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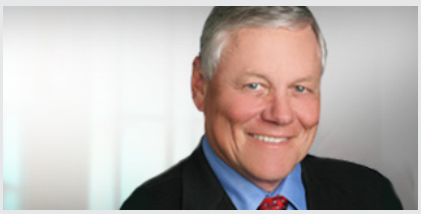

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PACS Paradigm Shift: Moving control of the data from display applications to an enterprise access infrastructure

A "call to action" through a compelling view of how departmental PACS and enterprise imaging environments in general are changing.

Healthcare delivery organizations (HDOs) are experiencing a paradigm shift from departmental views of medical images—typically seen in radiology and cardiology—to a single, enterprise view that encompasses all medical images. The new paradigm has three major components. First, the **vendor neutral archive** (VNA) occupies the center of enterprise imaging operations to improve access and reduce storage and migration costs. Second, individual **diagnostic display applications** that are used in the various imaging departments across the enterprise become "plug-ins" to the VNA. The primary benefit of this architecture is that display applications relinquish "ownership" of image data, improving data exchange and performance. Third, an **enterprise worklist** application consolidates diagnostic workflow into a single view and determines the most appropriate display application to be launched from the VNA for interpretation. This new paradigm in diagnostic imaging is referred to as PACS 3.0.

This article was written as a "call to action" by presenting a compelling argument that departmental PACS is shifting to an enterprise imaging environment. In particular, HDOs continue to release RFPs for departmental-based PACS/VNA solutions, driven by a belief that a departmental solution from a single vendor will also satisfy enterprise IT requirements. Imaging departments must have the ability to choose the best application to treat patients. Similarly, IT must have the ability to own the infrastructure and applications that manage the data. Finally, the solution must provide enterprise access to medical images and related content from all departments, as well as integrate with one or more electronic medical record (EMR) systems.

The strategy of purchasing a combined PACS/VNA departmental solution all too frequently results in the purchase of a vendor's PACS, as well as the same vendor's PACS archive (marketed as a VNA). Despite assurances that images from other imaging departments can be managed by the VNA component, this is rarely the case. When the PACS vendor provides the VNA solution, the vendor still has control of the data. As a consequence, the organization is exposed to many of the traditional costs associated with PACS, including:

- Moving the data out of PACS/VNA system
- Changing the storage platform
- Adding other PACS to the system
- Adding modalities
- Integrating other applications

It is also important to recognize that while the vendor's diagnostic viewing application performs well when retrieving images from the same vendor's VNA, connecting to other enterprise systems is unlikely to deliver the same level of performance due to proprietary PACS/VNA data access methods.

Purchasing a combined PACS/VNA limits the ability of the IT department to build a medical content management platform that can serve the enterprise. In the PACS 3.0 paradigm, HDOs separate diagnostic applications from the VNA, implementing a "best of class" approach to achieve success. Fear of shifting to this paradigm, as well as the challenges of selecting best of class providers, can be significant. Organizations should be equally, if not more, fearful of failing to prepare for this paradigm shift.

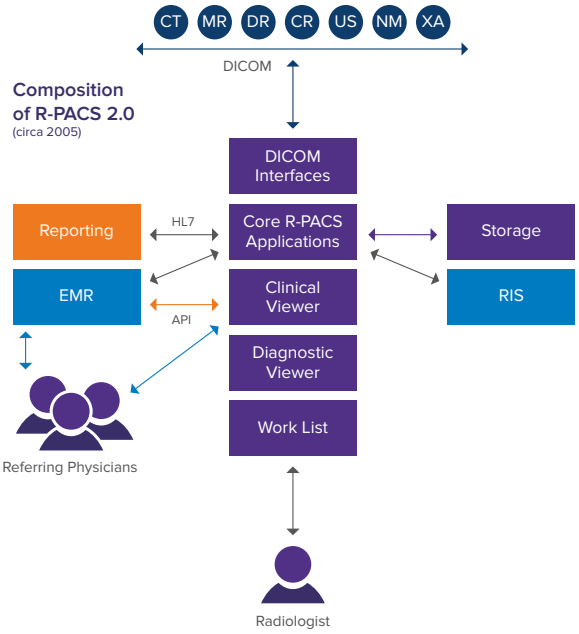

Figure 1.

Challenges of PACS technology

1. Infrastructure
2. Diagnostic display
3. Pixel tricks
4. Windows exclusivity
5. Closed system
6. DICOM only

Overview of R-PACS 2.0

Current-generation radiology PACS has come to be known as R-PACS 2.0. Figure 1 depicts the functional components of this system. The PACS is comprised of the components highlighted in purple, including the DICOM interfaces, the core PACS applications, the clinical and diagnostic viewer applications and the applications that support departmental workflow and creation of the reading lists. Some traditional PACS can be launched through a radiology information system (RIS) or other workflow solutions. Note that storage is included in the PACS configuration, because the PACS tightly controls the storage solution and the images stored there cannot be directly accessed by another application.

The RIS, the EMR system and reporting systems are usually separate and interfaced via HL7. Clinical users access the images through the EMR and end up using the R-PACS clinical viewer to display the images, which usually consist of only radiology studies. This design, the foundation of nearly all current-generation PACS, is now at least ten years old.

Exploring the problems with current-generation PACS

A great deal has changed in radiology, yet over the past several years, little of significance seems to have changed in radiology PACS (R-PACS). Today's medical imaging environment, including radiology and numerous other imaging departments, is striving to evolve past DICOM to achieve an "all object" construct. Unfortunately, R-PACS solutions are ill-equipped to make this transition. The time has come to investigate alternatives and arrive at a new PACS paradigm.

PACS technology challenges

The fundamental problem with current-generation PACS is that nearly all commercially available solutions are based on limited and aging technology. This applies to R-PACS and other departmental PACS as well because of their emulation of the R-PACS design, but with even less attention to the archival component. Let's explore the major technology challenges that prevent today's PACS solutions from keeping pace with modern requirements:

Challenge 1: Infrastructure – Many current PACS solutions cannot be configured with an adequate back-up system – a secondary, fully redundant instance of the PACS application suite. This goes beyond a mere disaster recovery (DR) solution toward a full business continuity (BC) solution. There are myriad definitions of what constitutes DR, the most basic being a simple means for creating a second copy of the data. If and when the first copy of the data managed by the primary PACS solution is somehow lost or damaged, a second (back-up) copy is used to replace the lost or damaged copy. Unfortunately, the term DR and the concept of DR have morphed over the years to imply full business continuity. A PACS DR solution, however, is not a BC solution. If the primary PACS application and/or its servers become unavailable, there is no quick fix for continuing business until the cause for the downtime is rectified.

A true BC solution requires a separate instance of the complete PACS application suite, including a separate instance of the directory database (Oracle, SQL, etc.) running on its own hardware, preferably in a second data center. Most current-generation PACS configurations fall short of this goal by having only a limited database on the DR solution.

