestern Alabama, and at 15 clinics and to test relevant research hypotheses pertaining to quality, security, and clinical issues.

Phase I deliverables included 1) installation of PACS equipment secured with Army Security Architecture for Medical (ARSAM) Systems Design Plan on all freestanding buildings on the NMMC campus, including NMMC-Tupelo, Women's Health Center, Longtown Imaging, Digestive Health, Internal Medicine Associates, and the Cancer Center, 2) training of NMMC's radiologists, 3) design of research database, and 4) collection and analysis of efficiency, satisfaction, and outcome data regarding the NMMC-Tupelo campus.

Phase II deliverables included 1) installation of PACS equipment secured with ARSAM Systems Design Plan at five\* community hospitals (four in northeastern Mississippi and one in northwestern Alabama), 2) training of all radiology staff members at these facilities, 3) multiple tests of security architecture, and 4) collection and analysis of efficiency, satisfaction, and outcome data regarding the community hospitals. *\*We encountered technical across-state-line difficulties with implementing PACS in the hospital located in Hamilton Alabama, so only four Mississippi community hospitals were implemented during the Phase-II timeline (October 2005 - September 2006). PACS, however, was implemented in the fifth community hospital in June 2008. Please see "Project Deviations" for a full explanation.*

Phase III deliverables include 1) installation of PACS equipment secured with ARSAM Systems Design Plan at 15 clinics, 2) training of radiology staff members at these facilities, 3) multiple tests of security architecture, and 4) collection and analysis of efficiency, satisfaction, and outcome data regarding the clinics.

This final report provides 1) an overview of the impact of the efficiency of radiologists and other medical personnel compared to baseline, 2) the satisfaction of physician providers compared to baseline, 3) the efficacy of primary care providers providing the initial interpretation of radiological studies – prior to the implementation of PACS, and 4) an assessment of ARSAM penetration to assess resistance to intrusion and device compromise.

## **Body**

In 2004, NMMC, in conjunction with its health system, North Mississippi Health Services (NMHS), proposed a three-phase initiative to install Picture Archiving and Communication Systems (PACS) and Teleradiology at its main hospital campus, five community hospitals in northeastern Mississippi, one community hospital in northwestern Alabama, and at 15 clinics. In addition to improving the quality of radiology services for people living in this rural region, including military personnel, military reserve personnel, and military dependents, the PACS

systems would be used to test security architecture for networked medical devices, an initiative of critical importance to the military, and to research clinical outcomes associated with PACS technology that are of significance to the military and other health care operations.

The hypotheses to be tested were that implementation of state-of-the-art PACS on the NMMC-Tupelo campus, five community hospitals, and other sites affiliated with the NMHS system will 1) improve radiology efficiency, 2) improve clinical outcomes, and 3) demonstrate that networked PACS can be made secure to intrusion and device compromise.

Expected results of the initiative included:

- 1) Increased efficiency of radiologists as measured by performance indicators
- 2) Decreased number of radiology support staff (film librarians)
- 3) Increased satisfaction of medical providers as measured by satisfaction surveys.
- 4) Improved treatment plans for clinic patients who undergo a CXR.
- 5) Improved clinical outcomes as measured by specific radiology indicators on the length of stay (LOS) and other indicators for CAP and stroke
- 6) Identification of highly effective security architecture for networked PACS systems that can be replicated for Army Medicine's networked medical devices, including PACS

Potential benefits of the three-phase project included:

- Demonstration of radiology service management at remote locations
- Demonstration of radiologists' efficiency in interpreting tests at remote locations.
- Information on the impact of PACS technology on clinical outcomes for hospitalized patients with CAP and stroke
- Information on the impact of PACS technology on treatment planning for clinic patients who undergo CXR.
- Demonstration of secure teleradiology services at remote locations

The project's relevance to the military is related to its capacity to:

- Simulate the military's management of radiology services in remote, noncombat settings
- Validate ARSAM security architecture for PACS
- Ensure availability of high quality radiological services for military personnel, reserve personnel, and dependents living in northeastern Mississippi.

### **Project Period Deliverables and Results**

Deliverables for this project were met. During the period from October 1, 2004 to June 30, 2008:

- PACS equipment became fully operational at the NMMC-Tupelo campus (including NMMC-Tupelo, Women's Health Center, Longtown Imaging, Digestive Health, Internal Medicine Associates, and the Cancer Center), all five community hospitals (Eupora,

Pontotoc, West Point, Iuka and Hamilton, AL sites), and at 15 primary care clinics in rural Mississippi (Pulmonary Clinic, Family Medicine Residency Center, Barnes Crossing, Med Serve, Eupora FMC, Okolona FMC, North Columbus FMC, Lowndes FMC, Pontotoc FMC, Fulton FMC, Baldwin FMC, Oxford FMC, Chickasaw FMC, Hamilton Medical Clinic and Saltillo FMC

- Radiology staff at all sites were thoroughly trained
- Data were collected, analyzed and reported (summary below)
- Network vulnerability assessment and penetration tests were completed with results reported; Network vulnerability recommendations were installed and assessment and penetration tests were completed with results reported.

## **Key Research Accomplishments**

We report our research accomplishments in each of the five research areas (Efficiency, Cost, Satisfaction, Clinical Outcomes and Security Architecture Testing). As appropriate, we report research area results for each of the three phases and a post-phase-3 assessment (conducted April through June 2008) which presents an overview of the project's impact.

### **■ Research Area: Impact of PACS on efficiency of radiologists as measured by performance indicators**

In all three phases, dramatic reductions were noted in *Report Turnaround Time* from pre- to post-PACS implementation. Report Turnaround Time is the time that elapses from the completion of the procedure until the radiologist's interpretation of the image is available for the clinician's review. Report Turnaround Time is the key measure for improved efficiency because it determines when the radiological study can be useful in clinical decision making.

Other measures of efficiency include the *radiologists' productivity*, specifically how many more films they can interpret because they don't have to spend time traveling in order to interpret them. Prior to the implementation of PACS, the emergency department physicians would interpret their own films and initiate treatment accordingly. The radiologists would also interpret the films and the *variances of interpretations* have been noted. The *number of lost films* is also important not only are lost films a lost opportunity to compare a current film with a historical film, it also takes significant time to look for the lost film.

### **Phase-1 NMMC-Tupelo Campus**

The baseline data for these comparisons are the 12 months prior to the implementation of PACS in November 2004 and the follow-up period is the 12 months post-PACS implementation.

- Report Turnaround Time decreased from an average time of 2.27 hours (11/2003 through 10/2004) to 1.04 hours in the following 12 months
- Radiologists' productivity increased by 9.1%
- Projected savings - \$518,430 in first 12 months of PACS.

- Emergency Services Department (ESD) interpretation variance decreased from 106 (11/2003 through 10/2004) to ZERO in the following 12 months.
- Lost films decreased from 230 (11/2003 through 10/2004) to ZERO in the following 12 months.

