Computed tomography, electronic health record, and private medical cloud—impact of information technology on clinical decision making

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Abstract: Integration of CT imaging data into the electronic health record (EHR) resulting in shared 'private medical clouds' accessible throughout larger health care systems has become reality. These data clouds have potential impact on clinical decision making as exemplified in the context of acute aortic syndromes (AAS) and transcatheter valve procedures. Modern systems allow additional semi-automated data analysis for computerized decision support.

Keywords: Computed tomography (CT); acute aortic syndrome (AAS); electronic medical record (EMR); private medical cloud; transcatheter aortic valve replacement (TAVR)

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The introduction of computed tomography (CT) to medical imaging in the 1970's has had significant impact on clinical decision making across specialties in medicine and surgery (1). CT has replaced other imaging modalities e.g., in the assessment of acute aortic dissection and pulmonary embolism. Importantly, because of its 3-dimensional data structure, it is superior for planning of minimally invasive surgical and endovascular procedures (2). In fact, CT has been an integral part of the development of endovascular stent treatment of aortic disease and novel transcatheter procedures for valvular and structural heart disease (3,4).

CT imaging is based on complex digital data acquisition and analysis, which became possible by advances in computer sciences. These advances in digital data storage and analysis have changed communication and data sharing in medicine. Over the last few decades the traditional paper medical record and printed X-ray films have been replaced by electronic medical records (EMR) and digital image review on computer workstations, respectively (5,6) (*Figure 1*). This has had significant impact on clinical decision making, exemplified by the management of acute aortic syndromes (AAS) and transcatheter aortic valve replacement (TAVR). In the case of AAS, immediate availability across a healthcare system supports rapid communication within a group of specialists supports emergent management. In the case of TAVR sharing of images across sub-specialties supports planning of the elective procedure.

Severe aortic stenosis is common in elderly patient and the only definitive treatment is aortic valve replacement (7). Less invasive TAVR has developed into a viable alternative to conventional open heart surgery for patient with high surgical risk (8,9) (*Figure 2*). More recent results demonstrate its clinical value in intermediate risk populations (10). Because of the lack of direct, intra-operative visualization of the valve and annulus, pre-procedural imaging including CT imaging is fundamental for indication and procedural

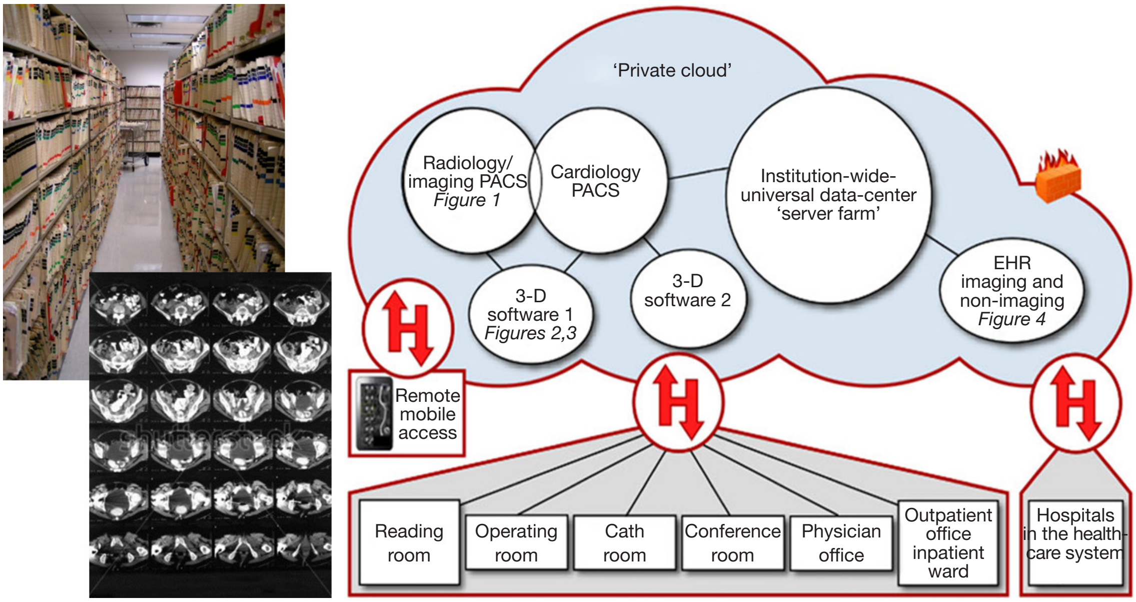

Figure 1 This figure shows storage of paper medical records and a printed CT 'film' in contrast to digital data storage in 'private medical data clouds'. CT, computed tomography; PACS, picture archiving and communication system. EHR, electronic health record.

