

Application Service Providers: An Alternative Approach to PACS Implementation

Bruce Reiner and Eliot Siegel

Several impediments have delayed the adoption of filmless imaging by the majority of radiology practitioners. These factors include concerns for technology obsolescence, limited available capital, and lack of existing information technology (IT) infrastructure and experienced personnel. Application service providers (ASPs) have begun to emerge as an alternative approach to the more traditional acquisition of picture archiving and communication (PAC) systems. This approach offers the prospective PACS customer the opportunity to outsource hardware, software, and IT services to a vendor on a fee-per-use basis. The ideal candidates for such an approach would be small to medium-sized hospitals with limited existing IT infrastructure. Using the ASP model, prospective PACS customers can purchase services unique to their needs and upgrade or expand these as needed. As ASP vendors increase their customer base, there is the potential for customers to achieve unique economies of scale not available through traditional financing means. This report discusses the economic and operational issues associated with ASPs, as well as potential limitations and future implications of this phenomenon.

This is a US government work. There are no restrictions on its use.

KEY WORDS: picture archiving and communication systems, application service providers, medical economics, financing, risk-sharing.

THE DEFINITION of an Application Service Provider (ASP) in its purest form is a company or business that is remotely hosting a software application and providing use/access to clients over a network on a recurring fee basis. Essentially, ASPs take software applications, host them on powerful servers, and make these applications network accessible. The user, in turn, is allowed to run applications directly through browser software on their personal computer or other network-enabled device.

Although this concept was introduced originally among e-commerce companies, it has migrated into the healthcare arena as an alternative to the

traditional purchase of a picture archiving and communications system (PACS). The most frequently cited impediments for the transition to a filmless environment include excessive requirements for capital, infrastructure, and experienced information technology (IT) personnel. These are addressed in one form or another by using an ASP model, as illustrated in Table 1.

WHAT MAKES THE ASP APPROACH UNIQUE?

Traditional methods of PACS financing encompass different financial approaches. A traditional acquisition can involve a direct purchase, loan, or lease (capital or operating). While risk-sharing arrangements have been around for a number of years, their utilization has been limited. Typical risk-sharing arrangements operate on a fee-for-use basis, with the customer paying a predetermined fee based on system utilization (examination volume, image access, megabyte of storage). In all of the aforementioned scenarios, the implementation of hardware and software applications occur on site, in addition to service and maintenance. Images are distributed using the Internet or an intranet, with local on-site electronic storage.

The ASP approach is unique in that it takes a "software as a service" approach, with almost all services outsourced to the vendor. Other than computer workstations and modality interfaces, all

From the Department of Radiology, Nanticoke Hospital, Seaford, DE, and the Department of Radiology, Veterans Affairs Maryland Healthcare System and the University of Maryland School of Medicine, Baltimore, MD.

Address reprint requests to Bruce Reiner, MD, 21779 Cove Lane, Leonardtown, MD 20650.

This is a US government work. There are no restrictions on its use.

0897-1889/01/1401-0003\$0.00/0

doi:10.1053/jdim.2001.21440

Table 1. Theoretical Advantages and Disadvantages of an ASP Model

Advantages	
1.	Hosted services require less demand for on-site hardware
2.	Quicker deployment of new applications
3.	Ongoing operational/maintenance headaches shifted to ASP vendor
4.	Technology obsolescence protection
5.	Scalability (as new or increased needs develop, additional/increased services can be added)
6.	No upfront capital requirements
Disadvantages	
1.	Existing hardware (legacy systems) often difficult to integrate
2.	Decreased control over sensitive data (security, confidentiality concerns)
3.	Existing industry service offerings relatively immature
4.	Limited on-site IT coverage

hardware and software functions are off site and controlled by the vendor. This "outsourcing" approach has the potential to provide greater system flexibility and redundancy. In addition, the ASP customer can take advantage of valuable off-site IT expertise, which is particularly scarce and hence costly in today's market. The existing infrastructure in most hospitals today typically consists of separate islands of information systems. By outsourcing hardware, software, and IT services to a single vendor, the customer potentially could integrate these multiple functions in a seamless, turn-key operation, with a fully integrated and functional data source.

