



What's Next for Infrastructure? The Future of Code-Driven Healthcare

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Abstract: The rapid evolution of healthcare technology has ushered in an era where infrastructure plays a pivotal role in transforming patient care and operational efficiency. As we reflect on the past decade, it's clear that the shift towards code-driven healthcare has fundamentally altered the landscape. With the advent of cloud computing, artificial intelligence, and data analytics, healthcare providers have begun to harness the power of infrastructure-as-code, allowing for more agile, scalable, and secure systems. This transition streamlines processes and enhances collaboration among multidisciplinary teams, ultimately improving patient outcomes. Moreover, the increasing reliance on electronic health records (EHRs) and telemedicine has underscored the necessity for robust, interoperable infrastructure that can adapt to the demands of modern healthcare delivery. The rise of DevOps practices within healthcare organizations has fostered a culture of continuous improvement and innovation, breaking down silos that once hindered progress. As we look to the future, the challenge will be to navigate the complexities of regulatory compliance and cybersecurity while ensuring that technology serves the needs of both providers and patients. Integrating advanced analytics and machine learning algorithms into healthcare infrastructure promises to revolutionize predictive modelling and personalized medicine, enabling a shift from reactive to proactive care. In this context, understanding the future of infrastructure in healthcare is crucial; it requires a commitment to embracing new technologies while prioritizing ethical considerations and patient privacy. As we stand on the brink of this new frontier, the question remains: how can we leverage code-driven approaches to enhance operational efficiency and truly transform the healthcare experience for all?

Keywords: Code-driven infrastructure, healthcare technology, cloud computing, DevOps, Kubernetes, patient care, data management, regulatory compliance, interoperability, artificial intelligence, machine learning, telehealth, remote monitoring, automation, data-driven decision-making, operational efficiency, healthcare innovation.

1. Introduction

The healthcare landscape is experiencing a significant shift, driven by rapid technological advancements & an increasing demand for better patient outcomes. As healthcare organizations navigate this evolving environment, they are compelled to rethink traditional models of care delivery & operational efficiency. The result is a growing interest in code-driven infrastructure an innovative approach that leverages automation, cloud computing, and data analytics to transform the way healthcare is delivered and managed. At its core, code-driven infrastructure involves managing IT resources through code and automation. This practice not only enhances agility and scalability but also promotes reliability in operations a critical consideration in the healthcare sector. With patient safety & compliance with strict regulatory frameworks at stake, the ability to adapt quickly while ensuring robust security measures is essential. Code-driven infrastructure offers healthcare organizations a pathway to achieve this delicate balance.

The rise of cloud computing has played a pivotal role in facilitating the shift toward code-driven infrastructure. By enabling the storage and processing of vast amounts of data, cloud technologies empower healthcare providers to harness real-time information. This capability is crucial for making informed decisions, optimizing workflows, and delivering personalized care to patients. Additionally, the scalability of cloud services allows organizations to respond swiftly to changing demands, whether it's accommodating a surge in patients or integrating new technologies.

Another vital component of this transformation is the adoption of DevOps practices. By fostering a culture of collaboration between development and operations teams, DevOps enhances the speed & quality of software delivery. In healthcare, where timely access to information can significantly impact patient outcomes, the ability to deploy updates and innovations rapidly is invaluable. DevOps not only streamlines the development process but also encourages a mindset focused on continuous improvement a principle that aligns perfectly with the healthcare industry's commitment to excellence. Orchestration tools like Kubernetes further amplify the benefits of code-driven infrastructure by enabling the efficient management of containerized applications.