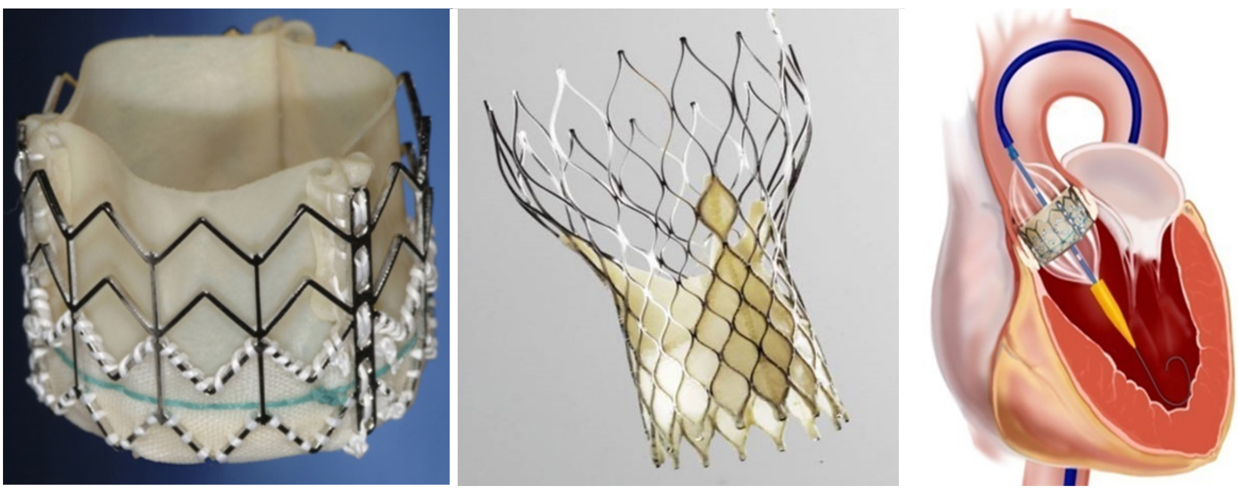

Figure 2 This figure shows two common TAVR stent/valve systems and an illustration of transcatheter implantation at the aortic annulus. TAVR, transcatheter aortic valve replacement.

planning (*Figure 3*). Specifically the reconstruction and analysis of the aortic annulus and evaluation of access vessels is a critical (*Figure 4*) (11,12). Data collected during history taking, physical examination and from laboratory and imaging studies are combined in the EMR and shared between multiple specialists in clinical and interventional cardiology, radiology, anesthesiology, surgery, nursing, etc. Availability at different times and multiple locations during pre-procedural evaluation, and peri- and post-procedural management is necessary (*Figure 5*).

AAS/dissections are medical/surgical emergencies, associated with significant mortality. Early diagnosis and treatment is critical (13,14) (*Figures 6-8*). Early CT imaging, which is typically performed at the point of initial contact in the emergency department is critical for definitive diagnosis. After initial diagnosis, patients are often immediately