The edge server, sometimes referred to as a local facility server, can provide a degree of autonomy to a major facility that is somewhat remote from the data center. If the PACS solution supports these edge servers at all, they may not be comprised of the full application suite or this local server may not have a local instance of the directory database. Without a complete application suite and an independent local database, the edge server cannot support local autonomous operations of the wide area network (WAN) connecting the remote facility with the main instance of the PACS solution if the main data center goes down.

Do not confuse DR solutions with BC solutions and do not confuse slaved edge servers for BC solutions. A true business continuity solution requires nothing short of a separate, fully-functional PACS solution that the department will operate from during both scheduled and unscheduled downtime on the primary PACS or the WAN connecting the facility with the data center. Unfortunately, the basic technology limitations of most current-generation PACS prevent them from being configured with a true BC solution.

Challenge 2: Diagnostic display – Today's radiology PACS feature diagnostic and clinical viewers that are web-delivered as fat or thin client software applications. This means that the complete software application package is originally installed on the PACS server while the pieces of the package designed to operate on the images is either manually or automatically downloaded (over the network or "Web") to the individual diagnostic and clinical display stations located throughout the enterprise. The two key issues here are: [1] the application software that operates on the image pixel data runs on the client's viewer hardware platform; and [2] the image pixel data has to be downloaded to the client hardware platform and any work product that needs to be saved has to be uploaded back to the core PACS system.

The consequential load on the local and wide area networks and the corresponding performance issues become unworkable at this point. Exotic and often proprietary compression schemes and fancy pixel streaming technologies intended to alleviate the performance issues simply do not meet today's performance challenges. In other words, the laws of physics cannot be beaten. Ever-increasing study sizes coupled with other applications that consume bandwidth have greatly outpaced network performance gains over the years to the point where at-home diagnostic work is painfully slow and more complex in-house processing of massive data sets, 3D and digital breast tomosynthesis for example, are frequently delegated to specialized/dedicated workstations. Client-side image processing and the requisite download of the image data is now an outdated display paradigm.

Another major display issue traces back to the origin of PACS. From the beginning, radiology PACS featured two major classes of display applications: diagnostic and clinical. For obvious reasons, the majority of application development was focused on the diagnostic display suite. Rather than design a clinical application suite that met the specific needs of the referring physician, most PACS vendors chose the shortcut. Assuming that referring physicians only require a simple subset of the radiologist's tools, they released clinical viewer applications that were a de-featured version of the diagnostic application suite.

Since the two classes of viewers in this case are based on the same code and accessed through the core PACS, they are inextricably linked together so that a software upgrade can impact one application positively and the other negatively. Today's referring physicians need to access and view all of a patient's medical images not just the radiology images. For this reason, it makes more sense for the clinical viewer to be a separate application that is independent of the diagnostic PACS and with access to the entire set of a patient's studies.

A clinical viewer, especially one that would be accessed through the EMR, would support a broader range of users and therefore would have access to more than radiology studies. To date, PACS vendors have not demonstrated they can deliver the required feature set for displaying the full range of medical imaging – radiology, cardiology, other 'ologies (DICOM and non-DICOM images) – all on the same viewer. Furthermore, intimately tying the clinical viewer to the PACS makes it even harder to access the image data created by other departments that are not readily accessible to that PACS. The department-specific clinical viewer is an outdated display paradigm.

Challenge 3: Pixel tricks – Current-generation PACS whose display applications feature client-side processing and therefore are required to transfer image data to and from the client display platforms have introduced numerous tricks in an attempt to beat the physics. Some have developed proprietary compression schemes and pixel streaming technologies to create the impression that the display is highly responsive by displaying a first image or first screen layout very quickly, before the rest of the study is downloaded. Seeing the first images is encouraging until the user realizes that you cannot actually begin processing the study until all of the images are onboard.

"To date, PACS vendors have not demonstrated they can deliver the required feature set for displaying the full range of medical imaging – radiology, cardiology, other 'ologies (DICOM and non-DICOM images) – all on the same viewer."

The diagnostic display application of many current-generation PACS displays the lossy compressed version of the priors to save download transfer time and many PACS clinical display applications routinely display only the lossy version of the images. Another common pixel trick is to pre-cache study data on a display station so it will already be onboard when the user sits down to access studies. The problem with this approach is the complication of having to accurately predict which new studies and relevant priors should be pre-cached to a specific workstation. If physician schedules change or reading priorities change the correct study list may not be on the correct display station. In some cases, the priors are not pre-cached so the user ends up waiting after all.

There are many data sets that probably should not be moved across the network in order to be diagnosed. Many have argued that it does not make sense to move any full data sets across the network. For example, digital breast tomosynthesis studies (DBT) are very large data sets. It is extremely difficult for the R-PACS featuring a client-side diagnostic display application to meet performance expectations when it has to deal with moving such a large data set. There are no pixel tricks available to solve this problem.

Perhaps the largest negative impact of client-side processing is on at-home reading, which has quickly become a hot button for many healthcare organizations. More physicians are making legitimate arguments for having the ability to interpret the study and dictate the report from home or any other location outside of the reading room. VPN tunnels to all of these potential locations is simply too expensive and impractical. Ever-increasing study sizes and neighborhood competition for broadband bandwidth make it extremely unlikely that a client-side application is going to meet performance expectations, yet vendors continue to claim that their current-generation R-PACS has a viable off-site reading application. Pixel tricks employed to solve performance issues are an outdated display paradigm.

Challenge 4: Windows exclusivity – Client-side processing applications usually require specific hardware configurations and nearly always run on Windows OS. This strategy is suited to IT departments that have zero interest in supporting multiple platforms. In today's healthcare environment, the practice of "bring your own device" (BYOD) is gaining popularity among all ranks of physicians and reluctant support of the IT department. Multiple options for OS and a reduction in the hardware requirements would improve efficiency for both diagnostic and clinical viewing by making more and less expensive platforms available to the physicians. Consequently, the restriction to Windows-only display platforms is becoming a significant limitation and clearly an outdated display paradigm.

Challenge 5: Closed system – Most current-generation PACS were simply not designed to work effectively with a foreign archive. If they are somehow induced to forward a study to a foreign archive, they require a "store and remember" software module to know how to retrieve the study. Most PACS are unable to send to a foreign archive the metadata changes made to studies in the PACS, i.e. merge, edits and deletes, along with updates communicated through an HL7 interface by the HIS and/or RIS. While most current-generation PACS have difficulty interoperating with a foreign archive, there are solutions for synchronizing the two disparate databases. Current-generation PACS were designed to be self-contained systems that were not intended to interoperate with the other systems in a larger healthcare environment. The PACS solution designed to be a closed system is an outdated PACS paradigm.

