Journal of Digital Imaging

Department of Defense Picture Archiving and Communication System Acceptance Testing: Results and Identification of Problem Components

Scott A. Allison, M.D., Clifford F. Sweet, M.D., Douglas P. Beall, M.D., Thomas E. Lewis, MBE, and Thomas Monroe, MSGT, USAF

The PACS implementation process is complicated requiring a tremendous amount of time, resources, and planning. The Department of Defense (DOD) has significant experience in developing and refining PACS acceptance testing (AT) protocols that assure contract compliance, clinical safety, and functionality. The DOD's AT experience under the initial Medical Diagnostic Imaging Support System contract led to the current Digital Imaging Network–Picture Archiving and Communications Systems (DIN-PACS) contract AT protocol. To identify the most common system and component deficiencies under the current DIN-PACS AT protocol, 14 tri-service sites were evaluated during 1998–2000. Sixteen system deficiency citations with 154 separate types of limitations were noted with problems involving the workstation, interfaces, and the Radiology Information System comprising more than 50% of the citations. Larger PACS deployments were associated with a higher number of deficiencies. The most commonly cited systems deficiencies were among the most expensive components of the PACS.

KEY WORDS: PACS, acceptance testing, workstation, clinical use determination, monitors, HIS, RIS, DIN-PACS, MDIS

INTRODUCTION

Picture archiving and communication system (PACS) has become an extremely useful tool for the healthcare industry. Preparing and acquiring a PACS is daunting and costly involving specialists from many fields as well as multiple equipment components which must somehow integrate with each other and provide clinical functionality. Given the overall cost to implement, maintain, and use PACS, a planned method for testing the installed system is imperative to verify safety and functionality before full clinical use.[1,2]

Acceptance testing (AT) is the technical evaluation of the PACS that demonstrates contractually appropriate functionality while serving as a payment milestone. It is a vital element of a successful PACS implementation. It ensures that the PACS is safe for clinical use. It verifies the customer's needs set forth by the contract. Acceptance testing also protects the vendor by clarifying particular site needs. Finally, the AT process ensures contract compliance, i.e., did the customer get what they paid for?[3–5]

As a whole, the Department of Defense (DOD) has the most experience of any group in developing and applying the acceptance testing protocol and has a long history of successful PACS implementations. The DOD routinely performs AT on newly installed PACS which began with guidelines set forth by the initial Medical Diagnostic Imaging Support System (MDIS) contract. During the early 1990s, the Tri-Service (Army, Navy, and Air Force) Radiology reengineering program and vendor participation with Loral Aerospace Systems and Siemens cooperatively developed MDIS contract systems (eventually

From the Department of Radiological Sciences, University of Oklahoma Health Sciences Center, 1200 North Everett Drive, ET-1606, Oklahoma City, OK 73104, USA.

Correspondence to: Scott A. Allison, M.D., Department of Radiological Sciences, University of Oklahoma Health Sciences Center, 1200 North Everett Drive, ET-1606, Oklahoma City, OK 73104, USA; tel: 405-271-5125; e-mail: scott-allison@ouhsc.edu

Online publication 2 June 2005

doi: 10.1007/s10278-005-5164-y

acquired by General Electric Medical Systems) which helped move the analog departments to digital and provide an example for the whole healthcare industry.[4–6]

Throughout the 5+ years use of the proprietary MDIS legacy systems during which ~50% AT failure rates were noted,[3] the military gained experience in refining and developing better PACS implementation protocols, particularly the AT process. In late 1997, a new contract was developed and awarded to IBM and Agfa, termed the Digital Imaging Network–Picture Archiving and Communications System contract (DIN-PACS). DIN-PACS is nonproprietary and is "performance based," stressing an open-systems network, ultimately striving for a purchased system that is "reliable and functional." These key features are an important change as it allows for flexibility in not only the deployment process, but also in the maintaining, repairing, and upgrading of a purchased system for future needs. Although the DIN-PACS contract has expired, it continues to be utilized as a guide for PACS purchasing and deployment, being modified and by the time of this publication renewed as DIN-PACS II.[8]

Table 1 lists the DIN-PACS contract provisions that must be addressed and met by the vendor during a PACS deployment. For example, adequate training to users of the equipment, from radiologists to ancillary staff, should be outlined and provided by the vendor along with documentation of the system components. Upgrades to the software and equipment during the 1-year warranty coverage must be provided at no additional cost to the government as well as further training if needed. Similarly, depending on site needs, variable outyear maintenance options are available which outline vendor and purchaser responsibilities over an 8-year period outside of the 1-year warranty. Structured payments provide incentives to reach contractually outlined deadlines for the implementation of the new system. Acceptance testing (AT) verifies these milestones, assuring functionality and assisting in a successful PACS deployment.[7]

