Title
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Journal
Radiology Artificial Intelligence, 3(6)

ISSN
2638-6100

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Publication Date
2021-11-01

DOI
10.1148/ryai.2021210152

Peer reviewed

Radiology: Artificial Intelligence

SPECIAL REPORT

Imaging AI in Practice: A Demonstration of Future Workflow Using Integration Standards

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Authors declared no funding for this work.

Conflicts of interest are listed at the end of this article.

Radiology: Artificial Intelligence 2021; 3(6):e210152 • https://doi.org/10.1148/ryai.2021210152 • Content code: AI

Artificial intelligence (AI) tools are rapidly being developed for radiology and other clinical areas. These tools have the potential to dramatically change clinical practice; however, for these tools to be usable and function as intended, they must be integrated into existing radiology systems. In a collaborative effort between the Radiological Society of North America, radiologists, and imaging-focused vendors, the Imaging AI in Practice (IAIP) demonstrations were developed to show how AI tools can generate, consume, and present results throughout the radiology workflow in a simulated clinical environment. The IAIP demonstrations highlight the critical importance of semantic and interoperability standards, as well as orchestration profiles for successful clinical integration of radiology AI tools.

Motivation for Demonstration

Artificial intelligence (AI) holds the promise of improving efficiency and quality of care in diagnostic radiology (1). AI tools are being developed to aid diagnosis and enhance processes at multiple points in the radiology workflow (2). To function in the clinical arena, AI applications must integrate with existing radiology systems (3). Standards-based application programming interfaces (APIs) between systems are required to enable seamless, in-context communication of data and tasks. Defining these APIs is best accomplished as a collaborative, iterative process. Modern development methods, which are based on defining use cases and rapidly deploying and testing prototype applications, can enhance and accelerate the development of API standards specifications.

The Radiological Society of North America (RSNA) Imaging AI in Practice (IAIP) demonstration was designed to foster collaboration between developers of radiology systems, including AI applications. RSNA coordinated between radiologists who defined use cases to be addressed and vendors of radiology systems and AI tools to showcase their ability to generate, consume, and present AI results effectively within the clinical workflow in a simulated clinical environment. This demonstration provided a deadline and a target outcome to drive needed multidisciplinary effort. In addition to collaborative engineering, adoption of AI in radiology will require appropriate dissemination of knowledge to radiologists, other clinical professionals, and patients—all of whom will need to learn about the benefits and potential pitfalls of AI technology, as well as the ways in which it will impact clinical practice.

The purpose of the IAIP demonstration was not to validate the efficacy of the AI tools presented, but to show how such tools can be integrated into the radiology workflow in a simulated clinical environment. These demonstrations serve as an educational instrument to raise awareness in the radiology community of emerging uses of AI throughout the imaging chain. The demonstrations highlight the integration standards required to embed applications into clinical systems, encourage industry collaboration and the use of interface standards, and give a glimpse into the future of radiology.

Clinical Scenario

An example clinical scenario was designed to highlight the ways in which AI can impact multiple steps along the imaging life cycle. In this scenario, a patient with symptoms of acute stroke presents to the emergency department, initiating a chain of events demonstrating points of integration for AI: *(a)* protocoling the ordered head and neurovascular CT imaging, *(b)* clinical decision support for detection of urgent findings, *(c)* worklist priority adjustment via AI results, and *(d)* reducing turnaround time through worklist prioritization and semiautomated structured reporting. At CT, pulmonary and thyroid nodules are detected, highlighting AI detection of incidental findings with insertion of appropriate recommendations within reports, facilitating appropriate follow-up and patient tracking. The story goes beyond acute clinical care, demonstrating how AI can assist in the consent process and in capturing data for future research. As imaging had to be stitched together from multiple patients to create this scenario, we named our patient "Frank N. Study."

Abbreviations

AI = artificial intelligence, AIR = AI Results, AI-WI = AI Workflow Integration, API = application programming interface, CDE = common data element, DICOM = Digital Imaging and Communications in Medicine, EHR = electronic health record, FHIR = Fast Healthcare Interoperability Resources, IAIP = Imaging AI in Practice, IHE = Integrating the Healthcare Enterprise, RIC = Radiology Informatics Committee, RSNA = Radiological Society of North America

Summary

A demonstration successfully embedded artificial intelligence (AI) tools at different points throughout the radiology workflow in a simulated clinical environment using semantic and interoperability standards. These standards should be required in all requests for proposals and contracts with radiology systems and AI application vendors.

