ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.3 , No.4, Pages : 14-20 (2014)
Special Issue of ICCEIT 2014 - Held on September 01, 2014 in The Solitaire Hotel, Bangalore, India

Challenges in Adoption of Big Cloud Data for Healthcare

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Abstract—Rapid growth in the use of mobile devices, smart phones, laptops, tablets, personal sensors is generating a data deluge and the whole world data is generated within last two years. Data in finance, research, entertainment and consumer marketing, are building a foundation for the increasing use of Big Data and analytics in healthcare. The potential of Big Data allows us to hope to slow the ever-increasing costs of care, help providers practice more effective medicine, empower patients and caregivers, support fitness and preventive self-care and to dream about more personalized medicine. As with internet, social media and cloud computing Big Data will transform healthcare to meet the expectations. Challenges in the adoption and success of Healthcare BigData on cloud include security and privacy. In this paper we study the challenges need to be addressed by the Health care organizations for adoption of Big Data on cloud and then provide the results of adoption of cloud model for healthcare companies.

Keywords: BigData, Healthcare, cloud computing, analytics.

INTRODUCTION

Over the next three years one billion Smartphone, three billion IP enabled devices will enter into service. 4.9 million Patients will use remote health monitoring devices. Three million patients will use a remote monitoring device via Smartphone hub. There will be 142 million healthcare and medical app downloads. By 2012 healthcare data generates 500 petabytes of data. By 2020 it is expected to grow 25000 petabytes. So BigData is really going to be a buzzword in the coming generation. BigData can be defined as the data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the strictures of the existing database architectures. We must choose an alternative way to process it and gain value from this data. There are four dimensions to bigdata commonly referred to as four v's. The first v representing volume which varies from terabytes to zettabytes. The second v representing variety like structured, semi-structure and unstructured data. The third v representing velocity from anytime batch processing to real-time streaming. The fourth v representing veracity means quality, relevance, and predictive value meaningful data. In the next section how each of these dimensions will be applicable to health care data is discussed.

VOLUME

The volume of global data overall is increasing exponentially. By 2020, there will be 35 zettabytes of digital data—a stack of DVD's that would reach halfway from the Earth to Mars However, only 20% of the world's data is structured which is suitable for computer processing, with unstructured data like handwritten notes, untagged text, audio and video files growing at 15 times the rate of structured data. In the next 3 years, more than 1 billion smart phones will enter service, 400 million new tablets will connect to the Internet and there will be 1 billion active personal computers in the world. In healthcare, growth comes both from digitizing existing data and from generating new forms of data. The already daunting volume of existing healthcare data includes personal medical records, radiology images, clinical trial data, FDA submissions, human genetics and population data, genomic sequences. Newer forms of big byte data, such as 3D imaging, genomics and biometric sensor readings, are also fueling this exponential growth.

The volume of worldwide healthcare data in 2012 is 500 petabytes. That is estimated to grow in 2020 to 25,000 petabytes a fifty fold increase from 2012 to 2020. Advances in data management, particularly virtualization and cloud computing, are facilitating the development of platforms for more effective capture, storage and manipulation of large volumes of data. Storing information in the cloud for access by desktop PCs and mobile devices allows small devices and single locations to become windows into a universe of information. Many companies are working to further advance data management platforms and frameworks. This includes traditional IT vendors like IBM, Cisco Systems Inc., and Oracle Corporation; platform companies like Google Inc. and Amazon.com, Inc., open source groups like The Apache Software Foundation (Hadoop), The Linux Foundation, Mozilla Foundation and Corporation, plus a myriad of smaller organizations and individual developers. Four companies' data collected in this paper DNAnexus, Appistry, NextBio and Genome Health Solutions are building products and services that rely on and enable their customers to manage extreme data volumes.

VARIETY

The enormous variety of data—structured, unstructured and semi-structured—is a dimension that makes healthcare data both interesting and challenging. Historically, the point of care generated mostly unstructured data: office medical records, handwritten nurse and doctor notes, hospital admission and discharge records, paper prescriptions, radiograph films, MRI, CT and other images.
Structured data is data that can be easily stored, queried, recalled, analyzed and manipulated by machine (although humans may not so easily read or interpret them). Historically in healthcare, structured and semi-structured

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data include electronic accounting and billings, actuarial data, (some) clinical data, (some) laboratory instrument readings and data generated by the ongoing conversion of paper records to electronic health and medical records.