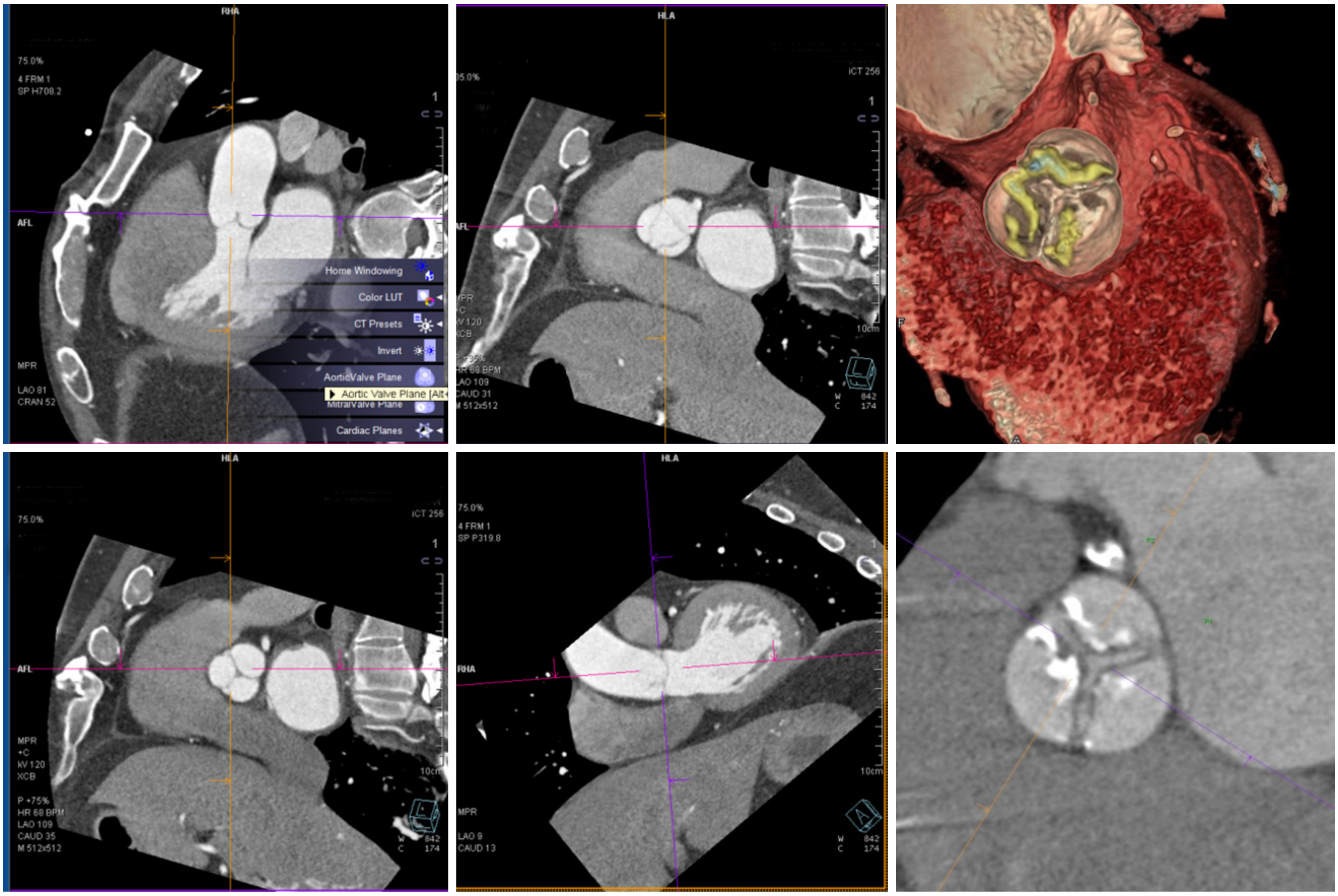

Figure 3 This figure shows CT images of a normal aortic valve (left panels) with regular systolic opening and diastolic closing. The right panels show a calcified valve with restricted opening in a patient with severe aortic stenosis. CT, computed tomography.

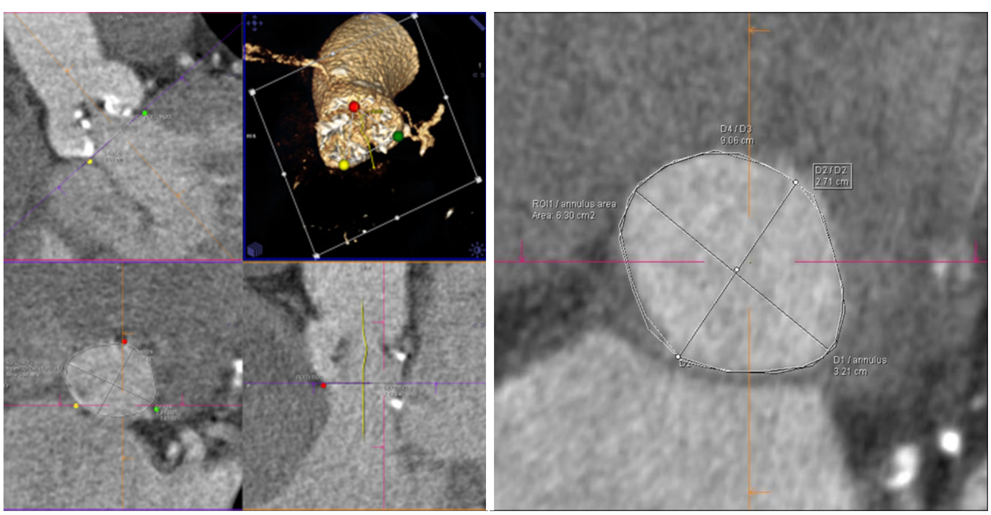

Figure 4 This figure shows reconstruction and measurements at the aortic annulus, using a semi-automated soft-ware program.