**Phase-2: Community Hospitals**

- At the hospitals in Eupora and Pontotoc, the wait for interpretations decreased from averages of 17 hours to less than two hours (Refer to Figure 1).

**Figure 1: Report Turnaround Time**  
**(From completion of procedures to radiologists' interpretations)**  
 (March 2004 thru August 2004 versus March 2005 thru August 2005)

	<b>Turnaround Time (March 2004 thru August 2004)</b>	<b>Turnaround Time (March 2005 thru August 2005)</b>
Pontotoc	13 hours	.5 hours
West Point	9 hours	1.8 hours
Eupora	17 hours	1.3 hours
Iuka	17 hours	1.8 hours
Hamilton**		

\*\* The NMMC-Hamilton Hospital is located in Hamilton AL. Due to technical issues involving transmission charges across state lines, it was not possible to implement PACS during Phase-2 as originally planned. PACS, however, was implemented at NMMC-Hamilton in June 2008, but we cannot yet report on its efficacy. The technical issue and its resolution are described in the "Project Deviations" section.

*Note: The Phase-2 cost savings in the community hospitals are described in Figure-4.*

**Phase-3: Clinics**

- We randomly selected 60 patients who received a CXR at one of the clinics prior to and after the implementation of PACS. The pre-PACS timeframe was January 2006 and the post-PACS timeframe was December 2006. Prior to the implementation of PACs in the clinics, an X-ray would be performed in the clinics and then transported by courier to the radiologist in Tupelo (a distance of over 90 miles for the most remote clinic). The Tupelo-based radiologist would interpret the study and send the interpretation via the electronic medical record (EMR) that links the hospitals and clinics. A chart review of the EMR was performed and the following elements were collected to examine the efficiency of the PACS system in the clinics (see Figure 2 for results):
  - When the patient visit occurred (*date and time – in minutes*);
  - When the radiologist's interpretation was available in the EMR;
  - When the PCP's signature appeared on the radiologist's interpretation (*to indicate the PCP had seen the radiologist's interpretation*); and
  - When the final primary care provider (PCP) signature appeared on the overall visit (*to indicate the PCP's closure on this episode*).

A 2-sample t-test, adjusted for unequal variance, where appropriate, was used to calculate the p-values.

**Figure 2: Pre and Post-PACS efficiency in NMHS clinic setting for the CXRs that were studied in the random sample.**

	Pre-PACS (hrs)	Post-PACS (hrs)	p-value
<b>Radiologist's interpretation available on EMR</b>	<b>49</b>	<b>1.6</b>	<b>&lt;.0001</b>
<b>PCP signs off on radiologist's interpretation in EMR</b>	<b>44</b>	<b>35</b>	<b>.2406</b>
<b>PCP final sign off on visit</b>	<b>90</b>	<b>37</b>	<b>&lt;.0001</b>

It appears that the radiologists have significantly reduced the turnaround time for reporting their interpretations on the patient's EMR. The PCPs, however, have not significantly reduced the time before signing off on having read the radiologists' interpretations. The PCP's final sign off on the patient's chart, however, did reduce significantly. *Note, the clinical impact of this assessment is reported in Figure 11.*

### **Post-Phase-3 Assessment – A Review of the PACS Project Conducted in April-June 2008**

#### **A. Clinic PACS Efficiency Assessment**

As noted in Phase-3 assessment above, there was a dramatic difference in the Report Turnaround Time, but based on the EMR timeline, the PCPs did not appear to incorporate this new information into their clinical decision-making. We performed another pre- and post-PACS implementation in two rural clinics, different than the two clinics analyzed in Phase-3. We randomly sampled 20 patients who received CXRs in each of the two clinics, both before (January 2006) and after (October 2007) PACS implementation. The efficiency changes are reported in Figure 3 and the clinical impact of this assessment is reported in Figure 13.

**Figure 3: Pre and Post-PACS efficiency in NMHS clinic setting**

	Pre-PACS Clinic-1 (hrs)	Post-PACS Clinic-1 (hrs)	Pre-PACS Clinic-2 (hrs)	Post-PACS Clinic-2 (hrs)
<b>Radiologist's interpretation available on EMR</b>	81.5	1.4	43.2	2.4
<b>PCP signs off on radiologist's interpretation in EMR</b>	53.2	2.1	98.3	120.6
<b>PCP final sign off on visit</b>	108.3	3.3	101.8	32.6

## **B. Overall Efficiency Assessment**

The following report on the impact of PACS on several measures of efficiency was produced by Gordon Hollingsworth, the Director of Radiology at NMMC, who has been integral to the development and implementation of PACS and has performed the efficiency assessments over the first three phases of this project. The time period of the noted changes is from pre-PACS (9/04) to post-PACS (6/08) and covers all three phases of PACS implementation (NMMC-Tupelo campus, community hospitals and the rural community clinics).

1. Report Turnaround Time for the entire system has experienced a 65% reduction (2.27 hours to 0.8 hours).
2. The specific report turnaround times for all of the hospitals during the phases of this project are reported in Figure 13.
3. Number of film interpretations per Radiologist - a 15% increase of volume per Radiologist has been experienced. This would translate to an improvement of approximately one FTE for this radiology group. In Phase-1, we described a 9% improvement in radiologist efficiency. Radiologists' efficiency has continued to increase because they no longer have to travel to the community hospitals to interpret studies. In addition, the overall volume of radiological studies has increased by about 15% from 2004 until 2008 and the radiologist group has been able to provide full coverage with the same FTEs.
4. The number of ESD physician first interpretation vs. radiologist interpretation has decreased to ZERO.
5. Number of lost films - lost films has decreased to ZERO.

### **► Research Area: Impact of PACS on costs for radiology personnel, film reduction and/or decreased courier usage.**

#### **Phase-1: NMMC-Tupelo Campus**

- Film librarian personnel decreased by 30%
  - Projected savings - \$300,000 per year starting in November 2004 and going forward
- Reduction in film usage
  - Projected savings - \$450,000 per year starting in November 2004 and going forward

#### **Phase-2: Community Hospitals**

- All four hospitals experienced cost savings as a result of PACS implementation. All hospitals reduced their film costs, but only two reduced their personnel costs. Radiology technicians at Pontotoc and Eupora also doubled as film librarians, so their positions were maintained when PACS was introduced. (Figure-4)

**Figure 4: Cost Reduction**

(February 2005 through January 2006)

	<b>Film Cost Reduction</b>	<b>Personnel Reduction/ Salary Savings</b>
Pontotoc	\$14,000	No change
West Point	\$14,100	\$10,729
Eupora	\$26,361	No change
Iuka	\$43,000	\$11,000

**Phase-3: Clinics**

The NMMCI administrators performed this evaluation. They noted a decrease in film costs, but an overall increase in their MIS support fees and increased bandwidth costs. These increases more than outweigh the film reduction savings and since January 2007, their radiology costs are up by 22% since the implementation of PACS. There is no decrease in courier costs, since the courier is still transporting other materials between NMMC-Tupelo and the clinics.