Table 1. DIN-PACS contract provisions[7]

Training	Support
Acceptance testing	Contract data and documentation
Upgrades	One-year on-site warranty
Reliability with uptime requirements	Maintenance—corrective and preventative
Outyear maintenance	Structured payment terms

Table 2. DIN-PACS AT protocol overview used between 1998 and 2000

Phase I CUD	System integration and modality thread testing
	DICOM conformance testing
Phase II Full AT	Workstation performance testing
	Performance period testing
	Teleradiology testing
	RIS
	System storage and archive
	Communication network/system security
	Printer interface
	Training
	Maintenance
	Contract data requirements lists (CDRLs)

The DOD testing team utilizes professionals with varied backgrounds including biomedical engineers, medical physicists, radiologic technologists, radiologists, and communications and interface specialists. The DIN-PACS AT process varies in time requirements depending on facility size with the DIN-PACS contract stipulating a 30-day time limit.[7] The AT process is divided into two phases: phase I is referred to as the clinical use determination (CUD) phase, and phase II is full acceptance testing.

At phase I of AT, the clinical use determination is imperative, verifying receipt of the ordered components, proper installation, and clinical safety with various "thread tests" and equipment testing. These tests are stratified into segments to check system integration and initial equipment installation. System integration testing entails sending data (i.e., threads) throughout all aspects of the system, from patient data, testing of the installed modalities, and even system failover capabilities.

Once CUD is passed, the full AT4 process commences (Table 2) incorporating standardized benchmark testing of the system components.[3–5] Phase II involves complete workstation testing along with further complete testing of key functions of the PACS such as the RIS, archiving, teleradiology, network, and security. Finally, full AT

addresses that contract requirements (CDRLs), appropriate training, and necessary maintenance were met.

The purpose of this work is to share the initial 2-year DOD AT experience under the DIN-PACS contract in identifying the most common system deficiencies in the PACS sites undergoing the deployment process. Experiential observations and comparison to the MDIS results will be discussed.

METHODS

Over a 2-year time period between 1998 and 2000, a total of 14 tri-service (Army, Navy, and Air Force) sites undergoing PACS deployments were tested (refer to Table 3). The acceptance testing process was conducted according to the DIN-PACS AT protocol. The protocol consisted of 12 segments, divided into two phases: the clinical use determination (CUD; phase I) and the full acceptance testing (phase II) (refer to Table 2). Over 400 system elements were evaluated.

Cited deficiencies were recorded and divided into 16 primary categories (refer to Table 4). These categories were ranked in order of clinical and technical importance by three radiologists, two clinical engineers, a PACS specialist, and a radiologic technologist using consensus to establish the ranking hierarchy. Each specific type of system deficiency was recorded, their relative frequencies established, and the various deficiencies were then ranked in order of importance. Following deficiency correction or appropriate plan for correction with retesting when needed, the systems could then be accepted.

RESULTS

All 14 sites passed AT phase I, clinical use determination (CUD). All systems passed AT but with major and minor deficiencies. There were 154 separate types of limitations within the 16 system deficiency categories. Table 5 lists the deficiency categories with the limitations as a percentage of the total 154 citations. The component most commonly cited for deficiencies was the radiologist's workstation (25.3% of the total number of deficiency citations). This was followed by the Hospital Information System (HIS)/Radiology Information System (RIS)/PACS broker interfaces (16.2%), the RIS itself (14.3%), the monitor displays (9.7%), and the Web-based image distribution systems (6.5%). Other common deficiencies were seen with modality interfaces (4.5%), archive devices (4.5%), maintenance (3.9%), fail-

Table 3. The 14 Tri-Service (Army, Navy, and Air Force) sites tested during PACS deployment under the DIN-PACS contract 1998–2000

Osan AFB	121st Hospital
Kunsan AFB	Camp Walker
Robins AFB	Camp Casey
Walter Reed AMC	Camp Humphrey
Pentagon Health Clinic	Camp Carroll
Womack AMC	Camp Hialeah
Irwin Army Community Hospital	Portsmouth NMC

Table 4. Sixteen categories of PACS deficiencies found during DIN-PACS AT

1. Modality interfaces
2. Archive devices[a]
3. HIS/RIS Broker interfaces
4. RIS[a]
5. Web-based imaging distribution system
6. Monitors[a]
7. Workstation[a]
8. Associated equipment
9. Film digitizer
10. Training
11. Network[a]
12. DICOM
13. Failover capability
14. Teleradiology
15. Security
16. Maintenance[a]

[a]Denotes most expensive components.

