Deep Science Publishing
https://doi.org/10.70593/978-93-49307-36-0_12

DeepScience
Open Access Books

Chapter 12: The future of smart hospitals and digital clinics powered by scalable artificial intelligence infrastructure

12.1. Introduction

One way to unlock the transformative potential of industrial artificial intelligence is to build a cooperative and accessible structure that facilitates the creation of novel and versatile AI models, allowing a broad range of stakeholders to benefit. Such a facility is described, which permits the effective development and execution of medical information research projects, as well as the assessment of the resulting AI models' generalizability. A healthcare AI information acquisition framework was used to create a scalable research consortium that may facilitate the development and distribution of AI technologies. Requirements to safeguard patient privacy, manage data effectively, and adhere to institutional standards while enabling a seamless and productive workflow are reviewed. In conjunction with the systematic treatment of clinical data, a broad collection of clinical data translation automation pipelines was produced. To support various research projects, these sources are unified under a general platform, which guarantees the coordinated management of all informed activities. Artificial intelligence (AI) applications in healthcare are committed to advancing patient safety, fostering cooperation with professionals and improving patient outcomes. There are currently existing AI technologies that can be combined with medical professionals to help the diagnosis and procedure of ill health, forecast and stratify risks and enhance patient and clinician productivity effectively. AI technology research devoted to information transparency, data science involvement and patient need conditions on confidentiality is increasing. With the Health Information Technology for Economic and Clinical Health Act in 2009, numerous services have adopted electronic health records (EHRs) that offer a wealthy provider of security data. Nevertheless, the bulk of EHR programs still shop patient records in heterogeneous frameworks often combined with previous models. Likewise, there is a lot of published but complex, difficult to implement and effective documentation. The study aims to provide a scalable, collaborative and resource-effective framework for acquiring and transforming clinical information through the machine-learning-ready creation of datasets.