Challenge 6: DICOM only – If it were not for industry-wide acceptance of the DICOM standard, there would be no such thing as a PACS. Nevertheless, there are numerous image data objects that are not natively DICOM and may not lend themselves to being converted to DICOM. PACS solutions designed for endoscopy, ophthalmology and dental frequently manage JPEG images and may not offer a DICOM conversion interface or have sufficient patient metadata associated with the objects. Digital still frame images and video clips captured with a mobile device in dermatology, surgery and the burn unit do not originate as DICOM images. It is a simple fact that a significant percentage of the medical images in a patient's longitudinal medical record are not natively DICOM. Current-generation PACS designed exclusively for DICOM images is an outdated paradigm.

PACS myths

The problems with current-generation R-PACS are not exclusively a technology gap. There are philosophical issues with system design and marketing. There are also business aspects holding back traditional PACS from embracing the change occurring in our industry. Let's explore some common "myths" that continue to shape R-PACS 2.0:

Myth 1: "Proprietary is good." A proprietary PACS solution (proprietary data formats, proprietary DICOM header elements, proprietary compression and streaming technology) allows the vendor to assume the paternal role and thereby control the solution so that the vendor can "protect the customer from themselves and other people" in the organization. An open solution is easily modified. A closed solution is nearly impossible to modify and certainly not without vendor approval.

Myth 2: "Vendor control of the data is good." Once again the vendor wishes to assume the paternal role, i.e. "it's for your own good" that the directory database cannot be accessed and that the data dictionary and schema are guarded like "crown jewels" behind intellectual property claims. Control of the data greatly complicates data migration and therefore becomes a significant impediment to replacing the vendor's PACS with another.

Myth 3: "An integrated, single-source solution is good." If the PACS vendor supplies all of the applications, there will be no finger-pointing and no messy interoperability issues. In fact many components of R-PACS 2.0 solutions were acquired through OEM relationships with other companies or obtained by acquisition of other companies. The vendor has had to integrate all these disparate applications to the core systems, often contorting the acquired applications to match the proprietary format that the core PACS is based on. Additionally, the API integrated specialty tools and applications are required to work through the core PACS but are not controlled by the PACS vendor. Instead of a unified solution built from the ground up, the result is a compromised assembly of parts that would make Dr. Frankenstein blush.

Myth 4: "Data migrations are inevitable (and good business)." Data migrations are required when you change your storage, when the PACS vendor changes its database structure and when a PACS is replaced. The migration problem not only moves from system to system, but grows exponentially larger as time goes by. The fear of and expense related to a data migration provide the vendor significant leverage over the customer's decision process. The data migration issue only keeps the customer more captive to the PACS and, failing to once and for all deal with the data migration issue, essentially "kicks the can down the road" for someone else to deal with when the problem is worse.

Myth 5: "A foreign archive changes nothing." Taking the "A" out of "PACS" is merely a shift in connectivity to the long-term storage solution. There is no reduction in PACS functionality. The PACS still has to support the "archive" application, even if the data is transferred to a foreign archive. Therefore the vendor claims this is not an argument for a reduction in the price of the core R-PACS 2.0 application suite. Indeed this has been the case in the market to date. Adding a replacement R-PACS 2.0 to an existing VNA environment does not effectively reduce the quoted cost of the PACS (software license, professional services and maintenance).

Myth 6: "If you think you need a VNA, we have a VNA." For years the PACS vendors fought the VNA concept. Now, virtually overnight, many PACS vendors have a VNA. There is obviously a semantics issue at play here. A name change ordered by marketing does not a VNA make. The "archive" component of an R-PACS 2.0 extracted from the core PACS, as opposed to a completely ground up development, is merely an enterprise archive (or "bit bucket") at best. An extracted R-PACS 2.0 archive that is now shared between the vendor's radiology and cardiology core PACS solutions and that does not truly interoperate with any other vendor's core PACS solutions, is also merely an enterprise archive.

Common PACS myths

1. Proprietary is good
2. Vendor control of the data is good
3. An integrated, single-source solution is good
4. Data migrations are inevitable (and good business)
5. A foreign archive changes nothing
6. If you think you need a VNA, we have a VNA

> “A VNA, however, is not merely a big bucket of DICOM data stored in a proprietary format. In reality, a true VNA adds a layer of workflow and interoperability to the management of all enterprise data.”

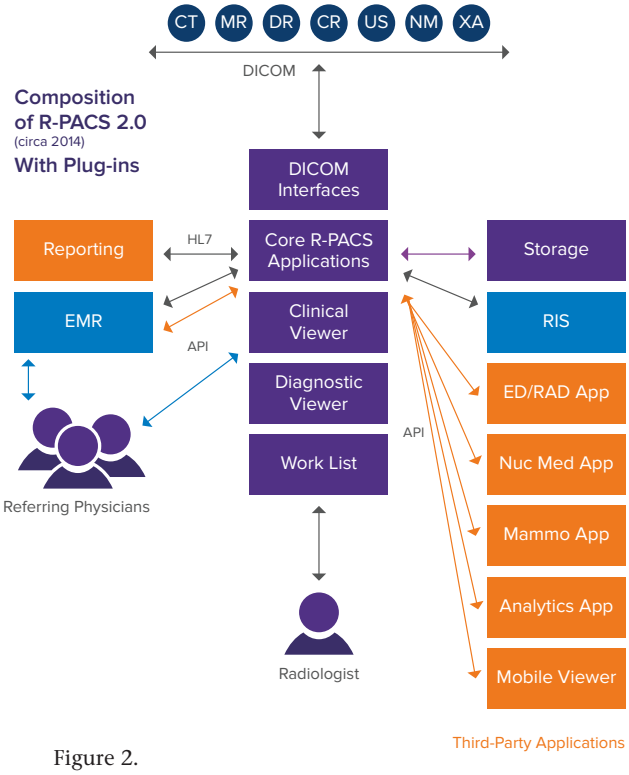

Figure 2.

VNA is not a “bit bucket”

In the PACS mindset, the VNA is simply a termination place for data. A VNA, however, is not merely a big bucket of DICOM data stored in a proprietary format. In reality, a true VNA adds a layer of workflow and interoperability to the management of all enterprise data. PACS vendors design their systems to work best with their own solutions. Ensuring their solutions work well with other vendors, especially other PACS competitors, is not a priority.

Most VNAs introduced by PACS vendors are simply enterprise archives stood up separately from the core PACS. They do not treat the image data acquired from other disparate PACS systems the same as their own data. The enterprise archive typically does not support the same level of access to this “foreign” data and the requisite format translations typically hinder the speed at which this class of data can be delivered to external systems. As a consequence, the other systems are required to manage a large working cache of this class of studies to enable proper performance, basically negating the benefit of the VNA.

Beware the bolt-on

The common PACS vendor strategy for addressing missing features is to “bolt on” third-party applications to the core PACS via API tool kits. For example, there are numerous third-party diagnostic applications on the market that would make excellent complements to current-generation R-PACS unable to meet these requirements. Unfortunately, the PACS vendor will only approve of the third-party applications if they are connected through the core PACS. The process of accessing each application, however, is arduous and lengthy. The third-party application is launched via workflow that requires study selection be made through the core PACS worklist. Software and connectivity issues aside, this strategy obviously keeps the core PACS at the center of department operations and the PACS vendor clearly in charge.