Key Points

- A collaborative effort between the Radiological Society of North America, radiologists, and imaging-focused vendors resulted in the successful demonstration of integrating artificial intelligence (AI) tools into the radiology workflow in a simulated clinical environment.
- Interoperability standards and orchestration profiles, including Digital Imaging and Communications in Medicine, Health Level Seven version 2, Fast Healthcare Interoperability Resources, Integrating the Healthcare Enterprise, Standardized Operational Log of Events, and common data elements, are necessary for successful integration of AI tools into the radiology workflow.
- Interoperability standards should be required in all requests for proposals and contracts with vendors for radiology systems and AI tools.

Keywords

Computer Applications-General (Informatics), Technology Assessment

Demonstration Team

The RSNA Radiology Informatics Committee (RIC) formulated the IAIP demonstration premise in October 2018. A project manager (T.M.S.S.) who oversaw the development and execution of the demonstration was selected in January 2020. This individual recruited 16 vendors, each of whom paid a participation fee. Vendors committed to attending meetings and to preparing and integrating products for the final demonstration. Vendors were split into three teams. In August 2020, eight attending radiologists and radiology trainees were named as volunteer clinical champions.

The interplay between the RSNA RIC, project manager, vendors, and clinical champions was truly synergistic. Vendors shared their domain knowledge about particular products and applications, including many applications not yet available on the market, while they benefitted from the expertise and insight of the clinical champions who provided feedback that motivated product enhancements and improved implementation design. All became well versed in the standards necessary for clinical integration.

Demonstrated Integration Standards

For clinical utility and reduction in cost and implementation time, the IAIP goals included both semantic and interoperability standards. The specific standards used are listed in Tables 1 and 2 (3–6). Workflow diagrams in Figures 1 and 2 walk through the standards used in our clinical scenario. A requisition created in the electronic health record (EHR) for acute stroke imaging is passed to the radiology information system via Fast Healthcare Interoperability Resources (FHIR). The order is then processed by the Integrating the Healthcare Enterprise (IHE) Order Filler profile and passed to the imaging modality via the Digital Imaging and Communications in Medicine (DICOM) Modality Worklist. Images are acquired and transmitted with associated metadata via DICOM to the clinical image viewer. A report is generated in the reporting system, then passed back to the EHR via FHIR. AI results are integrated as images and textual annotations into the image viewer via DICOM and as structured text data into the structured radiology report as common data elements (CDEs). Thus, the integration standards demonstrated work on a variety of pixel and nonpixel data, including structured data from the EHR and DICOM metadata.

Adapting to the COVID-19 Pandemic

Planning for the demonstration began in January 2020, followed by remote, distributed planning and Internet testing between vendors over the summer. The 16 vendor teams were to convene in Chicago, Illinois, in September 2020 for system testing, with systems to be shipped to McCormick Place for setup on the Friday before the RSNA 2020 Annual Meeting. In May 2020, it was announced that RSNA 2020 would be held virtually due to the COVID-19 pandemic. IAIP participants pivoted to create demonstration videos for online consumption, while continuing to implement and test AI tool integration. To address issues of Internet security, one company volunteered to host several application virtual machines to support integrations in a simulated, virtual environment. Although some companies chose to provide video clips of their tool integration, most chose to proceed with testing over the Internet to experience the benefit of integrating within the clinical workflow.

Radiologists and trainees from several institutions volunteered to serve as clinical champions and to develop narrative scripts for each demonstration. An introductory video was created to set the scene. Clinical champions provided invaluable insight in defining data flow and when and where CDEs should be added; they suggested changes to user interfaces and provided guidance on unbiased interpretation, as well as pragmatic modifications of AI results. Clinical relevance was emphasized throughout the demonstration. In September 2020, three team recording sessions were held, generating approximately 30 video hours (edited to approximately 15 minutes per video). The four IAIP 2020 videos depicting the integrated systems are freely available for viewing on the RSNA website (7), as well as on the RSNA's YouTube channel *(https://www.youtube.com/user/RSNAtube)* (8).