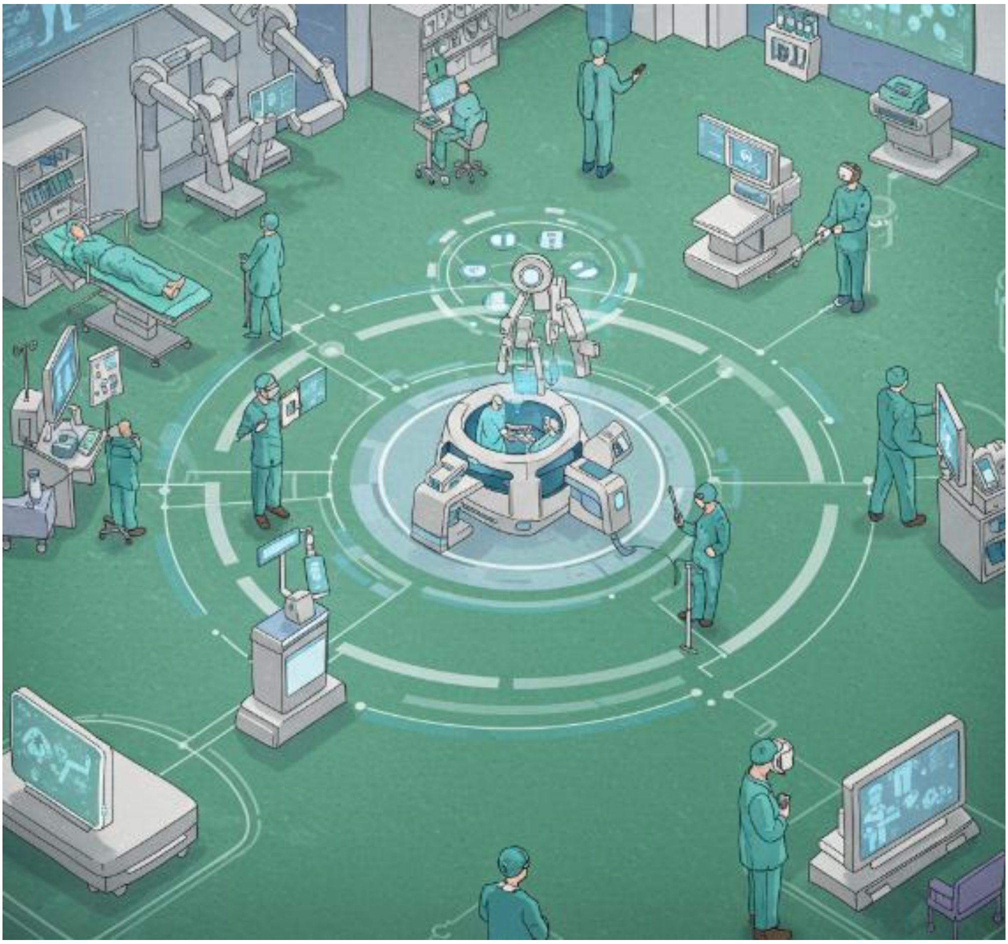

Fig 12.1: Smart Hospital infrastructure

12.2. Digital Clinics: A New Paradigm

Digital clinics represent a transformative approach to providing healthcare services. Currently, it is mostly utilized for remote consultations and digitally equipped walk-in clinics. Still, a fully developed digital clinic has yet to exist. The conceptual framework of digital clinics is, therefore, provided, and its distinguishing features are outlined.

Core features that make up digital clinics are accessibility, convenience, and a shift from doctor-centered towards patient-centered care. This conceptual advice is to be taken as an inspiration for the development of various digital forms of health care facilities in order to accelerate the digitalization of health services and put patients at their center. The most important services that should be integrated are vaccination centers, pharmacies that are connected to artificial intelligence systems, remote operation facilities, and telehealth hubs (digital clinics) with virtual specialists provided by high-speed network infrastructure. Through this, enhanced healthcare access to suburban and remote areas can be achieved, and the local workload at hospital facilities can be relieved as well.

Given these core features, digital clinics are to be filled with various innovative patient engagement strategies that allow patients to take a more informed role in their healthcare. Patients are offered colossal self-diagnosis kiosks that facilitate tracking common health indicators and peculiar incident rates. Sick patients can get immediate online consultations with a virtual general physician inside the kiosk. Such treatment is covered by national insurance that can relieve the immediate workload on district doctors' offices. The prevention of chronic disease management and remote outpatients care services covered by AI avatar doctors are continuously offered. Mobile healthcare applications, in-app appointments, and prescriptions issuance allow patients to take full advantage of the treatment process.

Patient experiences are tailored to demographic factors, previous health issues, and experience preferences. So, when patients step into the clinic, they feel as if they are immersed in a health retreat designed just for them: healthy tea pots are embedded in the walls, personalized health-related artwork is scrolling on screens, and a specific warm light type soothes patients. Designed numerous engagement strategies allow for valuable interaction between patients and health providers. Over time and with widespread implementation, such clinics have the potential to revolutionize patient care paradigms. A future care clinic is envisioned that can better diagnose specific symptoms and diseases than human generalists, while outperforming specialists in their diagnostic domain.

12.2.1. Concept and Features

The concept of digital clinics is defined as units within hospitals that are equipped to deliver comprehensive care using telehealth devices and communication software. As a transitional healthcare facility between smart pharmacies and smart homes, a digital clinic is conceptualized as a shared space operated through a subscription model. A digital clinic features are discussed regarding its form factor, intended services, and operational processes. Smart healthcare devices for diagnosis, treatment, and surgeries are also highlighted as facilitators to form the foundation of a smart hospital. The pandemic helps to drive the advancement of smart hospitals. Moreover, smart hospitals and digital clinics can leverage traditional infrastructure in a scalable manner and are not limited to a single facility or brand. Finally, it is expected that the built smart hospital and digital clinic will serve as a good counterpart for smart homes.

