WHITE PAPER

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Data Driven

Use AI and Imaging Data to Unlock Insights and Improve Healthcare

Applying artificial intelligence to the diverse data in a vendor-neutral archive can help healthcare teams improve medical imaging workflows and diagnostic accuracy

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Executive Summary

Medical imaging is a powerful clinical tool in increasing demand, but the field is experiencing global personnel shortages and unmet needs for diagnostic accuracy. The industry-wide shift to a team-oriented, value-based environment brings new opportunities and pressures. The result is a strong need for innovative solutions that can improve the accuracy and efficiency of medical imaging workflows and enhance collaboration across the healthcare enterprise.

Vendor-neutral archives (VNAs) and artificial intelligence (AI) offer powerful new ways to address these objectives. VNAs bring imaging data out of its departmental silos, improving collaboration and efficiency and creating a basis for next-generation analytics. AI allows for exploring massive amounts of data in search of correlations and patterns that may be too subtle for clinicians and researchers to observe otherwise.

Integrating AI capabilities with data from VNAs can unlock insights at the intersection of longitudinal, multi-modality, and multi-vendor imaging data across applications. These insights can be incorporated into practical solutions and integrated with picture archiving and communication systems and other imaging workflows. There, solutions can help streamline clinical productivity, enhance diagnostic accuracy, increase operational efficiencies, and promote the delivery of value-based, collaborative care. Applying AI to VNA and other data sources also maximizes the data's value as a strategic asset, opening the door to research insights that may inspire the next clinical or operational breakthrough.

Intel® technologies provide a high-performance, cost-effective foundation for deploying VNAs, creating and implementing practical analytics solutions, and maximizing value from healthcare data. Intel offers optimized AI frameworks and tools for developing and training analytic models, algorithms, and solutions without the need for specialized hardware. By building VNAs and analytics solutions on Intel technologies, healthcare enterprises and research organizations can optimize their technology infrastructure as they bring the power of advanced analytics to patients, clinicians, research teams, and other stakeholders.

The Challenge: Improve Imaging Workflows, Unlock Data Silos

Patient imaging data is a vital element of the health record, essential to diagnosing, treating, and evaluating the progression of many diseases and conditions. Yet too often, imaging data is locked in silos—inflexible, proprietary platforms—in picture archiving and communications systems (PACS), where the data is segregated by imaging modality (such as X-ray, magnetic resonance, or ultrasound) or medical specialty (such as cardiology, oncology, or neonatology).

These siloed PACS platforms generally meet the needs of the departments that deploy them, but as independent platforms, they inhibit collaboration and reduce efficiency for other health workers. Siloed data contributes to duplicate images and diagnostic procedures, driving up healthcare costs, increasing patients' radiation exposure, and adding to enterprise storage burdens.

Information in isolated PACS platforms is difficult for researchers and solution developers to access, limiting its use as a strategic resource. In an era of evidence-based medicine and genomics-fueled treatment breakthroughs, imaging data can be an important input to next-generation analytic solutions that explore heterogeneous data sources to generate novel insights.

Clinicians who review and interpret imaging studies encounter their own challenges. Imaging workflows are often manual, slow, and inefficient. Most nations face growing shortages of radiologists and other imaging specialists, and the demand for imaging services is rising around the world. This combination often produces overworked clinicians and high rates of burnout—half the radiologists surveyed in 2016 reported classic symptoms of burnout. Fatigue and overwork may also contribute to errors in interpreting images, producing average retrospective error rates of 30 percent. These errors can contribute to incorrect diagnoses, inappropriate treatments, and worse outcomes for patients.

Solutions are urgently needed that can improve the productivity and accuracy of medical imaging professionals, make patient imaging data securely and efficiently available to users who need it, and capture the full analytic value of this important data source. With rapid advances occurring in deep learning (DL), machine learning (ML), and other forms of artificial intelligence (AI), healthcare organizations have more to gain from modernizing their approaches to imaging data than ever before.