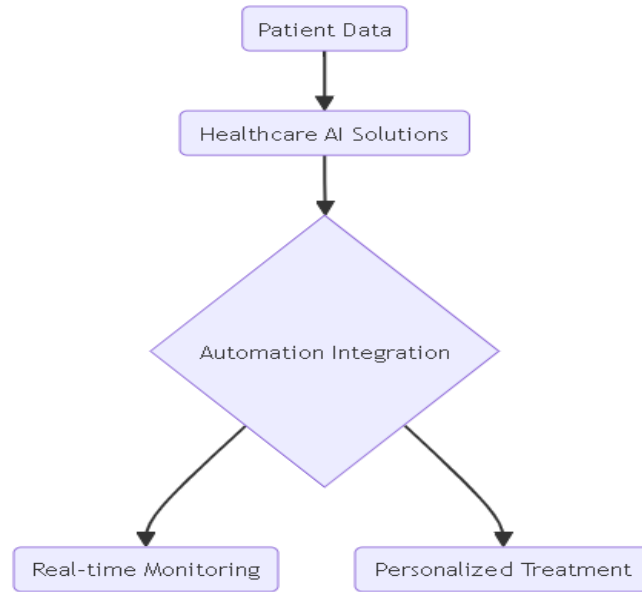


Figure 1: Code-driven infrastructure

With Kubernetes, healthcare organizations can automate the deployment, scaling, & operation of applications across diverse environments. This capability is particularly beneficial in managing complex healthcare systems, where multiple applications and services must work together seamlessly to deliver cohesive patient care. By embracing Kubernetes and similar tools, healthcare providers can enhance their operational efficiency, reduce downtime, and improve the overall patient experience. However, the transition to a code-driven infrastructure is not without its challenges. Healthcare organizations must navigate a landscape characterized by stringent regulatory requirements, data privacy concerns, & the need for interoperability among disparate systems. Achieving compliance while embracing new technologies can be daunting, but it is essential for ensuring that patient data remains secure and accessible.

Despite these challenges, the opportunities presented by code-driven infrastructure are immense. By automating routine tasks and leveraging data analytics, healthcare providers can free up valuable resources, allowing clinicians to focus on what they do best caring for patients. The integration of AI and machine learning into healthcare processes promises to further enhance decision-making, enabling providers to deliver personalized care that meets the unique needs of each patient. As we look to the future, it is clear that code-driven infrastructure will play a critical role in shaping the healthcare landscape. By embracing technologies that promote agility, collaboration, and innovation, healthcare organizations can position themselves to thrive in an increasingly complex and competitive environment. The journey toward a more efficient, data-driven, and patient-centered healthcare system is just beginning, and the possibilities are boundless.

2. The Current State of Healthcare IT Infrastructure

The landscape of healthcare IT infrastructure has evolved significantly over the years, yet many organizations still grapple with challenges stemming from outdated systems & processes. This section delves into the current state of healthcare IT infrastructure, highlighting the persistent issues posed by legacy systems, the transformative impact of cloud computing, and the burgeoning trend of code-driven infrastructure.

2.1 Legacy Systems and Their Limitations

For decades, healthcare organizations have relied on legacy IT systems that were often designed without the foresight to accommodate the rapid changes in technology and healthcare delivery. These systems are notorious for being fragmented and siloed, meaning they typically operate independently and do not communicate well with each other. This lack of interoperability creates significant hurdles in accessing and sharing patient data. For healthcare providers, this means spending extra time and effort to gather necessary information from disparate systems, which can ultimately lead to delays in patient care. Maintaining and upgrading these legacy systems can be prohibitively expensive. Organizations often find themselves in a cycle of costly repairs and incremental updates, leaving them with technology that is outdated & inefficient. This not only strains budgets but also diverts resources away from patient care and innovation. Additionally, the rigidity of these systems makes it difficult for organizations to

adapt to the evolving needs of patients and healthcare regulations, stifling their ability to implement new technologies and processes.

2.2 The Rise of Cloud Computing

In recent years, the advent of cloud computing has begun to reshape the way healthcare organizations approach their IT infrastructure. By migrating to the cloud, providers can access scalable resources that adjust to their needs, significantly reducing the need for physical hardware. This flexibility not only lowers costs but also enables organizations to allocate resources more efficiently, allowing them to focus on delivering quality care rather than managing complex IT systems. Cloud solutions have also fostered enhanced collaboration among healthcare teams. With data and applications accessible from anywhere, clinicians can share information and insights in real time, improving coordination & ultimately leading to better patient outcomes. Moreover, the cloud facilitates the implementation of advanced analytics & machine learning, enabling healthcare organizations to harness their data more effectively. By analyzing vast amounts of information, providers can uncover patterns & trends that inform clinical decision-making, streamline operations, and enhance patient engagement.