Table 5. Sixteen categories of PACS deficiencies ranked by number of limitation citations which totaled 154

Deficiency category	Number of citations	Percentage of total (%)
Workstation[a]	39	25.3
HIS/RIS/ACS broker interfaces	25	16.2
RIS[a]	22	14.3
Monitors[a]	15	9.7
Web-based image distribution system	10	6.5
Modality interfaces	7	4.5
Archive devices[a]	7	4.5
Maintenance[a]	6	3.9
Failover capability	5	3.2
Training	4	2.6
Associated equipment	4	2.6
Network[a]	3	1.9
DICOM	2	1.3
Teleradiology	2	1.3
Security	2	1.3
Film digitizer	1	0.6

[a]Denotes most expensive components.

over capability (3.2%), training (2.6%), and network, DICOM, teleradiology, and security (each with <2%).

The overall percentage of component failures among the deployment sites varied from 0 to 42% with the larger PACS yielding proportionately more deficiencies than the smaller systems. The most common component needing replacement was the diagnostic monitor. Interestingly, three of the most expensive portions of the PACS (RIS and workstations including monitors) had the greatest number of component failure citations. The RIS and RIS/HIS interfaces categories combined had the most deficiencies mainly because of the unidirectional interface with the military HIS, or composite healthcare system (CHCS), during the 2-year evaluation. Examples of various deficiencies are reported below:

Workstation: Thirty-nine deficiencies (of the 154) were discovered ranging from slow display response times and unreadable text annotations and graphics to nonfunctioning workstation tools such as ROI and hot keys.
HIS/RIS broker interfaces: Twenty-five deficiencies including nonoperational voice recognition, Windows NT platform errors intermittently interrupting workstation connection, exam status between HIS/RIS/QC-W/&DICOM Archive not synchronized, and archive reporting "full" status on half-full storage disks.
RIS: Twenty-two deficiencies including failing to upgrade report status to verified, system "locks up" when global worklist selected, and no full visibility of the contents of the archive.
Monitors: Fifteen discovered deficiencies with 100% of the newly installed diagnostic and 43% of the review monitors failing the grayscale matching test. Review monitors had "burned-in" images. Monitor brightness was noted on some to be less than the 70 ft L (240 n) requirement. Overall, monitors were the most commonly replaced item prior to full operation.
Web-based imaging distribution system: Ten deficiencies including unavailable radiology reports, nonfunctioning PC tools (magnifying glass, cine), inability to download images, as well as nonoperational program secondary to security issues.
Modality interfaces: Seven deficiencies including images sent to the QC workstation, but data elements were not populated onto the diagnostic station worklist.
Archive devices: Seven deficiencies including archive controller "locking up" unpredictably.
Maintenance: Six deficiencies with incomplete maintenance plan and materials from vendor.
Failover capability: Five deficiencies with unclear failover mechanism and inadequacy to support clinical operation.
Training: Four deficiencies including insufficient training as well as training given on nonoperational or noninstalled equipment.
Network, DICOM, teleradiology, security, and archive devices: Each category had less than three deficiencies. Examples include lack of redundant network switches, PACS QC workstation not configured for Storage Commitment Support, as well as not meeting the government's C-2 level security standards.

DISCUSSION

There was a dramatic reduction from the 50% AT failure rate under the MDIS contract systems[3] to virtually none using the current DIN-PACS protocols over the 2-year evaluation. The authors propose several viable reasons for this discrepancy. More advanced, reliable, and affordable technology was available by 1998 and incorporated in the awarded contracts under DIN-PACS vs. earlier MDIS systems. For example, many of the MDIS problems included WAN insufficiencies, miscalibrated CRs, and improper UPS functionality which were eventually corrected. The personnel were more experienced with PACS deployments. By this time, the vendors, too, had more familiarity and resources designed for PACS implementation. Whether for better or for worse, there was, and still is, increased enterprise-wide pressure to accept the PACS despite the presence of unresolved issues.

During the 2-year evaluation, a large number of cited deficiencies dealing with equipment such as the workstation and monitors were easily remedied. However, one may contend that some of these problems could have been corrected before the formal AT process. Several recommendations to come from this early DIN-PACS experience include having the vendor perform trial runs and

equipment checks prior to the formal AT. To help facilitate this, other recommendations made were to clarify and provide concise benchmark specifications and AT protocol requirements to the vendor and, additionally, to clarify that the vendor is responsible for the proper functioning of the modality interfaces as well as recommending that the vendor personnel involved should be the most experienced with the components being tested. The unidirectional nature of the military HIS (CHCS) created a wide range of deficiencies which could be avoided by mandating a bidirectional HIS interface with the RIS. One important suggestion has, and will continue to be, a key ingredient of not only AT, but also PACS implementation in its entirety: the professionals involved in the daily clinical operation and use of the system, i.e., the end users, must participate in the process. Finally, recommendations were made at the conclusion of the 2 years to make the AT process itself more concise by combining several elements of both phases to avoid redundancy.