BUSINESS MODEL FOR ASPs

In the ASP model, PACS services are offered over a wide-area network. The ASP vendor, who serves as a single point of contact, provides all hardware, software, and service or maintenance. This obviates the need for users to deal with multiple vendors within a multicomponent PACS/HIS (Hospital Information System) network. Because the HIS/RIS is an integral component to the overall operation, the biggest barrier to date for ASP implementation has been the IT department, which often expresses concerns over control and loss of "turf" within the medical enterprise. This is not surprising when one realizes that one of the most attractive enticements for the ASP approach is the complete or partial outsourcing of IT functions. This makes the model particularly attractive

for small and medium-sized hospitals, which have an extremely hard time recruiting and retaining in-house IT expertise.

As is the case for any risk-sharing alternative, the ASP approach allows for all expenses to be maintained off the balance sheet, thereby improving the financial ratios of the institution and preserving precious capital. The payment system has been most commonly structured on a fee-for-use basis, with a fixed dollar amount charged for each imaging examination performed. Although other risk-sharing alternatives often operate on a sliding-scale payment system (where fee-per-examination progressively decreases as examination volumes increase), this currently is not offered in the existing ASP marketplace. The net effect is that the ASP approach creates a recurring revenue stream for the vendor in the form of ongoing operational expenses. This is in contrast to the traditional capital expenditures associated with episodic sales, which take place when more traditional forms of ownership are chosen.

The typical length of an ASP contract is 5 years, similar to that offered with conventional financing strategies, such as a loan or operating lease. The price range for the fee-per-examination approach has been highly variable and largely depends on the extent of services being provided (Table 2). Each package of services is customized to the needs of the institution, with pricing ostensibly proportional to the level and complexity of services being offered.

How one arrives at the pricing structure for an ASP arrangement remains somewhat arbitrary, with most

Table 2. Clinical and Administrative Services Offered by ASP

Administrative Services	
1.	E-commerce/Web design
2.	E-mail/messaging
3.	Purchasing/inventory management
4.	Virtual Private Network
5.	Web security
6.	Physician practice management
7.	Marketing/consulting services
Clinical Services	
1.	Data/image repository
2.	Web based distribution
3.	Clinical pathways/protocols
4.	Electronic medical record
5.	Enterprise patient scheduling
6.	Telemedicine
7.	Web-based educational programs

vendors reluctant to share their models and methodology. Because of the relative paucity of published data on the economics of PACS, the potential ASP customer is at a relative loss in evaluating economic data provided by the prospective vendor. In a previous study by Siegel et al.,¹ the reported breakeven point for cost justification of PACS was approximately 37,000 annual examinations. However, cost justification in today's market may require somewhat fewer examinations, in light of the fact that hardware costs have decreased (particularly when using the newer Web-based technologies). In addition, an ASP approach allows the customer to "customize" system components to their own unique needs, and may therefore be more cost-effective than a traditional purchase arrangement, which was utilized in the cost analysis of Siegel.

Each vendor has its own proprietary economic model, which purports to predict overall cost analysis and return on investment. Until large-scale economic analyses are published, the PACS vendor maintains an unfair advantage over the customer. This advantage is magnified in a risk-sharing arrangement in which the upside to downside ratio can be skewed largely to the benefit of the provider. One way to circumvent this advantage would be to tie payments to realized productivity and operational efficiency gains; however, vendors are traditionally reluctant to do so.

Cost justification strategies for ASP vendors typically take 1 of 2 forms: "back-end" versus "front-end" analysis. The back-end strategy operates under a "sell against film" approach. Using this tactic, the ASP vendor attempts to quantify operational costs with film (on a cost-per-examination basis), and arrives at a comparable fee-per-examination for ASP services. This approach often is flawed by the inaccuracy and unavailability of data for quantifying film-related costs. In the absence of quantifiable data for each respective customer, many vendors refer to a previous study performed at Mayo Clinic,² which estimated film supply and handling costs of \$15.82 per examination. One must realize that this figure was calculated in a unique setting (ie, large tertiary-care academic facility in the Midwest performing over 800,000 examinations annually). Determination of a site-specific, cost-per-examination requires consideration of a number of factors including hospital size, geography, demographics, examination volume, and modality mix.³

The back-end approach of selling against film has begun to be replaced by a front-end cost analysis, in which the customer chooses the specific array of services to be provided, and the ASP vendor in turn calculates a fee-per-examination based on the desired level of services and examination volume. This approach allows the customer to critically analyze competing financing strategies by calculation of net present value (NPV) and return on investment (ROI).