Already, new data streams, structured and unstructured, are cascading into the healthcare river from fitness devices, genetics and genomics, social media, research and other sources. Relatively little of this data can presently be captured, stored and organized so that they can be manipulated by computers and analyzed for useful information. Healthcare applications particularly need more efficient ways to combine and convert varieties of data, including automating conversion from structured to unstructured data.

The structured data in electronic medical records (EMRs) and electronic health records (EHRs) include familiar input record fields such as patient name, date of birth, address, physician's name, hospital name and address, treatment reimbursement codes, and other information easily coded into and handled by automated databases. The need to field-code data at the point of care for electronic handling is a major barrier to acceptance of EMRs by physicians and nurses, who lose the natural language ease of entry and understanding that handwritten notes provide. On the other hand, nearly all providers agree that an easy way to reduce prescription errors is to use digital entries rather than handwritten scripts.

IBM is an obvious instance of a big company tackling the problem of using varied data sets. Watson, with its unique natural language capabilities, is the primary example. Also in this paper's universe, Health Fidelity is using natural language processing to convert unstructured into structured data. Other companies dealing with data variety include Explorys, Practice Fusion, athenahealth Inc., Humedica, and One Health.

The potential of Big Data in healthcare lies in combining traditional data with new forms of data, both individually and on a population level. We are already seeing data sets from a multitude of sources support faster and more reliable research and discovery. If, for example, pharmaceutical developers can integrate population clinical data sets with genomics data, they may move closer to getting more and better drugs approved in the first place, and more importantly, to getting the right drug to the right patient at the right time.

VELOCITY

The constant flow of new data accumulating at unprecedented rates presents new challenges. Just as the volume and variety of data that is collected and stored has changed, so too has the velocity at which it is generated and the speed needed to retrieve, analyze, compare and make decisions using the output. The migration from checks to credit cards is a familiar example of the move from slow, batch-processed data handling to real-time data processing.

Most healthcare data has traditionally been quite static—paper files, X-ray films, scrips. But in some medical situations, real-time data (trauma monitoring for blood pressure, operating room monitors for anesthesia, bedside heart monitors, etc.) become a matter of life or death. In between are the medium-velocity data of multiple daily diabetic glucose measurements (or more continuous control by insulin pumps), blood pressure readings, and EKGs.

Future applications of real-time data in the ICU, such as detecting infections as early as possible, identifying them swiftly and applying the right treatments (not just broad-spectrum antibiotics), could reduce patient morbidity and mortality or even stop hospital outbreaks. Real-time streaming data can already monitor neonates in the ICU, to predict life-threatening infections sooner.19 Being able to perform real-time analytics against such high-volume data in motion could revolutionize healthcare. Medical device companies, like Baxter International, Boston Scientific Corporation, Hospira, Inc., Medtronic Inc., and Zoll Medical Corporation have been at the forefront of capturing and displaying real-time data in ambulances, operating rooms, hospitals, and increasingly, at home. Smaller companies such as Abiomed Inc., Alere Inc., and ResMed Inc. are particularly focused on home monitoring devices. Diagnostics is an arena where many new devices, techniques and algorithms are being developed, even if few have reached the market.

VERACITY

Traditional data management assumes that warehoused data is certain, clean, and precise. However, as anyone who has suffered bank, credit or insurance errors knows, data is sometimes uncertain, imprecise or just plain wrong. Data quality issues are a particular concern in healthcare for two reasons: 1. It matters—life or death decisions depend on having the information right. 2. The quality of healthcare data, especially unstructured data, is highly variable and all too often incorrect.

Unreadable handwritten prescriptions are perhaps the most infamous example. Veracity in healthcare data faces many of the same issues as in financial data, especially on the payer side: Is this the correct patient, hospital, payer, reimbursement code, dollar amount? Other veracity issues are unique to healthcare: Are diagnoses, treatments, prescriptions, procedures, outcomes correctly captured? Improving coordination of care, avoiding errors and reducing costs depend on high-quality data, as do advances in drug safety and efficacy, diagnostic accuracy and more precise targeting of disease processes by treatments. However, high Variety and Velocity hinder the ability to cleanse data before analyzing it and making decisions, raising issues of data "trust."