The evolving AT process can be facilitated and made successful by several strategies, most of which are incorporated in the DIN-PACS contract requirements[7] and contributed to the successful deployments between 1998 and 2000. A combination of careful vendor selection with proper scale of deployment for each particular site and appropriate monetary incentives is one such strategy. This is imperative when considering differing site needs, i.e., the larger deployment sites not surprisingly had a higher number of citations. Indirectly associated with monetary incentives for the vendor is the warranty timeline which does not begin until PACS acceptance. Adherence to the testing protocol by experienced personnel with meticulous follow-up of outstanding issues also plays a large role to ensure a smooth deployment.

Acceptance testing provides an objective way to evaluate the PACS installation, minimizing the inevitable complaints from end users and system support personnel. It requires extremely detailed planning and development of testing criteria prior to writing the contract. Because of the "lag time," the newest technologies are often not included. Because the initial DIN-PACS contract was written, improvements in software, development of "brokerless" interfaces, and widespread use of flat-panel displays, which are inherently brighter than even new CRT monitors, could potentially prevent some of the more common deficiencies identified during the initial 2 years of DIN-PACS experience. Continued evaluation of emerging technologies will be an important part of future acceptance testing which can lead to successful PACS implementation alleviating many of the medicolegal, quality, and budget concerns.

CONCLUSION

Acceptance testing protects both the PACS customer and vendor by verifying the expected functionality, clinical safety, and performance. It is a collaborative process requiring defined testing protocols and benchmarks. The Department of Defense's experience with AT and successful PACS deployments during the MDIS and subsequently with the DIN-PACS contracts is extensive serving as an effective example for the industry as a whole.

The DIN-PACS AT protocol used for this study between 1998 and 2000 revealed that problems involving the workstation, interfaces, and RIS comprise >50% of the total number of deficiency citations. Larger PACS deployments were associated with a proportionally higher number of deficiencies. The systems most commonly cited for system deficiencies were also among the most expensive components of the PACS. The AT failures noted with the earlier MDIS contract were virtually nonexistent, with the 14 tri-service sites passing AT under the DIN-PACS requirements. Technological advancements, monetary incentives, experienced personnel, involved end users, and proper vendor selection have aided, and will continue to aid, in successful PACS deployments by strengthening the acceptance testing process.

REFERENCES

1. Samei E, Seibert JA, Andriole K, et al.: AAPM/RSNA tutorial on equipment selection: PACS equipment overview: general guidelines for purchasing and acceptance testing of PACS equipment. Radiographics 24:313–334, 2004

2. Romlein J, Norton GJ, Lyche DK, et al.: PACS: acceptance test, quality control, warranty, and maintenance continuum. In: Blain GJ, Horii SC (eds). Proc. SPIE: Medical Imaging 1999: PACS Design and Evaluation: Engineering and Clinical Issues. 3662, 1999, pp 111–119

3. Lewis TE, Horton MC, Kinsey TV, et al.: Acceptance testing of integrated picture archiving and communications systems. J Digit Imaging 12:163–165, 1999

4. Richardson NE, Thomas JA, Lyche DK, et al.: The philosophy of benchmark testing a standards-based picture archiving and communications system. J Digit Imaging 12:87–93, 1999

5. Shelton PD, Lyche DK, Norton GS, et al.: Benchmark testing the digital imaging network picture archiving and communication system proposal of the Department of Defense. J Digit Imaging 12:94–98, 1999

6. Chacko AK, Wider R, Romlen J, et al.: PACS: implementation in the US Department of Defense. In: Blain GJ, Siegel EL (eds). Proc. SPIE: Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues. 3980, 2000, pp 139–146

7. Wechter AR, Johnson, BS, Richardson N: DIN-PACS An Introduction. Defense Supply Center Philadelphia (DSCP), regarding contracts SP0200-98-D-8701 and SP0200-98-D-8702. https://dmmonline.dscp.dla.mil/equip/documents/dinpacs.doc

8. DIN-PACS II on the web: https://dmmonline.dscp.dla.mil/equip/din-pacs.asp and https://dmmonline.dscp.dla.mil/equip/ppt/DINPACSIIKickoff10NOV04.ppt