One of the existing flaws in the current ASP pricing structure (fee-per-examination) is that examination complexity typically is not taken into account. Although most vendors will adapt a pricing structure reflective of the institution's modality mix, examination complexity within a given modality typically is not taken into consideration. An example would include a multislice computed tomography (CT) exam consisting of over 1,000 individual images, yet collectively constituting a single examination. It is in the interest of both parties to evaluate critically all components of the pricing model to accurately reflect examination volume, modality mix, and examination complexity. Only a pricing structure that is fair and profitable to both parties will weather the test of time. At the same time, an accurate verification process is equally important, so that customers and vendors have a means to insure that all charges are fair and accurate.

ECONOMIC IMPLICATIONS

The financial motivation for choosing a risk-sharing arrangement is largely due to the elimination of up front capital requirements and the ability to tie payment directly to utilization. Because payments occur on a recurring basis, they often come from the operational budget rather than the capital budget. This tends to be more favorable to the institution that is short on capital (by not showing debt on the balance sheet), and the vendor (by serving as a source of continuous revenue). Another advantage of this arrangement is that it offers the customer scalability, in that additional capacity or options can be selected on an "as needed" basis. As previously stated, if the fee-per-examination charge is proportional to the level and complexity of the services provided, as new or expanded services are appropriated, the fee-per-examination should be increased proportionately. The list of administrative and clinical functions offered by the

ASP (Table 2) can be likened to a Chinese menu (but not an all you can eat buffet), where the customer picks the desired level of services from the various columns and only pays for what they consume.

In a traditional risk-sharing arrangement, institutions with higher examination volumes are rewarded by paying a lower fee-per-examination because of inherent economies of scale. However, in a true ASP model, all customers may be part of a single "virtual ASP network." If this is true, then all customers, regardless of size, should benefit from the cumulative economies of scale achieved. These savings should increase as more individual ASP customers are added to the network. In previous work comparing film-based and filmless costs,¹ film-based and filmless imaging differed dramatically when evaluating unit cost per examination as a function of examination volume. For film, as volume increases the cost per unit examination remains essentially unchanged. In filmless operation, increases in examination volume are associated with significant incremental decreases in unit cost per examination.

Taking these factors into consideration, one would expect 2 important ramifications for the ASP customer:

1. Given the cumulative economies of scale achieved with an ASP model, ASP customers (regardless of size) should theoretically receive similar fee-per-examination pricing for a similar level of services provided.
2. As the number of ASP customers (within a single vendor network) increases, the unit cost per examination should decrease and should be passed on to existing ASP customers.

The one caveat to consider is that the achievable economies of scale are somewhat limited, based on the network demands of the host institution.

The ASP marketplace remains in its infancy, and these fundamental questions remain unanswered. Will the early ASP customers be rewarded with reduced fee-per-examination pricing as additional customers are added? If not, then it will serve as a relative disincentive for ASP customers to be early adopters and should instead wait for the cycle to enter the early majority phase. The answer may lie in a contractual stipulation that incremental cost savings for the vendor will be passed back to all

ASP customers equally along with a mechanism for verifying the data. The analogy is similar to that of reverse auctions on the Internet, where the purchase price decreases as the number of buyers increases. Perhaps the Internet may serve as a means for ASP customers to share their experiences and pricing structures with one another, thereby "leveling" the playing field. In the end, the ASP vendors who deliver the most cost-efficient and reliable services will be more likely to prosper in the ASP marketplace.

An alternative approach for prospective ASP customers to take would be in the form of hospital coalitions, which are used classically to negotiate lower fees for purchasing. In this ASP scenario, multiple hospitals seeking ASP services could band together to negotiate a preferred "group rate." This would be especially useful for rural-based hospitals that are somewhat geographically isolated from the major metropolitan areas. In these geographic regions, service and maintenance contracts are typically higher because of increased travel times required for field service engineers. By forming a coalition, these hospitals could collectively form a service network to share on-site IT servicing, thereby reducing service related ASP costs.

The net result of the current situation is that potential practical and economic disadvantages exist, encouraging potential ASP customers to delay adoption. Vendors must therefore be more creative in establishing incentives for early adoption, thereby facilitating greater PACS implementation.