Underlying statistical issues bedevil large data sets, not just "garbage in, garbage out". The emergence of safety issues in marketed drugs that successfully completed large clinical trials shows that rare events may not be visible in any but the largest data sets. A deeper concern is the dawning realization that treatments targeting the average patient will, by definition, mistreat a significant portion of the population. The predictive value of analytic tools will not be realized if the data sets being analyzed are low quality or represent

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irrelevant measures. While many organizations are concerned with data quality in healthcare, they are focused on traditional IT issues, e.g., data management, warehousing, compliance, audit, fraud prevention,

DNAnexus offers a cloud-based, community-inspired, collaborative and scalable data technology platform that provides next-generation sequencing (NGS) data management, analysis, and visualization. Enables customers to store, manage, analyze, and visualize next-generation DNA sequencing (NGS) data through a web-based cloud service model.

Building a community-inspired cloud infrastructure from the ground up, to create a collaborative and scalable data platform.

Encryption, firewalls, and other safeguards support enterprise security and compliance with HIPAA, CLIA, and other regulations. Customers include research scientists and clinical research partners in pharma and biotech, as well as physicians using genomics in individual cases for diagnosis and treatment guidance.

Appistry Inc. adapts learning from FedEx and the Department of Defense to streamline the storage, management, analysis and interpretation of Big Data in genomics, including custom development.

Brings computation and storage together in a private cloud to improve the speed and performance of genetic analysis.

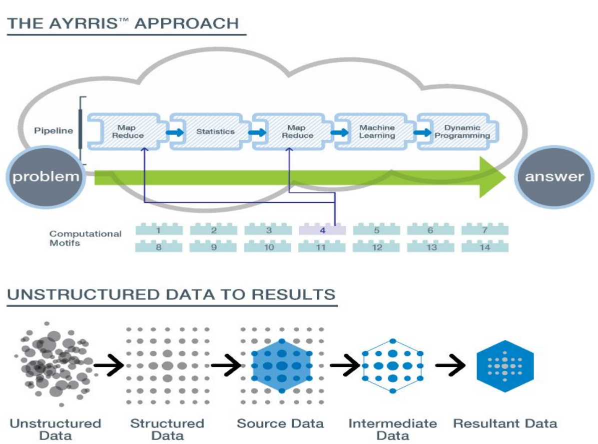

Fig 1: The Ayrris Approach

NextBio combines large public with private datasets to enable new -omics discoveries. Assembles vast amounts of curated and annotated clinical and molecular data enabling clients to make unique discoveries that would not be possible with their own private datasets alone.

Uses Big Data technology to make correlations between the billions of data points from the public domain with private genomic and clinical data sets.

DELIVERED AS SOFTWARE AS A SERVICE (SAAS)

A rich set of APIs enable clients to integrate NextBio within their workflows. Current clients include Pharmaceutical R&D and academic medical centers. Initial focus on oncology, now expanding into metabolic and autoimmune diseases.

Given the growing flood of healthcare data, and the late-adopting nature of the field, a big unmet need is to better manage this data. A key aspect is transforming data to usable information. Making unstructured data structured for machine management is an important stepping-stone to enabling data-driven healthcare.

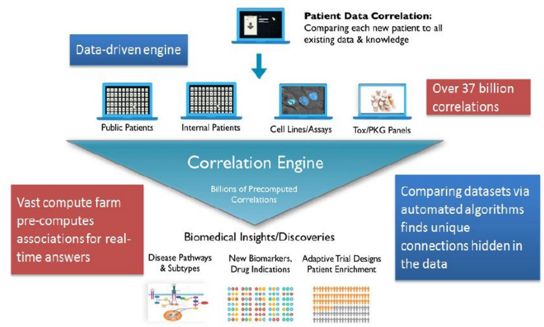

Fig 2: Data driven health care system

Predixion Software uses cloud-based predictive analytic software to explain patterns in hospital datasets to reduce readmissions and prevent hospital-acquired conditions. Pulls data from a variety of sources, using data mining, machine learning and mathematical algorithms to power predictions.

Current project is applying analytics to prevent MRSA infections and deaths in the hospital setting.
Working to use predictive analytics as a tool for prevention of chronic disease – e.g., diabetes.

Health Fidelity is using NLP to turn unstructured data (e.g., narrative medical records) into structured data suitable for computer management, to address needs in revenue cycle management, compliance, and analytics.