12.2.2. Patient Engagement Strategies

The rapid advancement in technology and artificial intelligence (AI) has transformed digital healthcare patient engagement strategies. Patients are no longer confined to physical consultations; instead, the adoption of patient engagement technology allows physicians to provide healthcare services digitally as done in a traditional clinical setting. The patient engagement strategies of a digital clinic are vital in optimizing the patient experience and establishing trust. This sub reflects practices and angles the detail as seen within the South Korean Context virtual clinical service provider. Also, prior to the detailed discussion, the patient engagement strategies will be overviewed in the text's components: health portal, digital marketing, telemedicine, and social media marketing. Many efforts have been put into the healthcare industry to promote health engagement between patients and healthcare providers. The information for patient engagement between 2016 and 2021 will be analyzed whereas the majority of the approaches will be noted. Virtual clinics increase the efficacy of the technology patient involvement strategy. Thus, this paper addresses that question as seen by a healthcare service that offers healthcare consultation and medical care digitally.

Patients frequently access protocols, questionnaires, and educational sheets digitally to regularly share their health records. Doing so boosts the frequency of service use by 4.54 times and the odds of consuming in the administration of directly purchased drugs by 1.36 times. Personalized information and feedback gathered via a manned communicating team substantially optimize patient experience and credibility. The emergence of telemedicine technology provides an opportunity for smart hospitals to perform medical examinations and treatments automatically, just like in conventional clinics. This leads to a range of key strategies for optimizing patient engagement, accessibility, and adherence to digital clinics to explore the potential progress of smart hospitals and virtual clinics. The digital clinic and AI technology, recognized as electronic healthcare (e-health) by physicians in practice, have been urged in previous research for more effective techniques and systems. However, AI-based virtual clinics across the existing healthcare facilities are still limited to online scheduling and default medication.

12.3. AI Applications in Smart Hospitals

There is a finalization of the series of review papers for the present issue. Here, the five different papers by their focus on providing an information technology perspective for competitive hospitals, an exploration of sweet spots for AI applications and the paths to pace their implementation in European hospitals are completed. This paper will also summarize a more technical article on a hospital system capable of adapting the AI models and will offer brief editorial conclusions underlining future research paths identified.

Study 1 presents a broad perspective of the innovative problem of the hospital sector adopting an IT focus. More particularly, the challenges for IT in hospitals are investigated and recommendations are provided as to how hospitals can meet these challenges and develop the right competitive positioning. Study 1 is also accompanied by supplementary material representing a qualitative survey on the feasibility and attractiveness of different smart hospital scenarios. A simulation of automated consultations with AI in a clinic setting was conducted, which describes how the AI is combined with a question-answering system and presents the methodology and results of a real-world test within 500 typical support cases of hospitalized patients. Four different ways in which AI can be evolved to become capable of providing meaningful assistance to clinical decision-making are presented: the path from primary articles to AI response, the development of the QA system and its use in the chosen applications, the methodology of the test in a clinic setting, and the results of the test. Paths by which AI models for alternative hospital IT systems can be developed and adequately or dynamically modified over time to keep pace with the changing IT environment are considered and the software architecture and methods enabling this adaptability, currently prototype. Evaluating a hospital's performance through modeling and simulation, underlying how a particular software environment for these purposes could be designed and illustrating its step-by-step application on a representative case example. Finally, planned paths of inquiry and technological development in the upcoming years are outlined.

There are four papers providing detailed methodological information and insights on how to address the current gaps. This editorial conclusion additionally aims to provide a brief summary of the main findings and underline the future research paths that are identifiable within this series of papers.

12.3.1. Predictive Analytics for Patient Care

The data-driven approach provided by predictive analytics (PA) stands out in the context of the rapid digitization of medical data and institution healthcare initiatives (Nguyen &

Nguyen, 2020; Patel & Cushing, 2021; Smith & Roberts, 2021). The development and availability of PA infrastructure and models for predictive tasks has become more accessible with a low-cost entry. By using historical data, PA can forecast patient outcomes and project the time and resources needed to care for each patient. With the rising availability of electronic health records, the training data for PA models have become widely available. Various tools, cloud-based services, and implementations are available that enable the quick start of hospital-specific predictive model development across a range of clinical and operational tasks. Moreover, a large spectrum of toolkits and methodologies have been designed to simplify and streamline the development and deploying of predictive models in a clinical setting. Several different off-the-shelf machine learning models and their corresponding tooling and documentation have been documented.