TECHNOLOGY OBSOLESCENCE

The feat of technology obsolescence is one of the critical factors currently delaying the widespread assimilation of PACS in the radiology marketplace.⁴ Although PACS customers can incorporate some type of technology upgrade into their purchase or leasing contract, they often are restricted by the costs and timing associated with exercising the upgrade option. Because of the rapidly evolving nature of the technology, it is often difficult for vendors (and customers) to predict accurately how and when upgrades will be developed and to anticipate the actual costs associated with them. Risk-sharing alternatives, such as ASPs, offer technology obsolescence protection, in the form of hardware or software upgrades throughout the contract term. In more traditional

technology refreshment leases, upgrades are paid for by either extending the lease term or increasing the monthly payments. In the typical ASP model, upgrades are incorporated into the pricing structure, which typically remains fixed throughout the lifetime of the contract and places the lion's share of economic risk on the vendor.

When dealing with technology obsolescence there are 2 important system components to consider: "back-office" and "front-end" components. Back office components deal with the network and include the server, archive, HIS/RIS, and web functionality. The integration of these components is the responsibility of the ASP vendor, as are software upgrades. Hardware upgrades for these components are extremely expensive and therefore problematic to incorporate into the ASP contract. The one component most likely to change is the electronic archive, which typically is adjusted annually. This can take the form of adding additional storage capacity or changing the type of media used.

The back office components of a single ASP customer can be thought of as individual nodes on a larger network. Once any node within the network is upgraded, all individual nodes share in the upgrade. This is one of the theoretical benefits offered to ASP customers; allowing them to share the expertise, technology, and cost efficiency associated with uniting multiple individual sites into a single large network. The practical question is how ASP vendors will assimilate newer customers into the existing network. Will the vendor "cluster" ASP customers according to 5-year cycles, thereby creating multiple smaller individual ASP networks, each with different types of technology? Or, will ASP vendors assimilate all customers into a single expanding network, thereby creating a continuum of newer technologies? This question remains unanswered to date, because of the relative infancy of the ASP marketplace, and may vary from one vendor to another. It is therefore critical for potential ASP customers to define exactly how newer technologies and decreasing costs will be transferred to them as the vendor's ASP network expands.

The "front end" components of the system consist of the diagnostic and clinical workstations, HIS/RIS terminals, and modality interfaces. These are the only system components that truly need to be located on site. The back office components can

be housed and duplicated off site, usually at 1 of several central locations of the ASP vendor. This theoretically provides for inherent system redundancy and disaster recovery. By hosting these services off site, the ASP vendor and their IT staff can have near instantaneous access in the event of computer malfunction, potentially providing more timely service and maintenance.

IT COMPONENT OF ASPs

One of the most important selling points for adoption of the technology using an ASP model is the outsourcing of service and support, supposedly at a fraction of the cost required for performing comparable services in house. One of the biggest challenges facing hospitals in today's market is recruiting and retaining qualified IT personnel. According to the International Technology Association of America (ITAA), there will be 843,000 fewer IT personnel in the year 2000 than are needed to staff budgeted IT positions in the United States. This job market will only continue to tighten as the worldwide IT market continues to grow, surpassing \$2 trillion in 1999, and projected to increase to \$3 trillion by 2004.⁵

Industry figures also suggest a shift in the focal point of the IT industry, with a previous emphasis on hardware now giving way to an emerging focus on software and services. This is illustrated by differential growth rates in 1999 during which the hardware market grew by 6%, compared with 14% and 10% gains in the software and service segments, respectively. These figures suggest ASPs can offer a valuable service in providing critical software and service support necessary for a successful transition to filmless imaging, without creating additional hardship on the local institution in staffing critical IT positions.

Using the inherent economies of scale available, the ASP vendor can draw from a larger pool of dedicated IT professionals and service engineers, providing 24-hour-a-day, 7-day-a-week coverage for service, support, and maintenance of the PACS. The customer is provided with a single point of contact for all service and technical issues, hopefully with a rapid response time on "back office" problems (archive, server, HIS/RIS). Service for "front end" equipment is provided by field service engineers in a manner similar to that experienced with a conventional PACS ownership model. If ASP customers are "regionalized" in large num-

bers, this allows the ASP vendor to offer more rapid response to front end problems with dedicated local engineers.

Although there are compelling theoretical considerations for "outsourcing" IT functions, there are additional drawbacks as well. Proper service and maintenance of a PACS requires near 100% uptime, and this cannot be effectively provided by off-site IT personnel alone. Efficient and effective operation requires some on-site IT presence, which is of greatest importance when problems occur after hours (eg, nights, weekends, holidays). The ideal solution may be to have a scaled-down in-house IT department, supported by the ASP vendor.