Solution Overview: Deep Learning to Enhance Medical Imaging

Vendor-neutral archives (VNAs) combined with DL-enhanced analytics can help health systems develop and deploy innovative solutions to medical imaging challenges.

VNAs use standards-based methods to aggregate data from multiple PACS implementations and imaging systems. VNAs enable efficient, secure access to radiological images stored in standard Digital Imaging and Communications in Medicine (DICOM) formats, and to the visible light images produced by ophthalmology, digital pathology, dermatology, and other types of exams. Next-generation VNAs may also integrate information from longitudinal electronic health records (EHRs) and include diverse data such as surgery procedure videos and readings from bedside devices. Reflecting the strong value that healthcare enterprises see in VNAs, the global market for PACS and VNA platforms is growing at a compound annual growth rate of 5.9 percent and is predicted to reach USD 4.1 billion in 2021.

Interoperable VNA data provides a valuable resource for advanced analytics, including DL-enhanced analytic solutions for medical images. DL is a branch of AI and ML that uses multilayered neural network structures and intelligent algorithms to form and train models that glean insights from analyzing vast amounts of data. Rather than needing all the rules spelled out for them, DL models can learn to identify and classify patterns and draw conclusions or "inferences," often with minimal human intervention. DL models may identify clinical changes that are too subtle to be detected otherwise and analyze image data more quickly than human experts can.

Once models are fully trained, they can be integrated into solutions and deployed as inferencing engines within PACS, VNA, modality, or research workflows. For example, a DL solution designed to reduce workflow bottlenecks might scan imaging results, identify and highlight anomalies, and route clinically significant or ambiguous images to the most experienced professionals. Such a triage function can optimize the use of precious human talent in image interpretation while contributing to a more sustainable healthcare system.

In addition to deploying emerging AI solutions within their imaging workflows, forward-looking healthcare enterprises are exploring opportunities to use their VNA data to foster development of next-generation DL and ML solutions. Strategic collaboration with research organizations and analytics innovators can accelerate solution development and strengthen a health system's position as an innovation leader. Collaboration can help organizations increase the return on investment (ROI) for VNAs by using imaging and pathology data, with appropriate security and privacy protections, as inputs for model training. Using VNA data this way may also enable healthcare systems to create new revenue opportunities and business models.

Intel provides high-performance technologies and optimized frameworks to accelerate the development and deployment of DL solutions. By basing their analytics infrastructure on end-to-end Intel® technologies, health systems can capture the workflow and quality benefits of advanced analytics while creating a flexible, cost-effective environment with the scalability to handle continued data growth.

Real-World Clinical Examples

DL solutions based on Intel technologies are driving progress in medical imaging analytics around the world. These solutions are aiding activities that range from helping prevent blindness to identifying and classifying cancers.

Eye Health Screening

Aier Eye Hospital, a Chinese company with hospitals around the world, piloted a DL solution it developed with a Taiwan-based company, MedImaging Integrated Solution (MiiS), to screen patients for age-related macular degeneration and diabetic retinopathy. Both are treatable conditions with a high prevalence rate in China that can cause irreversible vision loss if not identified early. However, many patients are not diagnosed early enough for intervention.

Aier and MiiS developed a way to screen a large population that currently lacks access to eye-health screening, to ensure that the right patients are selected for costly referral to specialists for further evaluation and timely treatment. Community-based, nonspecialist care providers can evaluate patients' eyes by capturing 2D images taken by a handheld ophthalmic scope from MiiS. Working with Intel, Aier and MiiS have developed a DL-based solution that analyzes and classifies the images resulting from these exams and advises on the need for follow-up with an ophthalmic specialist. Results are automatically entered into the EHR, allowing for human review and providing input for a possible specialist exam. Aier provided MiiS with de-identified data from thousands of ophthalmology exams to train the DL model and expects the resulting solution to increase diagnostic capacity across China and help reduce blindness through earlier diagnosis.