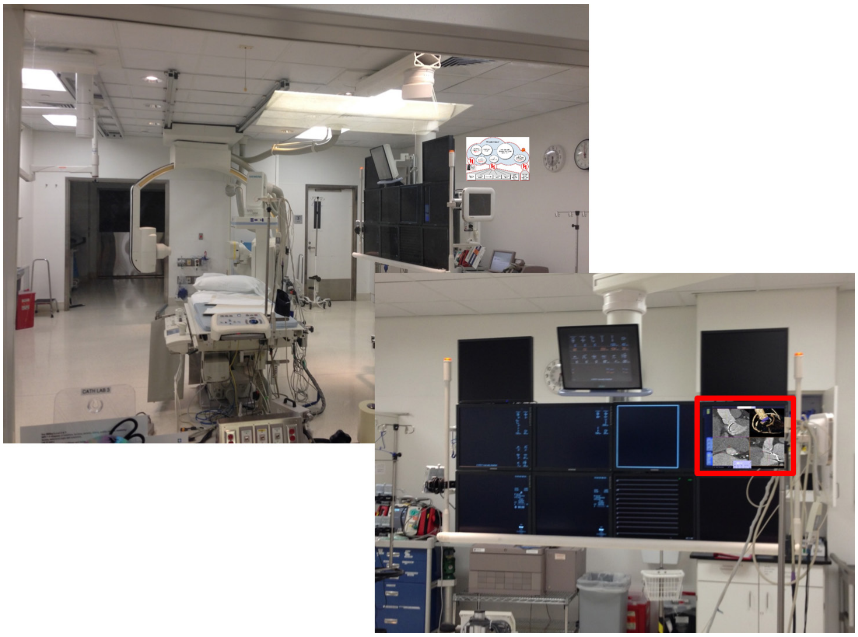

Figure 5 This figure shows a hybrid procedure/operative root with ability to display pre-procedural imaging data during the procedure.

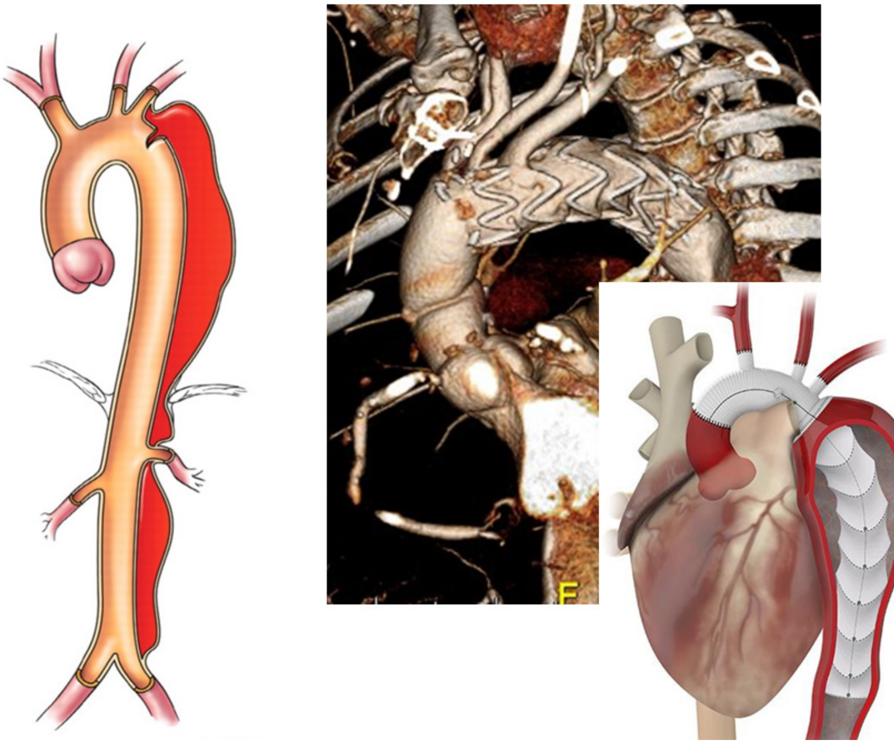

Figure 6 This figure shows different classes of type-A dissection processes. Left panel class I dissection with pericardial effusion; middle panel class II dissection/intramural hematoma; right panel class III intimal tear/penetrating ulceration.