2.3 The Shift to Code-Driven Infrastructure

As healthcare organizations begin to recognize the limitations of traditional infrastructure, there is a noticeable shift towards code-driven approaches, particularly the adoption of Infrastructure as Code (IaC). This paradigm shift allows healthcare providers to define and manage their IT infrastructure through code, automating tasks related to provisioning, configuration, and management. By embracing IaC, organizations can achieve greater agility in their operations. Automated processes reduce the risk of human error, streamline workflows, & accelerate the deployment of new applications and services. This is particularly crucial in healthcare, where timely access to information can directly impact patient outcomes. The move towards a code-driven infrastructure also aligns with the increasing demand for innovation in healthcare. As organizations adopt more agile practices, they can experiment with new technologies & methodologies without the burden of lengthy deployment cycles or complex manual processes. This flexibility empowers healthcare providers to respond more effectively to changing patient needs and emerging industry trends, ultimately driving improvements in care delivery.

3. Key Technologies Shaping Code-Driven Healthcare

The healthcare landscape is rapidly evolving, and at the forefront of this transformation is the concept of code-driven healthcare. By leveraging innovative technologies and practices, healthcare organizations are reshaping how they deliver care, manage resources, and engage with patients. In this section, we'll explore three key technologies that are instrumental in driving this change: Kubernetes and containerization, DevOps practices, and data management and analytics.



Figure 2: Shaping Code-Driven Healthcare

3.1 Kubernetes and Containerization

Kubernetes has quickly become the go-to solution for container orchestration, and its impact on healthcare is profound. The platform allows organizations to manage, deploy, and scale applications seamlessly, making it a game-changer for healthcare providers facing the ever-increasing demands of patient care.

- **Fault Tolerance**

In an industry where every second counts, system resilience is non-negotiable. Kubernetes enhances fault tolerance by automatically managing and restarting containerized applications if they fail. This means that in the event of a server issue or application error, healthcare providers can maintain continuity of care with minimal disruption. The ability to recover quickly not only protects patient safety but also builds trust in the healthcare system.

- **Microservices Architecture**

Kubernetes also facilitates the development of microservices, which is particularly advantageous for healthcare organizations looking to innovate without risking widespread outages. By breaking down applications into smaller,

independent services, teams can update and deploy features without affecting the entire system. This modular approach fosters agility, enabling healthcare providers to experiment with new technologies and improve their services more rapidly.

- **Scalability**

One of Kubernetes' standout features is its ability to scale applications dynamically. For healthcare organizations, this means they can adjust resources in real-time, responding to fluctuating patient volumes without compromising service quality. Imagine a scenario where a hospital's patient intake surges during a flu outbreak; Kubernetes enables the rapid scaling of applications and resources to meet this sudden demand, ensuring that healthcare providers can deliver timely care without bottlenecks.

3.2 DevOps Practices in Healthcare

The integration of DevOps practices is vital for healthcare organizations striving to implement a code-driven approach effectively. By bridging the gap between development and operations, DevOps fosters a culture of collaboration and efficiency, which is crucial in the fast-paced world of healthcare.

- **Infrastructure as Code (IaC)**

Infrastructure as Code (IaC) is another key component of DevOps that empowers healthcare organizations to manage their infrastructure through code. This practice not only enhances consistency and repeatability but also provides version control over infrastructure configurations. When changes need to be made such as deploying a new application or updating existing systems IaC allows teams to execute those changes reliably and efficiently. This level of control is especially crucial in healthcare, where compliance and security are paramount.

- **Monitoring and Feedback Loops**

DevOps emphasizes the importance of real-time monitoring and feedback loops. By continuously observing application performance and user experiences, healthcare organizations can identify and address issues promptly. This proactive approach is essential in preventing disruptions that could negatively impact patient care. For example, if a scheduling application starts experiencing lag, real-time monitoring allows IT teams to pinpoint the problem and implement a solution before it affects healthcare providers or patients.

- **Continuous Integration and Delivery (CI/CD)**

At the heart of DevOps is the principle of continuous integration and delivery (CI/CD). By automating testing and deployment processes, healthcare organizations can release new features and updates at an accelerated pace. This rapid iteration allows providers to respond to the evolving needs of patients and healthcare professionals alike. For instance, if a new regulatory requirement emerges, CI/CD pipelines enable teams to swiftly adapt their software solutions without extensive downtime.

3.3 Data Management and Analytics

In the realm of code-driven healthcare, effective data management and analytics are fundamental to improving patient outcomes and enhancing the overall quality of care. As healthcare organizations accumulate vast amounts of data, the ability to analyze and leverage this information becomes increasingly critical.

