

# Enterprise Cardiovascular System to Support Multimodality Imaging and Clinical Effectiveness

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## Abstract

An enterprise cardiovascular PACs system across the Cleveland Clinic has been established and enhanced to support cardiovascular angiography, echocardiography, and vascular ultrasound and is evolving to support nuclear cardiology, cardiac CT and MR. The system must support the diversity of the multivendor modalities across the health system and provide access to clinical information at all points of patient contact including operating rooms, reading rooms, exam rooms, and offices. Capabilities that go beyond those associated with standard PACS are key and include structured reporting, warehousing of clinical data, enterprise architecture, patient context sharing to provide integration with third party application, and remote viewing access. As multimodality imaging and structured data become increasingly more important in the delivery of high quality integrated cardiovascular patient care, continued focus on clinical effectiveness of system integration is key.

## 1. Introduction

Over the past several years, an enterprise cardiovascular PACs system across the Cleveland Clinic Health System has been established and enhanced to support cardiac catheterization, echocardiography, and vascular angiography and ultrasound and is evolving to support nuclear cardiology, cardiac CT and MR. The central component of the system is syngo Dynamics (Siemens, Ann Arbor Michigan), a cardiovascular PACS and reporting system. The Cleveland Clinic health system consists of 3 regions – central, east and west. On the main campus, there are individual servers for CATH, ECHO, PEDS, and VASC. The eastern region hospitals each have a individual server: Hillcrest, Euclid, South Pointe, Marymount, and Huron. The western region hospitals are Fairview, Lakewood, Lutheran, and Medina. The Cleveland Clinic also has a hospital in Westin, Florida. sD clients are installed on approximately 1000 computers throughout the Heart and Vascular Institute on the main campus. This extensive distribution of client

software is greatly positive, permitting access to clinical information at all points of patient contact including procedural and operating rooms, reading rooms, exam rooms, and physician offices. Enterprise functionality in patient searching and access to prior exams is a key architectural feature of the cardiovascular PACs environment. The installed version must currently match the server software version, so significant upgrades require reinstall or an upgrade of the client software. This has been completed several times and has been greatly assisted by a packaged push deployment of the application through the IT central support process. Software patches to a particular version can be easily deployed through a server-client process whereby patches uploaded to the server are distributed to clients on a future connection.

## 2. System components

Several key components of the enterprise cardiovascular system are described in this section and include remote access, interfaces, enterprise support, structured reporting, advanced processing, nuclear and ECG support, integration of cardiac CT/MR, electronic billing and administrative reporting.

### 2.1. Remote access

The syngo Dynamics Web Portal provides a low-bandwidth solution for remote viewing. Access to the web portal is dependent upon secure connectivity to the Cleveland Clinic network. DICOM files that are stored on the server are compressed using a VC1 Microsoft codec through an encoder process. These compressed files are stored and delivered on demand through the web portal. The encoding server has been scaled to handle various loads with multiple processors and various amounts of memory. A typical echocardiographic exam is compressed by a factor of 50 over the standard DICOM files stored with JPEG compression. This is possible with significant preservation of spatial resolution due to the temporal redundancy in the echocardiographic sequences

some of which are stored with acoustic frames rates up to 100 frames per second. In addition to lowering the bandwidth requirements, the web portal is easily accessed without the need for a full client install. This deployment advantage is very useful in remote and home environments, as the requirements for successful install and function are considerably less.

## **2.2. HL7 interfaces**

An ADT interface to each server allows patient demographic information to be verified. If an exam is not matched it is queued into a list to be managed for corrections. Filtered ORM (orders) for Heart and Vascular inpatients and outpatients are sent directly to the sD order cache. After passing demographic reconciliation each exam on a server that is used for reporting is also examined to find a potential order match. Matching rules can be customized, but an exact match on order type and a date match that is close to the date of service (for inpatient orders) is desired. When successfully matched to an order, the exam record is populated with the order number and ordering physician. Result messages are sent from sD to our EMR system (Epic). The data fields populated in the result allow the result message to be matched against the order and for the ordering physician to be notified of the result of the solicited exam.

## **2.3. Enterprise support**

The ADT interface also contains information to link various medical record numbers used by the various hospitals within the Cleveland Clinic Health System. The master patient index, or MPI, is therefore available to link exams performed across the health system when users search across servers. An enterprise search mode provides this capability along with a means to find prior exams for a particular patient across the enterprise. This capability is also employed on the main campus to search across the various modalities stored on separate servers, and therefore provides a means to see all exams for a given patient such as echocardiography, angiography, nuclear medicine, ECG, cardiac CT, and cardiac MR.

## **2.4. Structured reporting**

Structured reporting for 18 types of vascular ultrasound exams and ten echocardiographic exam types are currently deployed. The ability to transfer DICOM SR data from modalities to the database and reporting environment allows accurate measurement transfer without transcription. With measurement data available, dependent calculations are automatically derived and all values are available for qualitative rule based descriptions in the reporting environment. Elements on the various

reports can be defined as mandatory to facilitate completeness and enhance quality control initiatives to improve consistency of reporting. The reporting environment has been enhanced to provide greater capability in construction of complex sentences built from multiple observations and measurements/calculations. The ability to flag reports with critical results is possible. These critical findings can be highlighted in the electronic medical record (EMR) for greater attention and potential action.