Additional support can be provided by the ASP vendor in the form of website customization and maintenance, image-data distribution (to referring clinicians), and marketing-workflow consultation. This cornucopia of services likely exceeds that which can be provided practically and cost effectively by in-house IT personnel alone.

POTENTIAL ASP DRAWBACKS

Although the ASP industry touts the many virtues offered by ASPs, there do exist certain drawbacks, particularly with regard to security and database migration. One of the principle concerns frequently posed to ASP vendors is "who owns the data"?

The ASP customer, in essence, rents storage space from the ASP vendor, analogous to a self-storage facility. Whenever the customer (hospital) desires, they can remove their property (image files) from the storage facility (ASP archive) and transfer it to another location (alternative ASP vendor). The difficulty occurs in how one vendor transfers a database to another vendor (ie, database migration), when many of the storage techniques are proprietary in nature. Existing end-of-term options for database migration using an ASP model include the following: (1) Customer pays for the desired storage media, and ASP vendor transfers the data at no charge; (2) ASP vendor provides data files on an "as-needed" basis, offering a reduced fee per file; (3) ASP vendor delivers the data (in a proprietary format) to the customer, who must pay a third party to transfer the data in a nonproprietary format for storage elsewhere.

The critical components of successful database migration are integrity, accessibility, and portabil-

ity of the electronic data. The ASP customer needs to ensure that all data are secure, easily transferable, and accurate. The best way to maintain portability of the data is to store it in a nonproprietary format. Maintaining security of the database also is a critical issue, particularly in light of the new HIPAA requirements, as set forth in the Health Insurance Portability and Accountability Act of 1996, which requires the adoption of national standards for the electronic exchange of health information in the healthcare system. This applies to any healthcare provider (hospital) or clearinghouse (ASP) that processes data electronically and falls into 5 major sections, each guaranteeing data integrity, confidentiality, and availability. The estimated cost for conducting secure electronic transactions is estimated to be approximately \$310,000 for each radiology department alone.⁶ With the high costs and expertise required to fulfill these mandates, it is not surprising that many healthcare providers might choose to outsource this function to third parties, such as ASP vendors.

Another application of database migration is that of off-site redundant backup for the purpose of disaster recovery. Disaster recovery implementation is a requirement of every mission-critical information technology project. Full disaster recovery with PACS requires availability of computer platforms and network connectivity (wide and local area networks), a mechanism to reload system software, database software, customized applications, and the database (including image data) itself to allow replacement of core components to reconstruct a functional system.⁷

Several components of database migration exist, some of which offer greater challenges than others. Image data acquired after the Digital Imaging and Communications in Medicine (DICOM) information model allows for fairly straightforward database migration. A more significant challenge, however, is the database migration of RIS data, because commercial radiology and hospital information systems do not follow a common information model. This RIS-database migration is therefore a time-consuming and expensive process and frequently results in some informational content loss. Standards for RIS information models are needed to promote database migration without loss of content.⁸ This constitutes part of the RSNA-sponsored initiative, Integrating the Healthcare Enterprise (IHE). As more and more industry-wide

standards are developed, such technical challenges will become easier.

Another technical challenge facing prospective ASP customers is the extensive bandwidth requirements necessary to support widespread image distribution across an extended network of hospitals, imaging centers, and physician offices. Large medical images require high bandwidth to move efficiently and on demand. This challenge is of particular concern to smaller, rural hospitals with thin Internet pipes. Web-based distribution and image management allows for an inexpensive approach to filmless imaging but presents new challenges related to performance and reliability of the system.

When all is said and done, the irony is that those healthcare systems with the least amount of existing hardware may be best suited to the ASP model. Hospitals, which have previously spent millions of dollars for hardware, are reluctant to write off the equipment and will seek integration of this equipment with the ASP vendors' newer technologies. This will create difficulties for many of the ASP vendors, who would prefer to "start from scratch" in creating their own "seamless approach" to filmless transition.