**Post-Phase-3 Assessment – A Review of the PACS Project Conducted in April-June 2008**

An extension of Mr. Hollingsworth’s overall PACS efficiency analysis includes the following financial considerations:

1. Number of film librarians – although the volume of radiological studies continues to rise, we have experienced a reduction in film librarian hours by 20,000 hours per year. This amounts to a savings of \$300,000 per year over each of the last four years. The number of film librarians has remained stable after the reduction in Phase-1. These film librarians are responsible for managing historical films. The number of film librarians may decrease in time, but it will take a number of years.
2. Film costs are reduced by \$600,000 per year at NMMC-Tupelo, compared to pre-PACS film costs. In Phase-1, we recognized a \$450,000 savings in NMMC-Tupelo’s film savings and expected that savings to be annual. Since that time, however, more units and physicians on the Tupelo campus have converted to PACS and the film savings have increased. NMMC-Tupelo does not have increased MIS support fees or bandwidth costs because of their main-campus location. The annual film savings of \$600,000 is genuine.

► **Research Area: Impact of PACS on satisfaction of primary care provides (clinic-based physicians and nurse practitioners).**

**Phase-2: Community Hospitals**

**a. Referring Physician Survey**

This is a 5-point survey with the referring physician marking 5 as being excellent and 1 as being poor. Their results are compiled and compared to the baseline survey that was conducted from PCPs from the entire region. Note, the original pre-PACS questions primarily referred to radiological studies being performed at the hospitals. In each of the four categories of

satisfaction questions, the cumulative score increased from the baseline survey in 2003 to post-PACS in 2006. Refer to the 2006 column in Figure 5.

- In each of the four categories of satisfaction questions, the cumulative score increased from the baseline survey in 2003 to post-PACS in 2006. Refer to the 2006 column of Figure 5.
- Physician response rate increased from 11.8 percent in 2003 to 33.9 percent in 2006

**Phase-3: Clinics**

In June 2007, 25 PCPs in the 13 clinics that have implemented PACS returned the survey (*the remaining two clinics implemented PACS after this survey was conducted*). This is a 5-point survey with the PCP marking 5 as being excellent and 1 as being poor. Their results are compiled and compared to the baseline survey that was conducted from PCPs from the entire region. Note, the original pre-PACS questions primarily referred to radiological studies being performed at the hospitals. In each of the four categories of satisfaction questions, the cumulative score increased from the baseline survey in 2003 to post-PACS in 2007. Refer to the 2007 column of Figure 5.

**Post-Phase-3 Assessment – A Review of the PACS Project Conducted in April-June 2008**

**Physician Provider Satisfaction Surveys**

The same survey tool was used as before, but instead of asking specific populations of physicians regarding their satisfaction with PACS, we e-mailed surveys to all of the physicians (340) who have staff privileges at an NMHS facility. Twenty-two physicians returned the survey.

This is a 5-point survey that asks the physician to mark 5 as being excellent and 1 as being poor. The 2008 survey results are compiled and compared to the baseline survey that was conducted in 2003, the referring community hospital physicians in 2006 and clinic’s PCPs in 2007. Whereas all post-PACS surveys show an improvement in physician satisfaction, the highest satisfaction occurred in 2006 and reflects PACS being implemented in the clinics.

**Figure 5: Summary of PACS Physician Surveys**

<i>Referring Physicians/Clinic-based PCPs</i>	<b>2003</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>
<b>Scheduling &amp; Registration</b>	<b>3.65</b>	<b>4.33</b>	<b>4.42</b>	<b>4.23</b>
- Time it takes to schedule outpatients		4.25	4.40	4.15
- Responsiveness for urgent patients		4.42	4.44	4.30
<b>Physician Needs</b>	<b>3.74</b>	<b>4.15</b>	<b>4.66</b>	<b>4.19</b>
- Availability of radiologists to review films		4.36	4.76	3.93
- Timeliness of receiving preliminary reports		3.97	4.60	3.93
- Timeliness of receiving final reports		4.01	4.72	4.07

- Timeliness in completion of urgent exams		4.29	4.76	4.50
- Report turn-around time for urgent patients		4.14	4.64	4.54
<b>Patient Needs</b>	3.72	<b>3.97</b>	<b>4.43</b>	<b>3.94</b>
- Waiting time in the department		3.57	4.43	3.90
- Customer service attitude & tech performance		4.37	4.43	4.00
<b>Radiologists</b>	3.93	<b>4.16</b>	<b>4.48</b>	<b>4.12</b>
- Quality & accuracy of interpretation		4.20	4.74	3.86
- Availability for consultation		4.15	4.64	4.21
- Calling of positive reports to physicians		4.15	4.08	4.29

To supplement the empirical data, which trends strongly to greater satisfaction with radiology services, PACS physician survey respondents write-in comments are presented in Figure 6.

**Figure 6: Physician write-in comments on 2008 regional PACS survey**

<p><b>Do you feel that the implementation of PACS has changed the way you treat patients? For example, if the turn around time for reports is faster, has this helped with your ability to diagnose and treat patients?</b></p> <ul style="list-style-type: none"> <li>• Turn around time for plain films slow.</li> <li>• Has helped some.</li> <li>• I try to read my own and usually the patient is gone before report is generated.</li> <li>• Very helpful to be able to view and compare films not just reports even from my home.</li> <li>• I like the imaging system for many reasons: 1) the over-reads are more timely and sometimes before the patient leaves the office, but not always; 2) PACS lends itself to conferencing with consultants as well as the radiologists; 3) the ability of reviewing the x-rays with the patient in the exam room is an added benefit, as well; and 4) the ability to review x-rays performed at multiple locations is a great benefit, as well.</li> <li>• Since we have to see the study more than report, PACS has dramatically helped our patient care. We save time looking for the films. More than one physician can review at the same time.</li> <li>• Yes, it allows me to view the film instead of waiting on a radiologist. It allows me to better interpret ultrasound findings as the report given by the radiologist is often sub-quality.</li> <li>• Yes, I am more impressed with the quality than the speed.</li> <li>• Yes – the ability to receive a report in a timely fashion has led to my being willing to wait for the radiologist’s report rather than make treatment plans based on my preliminary reading.</li> <li>• PACS is great for viewing own X-rays.</li> <li>• Yes, improved diagnostic studies, turnaround time and consultations.</li> </ul>
--

► **Research Area: Improved clinical outcomes**

**Phase-1: NMMC-Tupelo Campus**

Two clinical conditions for which early and efficient radiological results are critical for diagnosis and treatment and that present at relatively high base rates in patient populations were selected for study: community-acquired pneumonia (CAP) and ischemic stroke.