Fig 12.2: Healthcare Predictive Analytics

PA healthcare applications have the potential to greatly increase diagnostics accuracy, stimulate new treatment options, and proactively care for individual patients across a range of treatment scenarios. For example, a prediction-based approach has been used to develop an estimation model for the progression of patient symptoms. Similarly, interaction composition tools together with PA were employed to forecast the upcoming flu peak epidemic. Methodology for developing and evaluating PA models is available. Several case studies and implementations of PA in healthcare are available, covering a wide range of different healthcare fields, such as oncology, telemedicine, emergency care, and pharmacy. Various on-the-shelf implementations of PA models in a hospital setting are available for both researchers and institution owners. However, many challenges to the successful deployment and operation of these tools remain. In a clinical setting, the implementation of PA models is hard to integrate into existing hospital management systems, and data privacy concerns remain an open issue. Despite this, many more PA applications and implementations in the healthcare sector are expected to appear in the coming years. With such a wide variety of both immediate and ongoing research and implementation efforts, the PA development trend is likely to increase further throughout the decade ahead.

12.3.2. Robotic Surgery and Assistance

Transformation in healthcare technologies is persistently evolving toward globalization in digital health, telemedicine, mobile health, electronic health records, AI-assisted healthcare, and electronic prescription services (Zhang et al., 2022; Shaik et al., 2023). This digital wave brings enormous advantages to patient healthcare with fast, smart, easy, and accurate services wherever they are. Scalable AI infrastructure based on upgraded computing networks accelerates this transformation. In digital hospital environments, patient data, previous medical history, and drug responses are networked by AI servers to derive a patient profile with high efficacy and tolerability with precision for suggested therapeutics and personalized treatment based on data.

Advanced digital portable sensors can be connected to mobile phones to detect and diagnose various diseases. Files, results, each patient's previous illnesses, prescriptions, and therapy tolerance are uploaded to the Cloud. Artificial intelligence servers accelerate transfer learning and algorithms filter and match patient status with previous known cases from other hospitals. These known therapies are selected as optimal considering memory sickness iterative verification leading to avoiding incorrect therapy. Furthermore, immune-oncological therapy is detected in most cases and prescribed with good prognosis.

While curing a patient, robotic digital hospital assistants' responsibilities include helping medical doctors at the treatment process, delivering drugs or materials while setting robotic arms and viewing actual treatment records. It digitizes the therapeutic treatment workflow, and accumulated therapy is queried from on-network AI-servers to prevent commercially prescribed therapy and ensure high efficacy in safe practices.

Uncertain pandemics demand an innovative response in healthcare for solutions. Prior to this use case, there were no hospital rooms with negative pressure for infectious patients. As a quick response, a hospital has reconstructed two rooms to gain negative pressure and carried out therapeutic treatment to ensure safe practice. Prominent part of the project requirements was to carry out therapy for the treatment and operational processes in a way to prevent the rotation of dangerous contaminated clean objects in the hospital. As a solution, deep research and several ideas were implemented in an automated robotic system, which was put in the hospital rooms and iteratively treated hundreds of patients with success and zero contamination.

12.4. Scalable AI Infrastructure Explained

In the sophisticated future of smart hospitals and digital clinics, scalable AI infrastructure will be responsible for connecting AI products with numerous and varied healthcare systems. To establish scalable AI infrastructure, it is essential to first define what it encompasses in this context. Scalable AI infrastructure consists of a collection of hardware and software that hosts AI solutions and allows them to expand or contract in size, volume, or degree, in order to meet the evolving needs of different healthcare settings. Scalable AI infrastructure is critical for the deployment of healthcare AI in any clinical settings, from rural clinics to large hospitals. Whether considering the size of a hospital's campus, or the extensive network of clinics within a health system, scalable infrastructure is essential for not only incorporating AI technology into a system but also for being able to adapt it over time.