- **Identify Trends**

Through advanced analytics tools, healthcare providers can sift through large datasets to identify trends that inform better decision-making. For instance, by analyzing patient data over time, providers can uncover patterns related to treatment efficacy, disease prevalence, and patient demographics. These insights enable healthcare professionals to make more informed choices, ultimately leading to improved patient care and resource allocation.

- **Predictive Analytics**

Predictive analytics is another powerful application of data in healthcare. By employing machine learning algorithms, organizations can anticipate patient outcomes and optimize resource allocation. For example, predictive models can identify patients at high risk for readmission, allowing healthcare providers to implement preventative measures and allocate resources effectively. This proactive approach enhances patient care while also reducing costs and improving operational efficiency.

- **Personalize Treatment**

Data-driven insights also pave the way for personalized treatment plans tailored to individual patients. By leveraging analytics, healthcare organizations can analyze a patient's medical history, genetic information, and lifestyle factors to create customized treatment strategies. This approach not only enhances patient satisfaction but also improves health outcomes, as treatments are designed to meet the specific needs of each individual.

4. Challenges and Considerations

As healthcare organizations navigate the transition to code-driven infrastructure, several challenges and considerations must be addressed to ensure successful implementation and long-term sustainability. From regulatory compliance to data security, and interoperability, these factors are crucial for building a resilient and effective healthcare ecosystem.

4.1 Regulatory Compliance

In the ever-evolving landscape of healthcare, regulatory compliance is a foundational element that organizations must prioritize. Regulations like the Health Insurance Portability and Accountability Act (HIPAA) in the United States are designed to safeguard patient information, but they also impose significant obligations on healthcare providers. To ensure compliance, organizations need to implement robust security measures tailored to their unique environments. This might involve deploying encryption protocols to protect sensitive data both at rest and in transit. Access controls play a critical role as well, restricting access to patient information to only those who need it to perform their jobs. Regular security audits are another vital component of a compliance strategy, helping organizations stay ahead of potential vulnerabilities and demonstrating their commitment to safeguarding patient data.

When integrating code-driven infrastructure, organizations face the challenge of aligning their digital initiatives with these stringent compliance requirements. This process often involves conducting comprehensive assessments of existing systems and practices to identify potential gaps in compliance. It is crucial to have a deep understanding of the regulations that govern patient data, which can vary not only by country but also by state and locality. Furthermore, fostering a culture of compliance within the organization is essential. Staff training on regulatory requirements and the importance of data privacy can significantly reduce the risk of unintentional breaches. By integrating compliance into the organization's ethos, healthcare providers can ensure that everyone understands their role in protecting patient information and maintaining trust.

4.2 Data Security and Privacy

As healthcare organizations increasingly rely on digital solutions, the urgency of addressing data security and privacy concerns cannot be overstated. With the proliferation of electronic health records (EHRs) and other digital tools, the risk of data breaches and cyberattacks has surged, threatening not only patient privacy but also the integrity of healthcare operations. Regular security audits should also be a cornerstone of any data protection strategy. These audits help organizations identify vulnerabilities in their systems and assess the effectiveness of their security measures. In addition to technical safeguards, fostering a culture of security awareness among staff is vital. Training programs that educate employees about the risks of phishing attacks, social engineering, and other cyber threats can empower them to be vigilant and proactive in safeguarding patient data.

To mitigate these risks, organizations must adopt a multi-faceted approach to security. This includes the implementation of advanced security protocols such as end-to-end encryption, which ensures that data is protected from unauthorized access throughout its lifecycle. Access controls are equally important; by ensuring that only authorized personnel can access sensitive information, organizations can significantly reduce the likelihood of internal threats. Moreover, healthcare organizations must remain agile and adaptive in the face of evolving cyber threats. This means staying informed about the latest cybersecurity trends and investing in advanced security technologies. Implementing incident response plans can also ensure that organizations are prepared to respond swiftly and effectively in the event of a data breach, minimizing potential damage and maintaining patient trust.

4.3 Interoperability Challenges

One of the most significant hurdles in transitioning to a code-driven healthcare environment is the challenge of interoperability. Healthcare organizations often rely on a myriad of systems and applications, each with its own data standards and protocols. This fragmentation can hinder effective communication and data sharing, leading to inefficiencies and potential gaps in patient care. Investing in interoperability solutions not only improves operational efficiency but also enhances patient outcomes. For instance, when healthcare providers can easily share patient data, they can better track patient histories, medications, and treatment plans, resulting in more coordinated and personalized care. Furthermore, interoperability can empower patients by giving them greater access to their own health information, allowing them to engage more actively in their care.