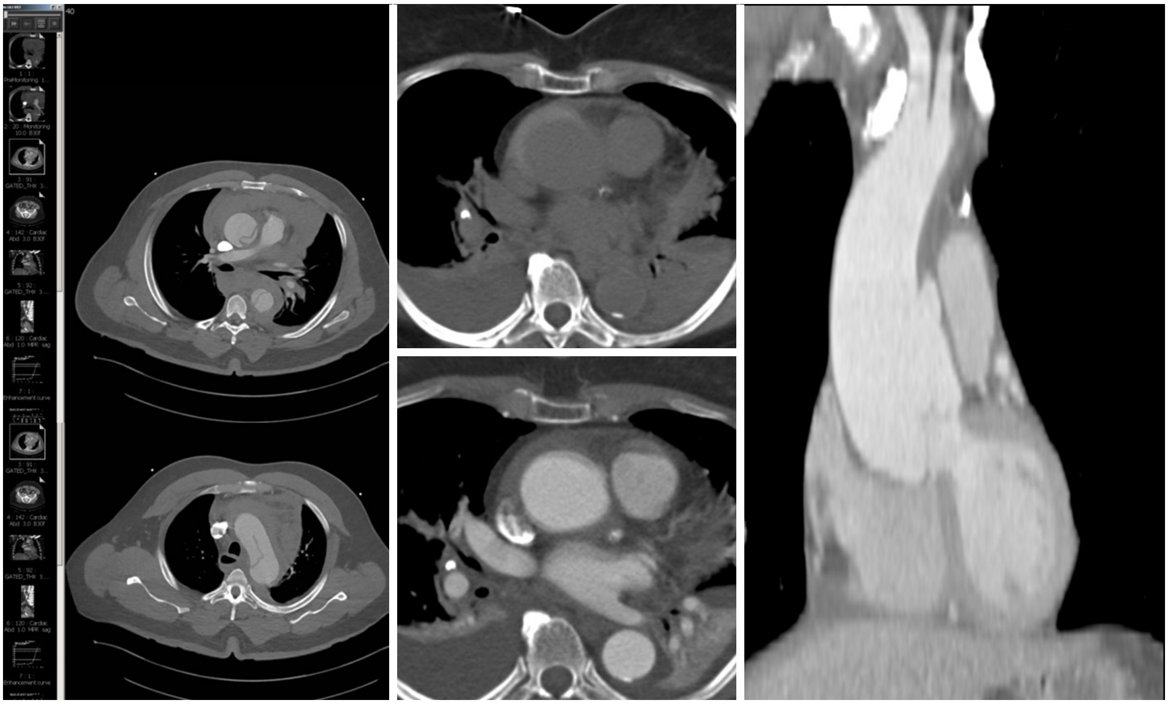

Figure 7 This figure shows illustrations and a volume rendered CT image of a type-B aortic dissection process. CT, computed tomography.