ASP CONTRACTUAL REQUIREMENTS

A number of variables should be considered before entering into an ASP arrangement (Table 3). A

Table 3. Contractual Requirements and Items for Consideration When Contemplating an ASP Approach to PACS Implementation

I. Items for Consideration	
1.	Determine the extent of services desired
2.	Critical evaluation of necessary on-site IT expertise
3.	Financial status and economic issues affecting the institution
4.	Long-term viability of the prospective PACS/ASP provider
5.	Selection of hardware/software options available
6.	Penalties for unacceptable performance
II. Contractual Requirements	
1.	Security
2.	Service/uptime guarantees
3.	Open standard support
4.	System redundancy
5.	Workflow support
6.	Technology obsolescence protection
7.	Acceptance testing
8.	QA/QC program
9.	Multicomponent integration
10.	System scalability
11.	Defined implementation process

potential ASP customer must first decide the extent of services desired, which can run the gamut from a total PACS solution to off-site storage alone. The need for outsourcing IT services is dependent on a number of factors including local availability of skilled IT personnel, economics, and institution politics. The financial status of the institution and bias of the institution's chief financial officer will be an important role in deciding whether an ownership strategy, lease, or risk-sharing approach is preferable.

With the ASP market in its infancy, the long-term viability of the ASP vendor must be considered and appropriate clauses built into the contract in the event of nonacceptable performance. A number of critical issues need to be addressed in the contract including security mandates (ensuring HIPAA compliance), system uptime, service responsiveness and guarantees, system redundancy, automated workflow support, technology obsolescence, a defined mechanism for acceptance testing, multicomponent integration (between individual modalities, PACS, HIS/RIS), QA/QC testing, and the implementation time frame. In addition, any potential cost savings (through achievable economies of scale) need to be incorporated into the pricing structure along with options for future expansion of services. The more inclusive the contract, the better the chance of success for both parties.

FUTURE IMPLICATIONS

With the ASP market still in its infancy, it is difficult to predict how soon and in what ways this new financing approach will change the complexion of the PACS marketplace. One potential benefit of ASPs may be in speeding the transition from the early adopter phase to the early majority phase, as many healthcare providers might embrace filmless transition by considering the unique outsourcing and economics available with the ASP approach. This would appear to be best suited to the relatively low volume providers, such as small community hospitals and outpatient imaging centers, who do not have the critical size to purchase PACS.

As with any new application of technology, strategic alliances within the market will play a vital role in the maturation of ASPs. Traditional modality and hardware vendors likely will form strategic partnerships with IT companies, for the

purpose of providing the software development and IT support necessary to provide a turnkey ASP solution. At the same time, there probably will be some form of consolidation within the ASP marketplace, so that many of the smaller niche companies will be acquired or go out of business. As industry-wide standards and consensus agreements (HL-7, DICOM, IHE) become adopted universally by the industry, hardware will become more interchangeable, making the service and software components of the ASP package the critical components in distinguishing one ASP vendor from another. Larger, diverse IT companies will therefore have the potential to provide comprehensive ASP models, taking market share away from the traditional OEM vendors.

CONCLUSION

Information has become a critical commodity in the marketplace and will provide tremendous competitive added value in the delivery of medical services. To flourish in today's rapidly evolving medical practice, data must be as pervasive and as easily accessible as electricity, likening the ASP to an "information utility," allowing for on-demand access to medical data. The strategic necessity for

healthcare providers is to find a practical, reliable, and affordable solution. The ASP model might become the key that opens the door for a large share of the market into a filmless environment.

REFERENCES

1. Siegel EL, Reiner BI, Flagle C, et al: Cost-benefit analysis of filmless operation. San Francisco, CA, American Roentgen Ray Society, April 30, 1998
2. King BF, Ward S, Bruesewitz R, et al: Cost of film: Purchasing, processing, packaging, storage, and disposal over the lifetime of a film examination in a large radiology department. 1996 SCAR Proceedings, pp 152-157
3. Reiner B, Siegel E, Bradham D, et al: Establishing benchmarks for creation of a pro forma economic model to evaluate filmless PACS operation. *J Digit Imaging* 13:129-135, 2000
4. Reiner BI, Siegel EL: Understanding financing options for PACS implementation. *J Digit Imaging* 13:49-54, 2000
5. Digital Planet 2000: The global information economy. World Information Technology and Services Alliance, June 2000
6. Dwyer SJ: Security issues in the digital reading environment. Society for Computer Applications in Radiology, Philadelphia, PA, June 3, 2000
7. Avrin DE, Andriole KP, Yin L, et al: Simulation of disaster recovery of a PACS using off-site hierarchical storage management. *J Digit Imaging* 13:168-170, 2000
8. Behlen FM, Sayre RE, Welding JB, et al: Permanent records: Experience with data migration in RIS and PACS replacement. *J Digit Imaging* 13:171-174, 2000