Showcase Results Dissemination

Although the demonstration was presented to RSNA attendees as a set of online videos, integration of the 26 products

Table 1: Semantic Standards Used in the RSNA 2020 IAIP Demonstration

Code System Name	Function or Use	Example from RSNA 2020 IAIP Demonstration
RadReport Template Library *(www.radreport.org)*	Provide examination-specific structured and/or coded templates for radiology reports to create consistent and comprehensive diagnostic reports	CT Angiography (CTA) Head and Neck with Contrast—Stroke Protocol (template ID RPT50620)
RSNA/ACR Common Data Elements (CDEs) *(www.radelement.org)*	Collect and store radiology datasets and their attributes in a uniform fashion as defined in a data dictionary (eg, stroke anatomic location, dimensions, image number)	CT Stroke (RDES22)
Radiology Lexicon (RadLex®) *(www.radlex.org)*	Define radiology-specific terms that can be used as a common language to communicate diagnostic results in radiology reports; also facilitates use of terms in clinical decision support tools, for data mining and data registries, and for use in education and research	Ischemic (RadLex ID RID6285)
Logical Observation Identifiers Names and Codes (LOINC)–RSNA Radiology Playbook *(www.loinc.org)* *(http://playbook.radlex.org/playbook/SearchRadlexAction)*	The RadLex Playbook provides a standard naming system for radiology procedures that is based on the elements that define an imaging examination (eg, modality and body part); this facilitates operational and quality improvement activities (eg, workflow, charge master, radiation dose tracking); the RadLex Playbook has been harmonized with the radiology portion of the LOINC standard and includes a new information model for describing imaging procedures	"CTA Head vessels and Neck vessels WO and W Contrast IV" LOINC code 82680-0 RadLex code RID10321

Note.—ACR = American College of Radiology, IAIP = Imaging AI in Practice, RSNA = Radiological Society of North America.

involved was achieved through iterative remote testing. These systems were able to perform the functions needed to support a clinical scenario that included imaging examination ordering, protocoling, acquisition, display, interpretation, reporting, and follow-up recommendations. During the online-only RSNA 2020 Annual Meeting, the demonstration videos were made accessible to meeting registrants through the AI Showcase component of the online meeting. The IAIP demonstration videos were viewed by 850 distinct attendees during the meeting week, on par with informatics demonstrations at previous in-person RSNA meetings. The video format allowed for persistent access and broader exposure. The four demonstration videos were made available as enduring materials through RSNA's YouTube channel (8), receiving a total of 4780 views as of June 1, 2021.

Lessons Learned

Perhaps the most important lesson learned in development of the IAIP demonstrations was the need for consistent and coordinated interoperability standards and orchestration profiles. Whereas many imaging-focused AI vendors expected to work exclusively with DICOM objects, many of the reporting-focused vendors expected to work with FHIR resources. At the time of the demonstration, IHE profiles for AI Workflow Integration (AI-WI) and AI Results (AIR) were in development but not yet published, so there was no consensus for conversion between DICOM and FHIR resources in this context. Given time constraints, only initial steps toward AI results integration into reporting systems was achieved. Continued development of these integrations is a goal for future work in the 2021 RSNA IAIP demonstrations.

In addition to consensus for conversion between DICOM and FHIR resources, use of the IHE AI-WI and AIR profiles will afford automation of data transfers, resulting in increased efficiency and scalability of workflows to greater numbers of studies and more complex examinations. While none of the AI use cases included in these demonstrations were designed to compare results across multiple studies obtained at multiple points in time, the use of metadata for workflow orchestration in the AI-WI profile should facilitate comparison to prior imaging and prior AI results. Given the metadata inputs required for these profiles to function, standardization in naming of study types and series acquired will help facilitate these workflows and identification of prior studies for comparison.