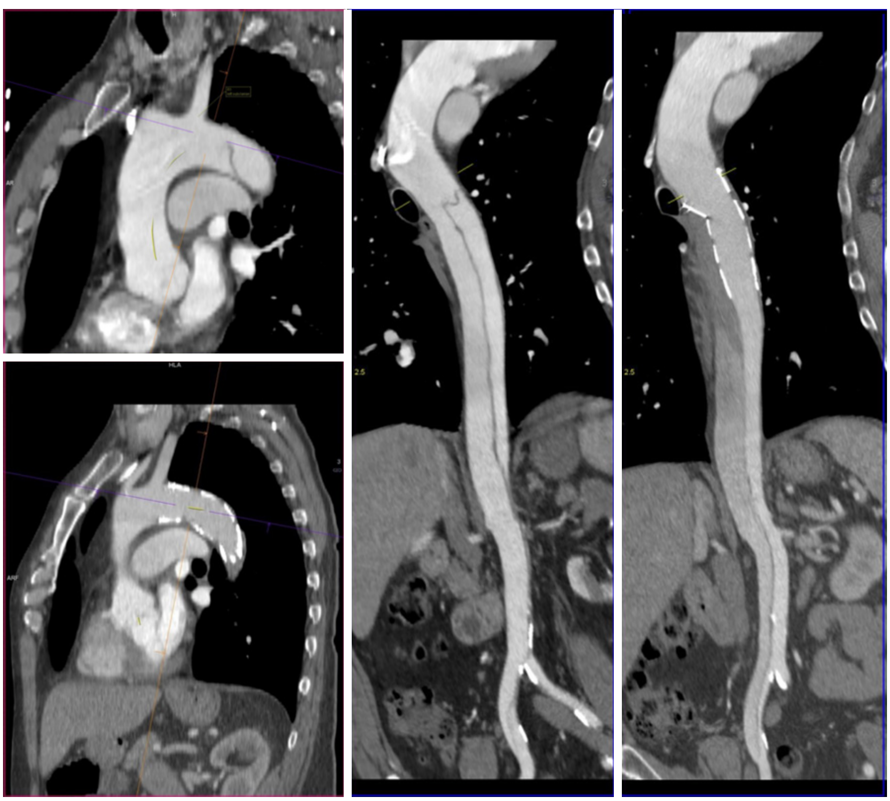

Figure 8 This figure shows a type-B dissection prior to and following endovascular repair.

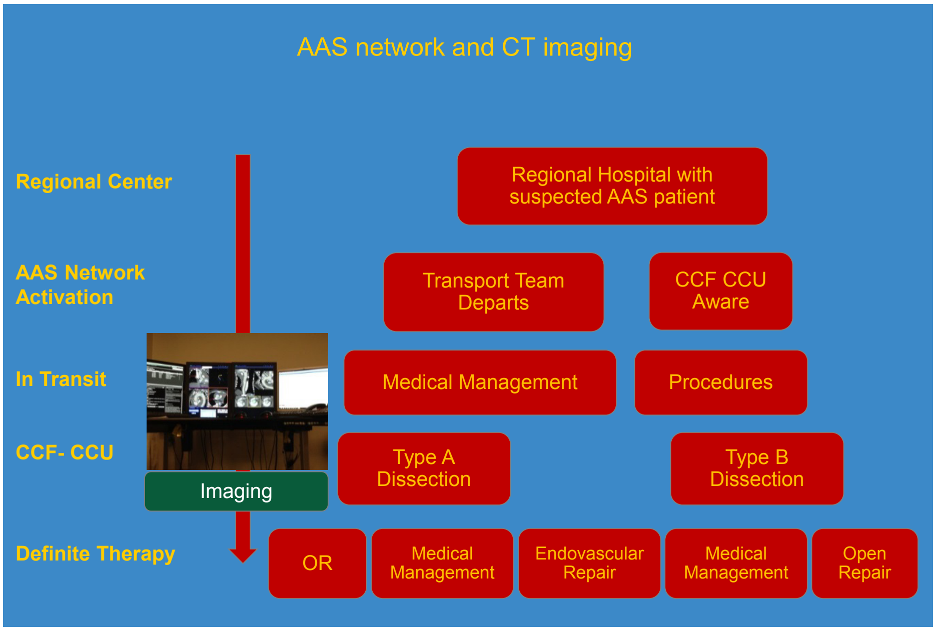

Figure 9 This figure shows the important role of imaging in the time period between initial presentation and definitive management.