## **2.5. Advanced processing**

Advanced US processing is possible using the Siemens ultrasound workplace (v3.5) that can be installed in an integrated fashion with syngo Dynamics. Exams can be opened through this environment to access various advanced processing modules (CAPS) including Velocity Vector Imaging (VVI) for cardiovascular strain analysis. 3D ultrasound data, while still processed using proprietary software packages, can be stored to syngo Dynamics wrapped into DICOM files. Once part of the exam, 3<sup>rd</sup> party integrations have been created to open selected 3D acquisition files into either Philips Qlab or GE EchoPac environments. Further efforts to share measurement results from these packages back to the standard reporting environment in syngo Dynamics is possible. For quantitative angiography, another 3<sup>rd</sup> party application, Quantcor (Pie Medical), is utilized in a similar fashion with specific image data transferred for analysis.

## **2.6. Nuclear and ECG support**

The integration with nuclear medicine post processing and analysis software is also available. Corridor 4DM (Ann Arbor, Michigan) can be launched automatically from syngo Dynamics triggered on open by mapping of the modality tag (NM). Parameters resulting from analysis including EF, volumes, and perfusion scores can be passed from the 4DM application back to sD for structured reporting needs. ECG waveform data can also be integrated in a variety of manners. The sD 3<sup>rd</sup> party launcher can pass patient context data to the GE MUSE web server to request a patient's exams and allow the user the ability to view PDF waveform displays. Other 3<sup>rd</sup> party vendors, SCIMAGE's Picom for example, can also be launched to display ECG data using a similar context sharing means, but in this case provide user access to the full waveform data that can be measured and manipulated.

## **2.7. Cardiac CT and MR**

Cardiac CT and MR data is also currently stored on a

syngo Dynamics server, however, for improved reviewing capabilities and advanced processing the syngo Via server-client architecture is deployed to provide advanced review and analysis capabilities. Syngo Via is installed on the sD server and an integration has been made to exchange data directly from syngo Dynamics to syngo Via. When a cardiac CT or MR exam is selected, the Via application is automatically used to display the exam to the user. Via can be configured to provide customized workflow to improve and optimize the analysis of various data sets. For example coronary CT angiography data sets can be preprocessed to extract the major coronary vessels for streamlined analysis. The cardiac CT or MR slices or volumes are processed on the server and the server delivers a view of the data to the client application. Users interacting with this client control server processing which in turn updates the client.

### **2.8. Electronic billing**

A customized application has been developed to extract billing information stored in the report generation process within syngo Dynamics. Users are able to specify exam specific diagnosis codes and procedural ICD9 codes. The billing application creates both technical and profession charge records of a standard format acceptable to the CASS billing system utilized by the Cleveland Clinic. Charges can be assigned to various groups of physicians with different billing needs. Currently the charges are processed in daily batch files.

### **2.9. Administrative functionality**

We have utilized SQL reporting service tools to develop reports to effectively manage the information required to provide administrative data on tasks such as exam volumes by location and volume of procedures by type. We've built tools to provide staff with data that for example compares their individual ultrasound reading turn around time to the average of their group. Current efforts in this area also include reporting key quality parameters of report completeness in various clinical scenarios to administrative, leadership physicians, lead technicians as well as to individual users.

### **2.10. External image exchange**

As a major tertiary hospital, the CCHS sees patient with a history of medical exams performed at other institutions. During e-consults and surgical consults, these exams on media (CD/DVD) are often sent or hand-carried for review. We import most of the DICOM compatible exams into the PACs to simplify physician access. This process also provides a mechanism to associate the data with other records that may exist to

provide comparative reviews. Unfortunately there are still many media exchange formats using non-standard formats and cause significant review problems. Consideration of electronically reporting these consult results via syngo Dynamics is being considered. In addition to importing exams from media, consideration for electronic upload of exams through an exchange vendor is also being explored.

## **3. Conclusion**

Service and support are significant components of any clinical system and we've established a strong working relationship with several vendors to integrate these tools, troubleshoot problems, and explore the future of cardiovascular informatics. Internal relationships with our organization are key too, including those between the cardioPacs team and IT (network, desktop support, hospital information interfaces), billing specialists, developers, lab managers, administrators, and clinician leaders covering the broad range of functionality.

The benefits of the integrated system include improved data access and workflow efficiency. Integration of imaging and reporting functionality and therefore a centralized cardiovascular data repository

The integration of the parts that create efficiency bring together the use of standards from across the industry - DICOM, HL7, ICD9, CPT4 – and allow interoperability between systems. As multimodality imaging and structured data become increasingly more important in the delivery of high quality integrated cardiovascular patient care, continued focus on clinical effectiveness of system integration is key to continued success.

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