Fig 3: Cloud based Predictive software

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based on data mining, cluster analysis, statistics, data visualizations, artificial intelligence machines, text analytics, and Natural Language Processing (NLP) to mine data for patterns and meaning. Perhaps counter-intuitively, in some cases turning unstructured information (medical charts and provider notes) into data is a needed first step. Explanatory analytics uses a collection of tools

Health Fidelity's NLP technology converts complex and specialized medical narratives and breaks out critical content to make it available in real time. It runs multiple data streams in many formats—note types, domains, linguistic forms, jargon, grammatical relationships and contexts—through NLP for comprehensive data extraction.

This complex and unique process was initially funded by the National Institute of Health and National Science Foundation. Because of its roots in academia, there is already a broad range of peer-reviewed literature supporting the technology.

Clients include healthcare IT vendors that serve medical practices, provider networks, and large healthcare organizations.

Early use cases focus on revenue cycle management, (including ICD-10 conversion), compliance, (including meaningful use and accountable care), and analytics focused on cost reduction and quality improvement.

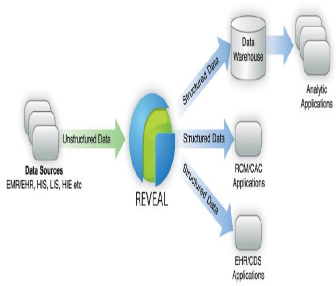

Fig 4: Unstructured to structure data

DATA SECURITY

In addition to privacy concerns all the companies interviewed were concerned about data security, unintentional exposure or loss of data to unauthorized parties. Use of the Internet, cloud computing and pooling of data all raise the data security stakes. Healthcare data contains the intimate details of a person's life and we must respect and protect it with the highest security possible.

CLOUD CHALLENGES IN HEALTHCARE

PRIVACY CHALLENGES

Privacy and security rank at the top of the list of reasons for slow adoption rates. Putting personalhealth information into a 3rd-party, remote data center raises red flags where patient privacy lawsare concerned. The possibility that patient data could be lost, misused or fall into the wrong hands affects adoption. What recourse does an organization have should a cloud provider lose data? It has happened, and it has the potential to be a very expensive problem to resolve. Violation of patient confidentiality carries heavy fines, including significant costs of recovery and patient notification.

A potential solution is a private cloud model. In this case the data still resides at the customer data center and a certain degree of control still exists for organizations to manage patient privacy. The organization can also ensure that the data center complies with certain standards, such as NIST 800-146 Cloud Computing Synopsis and Recommendations. This model may be more expensive, but security and privacy are more visible.

SECURITY CHALLENGES

This may be a moot point where healthcare providers are concerned. One of the benefits of cloud technology is the ability to access resources that would otherwise be unattainable. A cloud provider will have security experts deploying the latest patches and software to its data center. Secure access
to the physical property will be well guarded, and many policies, processes and mechanisms will be in place to ensure data security. Add to that the fact that any applications operating through the cloud will store all their data in the cloud. This means there is no protected health information (PHI) residing on hospital computers, which is a more secure situation than today's current environment.

Health and human services studies show that PHI violations have come from the theft of computers taken from facilities, loading docks and even physicians' vehicles. These thefts have been more for the computer and less for the PHI. This raises the question: Wouldn't it be better to have everything in the cloud?

WORKFLOW CHALLENGES

As it can be difficult to enact change throughout healthcare provider organizations, we may assume that adoption of a cloud model would present significant change management issue for providers. Current processes are often inefficient, relying on paper in many cases to manage patient care.

Any transition to a cloud would require significant support from the technology partners to ensure a smooth transition for users. Take for example, the current practice of requesting a diagnostic exam. A physician fills out a request form with patient details, history and reason for exam. This gets sent to the radiology department for scheduling. The clinical staff books the exam and informs the doctor, who advises the patient, who has a conflict with the appointment time. Back and forth it goes. Now, consider an electronic scheduling system based in the cloud, whereby the doctor enters all the relevant information and the system determines the most appropriate exam and notifies the patient directly of possible options. The patient logs in, selects the best time for the exam, and the system books the exam. It seems simple, but change management is required to ensure the transition is smooth.