Infrastructure with the ability to scale is crucial for healthcare systems with diverse geolocations and a multitude of facilities. Scalable AI infrastructure fundamentally must be deployable in various environments, which requires the flexibility and adaptability of these products. All healthcare systems vary in location, size, and available tools. A component of infrastructure that is suitable or functional in one system may not work in another. Furthering this complexity, some hardware or software resources may be confined to a specific environment or vendor. For instance, a cloud solution for one health system may be unable to interface with their facility due to an incompatible service or network product. Also addressed are software and environmental concerns, such as data storage capabilities, processing power, medical device connectivity, and EMR interoperability. Scalable infrastructure improves model quality by affording the ability to use data originating from a wider base and enhances patient outcomes and operational efficiency by deploying more powerful or bespoke AI tools. To effectively streamline deep learning algorithms with clinical care, a discussion on overcoming common obstacles of implementing scalable AI infrastructure in healthcare is included. Embraced by many complex and large healthcare AI companies, cloud computing and big data technologies are explained regarding how they enable infrastructure to be scalable.

12.4.1. Definition and Importance

Scalable AI infrastructure—an economical and efficient infrastructure designed to carry the vast amounts of data required by AI—is a critical but often under-recognized component of AI applications. Real-time identification and processing of data generates vital insights used in different AI models. This is especially important in healthcare settings such as hospitals and clinics, where vast amounts of streaming data need to be accurately processed. Scalability enables infrastructure to keep optimal performance even with varying workloads. Scalable AI infrastructure also allows different hospitals and clinic outlets to use identical infrastructure that serves varied needs. It supports a diverse set of scalable AI models, which can augment the abilities of physicians and decision-makers in different clinical settings. More efficient disease mapping and patient prognosis models may improve decision making by adaptively reallocating medical staff and resources. Such proactive measures may lead to better patient care outcomes. It is shown that the scalable resource allocation in the clinics usually brings improvements in terms of days of fever until recovery. In supporting better patient care, there are multiple challenges—mainly related to the availability of the data and the cost—and these are further discussed with potential solutions. Finally, possible trends for the future in terms of the scalable infrastructure to be placed in hospitals, clinics, and healthcare (bio)informatics are described.

12.4.2. Components of Scalable AI Infrastructure

The goal of modern clinical disciplines is to provide the highest level of care to the patient. An increasingly important role in achieving this goal is played by currently used developments in the field of informatics and digital technologies. The advent of computer networks in healthcare systems has opened up new perspectives not only to improve the quality of services provided to the population but also the economy of healthcare. There is an accelerated search for a new philosophy of the healthcare system to create conditions for optimal use of information resources. Recent developments in the field of medicine and informatics have shown that the most promising are the development and application of a place in the overall process of organization of information systems in medicine. An automated system of M. D. And clinics that contribute to the development of data banks to solve the medical and scientific tasks, processing massive amounts of data, providing storage, search, and output of information in a convenient form as other valuable developments. Since the beginning of the development of digital clinics, a number of fundamental works have appeared on various aspects of organizing the design and operation of such systems. However, the tasks of increasing the efficiency of digital clinics and creating automatic decision-making systems to provide practical assistance to the healthcare worker remained open. This position of the clinical task is dictated by the increased requirements for the quality and speed of diagnosis and treatment, the growth of biological, medical and medical technology research, the number of publications on medical and biological problems.