Another key lesson learned was the need for radiologist interaction with AI results. Even when AI results are not optimal, the mechanism of integration into a structured report can still provide efficiency gains if the results can be adjusted before

Table 2: Interoperability Standards Used in the RSNA 2020 IAIP Demonstration

Standard	Function or Use	Comments
DICOM PS3.3: A.35.4 Key Object Selection Document IOD	Visualize key image(s) possibly with AI result (eg, 2D nodule measurement)	Potential to modify AI result on PACS, VNA, or image viewer
DICOM PS3.3: A.35.13 Comprehensive 3D SR IOD	Convey AI measurements using TID 1500 template	Potential to modify AI result on PACS, VNA, or image viewer
DICOM PS3.16: TID 1500 Measurement Report SR	In conjunction with SR IOD above, convey values of AI results, such as measurements and units	Potential to display, then modify, AI result on PACS, VNA, or image viewer
DICOM PS3.3: A.51 Segmentation IOD	Visualize AI results: region outline, such as denoting affected stroke area or nodules	Potential to modify AI result on PACS, VNA, or image viewer
DICOM PS3.3: A.75 Parametric Map IOD	Visualize saliency map: the area or information of high attention by the AI model used in making its inference	Describes AI analysis, not intended to be modified
DICOM PS3.3: A.33 Presentation State IOD	Visualize AI results annotations: such as outlining affected stroke area or nodules, may include annotations over image	Advantage over secondary capture in that layers can be toggled on and off for viewing
DICOM PS3.3: A.8 Secondary Capture Image IOD	Visualize AI results: such as outlining affected stroke area or nodules, may include annotations over image	Advantage that almost any PACS or image viewer can display a secondary capture image
FHIR R4 Observation Resource and Application Programming Interface (API)	Reporting used by reporting systems to import previously reviewed and confirmed measurements	Potential to modify AI result within reporting system, possibly without being able to visualize on an image
FHIR R4 Consent Resource and API	Patient consent to use patient data (eg, imaging studies) for future AI algorithm development or other use case	N/A
FHIRcast	Share patient-study context: An FHIR http–based method to share patient and study context between the PACS, VNA, or image viewer and reporting application	N/A
IHE Standardized Operational Log of Events (SOLE)	Workflow steps: specifies method and codes to identify incremental steps in radiology practice	N/A—used for business and process analysis
IHE Radiology AI Results (AIR) Profile	AI results: describe clinical use case, how and where AI results are created and viewed	Further specifies and constrains DICOM standards listed above to optimize interoperability
IHE Radiology AI Workflow for Imaging (AIW-I) Profile	AI workflow: describe workflow to incorporate AI into daily clinical radiology practice	In the 2020 IAIP demo, focus was on prioritization of radiology worklists that were based on acute AI finding of ischemic stroke; other steps occurred as the clinical scenario unfolded in the course of the patient's care
IHE Radiology AI Interoperability in Imaging White Paper	Interoperability requirements: describe AI requirements from the first step of gathering data to final system monitoring	A preliminary version of this white paper was reviewed for the 2020 demo

Note.—AI = artificial intelligence, DICOM = Digital Imaging and Communications in Medicine, FHIR = Fast Healthcare Interoperability Resources, IAIP = Imaging AI in Practice, IHE = Integrating the Healthcare Enterprise, IOD = information object definition, N/A = not applicable, PACS = picture archiving and communication system, SR = structured reporting, VNA = vendor-neutral archive, 3D = three dimensional, 2D = two dimensional.

generating structured data. A corollary to this lesson was the realization that some CDEs may be generated at different points in the clinical workflow and by different AI tools. For example, intracranial hemorrhage may be excluded at non–contrast-enhanced head CT, while presence and location of large vessel occlusion may not be determined until CT angiography is performed. This presents a challenge for integration in identifying the most accurate results for each CDE across multiple AI models and/or radiology reports, so implementation with radiologist input is essential.

Furthermore, the capture of the interaction between the radiologist and the AI results is important information for feedback on AI tool performance and future model development. This point is emphasized in the postacquisition workflow (Fig