As a part of this workflow transition, serious consideration should be given to staffing needs within the organization's IT department. As the cloud starts to permeate the clinical environment, no longer will the same skill sets be required. Different technology will need to be supported, new training will be required and new skill sets will need to be defined. An organization that had staff working on managing backups and archiving will now migrate to network connections and clinical applications. IT staff will focus on the rollout of the electronic medical record (EMR) instead of managing the storage layer the EMR sits upon. Access to this kind of skill set is in high demand today.

These challenges contribute to slow adoption of cloud technologies but should not stop cloud progress. Organizations are weighing the benefits against the risks. As more providers migrate to the cloud, we will see these challenges overcome with new and innovative solutions.

RESULTS

BENEFITS OF CLOUD ADOPTION FOR HEALTHCARE

While many challenges have contributed to slow adoption of the cloud, there are equally as many benefits for providers to embrace this new technology across the enterprise. These benefits encompass both business and clinical areas. In today's world of cost cutting, many facilities must show clinical benefit in order to justify expenditures, and the cloud technologies are potential tools to do just that.

CLINICAL BENEFITS

The single biggest clinical benefit that cloud technology can provide is access to applications that were previously unattainable. For example, the implementation of digital pathology, managed through cloud services, has a huge clinical impact on an organization. The organization can roll out a service that would have cost millions just for the storage alone, but now can pay for it as they useit. Access to pathologists who previously were reachable only near centers of excellence means thatremote facilities can offer new services to the local patient population, relying on remote experts torender their diagnoses. Patient care can be improved by providing this service through the cloudfaster and more efficiently. Since patients don't need to travel, waiting lists are more easily managed as more patients can have the same tests in more locations with a larger availability of experts.

These same experts can access patient data remotely and on demand through the Internet via avariety of connected devices. Physicians can review the latest diagnostic results from home and perhaps determine that the patient can be discharged immediately, rather than wait for their afternoon rounds.

Collaboration between researchers or physicians and allied health professionals suddenly becomes a reality, as patient information is centrally located and accessible to authorized users. Patient information is now being shared between caregivers, regardless of location, allowing for better-informed decisions.

BUSINESS BENEFITS

Obviously there must be some business benefit for a new technology to be adopted, or it won't be considered. Cloud technologies provide tremendous benefits that can contribute to the welfare of a provider organization. Healthcare providers are in the business of treating and caring for patients. They are not IT focused;their purchasing patterns indicate that investment into IT falls far below other industry standards. In many cases providers' IT staffs are stretched very thin, and other staff must assist. For example, in radiology it is often a medical technologist with a technical affinity but no formal technical background, who becomes the PACS administrator. The cloud offers providers the ability to access specific experts to manage and maintain their systems. A cloud provider will have a block storage expert, a network security expert, and an archiving and backup expert who will manage the different components. Providers need not build up these skill sets, but instead can, for example, focus on a clinical applications specialist for PACS who helps clinical users maximize the application. These experts can spend the time and effort to implement the best practices for each component, which ultimately delivers added benefit to the clinical users and their patients.

Today's purchasing environment usually works in cycles. A department will be given capital forthe next 5 years and then will need to reapply and compete for funds to continue to operate theirsystems. The cloud provides a way to manage the investments while guaranteeing that they cancontinue to operate.

Take the radiology example again. The department adds a new CT scanner and their data volumeincreases by 10%. Their storage is not scaled to handle this added volume, and so they will depletetheir available storage faster than expected. In a cloud model, the facility has access to the neededcapacity and performance to meet the demand of the new CT. This "unlimited" scalability allows for the IT department to meet the interests of various departments simultaneously and respond more quickly to changing needs. This model lowers the barriers for adoption of innovative new technologies and helps to address the massive overhaul and modernization needs in healthcare.

Cloud models provide transaction-based pricing. As a facility uses more storage, they pay for it. Traditional capital models mean that the storage purchased in year 1 sits mainly idle waiting for data to be captured. The ROI is low as utilization rates are very low to start. With cloud technologies, utilization rates are 100% from the start. And the cloud provider is responsible for maintaining the hardware. For example, by year 5, cloud technology has probably been refreshed by the cloud provider, while in the traditional scenario the organization would be looking to replace the capital equipment and migrate the data: a costly proposition. Cloud technology shifts the paradigm for the delivery of healthcare. Consistent delivery of IT services and scalable hardware and software on a pay-per-use model enables healthcare providers to focus on what they really should be focused on: effective delivery of patient care.