Another bolt-on for many current-generation R-PACS is the zero or near zero multi-platform viewer with server-side (as opposed to client-side) rendering. Unfortunately, this upgrade was a matter of expediency to meet the demands of referring physicians for a multi-platform and better-performing clinical viewer. It takes time and attention to detail to develop this class of display application in-house so many of the PACS vendors simply looked to OEM partners to provide this tool.

Figure 2 illustrates that many of the advanced application requirements, including the new generation mobile clinical viewer, are actually satisfied by interfacing third-party applications to the core R-PACS. Users must navigate the menu tree of the R-PACS to get to these advanced applications and the source of the images remains the core R-PACS, even if this configuration is deployed in a VNA environment. Third party applications are “second-class citizens” to the R-PACS, producing poorer performance and limited access. A major flaw in this system architecture is that the R-PACS remains at the center of department operations and therefore continues to exert its idiosyncrasies over workflow.

Impact of VNA and universal viewing on radiology PACS

The paradigm shift in R-PACS architecture began with the concept of the vendor neutral archive, first introduced in 2006. In an early blog entry on this subject, I referenced an article[1] published in October 2006 by Nadim Daher, medical imaging market analyst with Frost & Sullivan. There are numerous early articles and papers referenced in the Wikipedia entry[2] on VNA.

[1]Daher, Nadim (2006-10-18). “Enterprise PACS Archive Management Middleware - Who’s Who?”

[2]http://en.wikipedia.org/wiki/Vendor_Neutral_Archive

The initial focus of the VNA concept was taking the "A" (archive functionality) out of the R-PACS and replacing it with an external "PACS-neutral" archive. The name that eventually took hold was vendor neutral archive (VNA). There were numerous benefits envisioned for this concept including:

- Consolidating separate long-term storage solutions associated with multiple departmental PACS into a single enterprise storage solution.
- Improving disaster recovery (DR) infrastructure, which frequently means replacing less reliable near-term storage solutions with on-line spinning disk media.
- Adding a business continuity (BC) component to the VNA that supports all PACS and enables the deployment of a BC component to the R-PACS (a fully functional second instance of the PACS application suite).
- Facilitating image data exchange between disparate departmental PACS by reconciling the idiosyncrasies in the DICOM header elements.
- Eliminating future DICOM data migrations due to storage replacements, PACS upgrades, and migration between incumbent and replacement PACS by eliminating the need to move the entire data set to the replacement PACS.
- Eliminating future data migrations between an incumbent VNA and a replacement VNA by including in the VNA software package the GUI-based tools that would allow the user to accomplish any future migrations without professional services fees.
- Simplifying and reducing the cost of periodic media migrations.
- Adding centrally managed and intelligent metadata-driven information lifecycle management (ILM) to the long-term archiving operation.

The above list of functionality is not all-inclusive, as many more useful features and methodologies have been added to the VNA requirements list over the past eight years. This list, however, conveys the key functions that remain largely missing from current-generation PACS to this day.

UniViewer expands the vision

The paradigm shift in R-PACS architecture continued into 2009 with the concept of image-enabling the EMR using a multi-disciplined clinical viewer, referred to as a universal viewer or "UniViewer". This effort was principally motivated by the desire to achieve compliance with stage II of the federally-mandated meaningful use initiative. The initial focus of the UniViewer concept was to take the modality-specific clinical viewer component out of the departmental PACS and expand its functionality to include the tools required to display any type of medical image. This would combine multiple, separate PACS-specific viewers into a single "multi-modality" viewer, thus simplifying the interface to the EMR. There were numerous benefits and characteristics envisioned for this concept including:

- The ability to access and display in a consistent and highly performant manner radiology, cardiology and essentially any DICOM image objects.
- A methodology that provided integrated access to any of the patient's images (regardless of which imaging department produced those images) resulting in a unified presentation in a single viewing session.
- Integrating via the EMR API, allowing the UniViewer to aggregate all of the imaging studies associated with a patient, not just those available to the EMR.
- Direct access to the UniViewer for users that are authenticated through the local AD or LDAP.
- Introduction of a new display technology based on a zero or near-zero client paired with server-side rendering – a technology that would provide superior performance over low bandwidth networks and open accessibility to any OS, any browser, etc.
- A local working cache to pre-stage images from any PACS that is limited to DICOM data transfers, as opposed to the more efficient web services that most VNAs support. Of course this also implies support for one or more methodologies to keep the UniViewer cache in sync with those contributing databases (ideally the UniViewer would not have a cache and would only need to interoperate with the VNA to deliver images).
- Initially, only the basic image display features and functions would be provided, including those that the majority of referring physicians would need to manage patient care and meet meaningful use criteria.

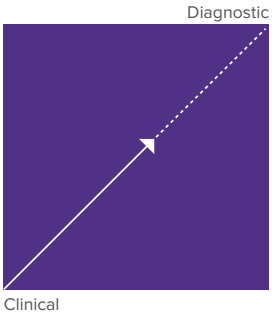

Figure 3.

As expected with any display application, the issue of feature/function has undergone constant change. The basic features/functions of the traditional clinical viewer often do not satisfy the needs of true image users in the physician community. Ideally, the clinical viewer should provide display tools nearly identical to those available to the radiologists and cardiologists interpreting the studies. Naturally there is considerable interest in how far UniViewer vendors will expand their display technology. Figure 3 is a simple way of looking at image display applications. The line extending from "clinical" display applications to "diagnostic" display applications is somewhat of a continuum representing the ever-increasing demands of users for more and better tools.

There are, of course, technology requirements associated with the more advanced tools required for diagnostic interpretation but the hope is that zero or near-zero clients paired with server-side rendering technology can support all of the tools currently included in the most advanced diagnostic workstations used in imaging departments. UniViewers should be evaluated based on where they sit along this continuum, how far along the continuum toward "diagnostic" a vendor plans to take its product and how soon.

The issue of non-DICOM

We have recently seen another shift in the R-PACS paradigm related to non-DICOM image objects. There is increasing interest in adding non-DICOM, non-image objects to the VNA, such as PDF versions of reports (cardiology), administrative and clinical forms, exam worksheets, etc. PACS typically do not handle these object types very well, if at all, and EMRs may only handle a few of these object types. The VNA thus became the logical choice for managing these non-DICOM objects.