Thyroid Cancer Screening

Another initiative in China uses DL for thyroid cancer screening. Thyroid cancer is rising at double-digit rates in China, particularly among young and middle-aged women, and China is committed to expanding its health system's capacity to screen for this disease. Ultrasound images offer a cost-effective means of diagnosing thyroid cancer, but benign thyroid nodules are so common that effective diagnosis requires having a radiologist carefully review each ultrasound study. Because China has too few trained radiologists to keep up with the demand for detailed image review, many individuals lack treatment or undergo costly biopsies to obtain a clear diagnosis and initiate treatment.

Zhejiang University developed a DL solution that will be used to increase both accuracy and throughput in thyroid cancer screening. Deployed as a real-time inferencing appliance in clinical environments, the DL solution proved more accurate than trained radiologists. Using DL has made it possible to shift many non-acute cases to less experienced radiologists, helping optimize the time of experienced radiologists and allowing them to concentrate on difficult-to-diagnose cases. Zhejiang University researchers developed the solution with Zhejiang DE Image Solutions Co., Ltd., and worked with Meridian Medical Network Corp to optimize the solution's performance.

Practical Value from Vendor-Neutral Archive (VNA) Data and Artificial Intelligence (AI)

Using VNA data with advanced analytics can help health systems:

- Improve quality of care by incorporating new insights into clinical-decision support models that increase diagnostic accuracy and speed
- Streamline clinical workflows through AI-enhanced imaging triage, allowing highly trained professionals to focus on the most complex images and helping reduce stress
- Contribute to operational efficiency, system capacity, resource utilization, and value-based care by enabling faster diagnostics results, enhancing cross-enterprise collaboration, and reducing duplicate or unnecessary procedures
- Drive clinical, operational, and research breakthroughs by adding imaging and pathology information to the pool of data available for research and analysis
- Accelerate innovation by participating in research and commercial partnerships, such as engaging with third parties to develop algorithms based on the health system's data set

Pathology Analysis of Lung Tissue Samples

Approximately 13.2 million people around the world are diagnosed with cancer each year. Many of these diagnoses are based on a pathologist's examination of microscopic tissue samples. With populations aging and cancer on the rise, many nations face current or impending shortages of pathologists.

In the United Kingdom (UK), a research team led by the University of Warwick is using DL to improve a digital cellular pathology model that examines microscopic lung tissue samples in search of cancer cells. A pathologist's caseload typically consists of primarily normal, healthy tissue. By using AI to identify and highlight the abnormal images, the DL solution can allow pathologists to concentrate on the images that need their attention. In addition, the vast number of cells in a typical pathology specimen makes estimating and grading tumors a complex task. By using consistent algorithms, the DL solution brings greater objectivity to the process of grading tumors, which can help ensure that patients receive appropriate treatments. As healthcare organizations migrate toward adopting digital pathology systems, the DL solution will help provide a means of increasing ROI and gaining additional value from those systems.

Researchers will incorporate the DL pathology solution into workflows aimed at optimizing the analysis pipeline of pathology images. The project brings together experts from the UK's National Health Service, the Alan Turing Institute, University Hospitals Coventry and Warwickshire NHS Trust, and Intel.

Information Flow for Deep Learning

To develop medical imaging DL solutions, clinical research teams and other innovators use massive volumes of imaging data and advanced algorithms to create and train DL models. Once models are sufficiently trained, they are incorporated into deployed solutions to act as inferencing engines, analyzing new sources of data in practical workflows and drawing conclusions or inferences that support the clinical workflows. Practical DL solutions can add value in medical imaging practices, research centers, hospital clinics, or other distributed environments.