However, achieving true interoperability requires collaboration among stakeholders, including healthcare providers, technology vendors, and regulatory bodies. Open dialogue and partnerships can facilitate the development of solutions that meet the needs of all parties involved. It is essential for organizations to advocate for and participate in industry-wide initiatives aimed at improving interoperability standards and practices. To overcome interoperability challenges, organizations should prioritize the adoption of open standards and application programming interfaces (APIs). By using standardized formats for data exchange, healthcare providers can facilitate seamless communication between disparate systems. This is particularly crucial for care

coordination, as it enables healthcare teams to access comprehensive patient information from various sources, ultimately leading to better-informed clinical decisions.

5. The Future of Code-Driven Healthcare

The healthcare landscape is undergoing a seismic shift as we move toward a more code-driven future. This evolution is not just about integrating technology into existing practices; it represents a fundamental change in how care is delivered, managed, and experienced. With advancements in artificial intelligence (AI), machine learning (ML), telehealth, and a culture of innovation, the potential for improved patient outcomes and more efficient healthcare systems is immense.

5.1 Embracing Artificial Intelligence and Machine Learning

At the forefront of this transformation are artificial intelligence and machine learning. These technologies are no longer confined to the realm of science fiction; they are actively shaping the future of healthcare. By harnessing the power of AI and ML, healthcare organizations can automate routine tasks, enhance diagnostic accuracy, and ultimately improve treatment outcomes. Consider the potential of AI algorithms in analyzing medical images. Radiologists often face an overwhelming volume of scans, which can lead to fatigue and oversight. AI can assist in this process by quickly identifying anomalies that might be missed by the human eye, thus facilitating early disease detection. For instance, AI models have shown remarkable success in detecting cancers in mammograms and identifying signs of diabetic retinopathy in retinal images. The result is not just faster diagnosis but also the potential for earlier intervention, which can significantly improve prognosis. Moreover, AI can provide decision support to clinicians, synthesizing vast amounts of data from patient records, clinical guidelines, and the latest research. By presenting relevant information and recommendations at the point of care, these systems empower healthcare providers to make informed decisions more quickly. This not only enhances the quality of care but also helps to alleviate the cognitive load on physicians, allowing them to focus on patient interaction and complex decision-making.

5.2 Enhancing Telehealth and Remote Monitoring

The acceleration of telehealth services, particularly spurred by the global pandemic, has demonstrated the power of technology in expanding access to healthcare. Patients can now receive consultations and follow-up care from the comfort of their homes, breaking down geographical barriers and improving convenience. As code-driven infrastructure continues to evolve, healthcare organizations are likely to further embrace telehealth and remote monitoring solutions. Remote monitoring devices can track patients' vital signs and health metrics in real-time, allowing for timely interventions before issues escalate. This proactive approach not only enhances patient outcomes but also reduces the burden on emergency services and hospitals. Telehealth platforms are becoming increasingly sophisticated, integrating with electronic health records (EHRs) to provide a seamless experience for both patients and providers.

These systems allow for efficient appointment scheduling, prescription management, and secure messaging, fostering better communication between patients and their healthcare teams. This convenience can lead to increased patient engagement and adherence to treatment plans, ultimately contributing to improved health outcomes. Furthermore, as more patients become comfortable with virtual care, the scope of telehealth can expand beyond basic consultations. Specialists can reach a wider audience, and multidisciplinary teams can collaborate more effectively, regardless of location. This shift not only enhances the efficiency of care delivery but also democratizes access to specialized services that were once limited to urban centers.

5.3 Fostering a Culture of Innovation

To truly capitalize on the advancements of code-driven healthcare, organizations must foster a culture of innovation. This cultural shift involves encouraging experimentation and embracing change at all levels of the organization. By prioritizing innovation, healthcare providers can adapt to the rapidly evolving landscape and find creative solutions to the challenges they face. Investing in staff training is essential for fostering this culture. Employees need to feel empowered to explore new technologies and approaches, which can be achieved through ongoing education and support. This might include workshops on the latest AI tools, training sessions on telehealth best practices, or hackathons to brainstorm innovative solutions to specific healthcare problems. Cross-functional collaboration is also key. When individuals from various disciplines come together to tackle challenges, they bring diverse perspectives and ideas to the table. This collaborative approach can lead to groundbreaking innovations that enhance patient care and streamline operations.