Community Acquired Pneumonia: In our initial review, we selectively examined the pre- and post- PACS CAP population for two well-established clinical outcomes: 1) Length of Stay (LOS), and 2) Mortality. Because CAP has a seasonal component, our selection criteria included the same three-month time periods (Oct-Dec) for before- and after-PACS. In order to assess a patient population in which we felt that PACS improvements (timeliness of reports) would have the most impact on treatment and outcome, we selected a subpopulation of patients with CAP namely, those that were admitted directly to the Emergency Services Department (ESD) rather than those transferred in or treated by their physicians prior to admission through the ESD. Results appear in Figure 7. Whereas the time to antibiotic administration decreased slightly (205 minutes to 195 minutes) it would be surprising if the 10 minute difference was related to the improvement in mortality (18.2% to 10.5%, NS). (Figure 7)

**Figure-7: Community-Acquired Pneumonia (CAP)**

	<b>Pre-PACS Oct-Dec/03</b>	<b>Post-PACS Oct-Dec/04</b>	
<b>No. Patients</b>	<b>44</b>	<b>57</b>	
<b>Antibiotic time (min)</b>	<b>205</b>	<b>195</b>	<b>NS</b>
<b>BldCulture time (min)</b>	<b>183.5</b>	<b>233.2</b>	<b>NS</b>
<b>LOS (days)</b>	<b>6.4</b>	<b>6.3</b>	<b>NS</b>
<b>Mortality</b>	<b>18.2%</b>	<b>10.5%</b>	<b>NS</b>
<b>Cost of care</b>	<b>\$9,514</b>	<b>\$9,361</b>	<b>NS</b>

Ischemic Stroke: The implementation of PACS improved the interpretation of the CAT scans from 38 to 27 minutes, but it did not appear to change the stroke outcomes. (Figure-8)

**Figure-8: Ischemic Stroke**

	<b>Pre-PACS Dec-Oct 03</b>	<b>Post-PACS Dec-Oct 04</b>
<b>No. Patients</b>	<b>55</b>	<b>62</b>
<b>CAT Scan Interpretation</b>	<b>38 min</b>	<b>27 min</b>

<b>LOS (days)</b>	<b>5.9</b>	<b>5.9</b>	<b>NS</b>
<b>Mortality</b>	<b>5.5%</b>	<b>8.1%</b>	<b>NS</b>

### **Phase-2 Community Hospitals**

At its community hospitals in Eupora, Pontotoc, and West Point, NMMC is monitoring clinical outcomes as they relate to the implementation of PACS for two conditions: community-acquired pneumonia (CAP) and ischemic stroke, which were selected due to their high base rates of incidence among admissions to community hospitals and because diagnosis and initial treatments of CAP and ischemic stroke are dependent upon radiological studies.

Reviewers of the Phase 1 portion of this project (implementing PACS on the NMMC-Tupelo campus) recommended incorporation of process indicators that were relatively close to and dependent on PACS to more reliably assess its impact. The timing of the first dose of antibiotic was selected as the process indicator for CAP and the administration of tissue plasminogen activator (tPA) as the process indicator for ischemic stroke. As in Phase 1, overall outcome indicators (length of stay, mortality and cost) were also measured pre- and post-PACS implementation

Refer to Figure 9: NMMC-Eupora had the most patients diagnosed with CAP pre- and post-PACS (even with a 29% decline in the post-intervention period). This patient population also was the most similar (age and severity ranking) between the two assessment periods. During this timeframe, the radiologists' turnaround times dropped from 17 hours to 1.3 hours (88 minutes), and the median time from emergency department admission to administering antibiotics dropped from 176 to 98 minutes. This is well below the four hour (240 minute) goal for antibiotic administration and may have contributed to the slight decrease in LOS, 5.81 to 5.47 days (5.8%) and the significant decrease in mortality (3.96% to 1.39% (65% decrease)). The median cost of the admission also dropped slightly, from \$5,407 to \$4,962 (8.2%).

The other two hospitals, West Point and Pontotoc, also had positive LOS, mortality and cost outcomes, but their patient populations were different (age and severity) between the two time periods and their change in median antibiotic administration time was not significantly different. West Point did not demonstrate any change in its median time to antibiotic administration. This facility has regular daytime on-site radiologist coverage and experienced the least improvement in radiologist study turn-around time (9.0 to 1.8 hours: Figure 1). The regular presence of a radiologist may account for the lack of improvement on antibiotic administration, i.e., the availability of PACS did not change their practice sufficiently. In short, it is difficult to project if the implementation of PACS may have been associated with the positive outcomes at West Point.

**Figure 9: CAP Outcome Analysis Table**

	Number of pts.	Ave. pt age	Ave. pt severity	Median time to antibiotic (mins)	Ave. length of stay (days)	Patient mortality	Median Cost
<b>EUPORA</b>							
<b>Pre-PACS (April-Sept 2004)</b>	101	67	2.09	176	5.81	3.96%	\$5,407
<b>Post-PACS (April-Sept 2005)</b>	72	61	2.04	98	5.47	1.39%	\$4,962
<b>PONTOTOC</b>							
<b>Pre-PACS (April-Sept 2004)</b>	17	72	1.81	120	4.29	0.00%	\$5,244
<b>Post-PACS (April-Sept 2005)</b>	37	65	2.19	115	3.84	0.00%	\$5,538
<b>WEST POINT</b>							
<b>Pre-PACS (April-Sept 2004)</b>	51	66	2.08	120	6.67	7.84%	\$5,611
<b>Post-PACS (April-Sept 2005)</b>	45	49	1.91	120	4.13	0.00%	\$4,754

Refer to Figure 10: Only one hospital, West Point, administered tPA to one patient. It was during the post-PACS timeframe, but as noted earlier, West Point already had about 40 hours per week of on-site radiologist time, so it is impossible to attribute this tPA usage to the implementation of PACS. Although the numbers of stroke patients are low, based on this 6-month pre- and post- PACS implementation analysis, it does not appear that PACS has made an impact on the care of stroke patients with regard to tPA administration, the chosen process marker. Whereas mortality decreased in all three hospitals, the LOS and median costs of care decreased in the two hospitals that did not administer the tPA.