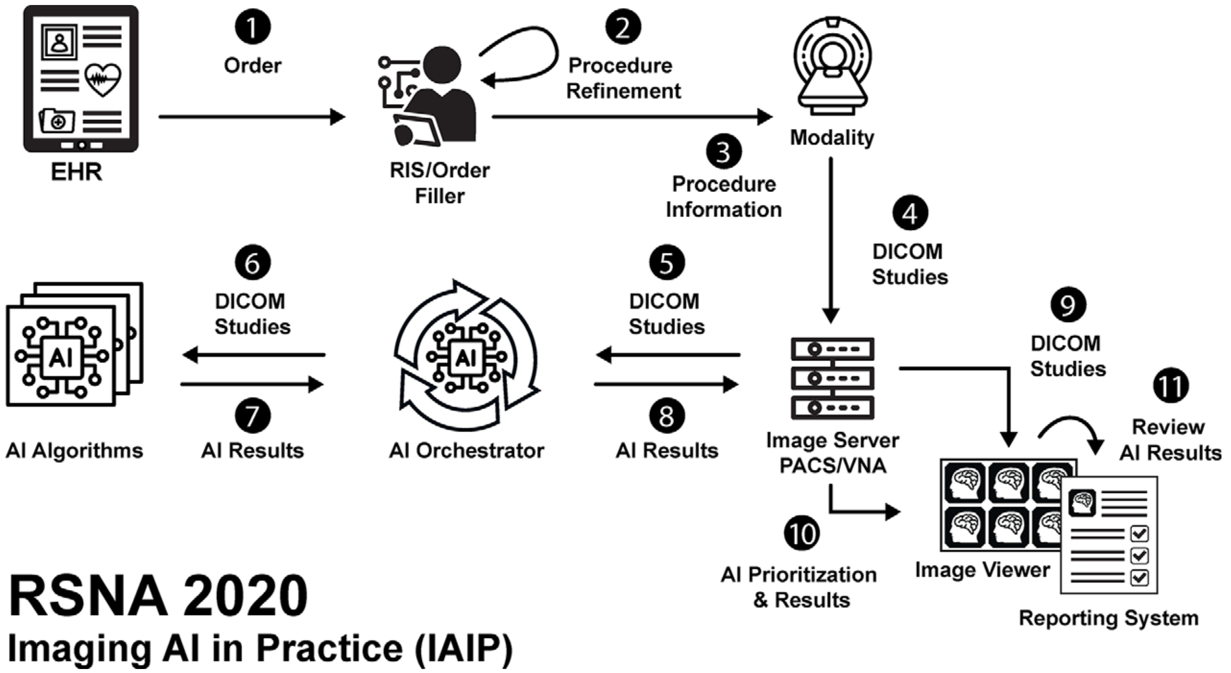

Figure 1: Image acquisition workflow diagram. **1**, An order is placed in the electronic health record (EHR) and transmitted via Health Level 7 version 2 or Fast Healthcare Interoperability Resources to the radiology information system (RIS) using the Integrating the Healthcare Enterprise Order Filler profile. **2**, The exact procedure may be refined or protocolled in the RIS prior to **3**, being communicated to the modality via Digital Imaging and Communications in Medicine (DICOM) Modality Worklist. **4**, The images are acquired by the scanner and sent with associated metadata in DICOM format to the image server, which may then **5**, forward the DICOM images to an AI orchestrator. **6**, The AI orchestrator then de-identifies the images if necessary and sends them to the appropriate AI algorithm(s). **7**, The AI algorithms process the images and return the AI results to the AI orchestrator, which then **8**, associates the AI results with the appropriate imaging study and sends the results back to the image server. **9**, **10**, The image server will forward the DICOM studies and AI results to the image viewer, where **11**, the studies and associated AI results are reviewed, and a report is generated. AI = artificial intelligence, PACS = picture archiving and communication system, RSNA = Radiological Society of North America, VNA = vendor-neutral archive.

2) portion of the demonstrations, where these data are fed back into the research server.

Collaboration of radiologists and vendors proved essential in the fast-paced development environment used for the IAIP showcase, which resulted in clinically relevant tools that were also technically feasible. Multiple tasks throughout the radiology workflow can be augmented by AI tools. In order for such applications to be adopted clinically, they must be embedded seamlessly into the workflow. Integration standards and orchestration frameworks proved to be key to the demonstration's success; it is recommended that they be included in any request for proposals or contract with imaging system vendors.

Acknowledgments: The authors would like to thank the members of the RSNA IAIP Demonstration Team: Adam Flanders, MD, Charles Kahn, MD, Marta Heilbrun, MD, Tarik Alkasab, MD, PhD, George Shih, MD, Krishna Juluru, MD, Ali Dhanaliwala, MD, PhD, Madhavi Duvvuri, MD, Shaan Sadiq, MD, Tessa Cook, MD, PhD, Matt Morgan, MD, Ken Wang, MD, and Jamie Dulkowski. We would also like to thank the vendors who contributed to the demonstrations: 3M M-Modal, Ambra Health, Annalise.ai, Blackford Analysis, Fovia AI, GE Healthcare, Lunit, Medo AI, Nuance, NVIDIA, Philips Healthcare, Rad AI, RADLogics, Siemens Healthineers, Smart Reporting, and Visage Imaging.