As more and more UniViewers were deployed to image-enable the EMR, users became increasingly interested in accessing and viewing non-DICOM image and non-image objects that are [1] associated with an existing DICOM study and [2] comprise the entire clinical study. An example of the latter is a collection of still frame images and/or a video clip taken with a mobile device in a burn unit or a dermatology office. Issues arose as to how to acquire these objects (interface options), how to manage them (object format), and how to display them in what was largely a DICOM-oriented display world. There are numerous approaches to the acquisition, management and display issues. Some approaches are proprietary and some are standards-based. The best approach today will depend on the data export options that are supported by the image source, the interface options that are supported by the various systems that will acquire, manage and display the objects and the display capabilities of the UniViewer. No single approach in use today fits all of these variables. The future is somewhat clear, however.

A majority of PACS, VNA and UniViewer vendors have either already introduced or are working to develop a non-DICOM strategy based on a technology standard known as **cross-enterprise document sharing for imaging (XDS-I)** and more specifically **XDS-I.b** for use in acquiring, managing, and exchanging non-DICOM objects. An explanation of this technology is beyond the scope of this paper. A good place to begin learning about XDS technology and how it is deployed can be found on-line.[3] The most important characteristic of XDS is that it is based on a standard, which somewhat guarantees a high degree of compatibility among the various systems in a multi-vendor environment.

[3] http://wiki.ihe.net/index.php?title=XDS-I_Using_XDS.b_Technology

Acquiring non-DICOM images from independent imaging sources such as endoscopy cameras and mobile devices is further complicated by the fact that metadata identifying the patient, the study and the images has to be created and assembled and then tied to those images. In many use cases such as the acquisition of images in a burn unit, a dermatology office visit, surgery, etc., there is no formal order placed for the procedure. This complicates access to a patient's demographic information and creation of an accession number for the study. Vendors investigating this issue are looking at ways to tap the EMR for some, if not all, of the metadata which can be passed to a simple application, which marries the image object to the required metadata and then forwards the study to the VNA or UniViewer. In this sense, the VNA and the UniViewer must take on yet another feature routinely performed in a PACS – image acquisition and creation of a properly identified study object.

A shift in the VNA paradigm

Adding non-DICOM data to the VNA effectively demands a change to the initial design of the VNA, as it now has to be expanded/evolved to reveal the concept of a multi-object bus with plug-in applications. The plug-ins would include applications for handling DICOM objects, non-DICOM objects, XDS objects, document objects and perhaps back-office applications. In this sense, departmental/specialized PACS applications and the UniViewer become plug-ins to the VNA **image and object services bus**. The long-term value of the investment in the VNA is the data and the tools to manage the data. The multi-object bus allows interoperability with the data by viewing applications, data mining services, storage platforms and a host of other entities that will have multiple methods to interact with the data being managed by the VNA.

The image and object services bus is a specific example of a derivative of an **enterprise service bus (ESB)**, described in this Tech Target posting[4] as "software architecture for middleware that provides fundamental services for more complex architectures," adding that "in a general sense, an ESB can be thought of as a mechanism that manages access to applications and services (especially legacy versions) to present a single, simple, and consistent interface to end-users via Web- or forms-based client-side front ends."

In the context of the VNA, the image and object services bus connects a wide variety of data sources with data users while hiding the complexity that may be inherent in the processes that are required to make those transfers seamless to users. The services bus facilitates information sharing across the enterprise with the many disparate information and image management solutions that physicians are using to access the information. This strategy obsoletes the idea of a monolithic, proprietary, departmental PACS purporting to be a VNA.

Figure 4 illustrates a VNA image and object services bus that is comprised of three layers. The **access layer** provides the various interface methodologies that are required to connect to the various imaging sources, the worklist application, multiple departmental PACS and specialty diagnostic applications, the UniViewer and the EMR. The **workflow layer** is comprised of the many feature and function applications that are internal to the VNA. The **store/archive** layer is comprised of the interfaces to the storage solutions and DR/BC components of the VNA configuration. The VNA services bus is the great facilitator that allows the VNA to acquire the data, store it, cleanse it, manage it, route it, migrate it and add context to it.

One of the highlights of the **VNA services bus** is the addition of non-DICOM data exchange interfaces based on MINT and WADO-RS to the common DICOM interfaces that are required by most current-generation PACS. These additional interfaces remove the DICOM overhead that is stifling data exchange rates to the point that DICOM-oriented applications must be configured with working caches in order to meet performance expectations.

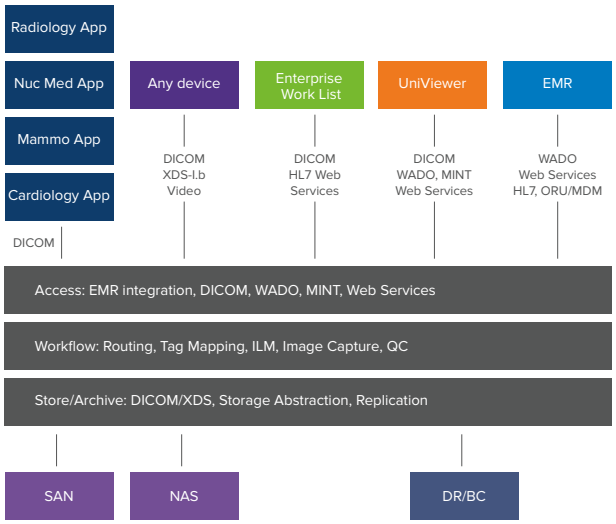

Figure 4.

> "In the context of the VNA, the image and object services bus connects a wide variety of data sources with data users while hiding the complexity that may be inherent in the processes that are required to make those transfers seamless to users."

[4] http://searchsoa.techtarget.com/definition/enterprise-service-bus

In addition to the applications illustrated in Figure 4, other important applications, which may plug into the access layer of the VNA image and object services bus are listed below:

- The **edge server/local cache server** which would be used for image acquisition and auto-routing. Properly designed edge servers can be more proficient at image acquisition than the departmental PACS. They can immediately optimize the DICOM header for the intended target PACS, optimize network transfer by compressing the data using the compression syntax preferred by the target PACS and perform the initial study reconciliation against the order. Specialized QC would still be done at the target PACS. This is yet another feature of the current-generation PACS that arguably belongs with the VNA because of these and other inherent advantages.
- The **analytics application suite** for business assessment, reporting, and data mining.
- The organization's **document management system**.
- **Back-office systems** such as accounts payable and billing.

Key aspects of the image and object services bus

The access layer abstracts the applications from owning and controlling the data and frees healthcare delivery organizations (HDOs) to decide which applications are required, when to replace them and what to add. This strategy essentially ends the vendor lock that has been the hallmark of PACS vendors.

The **clinical information lifecycle management application** in the workflow layer includes retention/deletion, lossy compression, movement to less expensive/performant storage/cloud and anonymization. The characteristics of each of the data sets produced by the health system are unique. Having one central interface to manage all the ILM policies is a tremendous benefit as opposed to having a multitude of systems where the various policies must be applied.