Healthcare providers can establish multidisciplinary teams that focus on specific initiatives, encouraging communication and teamwork across departments. Creating an environment where new ideas can flourish is paramount. Leadership plays a crucial role in this endeavor by actively encouraging staff to voice their ideas and suggestions. Recognizing and rewarding innovative thinking can motivate teams to push boundaries and explore uncharted territories in healthcare. By empowering teams to think creatively and take calculated risks, healthcare organizations can drive continuous improvement. This culture of innovation not

only enhances the quality of care but also attracts top talent who are eager to work in an environment that values forward-thinking solutions.

6. Conclusion

The landscape of healthcare is on the brink of a transformation, fueled by the rapid advancement of technology. As we look toward the future, it becomes increasingly clear that the integration of code-driven solutions will redefine how care is delivered, how organizations operate, and how patients experience healthcare. By harnessing the power of automation, data analytics, and innovative infrastructure models, healthcare providers stand to enhance their capabilities and improve patient outcomes. Kubernetes has emerged as a game-changer in managing containerized applications, providing a robust framework for deploying, scaling, and managing applications in a cloud-native environment. Its orchestration capabilities allow healthcare organizations to deploy updates quickly and efficiently, ensuring that providers can leverage the latest tools and technologies without disrupting patient care. The agility afforded by Kubernetes empowers healthcare teams to respond to changing demands and innovate rapidly, which is essential in a field that is continually evolving.

The move toward a code-driven healthcare ecosystem is marked by several key trends and technological shifts. One of the most significant developments is the widespread adoption of cloud computing. By migrating data and applications to the cloud, healthcare organizations can benefit from scalability, flexibility, and cost-effectiveness. This shift not only streamlines operations but also enables providers to access and share critical information across departments and with other organizations. In an era where timely decision-making can mean the difference between life and death, having real-time access to patient data is invaluable. DevOps practices are also gaining traction in the healthcare sector, fostering a culture of collaboration between development and operations teams. This cultural shift encourages continuous improvement and encourages organizations to break down silos that often hinder innovation. By adopting a DevOps approach, healthcare providers can streamline processes, reduce time-to-market for new applications, and ultimately deliver better patient experiences. The synergy created by integrating development and operations fosters an environment where innovation thrives, and patient care is paramount.

Data security is particularly critical as healthcare organizations become increasingly reliant on digital solutions. With cyberattacks on the rise, safeguarding patient data must be a top priority. Implementing robust security protocols, conducting regular audits, and training staff on best practices are essential steps in creating a secure environment. By prioritizing data security, healthcare organizations can build trust with patients and ensure that their information remains confidential. However, the journey toward a code-driven healthcare landscape is not without obstacles. As organizations adopt new technologies, they must remain vigilant about regulatory compliance, data security, and interoperability. The healthcare sector is governed by a complex web of regulations designed to protect patient information, and organizations must navigate these challenges carefully. Balancing innovation with compliance will require healthcare providers to prioritize security measures and build infrastructure that is resilient against cyber threats. Interoperability also poses a significant challenge in the code-driven healthcare landscape. For organizations to truly harness the power of data, systems must be able to communicate seamlessly with one another. This requires a concerted effort to adopt standardized protocols and invest in technologies that promote interoperability.

When systems can exchange information effortlessly, care providers can make informed decisions based on a holistic view of the patient, ultimately improving the quality of care. Patient-centric solutions must remain at the forefront of this transformation. The shift toward code-driven healthcare should be guided by the primary goal of enhancing the patient experience. Telehealth services, remote monitoring, and patient engagement platforms are just a few examples of how technology can empower patients to take control of their health. By prioritizing patient needs and preferences, healthcare organizations can cultivate a more positive and empowering healthcare experience. Despite these challenges, the future of infrastructure in healthcare is undeniably bright. By embracing innovation and fostering collaboration, healthcare organizations can position themselves as leaders in the code-driven landscape. The potential to leverage data-driven insights to improve patient outcomes is immense. For instance, predictive analytics can identify at-risk patients, enabling proactive interventions that can prevent complications and reduce hospital readmissions. Moreover, personalized medicine can become a reality as healthcare providers harness data to tailor treatments to individual patient needs.

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