Author contributions: Guarantors of integrity of entire study, **W.F.W.**, **T.M.S.S.**, **K.P.A.**; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, **W.F.W.**, **K.M.**, **T.M.S.S.**, **S.D.O.**, **M.D.K.**, **K.P.A.**; clinical studies, **S.D.O.**; experimental studies, **T.M.S.S.**, **S.D.O.**, **K.P.A.**; statistical analysis, **C.D.C.**; and manuscript editing, all authors

Disclosures of conflicts of interest: **W.F.W.** University of Wisconsin GE CT Protocol Project Medical Advisory Board participation. **K.M.** Clinical Champion, Imaging AI in Practice (IAIP): 2020; Co-chair, IAIP Steering Committee, 2021 (unpaid volunteer, Radiological Society of North America [RSNA] provided funds for demonstration [administrative assistance, arrangement for Zoom calls] but no funds for the paper itself); former trainee editorial board member of *Radiology: Artificial Intelligence*. **T.M.S.S.** Johns Hopkins School of Medicine, adjunct professor; Marquette University College of Engineering, adjunct professor; RSNA, IAIP technical project manager (consulting fees); RSNA Structured Reporting Committee, Society for Imaging Informatics in Medicine (SIIM) Clinical Data Informaticist Task Force co-chair. **S.D.O.** No relevant relationships. **C.D.C.** No relevant relationships. **M.D.K.** Consulting fees from Alara Imaging paid to author as a shareholder; honoraria for speaking engagements with various topics, including AI, from Honor Health SCGR-Wires (author retained complete editorial control for all of these engagements); travel support from Korean Congress of Radiology, RSNA, SIIM, Digital Pathology Association; periodic uncompensated consulting for Nuance; leadership roles as chair of board of directors for SIIM, co-chair of Common Data Elements committee, RSNA Radiology Informatics Committee (RIC) member, IAIP Task Force member for RSNA, and Informatics Commission member for American College of Radiology; stock/stock holder in Alara Imaging. **K.P.A.** Unpaid volunteer member of the RSNA RIC, RSNA provided funds for demonstration (administrative assistance, arrangement for Zoom calls) but no funds for the paper itself; co-chair of IAIP Demonstration; support for travel from RSNA for RIC committee meetings; unpaid appointed member of Massachusetts General Brigham Data Science Oversight Committee, which occasionally hears concerns and gives institutional guidance on data and tissue-sharing activities; associate editor of *Radiology: Artificial Intelligence*.

References

1. Saba L, Biswas M, Kuppili V, et al. The present and future of deep learning in radiology. Eur J Radiol 2019;114:14–24.
2. Langlotz CP, Allen B, Erickson BJ, et al. A Roadmap for foundational research on artificial intelligence in medical imaging: from the 2018 NIH/RSNA/ACR/The Academy Workshop. Radiology 2019;291(3):781–791.