Model-training workloads can run in private clouds, enterprise data centers, or hybrid environments. Deployed inferencing platforms can run on secure cloud or data center infrastructure, local inferencing appliances, or be integrated into compute infrastructure at the modality. Regardless of where they run, DL solutions, including inferencing, can be designed for access through the PACS, VNA, imaging modality, or the cloud.

Figure 1 shows a typical data flow for a DL solution that is trained using VNA data. The imaging data goes through several forms of image processing at the modality workstation in the clinical environment, including functions such as reconstruction, registration, segmentation, and noise reduction. These images are then entered into the PACS and later sent to the VNA.

DL training platforms can be designed to access information in the VNA through DICOM and cross-document training capabilities. The training solution can then preprocess the imaging data to provide annotation, de-identification, compression, image augmentation, registration, and segmentation, and run DL training to generate models.

Accelerating Artificial Intelligence (AI) Innovation

Using Intel® technologies and AI frameworks optimized for Intel® architecture, organizations can:

- Enhance solution performance, IT operations, and data management for vendor-neutral archives and analytics with an agile, scalable, and consistent architecture
- Speed algorithm development and model training with optimized AI frameworks and high-performance, industry-standard architectures
- Deploy AI solutions in the data center or the point of care, delivering high-throughput inferencing without specialized hardware

AI Solution Architecture

Intel offers a flexible, optimized architecture and an industry-leading technology portfolio for developing and deploying advanced analytics at any size, scale, or setting (see Figure 2). Using Intel technologies, researchers and other innovators can accelerate training performance while taking advantage of a unified framework that simplifies development, maintenance, and code reuse. Hospitals and clinics can deploy DL solutions on the same reliable, well-understood architectures that run their VNAs, EHRs, and other workloads, helping reduce total cost of ownership. Organizations also gain performance and scalability to keep pace with the ongoing growth in the volumes and variety of healthcare data.