The storage layer, like the access layer, abstracts the data from the storage. Having the ability to add storage of a different type, manufacturer, or method to existing storage can be done without removing the existing storage. Replacing the existing storage can be done without impacting the applications that utilize the data. Adding services like cloud storage, or back up tape libraries are done without impacting the applications. PACS companies frequently charge significant fees to take the data out of the current storage, run it back through the application and then archive it in the new storage platform. Healthcare systems often retain older storage platforms and pay higher support fees and higher costs associated with power and floor space due to the limitations of current strategies. Abstraction of the storage layer enables healthcare IT to make the decisions that are best for their organization as opposed to what is best for the PACS vendor.

The rationale for the concept of a VNA image and object services bus that accepts and services multiple application plug-ins is consistent with the early arguments for VNA. This version of the VNA consolidates all of the organization's data management infrastructure and storage solutions into a single enterprise class solution. It simplifies and consolidates system administration. It becomes the facilitator of interoperability and data exchange and is the enabler of the type of data mining that is critical to improving both business and healthcare. The VNA needs to be able to do more than simply store and manage all of this data generated across the enterprise. It needs to somehow be able to facilitate making sense of the data.

What's left for the PACS?

Considering current-generation PACS and the components, features and functions that have steadily been replaced over the past eight years:

- The VNA is positioned to replace the PACS archive and expand it for use across the healthcare enterprise.
- The UniViewer is positioned to replace the PACS clinical viewer for integration with the EMR.

R-PACS functions have been reduced to the following short list of supporting tools:

- Specialized QC
- Department workflow
- User worklist, and
- Diagnostic display / study interpretation

We have witnessed a consistent, deliberate and step-by step dismemberment of the R-PACS 2.0 paradigm. These changes were borne out of a necessity to meet current and near-term requirements that have clearly not been met by R-PACS 2.0 and that cannot be met by the outdated underlying R-PACS 2.0 technology and design strategy.

Yet another shift in the VNA paradigm

We may very well be at the genesis of specialized "apps" that "plug in" to the image and object services bus. In use cases where the user's entry point is the EMR and the EMR is the worklist creator, the user could be taken directly to the display application that is most suitable for the user role/login and the type of object being accessed. The user would not have to go through the R-PACS application to get to one of these specialized apps. In this scenario, the original URL call issued by the EMR would go instead to the VNA (not the UniViewer) so that the VNA could invoke the logic that would determine the proper display application to launch. There are also specialized diagnostic applications like nuclear medicine, oncology, digital breast imaging, etc., that would no longer require a PACS but would leverage an application that has the specialized tools required for the discipline and would interact with the image and object services bus through one of many available methods.

The beginning of the end for R-PACS 2.0

Many of the features and functions formerly associated with a departmental PACS are no longer considered the responsibility of the core PACS application suite. They are now provided by the VNA and the UniViewer, which are better suited to meet current user requirements. There are still unresolved issues and problems, however, with what remains of the R-PACS 2.0 generation of departmental PACS, including:

- Restriction to DICOM objects
- Restriction to Windows platforms for diagnostic display stations
- Requirement to move all of the study/image pixel data to the display platform, thus restricting the performance for at-home reading
- Inability to aggregate study awareness as well as data from across multiple, disparate departmental PACS

Simply put, there is a need for a new R-PACS paradigm, a completely new generation of R-PACS application that would fit seamlessly into the VNA and UniViewer construct. In this sense, the tools used inside the imaging department simply become just another set of plug-ins to the images and object services bus of the VNA.

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The advent of PACS 3.0

In the new PACS paradigm, it is no longer appropriate to preface PACS with a department identifier. The new PACS paradigm applies equally to any department that creates medical images. At present, the PACS 3.0 market is clearly in the "innovators" stage of Geoffrey Moore's **technology adoption curve**.

Several diagnostic radiology display applications are currently available to meet the criteria of a PACS 3.0 application suite by simply plugging into the VNA service bus. Some of these applications have been marketed as advanced diagnostic workstations that could be used to "upgrade" a current-generation PACS to postpone an outright PACS replacement. Some of these applications began as basic UniViewers with feature/function sets pushed to the diagnostic level.

Regardless of the origin, these applications all share a very important technology component – they are based on a zero or near-zero client; they feature server-side rendering; and, in most cases, they utilize powerful new pixel streaming methods for delivering the rendered image object to the user's desktop, laptop or mobile device. While specific features and functions vary greatly and some individual diagnostic display packages may not meet all the needs of a healthcare delivery organization (HDO), there are specific commonalities that distinguish PACS 3.0 applications from their R-PACS 2.0 predecessors:

- Ability to accept from the VNA and display both non-DICOM image and non-image data objects, whether that means employing DICOM-wrapping or XDS. This would include accepting a study that is comprised solely of non-DICOM objects. Native object formats such as JPEG, TIFF, PDF, MPEG, etc., can be wrapped or accommodated within XDS. The key issue with respect to dealing with non-DICOM data objects is not the object format but the interface (data exchange) methodology that would be used by the acquisition system (PACS, VNA, etc.) to communicate with the non-DICOM data source device (PACS, workstation, modality, mobile device).
- Support for any hardware platform, any OS and any browser – it is the type of transaction that is critical, not the OS, hardware or browser.
- Based on zero or near-zero client and feature server-side rendering with custom streaming and/or HTML data downloads to the client.
- Aggregation of study data across multiple, disparate departmental PACS and image repositories.
- Ability to support image acquisition and study QC on their own but do not usually support the range of acquisition tools that are available on the more advanced implementations of VNA.
- Enables basic departmental workflow, but lacks the range of features that are standard in packages from Clario, Medicalis, Primordial, etc.

It is relevant here to summarize the approach Perceptive Software (formerly Acuo Technologies) has taken to acquire non-DICOM image objects. Perceptive supports an internal XDS adaptor that stores all non-DICOM data objects in the Perceptive Acuo VNA. The process uses a web services interface to acquire the objects from the source device and then converts the objects to XDS objects. In the case of a mobile device, the images are first transferred from the mobile device to a PC running the XDS adaptor software.

The various display applications (diagnostic radiology, diagnostic cardiology, third-party specialty apps, UniViewer, etc.) plugged into the Perceptive Acuo VNA image and object services bus would use Web services to request whatever object type it can display: DICOM, JPEG, etc. The VNA responds by converting the XDS objects to whatever object format is requested. With this transcoding approach, the viewer does not necessarily have to be an XDS consumer.

What role can R-PACS 2.0 play in the new paradigm?

Although the archiving and clinical display applications associated with current-generation departmental PACS are not optimal, the core R-PACS 2.0 applications are still quite functional and can be integrated into the new paradigm framework. The most important modification to a current-generation PACS, and one that is relatively easy to implement, is the addition of a software application that registers the knowledge of studies it has sent to the VNA. Some vendors call this functionality "store and forward" and others refer to it as "store and remember."