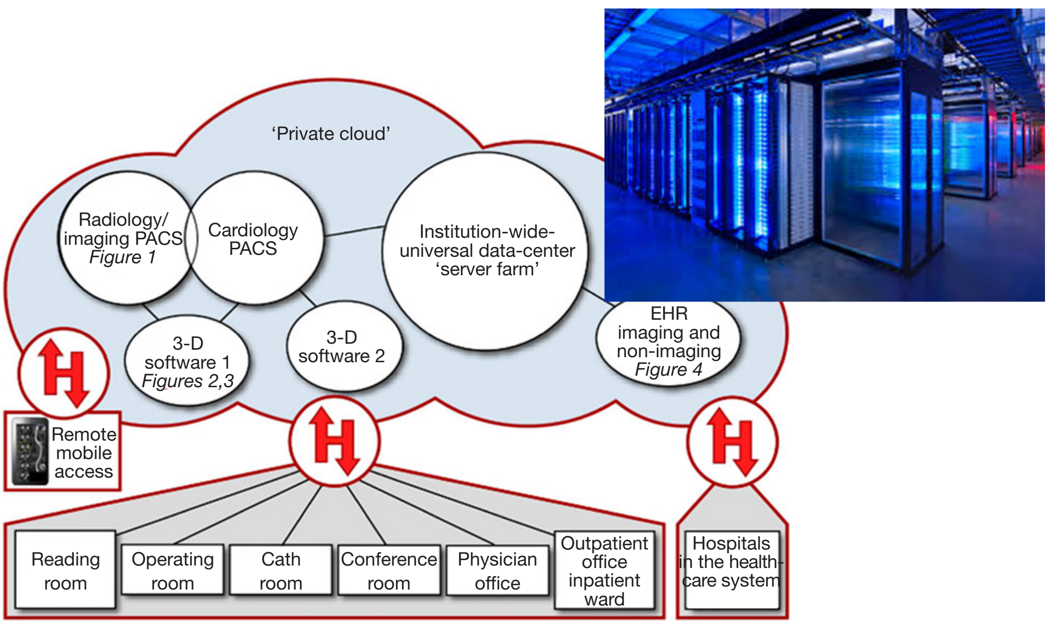

Figure 10 This figure shows the concept of a 'private medical cloud' maintained in a shared data center/server farm. PACS, picture archiving and communication system; EHR, electronic health record.

transferred to a tertiary center for definitive management (15,16). Emergent imaging and sharing of the imaging data is critical in the time period between initial presentation and definitive management (*Figure 9*). A shared 'private medical cloud' maintained from a central server farm/data center is an attractive solution (*Figure 10*).

The architecture of such IT networks includes scanners spread across a larger geographical region, which feed data

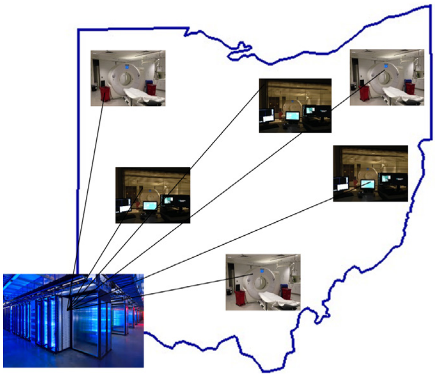

Figure 11 This figure shows multiple scanners in a larger geographic region, feeding into a common PACS. PACS, picture archiving and communication system.

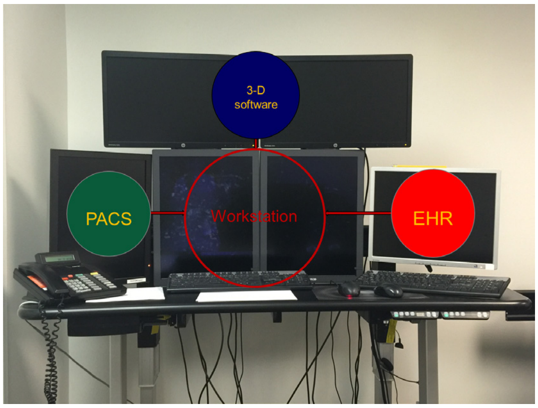

Figure 12 This figure shows a high end workstation, e.g., in the reading room.

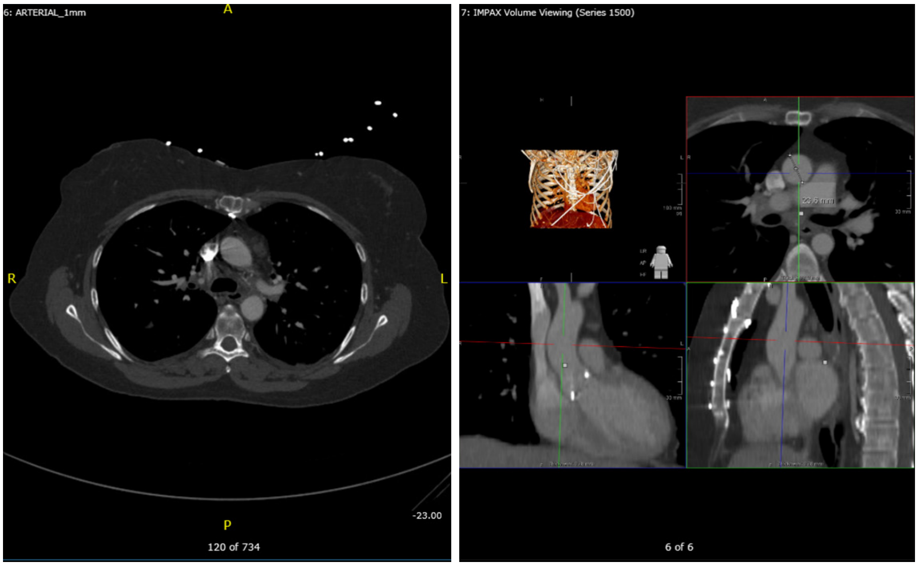

Figure 13 This figure shows integration of image data into the EMR. EMR, electronic medical record.