BENEFITS OF CLOUD COMPUTING FOR HEALTHCARE

"Patient centricity" has become the key trend in healthcare provisioning and is leading to the steady growth in adoption of electronic medical records (EMR), electronic health records (EHR), personal health records (PHR), and technologies related to integrated care, patient safety, pointof- care access to demographic and clinical information, and clinical decision support. Availability of data, irrespective of the location of the patient and the clinician, has become the key to both patient satisfaction and improved clinical outcomes. Cloud technologies can significantly facilitate this trend.
Cloud computing offers significant benefits to the healthcare sector: doctor's clinics, hospitals, and health clinics require quick access to computing and large storage facilities which are not provided in the traditional settings. Moreover, healthcare data needs to be shared across various settings and geographies which further burden the healthcare provider and the patient causing significant delay in treatment and loss of time. Cloud caters to all these requirements thus providing the healthcare organizations an incredible opportunity to improve services to their customers, the patients, to share information more easily than ever before, and improve operational efficiency at the same time.

CLINICAL RESEARCH

Many pharmacology vendors are starting to tap the cloud to improve research and drug development. The 'explosion of data' from next generation sequencing as well as the growing importance of biologics in the research process is making cloud-based computing "an increasingly important aspect of R&D". Currently, pharma firms do not have the capacity to run large datasets – especially DNA sequencing - as the size of the data can overwhelm their computers. Commercial cloud vendors have developed pharma-specific clinical research cloud offerings with the goal of lowering the cost and development of new drugs.

Electronic Medical Records. Hospitals and physicians are starting to see cloud-based medical records and medical image archiving services coming on line. The objective is to offload a burdensome task from hospital IT departments and allow them to focus on supporting other imperatives such as EMR adoption and improved clinical support systems. Collaboration solutions. Early successes of cloud-based physician collaboration solutions such as remote video conference physician visits are being trialed. Extending such offerings to a mobile environment for rural telehealth or disaster response is becoming more real with broader wireless broadband and smartphone adoption. Cloud technology supports collaboration and team-based care delivery and the ability to use applications based on business model requirements and a common set of clinical information.

CONCLUSION

With the increase in availability of mobile technologies and intelligent medical devices, telemedicine has grown to include not only tele-consultations and telesurgeries, but also health record exchange, video-conferencing, and home monitoring. Cloud computing and the related ease of services deployment and data storage is an enabler for telemedicine.
Healthcare organizations turn to cloud computing to save on the costs of storing hardware locally. The cloud holds big data sets for EHRs, radiology images and genomic data for clinical drug trials. Attempting to share EHRs among facilities in various geographic areas without the benefits of cloud storage could delay treatment of patients.

Cloud computing facilitates practice and population scale information and insights are available in near real-time. This availability ensures that the most current, complete insights and clinical knowledge are available to support care provider decisions and to enable a focus on value creation related to improving outcomes rather than consumption. Information contained within a cloud can also be better analyzed and tracked (with the proper information governance) so that data on treatments, costs, performance, and effectiveness studies can be analyzed and acted upon. Information can be harvested and repurposed for more appropriate referrals and medical research to support the promise of personalized health and care.

Health information exchanges help healthcare organizations to share data contained in largely proprietary EHR systems. CIOs may accelerate the deployment of HIE via a linkage to a strategic cloud implementation.

Healthcare organizations continue to depend on computer systems that are extremely vulnerable to data breaches caused by technology deficiencies, theft and insider misconduct. Cloud-computing systems can be designed to be safer than traditional client-server systems against the prevailing causes of healthcare data breaches. But while adoption of cloud computing is growing in healthcare, the vast majority of hospitals and healthcare systems still use client-server systems, almost universally for enterprise-wide electronic medical records. These systems center on local servers, usually housed in poorly-secured server rooms, directly accessed by desktop computers and laptops scattered throughout the enterprise. Patient health data is routinely downloaded and uploaded back and forth from desktop and laptop computers to the local servers.
A web-based secure private cloud also better addresses the insider threat to patient data from disgruntled employees – or even larcenous employees – or from patient-record snoopers and human error, the simplest of which can lead to disastrous results. The security differences between secure private cloud and client-server systems come down to the proximity of sensitive data to those who might misuse it, the number of people who have access and the number and safety of access portals.

By consolidating applications on shared infrastructure, there is an opportunity to share security controls, including overall penetration testing for web-based applications.

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