**Figure 10: Stroke Outcome Analysis Table**

	Number of pts.	Ave. pt age	Ave. sev ind	tPA administration	Ave. length of stay (days)	Patient mortality	Median Cost
<b>EUPORA</b>							
<b>Pre-PACS (April-Sept 2004)</b>	16	79	2.25	0	5.69	6.30%	\$4,482
<b>Post-PACS (April-Sept 2005)</b>	15	82	2	0	3.56	0.00%	\$3,487
<b>IUKA</b>							
<b>Pre-PACS (July-Dec 2004)</b>	4	71	2.5	0	3.75	25.00%	\$6,856
<b>Post-PACS (July-Dec 2005)</b>	13	69	2.5	0	3.93	7.10%	\$4,080
<b>WEST POINT</b>							
<b>Pre-PACS (April-Sept 2004)</b>	16	74	2.38	0	5.00	6.30%	\$5,169
<b>Post-PACS (April-Sept 2005)</b>	19	68	2.11	1	6.47	0.00%	\$6,547

### **Phase-3: Clinics**

During the randomly-selected 60 patient pre- and post-PACS chart review (described in Figure 2) two more data elements were collected to examine the clinical efficacy of the PACS system in the clinics:

- If the PCP documented his/her own interpretation of the study; and
- If the PCP's and the radiologist's interpretation agreed with each other. (Figure 11)

**Figure 11: Clinical impact of PACS of NMHS clinic patients**

	<b>Pre-PACS (%)</b>	<b>Post-PACS (%)</b>	<b>p-value</b>
<b>Cases of PCPs who documented their interpretation of their patients' CXR</b>	<b>28 pts (47%)</b>	<b>28 pts (47%)</b>	<b>1.00</b>
<b>Cases of agreement between PCPs interpretation and the radiologists' interpretation</b>	<b>25 pts (89%)</b>	<b>24 pts (86%)</b>	<b>1.00</b>

To better understand Figure 11, note the following observation.

1. Less than half (47%) of the PCPs documented their interpretations, even before PACS was implemented. This pattern of PCP documentation persisted after PACS, which means that only half of the PCPs' interpretations could be assessed for agreement with the radiologists' interpretation.
2. An additional interpretation of this finding is that the implementation of PACS did not appear to change the PCP's behavior, i.e., they interpreted their films at the same frequency, regardless of PACS. One of the basic premises of implementing PACS in the clinics is to provide the clinic-based PCPs with the radiologist's interpretation during the patient's visit. As noted in Figure 2, the turnaround time of the arrival of the radiologist's interpretation on the patient's EMR decreased from 49.0 to 1.6 hours. This incredible improvement, however, did not change the frequency of the PCPs recording their own interpretations on the EMR (47% pre and post PACS). And, understandably, it did not appreciably change the agreement between the PCP and radiologists agreement (89% pre and 86% post PACS).
3. There were seven cases (3 pre-PACS and 4 post-PACS) in which the radiologist's interpretation disagreed with the PCPs' interpretation. Figure 12 describes the differences that were found and their clinical impact.

It is not possible to assess the actual impact on the PCPs use of the information they received. Based on their comments in the satisfaction survey (Figure 6), it appears that the physicians are using the radiologists' interpretations to make their treatment decisions.

Each of the seven cases of disagreement between the PCP's and the radiologist's interpretation of the patients' CXR was reviewed by the clinic system's quality improvement physician. He determined if there was any clinical impact on the patient's care because of the disagreement.

**Figure 12**

<b>Pre-PACS Cases</b>	<b>Case Description</b>	<b>Clinical Impact</b>
1	The PCP interpreted the CXR of 52 yo male with coughing and wheezing as a "little patch of pneumonitis" and prescribed antibiotics for bronchitis. The radiologist interpreted the CXR as "within normal limits."	None – would also treat these clinical symptoms with antibiotics
2	The PCP interpreted the CXR of 16 yo female with back pain in her left flank area as "possible costochondral tear" and treated her with a mild pain medicine and an anti-inflammatory agent. The radiologist interpreted the CXR as a "negative examination."	None- would also treat the pt's pain with pain med & anti-inflammatory agents
3	The PCP interpreted the CXR of 68 yo female with cough, cold and congestion "infiltrate of left lower lung." and prescribed antibiotics for bronchitis. The radiologist interpreted the CXR as "within normal limits."	None – would also treat these clinical symptoms with antibiotics
<b>Post-PACS Cases</b>	<b>Case Description</b>	<b>Clinical Impact</b>
1	The PCP interpreted the CXR of 57 yo male with cough, chest congestion and wheezing as "chronic changes and light bronchial cuffing" and prescribed antibiotics and an inhaler for bronchitis. The radiologist interpreted the CXR as "unremarkable chest."	None – would also treat these clinical symptoms with antibiotics and an inhaler
2	The PCP interpreted the CXR of 6 yo female who is on a return visit for her bad cough as "a suspicious area in the left base for an infiltrate" and prescribed a different antibiotic and a corticosteroid for possible pneumonia. The radiologist interpreted the CXR as "and infiltrate in the lingular segment of the left upper lobe ... felt to represent a left upper lobe pneumonia."	None- it is difficult to make fine anatomical distinctions in a small child. The interpretation was similar and the treatment would be the same.
3	The PCP interpreted the CXR of 70 yo female with lung congestion as "no consolidations, infiltrates or effusions" and prescribed antibiotics and cough medicine for bronchitis. The radiologist interpreted the CXR as "a slight increase in the size of the vague nodular opacity in the right upper lobe."	Possible – would require a CT of the chest to examine nodular opacity. <i>Follow-up: PCP ordered the chest</i>

		<i>CT the following day.</i>
4	The PCP interpreted the CXR of 9 yo female with nighttime cough and shortness of breath as “clear” and prescribed antibiotics, cough medicine and a corticosteroid for bronchitis. The radiologist interpreted the CXR as “peribronchial wall change consistent with bronchitis.”	None – different terminology but same diagnosis and treatment.

While PACS increased the speed in the radiologists’ return of their interpretations, it did not demonstrate an impact on clinical outcomes in the current study. In retrospect, we may have assessed the impact too soon after implementation to see any difference in PCP behavior. Although PCPs indicated they are looking at the radiologists’ studies before making their decisions (per satisfaction comments) they did not appear to sign off on the radiologists’ notes significantly earlier than before (Figure 2). This may indicate that many of the PCPs have not yet incorporated this new technology into their practices. This assessment was performed shortly (1-2 months) after PACS was implemented in the clinics. We may want to reassess the clinics at a later interval, like after one year of experience using PACS.

**Post-Phase-3 Assessment – A Review of the PACS Project Conducted in April-June 2008**

**Clinical Outcomes Assessment**

The post-phase-3 clinical outcomes assessment involves both the hospital setting (phases 1 and 2) and the clinic setting (phase-3). The clinical outcomes assessment for the first two phases involved the rapidity of diagnosis and treatment of community-acquired pneumonia in the hospital emergency room setting. The clinical outcome assessment for the third phase involved the concurrence of agreement between the primary care provider’s (PCP) interpretation of a CXR obtain at the clinic and the radiologist’s interpretation.