into a shared picture archiving and communication system (PACS) as part of the medical cloud (*Figure 11*). This makes the images available from the central archive from workstations across the entire health care system. Access is possible with a high end workstation e.g., located in a reading room, which provides access to basic PACS review but also dedicated 3-D reconstruction with one or more software (*Figure 12*). On the other hand review of images is also possible via basic EMR workstations anywhere within the health-care system by any user with access privileges (*Figure 13*). Access is also possible from mobile devices (*Figure 14*) creating a mobile network of specialists (*Figure 15*) (17).

If such data networks are combined with 'smart workstations' and machine learning, they can provide decision support (18-20).

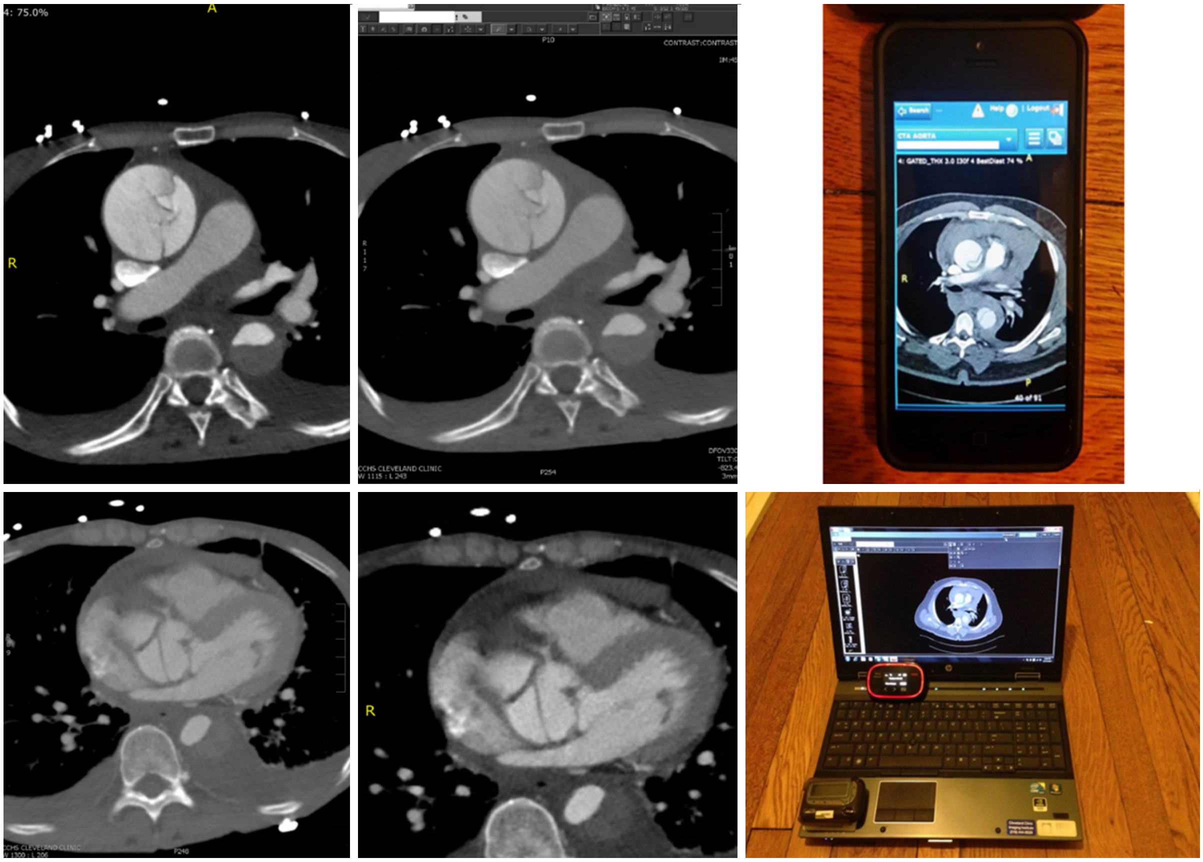

Figure 14 This figure shows mobile access from a laptop or phone.

Figure 15 This figure shows creation of a mobile network.

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Footnote

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jxym.2016.12.14). PS serves as the Editor-in-Chief of *Journal of Xiangya Medicine*. HL has no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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