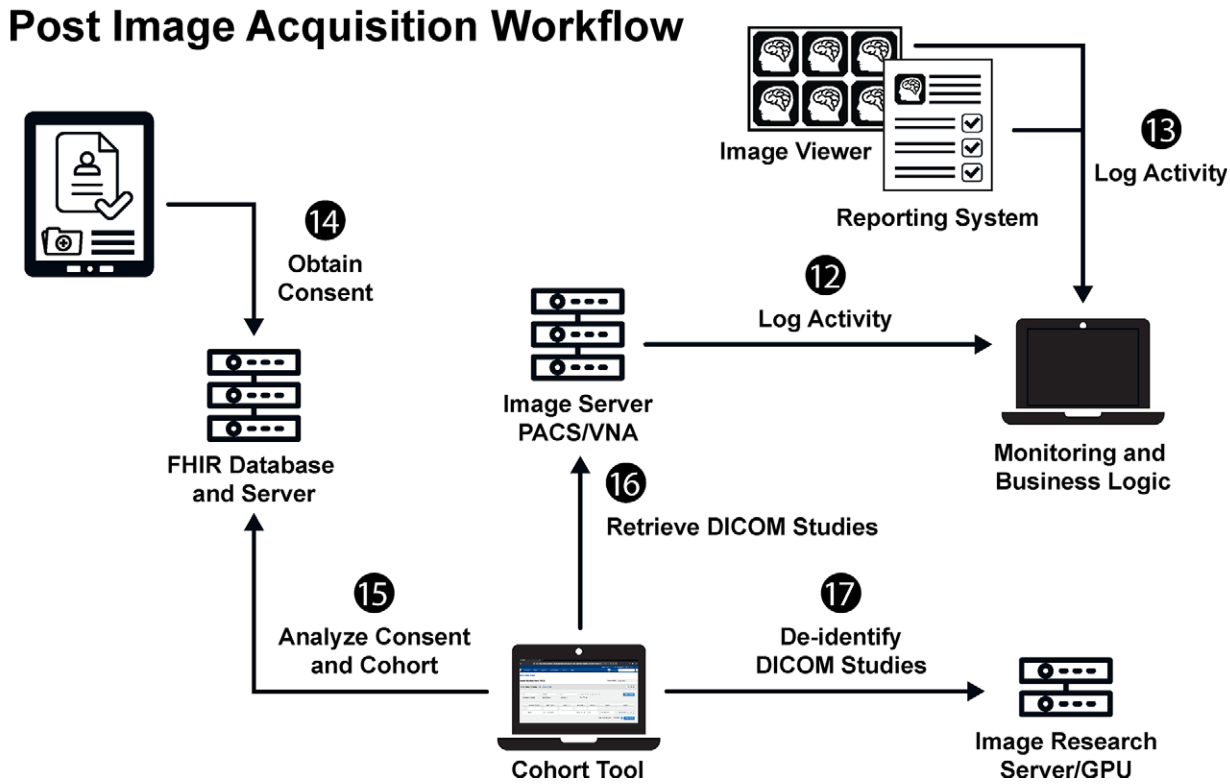

Figure 2: Postacquisition workflow. **12**, **13**, The image server and image viewer may log activities via the Integrating the Healthcare Enterprise standardized operational log of events profile for monitoring and business analytics. **14**, Consent for future research may be obtained and stored in a Fast Healthcare Interoperability Resources (FHIR) database. **15**, A cohort identification tool can then query the FHIR database to establish a research cohort and confirm consent, then **16**, query the image server for related Digital Imaging and Communications in Medicine (DICOM) studies, which may subsequently **17**, be de-identified and sent to an image research server with graphics processing unit (GPU)–accelerated computing capabilities for training future AI algorithms. PACS = picture archive and communication system, VNA = vendor-neutral archive.

3. Kohli M, Alkasab T, Wang K, et al. Bending the artificial intelligence curve for radiology: informatics tools from ACR and RSNA. J Am Coll Radiol 2019;16(10):1464–1470.
4. Wang KC, Patel JB, Vyas B, et al. Use of radiology procedure codes in health care: the need for standardization and structure. RadioGraphics 2017;37(4):1099–1110.
5. IHE Radiology Technical Framework Supplement: AI Workflow for Imaging (AIW-I). Integrating the Healthcare Enterprise. https://www.ihe.net/uploadedFiles/Documents/Radiology/IHE_RAD_Suppl_AIW-I.pdf. Updated August 6, 2020. Accessed June 14, 2021.
6. IHE Radiology Technical Framework Supplement. AI Results (AIR). Integrating the Healthcare Enterprise. https://www.ihe.net/uploadedFiles/Documents/Radiology/IHE_RAD_Suppl_AIR.pdf. Updated August 6, 2020. Accessed June 14, 2021.
7. Imaging AI in Practice Demonstration. Radiological Society of North America. https://www.rsna.org/education/ai-resources-and-training/ai-imaging-in-practice. Published 2020. Accessed June 14, 2021.
8. RSNA. Imaging AI in Practice Demonstrations. YouTube. https://www.youtube.com/playlist?list=PLEUiLXWVNND1TGgjsnjZybcOkGhotFy2U. Published 2020. Accessed June 14, 2021.