Supplementing the PACS archive function by implementing the software to interact with the VNA enables the core diagnostic display applications to efficiently exchange data. Other changes that need to be made to the existing R-PACS owned by the HDO include the following:

- End the vendor's control of the archived data and the physical storage solution by converting the R-PACS into a diagnostic radiology display application. This will enable the health system to either negotiate a much more favorable maintenance rate at renewal or to replace the system with a diagnostic display application that better matches the requirements. With a VNA already in place, there is no painful migration complicating the shutdown of one system and the go-live of a new one. In short, shut down the R-PACS 2.0 archive as soon as possible.
- Implement a UniViewer that is owned and managed by IT and tightly interfaced to the EMR. This will provide a zero or very friendly lightweight, cacheless clinical display solution that will enhance the experience in the EMR.
- Begin to move other image databases into the VNA as requests for storage are being considered and the physicians begin demanding to see those images through the EMR. Take account of all the image-producing systems in the organization and bring them into a controlled, robust and secure environment because few organizations realize how departmental imaging data is being stored, secured and backed up.

An R-PACS 2.0 system upgraded with "store and remember" can operate as one of several display applications that are plugged into the VNA services bus. Even without this significant modification, the R-PACS 2.0 system could function as the core radiology PACS application that would be used to interpret routine study types, while third-party specialty applications would directly integrate to the services bus for more advanced study types.

Ideally, PACS vendors should make another modification to enable their R-PACS 2.0 systems to behave better with the VNA. This relatively simple modification involves the addition of a highly-performing interface, such as Web services to allow the diagnostic display application to efficiently exchange data with the VNA without the need for a working cache. HL7 interfaces and workarounds exist to address the PACS-VNA synchronization issues, but elimination of the display cache eliminates the need to constantly sync the display cache with the VNA cache. The fewer databases managing the same objects, the better. Similarly, specialized third-party diagnostic applications – mammography, nuclear medicine, 3D – can also become plug-ins to the VNA services bus (even if they are currently server-based, web-delivered thin clients) if the server-based application supports a Web services interface.

Source of PACS 3.0 display applications

A small number of HDOs have paired individual diagnostic display applications with the VNA, creating what is referred to in this paper as a PACS 3.0 environment. Some of the display applications are thin clients and some are newer zero-clients. Only a few zero-client, server-side rendering display applications offer the range of features and functions that qualify as "diagnostic."

Where are these PACS 3.0 display applications likely to come from in the near future? The product development concept shown in Figure 3 suggests that a number of vendors currently delivering UniViewer applications will continue to develop display technology along the clinical to diagnostic spectrum. The zero-client, server-side rendering technology that is the fundamental core of PACS 3.0 is already here. It's the feature/function package that actually separates the basic clinical viewer from the diagnostic viewer. With the VNA doing all of the heavy lifting, this new generation of diagnostic display application paired with the VNA and a few other key subsystems (i.e. enterprise worklist) can certainly be considered a viable PACS replacement.

Transition to an enterprise worklist

An enterprise worklist application builds custom reading lists for individual physicians using information about the study, escalation rules, and physician preferences (i.e. the user's preferred PACS application). It supports the underlying technology / methodology for moving the study data to that diagnostic display application that best meets the assignment criteria. For example, the selection of a nuclear cardiology study from the enterprise worklist would trigger the opening of the third-party nuclear cardiology application instead of the core radiology or cardiology diagnostic application. Enterprise worklist extends this concept across multiple departments with multiple PACS and multiple facilities.

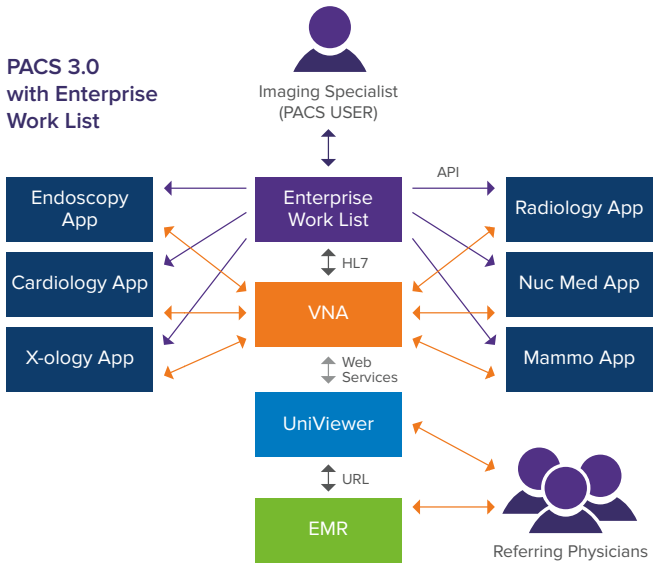

Figure 5.

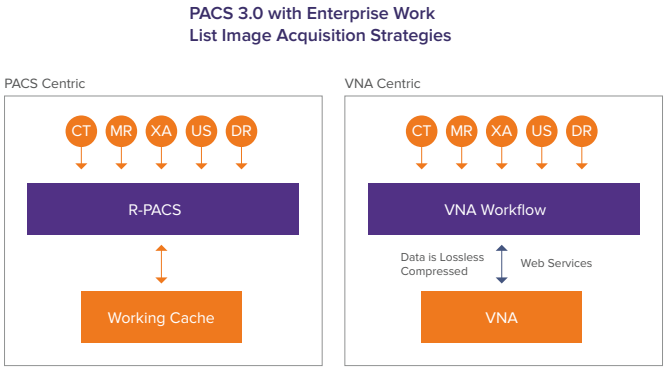

Figure 6.

Traditionally, the concept of worklist also encompasses what is generally referred to as workflow. Workflow and worklist encompass all of the features and functions of a departmental PACS that support image acquisition, study reconciliation, QA/QC, technologist notations, document scanning, study protocoling—everything to prepare and present the new study for interpretation. The concept of an "enterprise" workflow / worklist application encompasses all of the same features and functions, making the uniform set available to all of the imaging departments in the enterprise. Deploying an enterprise workflow / worklist application transfers yet another traditional function of the R-PACS 2.0 system to an external application that is another plug-in to the VNA services bus.

Figure 5 illustrates the concept of PACS 3.0. In this architecture, the VNA is at the center of data management and all various display applications. Imaging specialists access studies to be read from customized reading lists that are created by the enterprise worklist plug-in to the VNA. Referring physicians view studies using the UniViewer application either directly or from the EMR.

This diagram illustrates that the diagnostic radiology display application, whether it be an incumbent R-PACS 2.0 system or a server-side rendering PACS 3.0 application, is just another diagnostic display application plug-in to the VNA. The display plug-ins no longer "control" the image data. The VNA controls the image data and provides an entry point to the enterprise worklist.

In PACS 3.0, two options for image acquisition are illustrated in Figure 6. Image acquisition can continue to be managed by the core diagnostic display application/PACS. Alternatively, image acquisition can be managed by the workflow component of the VNA, which can be deployed as an edge server in remote facilities.