Clinical Impact of PACS on NMHS Hospital Patients

Figure 13 pulls together pre-PACS and two post-PACS intervals, the 2<sup>nd</sup> being the most recent, post-project summary period. The clinical outcomes measure we are using is the first dose of antibiotic that is given to patients who enter the emergency services department (ESD) in Tupelo and at the community hospitals (CHs) with signs and symptoms of community acquired pneumonia (CAP). The diagnosis of CAP is made upon the interpretation of the CXR, so it is a good clinical process marker to correlate with the rapidity of radiological interpretation. The timing of the first dose of antibiotics to treat CAP is also correlated with the clinical outcomes of CAP; specifically, higher mortality is linked to delayed antibiotic administration (over 8 hours). The goal for first dose antibiotics is less than 4 hours and this is used as a “core measure” for CMS and Joint Commission Accreditation of hospitals. Figure 13 shows that as the mean turnaround time of all radiological study interpretations decreased, so did the time to administration of the first dose of antibiotics.

Figure 13

<b>Facility</b>	<b><u>PRE-PACS</u></b> <b>Oct-Dec 03 (Tupelo)</b> <b><u>April-Sept 04(CHs)</u></b> <b>1<sup>st</sup> dose ABx-</b> <b>Minutes (<i>mean study</i></b> <b><i>turnaround time-hrs</i>)</b>	<b><u>1<sup>st</sup> POST-PACS</u></b> <b>Oct-Dec 04 (Tupelo)</b> <b><u>April-Sept 05(CHs)</u></b> <b>1<sup>st</sup> dose ABx-</b> <b>Minutes (<i>mean study</i></b> <b><i>turnaround time-hrs</i>)</b>	<b><u>2<sup>nd</sup> POST-PACS</u></b> <b>Oct-Dec 07 (Tupelo</b> <b><u>and CHs)</u></b> <b>1<sup>st</sup> dose ABx-</b> <b>Minutes (<i>mean study</i></b> <b><i>turnaround time-hrs</i>)</b>
Tupelo (Mean Time)	205 min (2.3 hrs)	195 min (1.0 hrs)	163 min (0.9hrs)
Eupora (Median Time)	176 min (17 hrs)	98 min (1.3 hrs)	118 min (1.3 hrs)
Iuka (Median Time)	NA (17 hrs)	NA (1.8 hrs)	135 min (1.1hrs)
Pontotoc (Median Time)	120 min (13 hrs)	115 min (0.5 hrs)	93 min (0.1 hrs)
West Point (Med Time)	120 min (9 hrs)	120 min (1.8 hrs)	111 min (1.7hrs)

Clinical Impact of PACS on NMHS Clinic Patients

Forty patient visits were randomly selected from two of the rural medical clinics that implemented PACS (20 charts from each clinic before and 20 from each clinic after PACS). The patients’ electronic medical records (EMR) were reviewed pre-PACS implementation (January 2006) and post-PACS implementation (October 2007) (Fig. 14). In the pre-PACS phase there is a considerable difference (89% for Clinic-1 and 50% for Clinic-2) in the numbers of PCPs who interpret (and document their interpretation) of their own studies. Once PACS was implemented, fewer PCPs in Clinic-1 interpreted their own studies than pre-PACS (70% vs. 89%). The Clinic-2 PCPs interpreted only 5% of their own studies post-PACS (vs. 50% pre-PACS) which indicates that PACS did have an impact on their practice (Figure 14). Once the PCPs became accustomed to receiving the radiologists’ interpretation, they no longer made their own interpretation.

Figure 14

	<b>Pre PACS</b> <b>Jan 06</b> <b>Clinic-1</b>	<b>Pre PACS</b> <b>Jan 06</b> <b>Clinic-2</b>	<b>Post PACS</b> <b>Oct 07</b> <b>Clinic-1</b>	<b>Post PACS</b> <b>Oct 07</b> <b>Clinic-2</b>
<b>Cases of PCPs who documented their interpretation of their patients’ CXRs</b>	17/19 (89%)	10/20 (50%)	14/20 (70%)	1/20 (5%)
<b>Cases of agreement between PCPs’ and radiologists’ interpretation</b>	15/17 (88%)	9/10 (90%)	13/14 (93%)	1/1 (100%)

Over the pre and post PACS periods, there were four cases of disagreement between the PCP’s and the radiologist’s interpretations for a 9.5% disagreement (42 overall cases). The Quality Director for the clinic system (also a PCP) reviewed the clinical circumstances of the four cases of disagreement (Figure 15). Despite the difference between the radiologist and PCP’s interpretations, our physician reviewer did not identify any deficiency in care.

Figure 15

<b><i>Pre-PACS Cases</i></b>	<b><i>Case Description</i></b>	<b><i>Clinical Impact</i></b>
1 (Clinic-1)	PCP interpreted the CXR of 70 yo female who presents with left hip pain after a recent fall as “no obvious infiltrate, bronchitis changes.” At the time of the office visit she was being treated with antibiotics and medrol for previous (10 days prior) c/o increased cough, congestion, rhinitis, generalized myalgias and chills. Pt stated her bronchitis-like symptoms were not improving and PCP prescribed Rocephin injection, Biaxin and continuing Medrol dosepak. The radiologist interpreted the CXR as “mild infiltrate or atelectasis suggested at the right base.”	<u>No change</u> in overall approach. Reviewing PCP would have prescribed 10 days of antibiotic rather than a 7-day course.
2 (Clinic-1)	PCP interpreted the CXR of 83 yo female who presents for nursing home placement as having “some mild pulmonary vascular congestion.” The radiologist interpreted the same film as “lung fields appear clear.”	<u>No change</u> The PCP commented on the CXR but did not change therapy because of it.
3 (Clinic-2)	PCP interpreted the CXR of 94 yo female with complaints of coughing and headache as “some signs of senile emphysema” and treated her with oral antibiotics and cough syrup. The radiologist state “no new infiltrate.”	<u>No change in care.</u> Levoquin is appropriate for coronary obstructive pulmonary disease (COPD) exacerbation.
<b><i>Post-PACS Case</i></b>		
4 (Clinic-1)	PCP interpreted the CXR of 64 yo female who presents with cough productive with a “bunch of junk” as thickening of bronchial walls indicating inflammation. The PCP oral antibiotics and Mucinex. The radiologist interpreted the CXR as “lungs are well expanded and clear.”	<u>None</u> – would also treat these clinical symptoms with antibiotics.