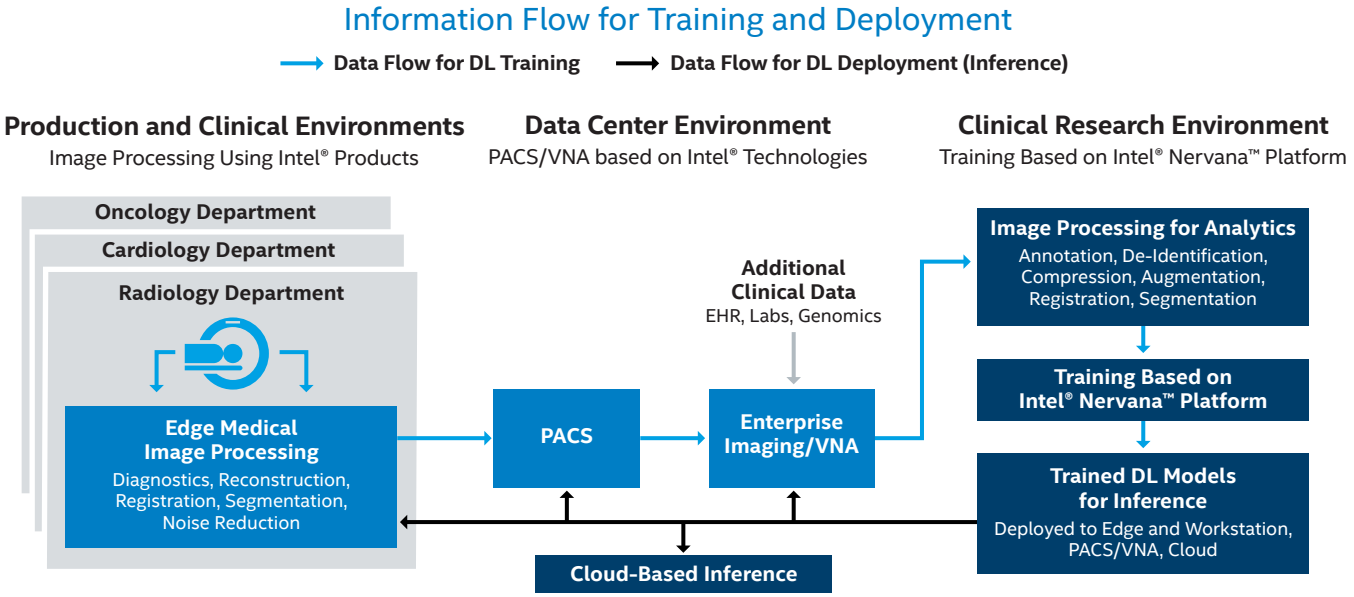

Figure 1. Clinical data flows from the modality or picture archiving and communication systems (PACS) to the vendor-neutral archives (VNA), where researchers can access it to train deep learning (DL) models. Deployed solutions use the trained models to perform analytic inferencing on new data sources, helping improve clinical and research workflows.

Data center technologies from Intel deliver high computational performance, memory capacity, and throughput for AI workloads. These capabilities are essential for loading and processing large medical images, particularly highly detailed 3D images. With up to terabytes of memory available, analytics innovators can simplify model development. They can also train their models on large, full-size images, potentially increasing model accuracy.

Intel technologies provide performance, agility, and cost-effectiveness for scalable storage infrastructure, including support for approaches such as software-defined storage (SDS) and federated data sharing. SDS replaces monolithic storage architectures with flexible, scale-out approaches. Federated storage architectures can reduce data movement, fostering secure collaboration while helping avoid the costs of storing, transferring, and managing multiple copies of large imaging files.

Key technologies for model training and solution deployment include Intel® Xeon® Scalable processors, which provide scalable performance and throughput, along with large memory capacity and high memory bandwidth. Intel® Solid State Drives based on breakthrough Intel® Optane™ technology target increased data throughput and scalability. Intel® Omni-Path Architecture supports high-speed data transfers and communications for model training and solution deployment. Field programmable gate array technology from Intel offers a fast, low-power option for high-throughput inferencing and other workflows. Algorithms can use Docker* for data processing and workflow management.

In addition to platform technologies, Intel offers extensive resources to simplify AI development and increase application efficiency. Performance-tuned AI frameworks such as Caffe*, TensorFlow*, and Theano*, optimized for the Intel® Xeon® processors and libraries, are available through open source communities. Intel® Math Kernel Library for Distributed Neural Networks incorporates optimized versions of fundamental operations used by convolutional neural networks.

Capture the Coming Wave

Artificial intelligence (AI) is poised to transform healthcare and other industries. Here are a few ways healthcare systems can prepare to take advantage of emerging opportunities.

- **Think strategically.** Bring clinical and operational visionaries together with data scientists and IT leaders to develop a flexible AI roadmap. Stay abreast of innovations and match them to organizational challenges.
- **Deploy a vendor-neutral archive (VNA).** In addition to delivering practical, clinical value, VNAs are an important stepping stone to AI-supported analytics.
- **Extract more value from VNA data. Recognize healthcare data—including the data in a VNA—as a strategic asset.** Consider partnering with analytics and healthcare innovators to speed progress and explore new business models based on VNA data. As you work with VNA vendors, discuss their plans for tagging and structuring data to increase its analytic value.
- **Integrate AI into picture archiving and communication systems (PACS) and VNA platforms.** Aside from using your own data to create and deploy AI solutions, watch for third-party solutions that can integrate AI into the enterprise PACS or VNA to improve imaging and other workflows.
- **Join the conversation.** Work with professional associations, technology providers, and other influencers to remove roadblocks. Reach out to educate policy makers, consumers, and patient advocacy groups.
- **Modernize IT infrastructure.** Scalable infrastructure and modern storage architectures are a necessity to manage data and benefit from advanced analytics. Take advantage of breakthroughs such as server-based solid state drives, low-latency memory and storage technology, and software-defined storage. Maintain a consistent architecture to minimize complexity and costs.