The latter approach offers several advantages. Configuring the VNA workflow application to be the recipient of new study data from the imaging modalities creates the opportunity to: [1] tag morph the incoming study; and [2] immediately apply a lossless compression scheme to the image data. This two-step process applied at the point of image acquisition would prepare the study to exactly match the requirements of the destination diagnostic display application and thereby improve overall system performance. The VNA workflow application supports DICOM modality worklist and XDS-I.b, or whatever other interface is required for non-DICOM image acquisition.

Once the new study data has been acquired and "pre-processed", the VNA workflow application can then forward the new study data to the appropriate PACS or send a notification to the appropriate worklist application and/or diagnostic application that a new study is available on the VNA. Various QC options exist when image acquisitions are managed by the VNA, which will be explored in more depth in a future paper.

The enterprise worklist is tightly coupled with the VNA and receives all historical HL7 information along with new HL7 activity, informing it of all studies in the health system. Studies can be directed, along with priors and the appropriate medical record numbers (MRNs) to ensure proper display on the diagnostic application that will most likely be used to interpret the study. Again, various scenarios exist for routing new studies and relevant priors. These topics will be the subject of a future paper.

Determinant-based launch is key

Whether the enterprise worklist is the function of a freestanding application or a function of the organization's EMR, the key to making PACS 3.0 work seamlessly and efficiently for users is the concept of determinant-based launch (DBL). DBL is the feature of the enterprise worklist that launches the right diagnostic display application based on pre-defined determinants such as study descriptor, ICD 9 code, imaging department, facility identifier, physician profile, etc.

When the user selects a study from the enterprise worklist, DBL logic notes all of the various metadata details that describe the study and checks a series of internal specialty study descriptor codes for a match that will determine the most suitable diagnostic application that should be launched for that study. For example, if the study descriptor codes identify mammography and mammography-related ultrasound studies, the enterprise worklist would launch the appropriate mammography application.

An automated multi-application enterprise worklist that determines the appropriate application to launch based on study parameters saves time. In a highly-specialized radiology environment, manual selection of the most appropriate application from a worklist pull down menu is an outdated paradigm.

The concept of DBL is the keystone of the enterprise worklist application, the application that unifies all enterprise imaging operations in a VNA-centric data management solution. The enterprise worklist with DBL technology is yet another application that can be more suitably performed outside of the conventional PACS 2.0 solution. The PACS 3.0 concept represents the step-by-step removal of traditional PACS applications including long-term data management, clinical viewing, specialty diagnostics, advanced visualization, workflow and worklist.

Success requires a best-of-class mindset

Obviously, a move to the PACS 3.0 construct requires a "best-of-class" mentality. The VNA vendor must develop the tools and system support solutions that collectively provide the overall data flow and interoperability of the various application plug-ins for the VNA image and object services bus. Best-of-class should no longer be a cautionary strategy for HDOs, especially those with specialized imaging departments, because many traditional PACS 2.0 configurations have evolved to become best-of-class due to the various third-party applications that currently supplement departmental PACS.

Summary

We have witnessed a step-by step deconstruction of radiology PACS over the past few years as specific limitations of R-PACS 2.0 can now be more easily and less expensively addressed by outside applications. Although existing R-PACS architectures have remained relatively unchanged since their inception ten years ago, radiology imaging and medical imaging have continued to evolve. These changes have resulted in a growing list of requirements that conventional radiology PACS has failed to meet.

The paradigm shift in R-PACS architecture began with the vendor neutral archive, whose initial focus was taking the "A" out of PACS. Since then, we have witnessed the replacement of the PACS clinical viewer with the far more useful UniViewer. As PACS vendors could not address new R-PACS requirements, such as advanced visualization, specialized imaging applications, discrepancy reporting, analytics and multi-site worklists, the quick fix was to simply bolt-on third-party applications to core R-PACS 2.0 solutions. This effectively created a best-of-class environment with a handful of applications that remained totally dependent on the core R-PACS 2.0 application, but without the benefit of a single service level agreement.

Diagnostic display applications have remained as thick or thin clients that required the download of the full pixel set and this has increasingly failed to meet performance criteria in the at-home reading environment. Perhaps the final blow to the outdated R-PACS 2.0 paradigm has been the requirement to add non-DICOM images and other digital assets to the patient's longitudinal medical record. R-PACS 2.0 solutions cannot adequately meet these increasingly common requirements.

> “Healthcare leaders must be bold about stopping RFPs for departmental solutions that include multiple archival components and focus on creating a PACS 3.0 platform that enables access to a complete patient record.”

This article has described a major paradigm shift toward an enterprise approach to information access. PACS 3.0 places a true VNA at the center of enterprise document and imaging operations. VNA workflow applications can interface to imaging devices, acquire images and prepare them for future interpretation. The VNA image and object services bus is a variation on the generic concept of the enterprise service bus into which all applications that operate on data simply “plug in.” VNA applications such as tag morphing, information lifecycle management, UniViewers and diagnostic display applications are plug-ins to this bus.

The recent appearance of an enterprise worklist featuring a DBL application completes the PACS 3.0 paradigm. In this case, the worklist becomes yet another plug-in to the VNA bus and selects the appropriate display application. PACS 3.0 is the ultimate best-of-class model for data management, enterprise display and diagnostic interpretation. While there is a role for the incumbent R-PACS 2.0 in this configuration, the new generation of diagnostic applications based on zero or near zero clients and server-side rendering are far more performance-oriented than their fat client cousins. The end of the R-PACS 2.0 paradigm has begun.

Recommendations for moving forward

This article is a “call to action” through a compelling view of how departmental PACS and enterprise imaging environments in general are changing. The changes are a result of a recognition that data that is produced by each imaging department should be managed and leveraged as both an asset and a liability along with a growing requirement to make this data universally available throughout the enterprise. The ability to make these much-needed changes is enabled through the introduction of new technologies and applications designed to integrate efficiently and work together to improve workflow and access to the patient’s complete medical record. The organization is encouraged to take a serious look at its existing imaging infrastructure, and determine whether the current solution is viable in light of the changing requirements, tools and strategies described here. Beyond the responsibility to investigate whether the current solution is viable, HDOs should ensure that departmental plans are consistent with an enterprise approach.

Healthcare leaders must be bold about stopping RFPs for departmental solutions that include multiple archival components and focus on creating a PACS 3.0 platform that enables access to a complete patient record. The PACS 3.0 platform will ensure that data is secure in a robust and flexible configuration, that ILM policies are enacted, and that the system provides a true business continuity solution.

HDOs must determine how to execute a plan that marshals all clinical data across the enterprise, provides easier access, and ensures its near- and long-term viability. In most cases, the solution begins with the selection of the right vendor neutral archive and development of an approach to wrest control of clinical content and storage from departmental system vendors. The era of PACS 3.0 has begun. Healthcare organizations that take action today will avoid future expense and gain a competitive advantage in our challenging marketplace.