**► Research Area: Identification of highly effective security architecture for networked PACS systems that can be replicated for Army Medicine’s networked medical devices, including PACS**

*BACKGROUND regarding phase-2 evaluation: NMMC contracted Sword & Shield Enterprise Security, Inc. (Sword & Shield) to conduct a network vulnerability assessment and penetration test of NMMC’s external and internal networks. The assessment examined NMMC’s implementation of the Army Security Architecture for Medical (ARSAM), a defense-in-depth network security architecture for FDA-approved medical devices. NMMC is using ARSAM in its deployment of the PACS within its hospital information system network. Sword and Shield Findings from May 2006*

- *From an external perspective, the overall security posture of the NMMC network was deemed to be satisfactory. The firewall and network devices provided an adequate level of protection to the NMMC internal network, and PACS network, from Internet-based threats.*
- *However, Sword and Shield was able to circumvent the ARSAM protections implemented at NMMC during the internal phase of testing by taking advantage of some PACS devices that were located outside of the protected enclave and also by taking advantage of other devices on the network which were not patched with all of the latest security patches or system/applications updates.*

**Post-Phase-3 Assessment – A Review of the PACS Project Conducted in April-June 2008**  
**Post-Phase-3 Assessment – A Review of the PACS Project Conducted in April-June 2008**

NNMC contracted with Sword and Shield to perform a network vulnerability assessment. The assessment was performed in June 2008 and Sword and Shield produced a report on July 11, 2008. The Executive Summary of the report is presented and NMMC’s response to the identified weaknesses is also presented.

**Sword and Shield’s EXECUTIVE SUMMARY (July 11, 2008)**

Sword & Shield Enterprise Security, Inc. (Sword & Shield) was contracted to conduct a network vulnerability assessment (NVA) and penetration test (PT) of the North Mississippi Medical Center (hereinafter referred to as NMMC) external and internal networks. The assessment examined NMMC’s implementation of the Army Security Architecture for Medical (ARSAM); a defense-in-depth network security architecture for FDA-approved medical device. NMMC is using ARSAM in their deployment of the Picture Archive and Communications System (PACS) within their hospital information system network.

The assessment was divided into two phases. First, an external assessment was completed under a “zero knowledge” scenario to represent a “hacker’s perspective.” NMMC provided Sword & Shield consultants with only a range of public IP addresses. Sword & Shield consultant targeted publicly-accessible NMMC assets from the Internet in an attempt to access the NMMC network, and subsequently the PACS network. While the assessment team was unable to gain access to any NMMC systems from the Internet, high-risk vulnerabilities were found. Under the correct circumstances, these vulnerabilities could lead to the remote exploitation of a system. Secondly, upon completion of the external assessment, an internal NVA/PT was completed. The phase took place while connected directly to the internal NMMC network to represent an “internal perspective.” For this phase, NMMC provided Sword & Shield consultants with detailed network information. The assessment was focused on the assumption that a person with malicious intent had connected an unauthorized system to the NMMC internal network and was attempting to gain access to sensitive data within the PACS network. From an internal perspective, the NMMC network contained deficiencies that led to the complete compromise of internal systems and, ultimately, the PACS network.

The PACS network is currently segmented from the rest of the internal NMMC network through the use of a router access control list (ACL). The ACL in place was sufficient in keeping normal traffic within the NMMC internal network from reaching the PACS network. However, the security controls provided by the router ACL can be easily circumvented through assuming the IP address of a “permitted” host, compromising a “permitted” host and using it as a proxy for access into the PACS network, or directly compromising the network router controlling the ACL. Vulnerabilities on the internal NMMC network enabled Sword & Shield consultants to both directly compromise the network router controlling the PACS ACL, as well as compromise “permitted” hosts that had access to the PACS network. These vulnerabilities were the result of missing security patches and system/application updates, blank or common passwords, and systems or applications deployed with widely known default/insecure settings.

Based on the analysis of the results, it is recommended that stateful filtering devices, such as a firewall, be used to regulate traffic between the NMMC internal network and PACS network segments. Proper configuration would allow only the specific services needed for normal network operation to pass between the two networks. It is also recommended to move as many of the devices associated with the PACS network into the protected PACS enclave. Fewer devices requiring access between the two networks will ultimately limit the number of attack paths into the PACS network.

Development and implementation of formal policies and/or procedures is also recommended to address patch management and configuration management. NMMC already deploys an internal patch management solution, but should make sure that it includes all systems within the NMMC network. Patches and updates to be applied to systems, applications, and network devices on a routine basis.

Finally, it should be noted that this security assessment focused solely on vulnerabilities within the NMMC network that would allow an attacker to access the PACS network. Based on the results of the hosts tested under this limited scope, it is recommended that a full network vulnerability assessment and penetration test be performed on the entire NMMC network to address other potential vulnerabilities.

If the recommendations contained in this report are implemented properly, the security posture of the NMMC network will be significantly improved.

### **NMMC’s Response to Sword and Shield’s Findings (July 11, 2008)**

NMMC's implementation of the ARSAM security design was unsuccessful in keeping a malicious user from gaining access to the PACS network. NMMC will continue to use the Router ACL method for separating the PACS network from the remainder of the NMMC network as it is successful in keeping "normal" traffic from within the NMMC network from reaching the PACS network. This will protect the PACS network from unsophisticated viruses, worms and malicious software which might infiltrate the NMMC network. NMMC's imaging modalities, which are more vulnerable to such attacks due to a lack of up-to-date software and

security patches from vendors, will be much less likely to be compromised from malicious software on the NMMC network.

NMMC's failure to achieve protection from an individual with malicious intent is due in large part to the fact that NMMC's PACS network is integrated with many systems outside of the PACS enclave: it is a part of the NMMC domain and uses domain authentication for user level access; it uses NMMC's DNS services; and it is integrated with NMMC's HIS, RIS, and interface engine, all of which are located outside of the PACS enclave. NMMC faces a situation similar to that of modality vendors in that it can not immediately apply patches or updates to the these systems that communicate with PACS. Like vendors, NMMC requires time to thoroughly test any impact the patches or updates might have on our production environment. This testing requires not only that NMMC test the PACS system in regard to the changes, but any other systems affected as well. For example, any changes to NMMC's interface engine would require validation of all systems integrated through it. This is a process that typically takes NMMC six-to-eight months to accomplish.

The Sword and Shield evaluations demonstrated that a sophisticated user with malicious intent could take advantage of the lack of timely patches to these external systems and use that advantage to circumvent the protections provided by the Router ACL method of separating the two environments.

The intent of the ARSAM security architecture with respect to how it would be utilized within the DOD environment is much more complex. The DOD implementation would intend to protect not only the PACS devices, but more specifically, to protect the remainder of the DOD systems from any user or device that resides on the PACS enclave. Any such implementation of the ARSAM architecture would require an enormous amount of resources dedicated to continuously monitoring potential for compromise in addition to constant patching of operating systems and commercial software packages which would, in turn, require continuous testing of how these patches would affect involved systems. Not unlike the situation vendors face when qualifying patches for devices for which they have obtained FDA 510K clearance, the DOD would be challenged to perform all of the necessary testing required before updating systems with patches. At the rate with which security patches are released, it would be difficult to maintain such an environment without an enormous amount of resources and effort.