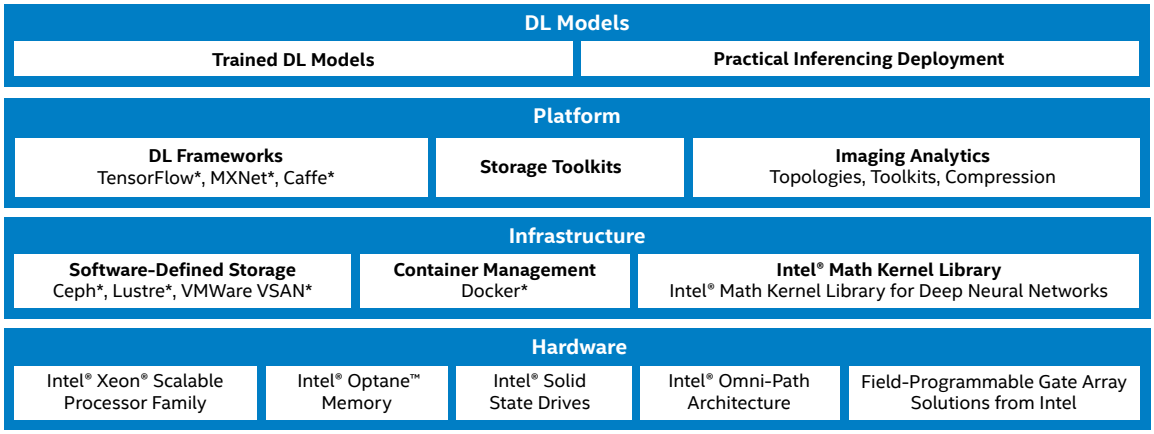

Figure 2. Flexible architecture, high-performance hardware, and optimized deep-learning (DL) frameworks enable cost-effective training and deployment for medical imaging analytics workloads.

The Intel® Nervana™ platform integrates hardware, software tools, and frameworks to reduce implementation time and simplify solution deployment. Developers can incorporate both structured and unstructured data into their DL solutions, including, but not limited to text, video, images, audio, and time-series data.

Conclusion

VNAs can help enhance quality of care, improve data management, and increase efficiency across the healthcare enterprise. VNAs can also increase the value of imaging and pathology data by enabling its use in building next-generation analytics solutions. Whether healthcare organizations create and train their own analytical and AI models or collaborate with external innovators, healthcare enterprises can prepare to capture the full value of their data using analytics solutions that target key performance indicators such as diagnostic accuracy, clinician productivity, departmental throughput, patient and clinician satisfaction, resource utilization, and patient outcomes.

Intel provides a comprehensive portfolio of scalable, cost-effective technologies and optimized frameworks to support high-performance VNAs and AI solutions. By building on Intel technologies and frameworks, researchers and solution developers can accelerate the creation of high-performance analytics solutions. Healthcare IT groups can streamline operations and enhance ROI with a scalable, flexible architecture. Together, hospital CEOs and IT leaders can help improve patient access to high-quality, value-based care, develop a healthcare ecosystem where analytics is the norm, and prepare for an AI-rich future.

Find the solution that is right for your organization. Contact your Intel representative or visit **intel.com/healthcare**.

Learn More

You may find the following resources useful:

- Modernize PACS Infrastructure with a Clinical Data Archive
- Intel® Nervana™ platform
- Intel® Xeon® Scalable processors
- Intel® Solid State Drives
- Intel® Optane™ technology
- Intel® Omni-Path Architecture
- Deep Learning Frameworks optimized for Intel® architecture
- Intel® Math Kernel Library for Distributed Neural Networks
- FPGA solutions from Intel

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[7] "Intel Is Empowering Medical Imaging AI for Instant Thyroid Nodule Screening," June 5, 2017, youtu.be/yUtY8InXkk0.

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