### **Project Deviations**

#### NMMC-Hamilton – delayed PACS implementation from Phase-2 until post Phase-3:

The community hospital located in Hamilton, AL is a component of NMHS, but because it is located in a different state, we cannot implement some programs in the same way as at our Mississippi community hospitals. The major technical obstacle was the cost of bandwidth to the Hamilton hospital. The MS community hospitals utilized a DS-3 line which is 45 megabytes. NMHS spends about \$4,000 per month for line charges per MS community hospital, but crossing the state line into Alabama is exponentially higher, making it impractical to implement PACS. Hamilton would use two T-1 lines which would be only 3 megabytes. And with the low

bandwidth the PACS service would be too slow to be useful (e.g., it would take 900 seconds for a CT scan with 385 images to arrive at the radiologist's screen).

To solve this technical problem we turned to Cisco and their wide area application services (WAAS). WAAS utilizes multiple technologies to optimize bandwidth across a WAN, including the following:

- Application acceleration: Cisco WAAS mitigates latency and bandwidth through advanced protocol optimizations, including read-ahead, message prediction, and caching.
- Throughput optimization: Cisco WAAS improves behavior of transport protocols to make them more efficient in WAN environments.
- Bandwidth optimization: Cisco WAAS minimizes the transmission of redundant data patterns through Cisco WAAS Data Redundancy Elimination (DRE) and compression.

In testing this technology we've found that a large imaging study that would take 900 seconds to come across the first time (to the radiology technician) would only take 23 seconds when the radiologist later accessed it.

We've had to invest in the Cisco WAAS routers in order to take advantage of this technology. The WAAS technology, however, has enabled us to implement PACS in Hamilton, AL using two T-1 lines and at what will be an affordable monthly rate. We also plan to install these WAAS routers at the rural clinics that are not adjacent to the rural community hospitals. These clinics use DSL or cable for their PACS transmissions and the routers will speed up the transmissions.

### **Reportable Outcomes**

To date, no manuscripts, abstracts, grant applications, patents, etc. have been submitted that are direct results of this project.

### **Conclusions**

Implementation of PACS technology on NMMC's campus in Tupelo, four community hospitals and 15 clinics has yielded information of potential value to other health care agencies serving rural regions:

### Summary of Findings

*Efficiency - faster report turn-around and better use of radiologist time*

- PACS technology is associated with dramatic decreases in radiological report turn-around in rural hospital and rural clinic settings.
- PACS technology improved the radiologist's efficiency in reading films by 15%, thereby enabling the existing radiologist staff to manage an increase in film volume by interpreting more studies during a work cycle.

*Cost – cost savings depends on the setting of PACS*

- NMMC-Tupelo campus reduced personnel (film librarian) costs by \$300,000 per year and this level has remained constant. NMMC-Tupelo reduced film costs by \$450,000 per year in year-1, but by year-4 this savings has increased film savings to \$600,000 per year. NMMC-Tupelo did not experience an increase in transmission costs, so these savings are not offset.
- All four community hospital sites reduced film costs by an average of \$24,340 per hospital per year. Two of the community hospitals also experienced a reduction in personnel (film librarian) costs an average of \$11,000 per hospital per year after implementation of PACS.
- The clinic system's film cost savings were offset by their increase costs in IT support and transmission costs. This results in a 22% cost increase radiological study support in the clinic system because of PACS.

*Satisfaction – physicians like PACS*

- Clinic-based PCPs and referring physicians reported greater satisfaction with radiological services following introduction of PACS capabilities.

*Clinical Outcomes – ESD administration of first dose antibiotic to CAP patient is likely the best process marker on the clinical impact of PACS.*

- Community hospital data (Figure 13) support the hypothesis that the use of PACS technology increases the speed with which antibiotics are administered as indicated for CAP.
- The low usage of tPA in the management of ischemic stroke makes it an unreliable process indicator for efficacy of PACS in the management of stroke.
- The implementation of PACS in the clinic system did affect the frequency of PCPS interpreting their patients' CXRs. PACS reduced PCPs interpretation of CXRs once the PCPs became aware of and comfortable with the radiologists' interpretation timely arrival.

*Security Architecture Testing*

- Initial network sensitivity and penetration testing, performed in May 2006, revealed that ARSAM protections implemented at NMMC were inadequate and that additional precautions needed to be taken in the security system architecture.

- The second, and final, network sensitivity and penetration testing, performed in July 2008, revealed similar findings as the first testing, namely that although it was difficult to externally penetrate the system, there was complete compromise during the internal penetration testing.
- NMMC finds that the major ARSAM security impediment is the timely implementation of security patches. Commercial software vendors inconsistently provide security patches and because of the impact on multiple systems, it can take six-to-eight months to test some patches before they can be installed
- NMMC finds that it difficult to maintain the ARSAM architecture without considerable increase in its current resources and efforts.

In summary, the four year phase-in of PACS technology at NMMC's main hospital campus in Tupelo, five community hospitals, and 15 clinics has yielded mixed results. As hypothesized, the introduction of PACS at hospitals and clinics comprising NMHS yielded increased efficiency in radiological services, decreased radiologic staffing (film librarians), improved the delivery of first dose antibiotic to patients with CAP, and increased satisfaction of primary care providers with radiological services. In contrast to expectations, however, it did not appear to measurably improve clinical outcomes for people with ischemic stroke. Perhaps most surprising was the variation in the cost savings data: while PACS was associated with decreased radiological expenses at NMMC-Tupelo and all four community hospitals, it actually increased radiological expenses by 22 percent at the clinics. Security testing found that the system has not responded satisfactorily to network vulnerability assessments and penetration tests conducted by an independent vendor (Sword & Shield).

As required by the Research Technical Reporting Requirements, “So what?” Work completed during the three phases of PACS implementation and research at NMMC does indeed have implications for rural hospitals/health systems and for the military. PACS technology has dramatically increased the turn-around time for radiological images and increased significantly the number of “first reads” made by radiologists rather than other physician specialists. PACS technology will likely be instrumental in improving physician satisfaction with radiological services at other rural clinics and hospitals, which struggle to recruit and retain qualified health care providers. When contemplating implementation of PACS, some hospitals may be able to project cost savings from personnel or supply (film) budgets.

The results of network sensitivity and penetration testing completed at NMMC suggest that its implementation of ARSAM did enhance the protection of the PACS network from unsophisticated viruses and malicious software, yet in spite of a progressive information technology department, NMMC finds that it cannot protect against a sophisticated user with malicious intent who had gained internal access to our network. These findings would recommend that other rural hospitals include stringent, formal policies and/or procedures to address security patch management and configuration in the implementation of their PACS

systems and that they plan for a large increase in resources required to keep those policies and procedures fully implemented. Test results regarding security patch management are also of significance to the military's efforts to deliver radiological services from remote, noncombat sites to battlespaces utilizing existing DOD network resources.

The health system's experiences will be used to formulate recommendations for installation, implementation, and application of PACS systems, including highly effective security architecture. Data collected on indicators pertinent to clinical outcomes will be used to document the impact of PACS technology in civilian applications.

**Appendices**

*Not applicable*