12.5. Current Trends in Smart Hospitals

The grand challenges of the last century were explained, resulting in a number of trends that hospitals currently face: in-patient treatments need to be efficient, outpatient treatments and after-care still have to be of high standard; there is a steadily growing population; and costs need to be controlled. To improve quality and control costs, hospital care is becoming more sophisticated using advanced but hugely expensive technology. It is expected, due to demographic change, that patients in future will be older and have more complicated medical problems which require an even larger development in medical treatment and technologies. This outlook suggests that healthcare on the one hand will become an economic growth market, generating employment and setting new standards. On the other hand, it will challenge service providers, resulting in a considerable consolidation, and force them to focus, bringing about a decrease of small specialized establishments. There is also the threat that cities will create consulting firms tasked with making profitable inroads for entrepreneurial services. The current development can be best summed up as a harsh inter-institutional and global competition to obtain a capability for rapid substantial changes, and a race to develop economic force.

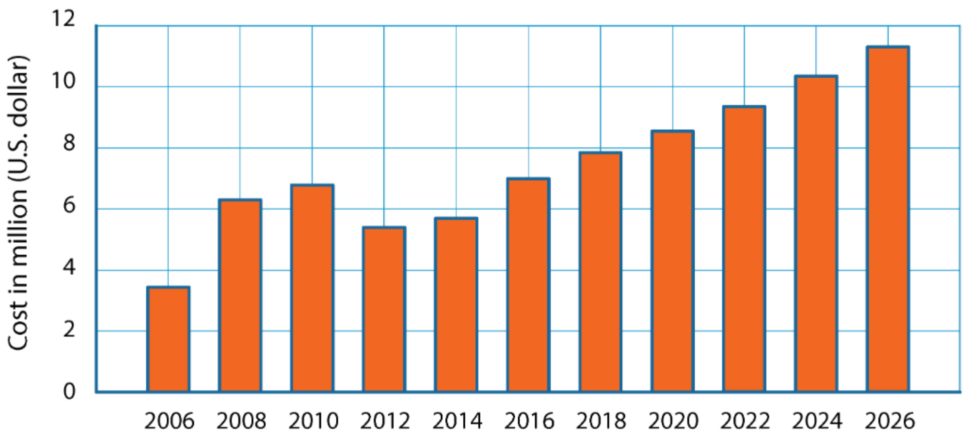

Fig : The Future of Smart Hospitals and Digital Clinics Powered by Scalable AI Infrastructure

12.5.1. Telemedicine Integration

The future of Smart Hospitals and Digital Clinics in the healthcare industry will rely on the reuse of state-of-the-art scalable AI processing infrastructure to enable the new data-driven features and services. Telemedicine is based on Digital Clinics concept and allows consultations by video and auxiliary data streaming enabling maximal coverage of medical services. The topic of medical services is the most tested through daily practice by pandemics. Smart Hospital supports clinics with real-time AI data analytics on Large-

Scale facilities and generates BigData sets for Scientific Research. Pro-active AI-based smart care serves as a reference use case designed to test all new technologies within the integration model. So far tested and validation results of the end-to-end integration of AI-driven services and infrastructure are given with optimized connectivity, data storage and AI processing hardware and tested Ethical Health Data Management system. Moreover, several technology challenges and recommendations for standardisation are given. These new data-driven features, enhanced by recent progress in artificial intelligence applied to a large-scale medical data set, generate the anticipation of smart AI-empowered medical services like: telemedicine consultations supported by auxiliary signals, real-time AI data analytics in the emergency room and telecare services, up to AI-based decision support exploration clinics. These issues will be the most validated through daily use in pandemic escorted by efforts for predictive testing and treatment based on clinical data from Smart Hospital and proactive AI-based smart care. The final aim is a novel model of Smart Hospital deployment including a new healthcare service model supported by digital infrastructure in the hospital ecosystem.

12.5.2. Wearable Technology

The advancements will allow for the healthcare sector to keep pace with the current digital age while further providing an in situ insight on how developing countries will catch up with the inevitable evolution of health services. The resources attainable online portal will pile up the best AI infrastructure utilizations, backed up by clinical studies. The AI infrastructure build up was to be in line with the disposable resources all around the world, enabling medical institutions to glimpse the potential future of clinic 4.0. The ecosystem of healthcare will expand dramatically along the induction of AI infrastructure.

The healthcare revolution triggered by artificial intelligence (AI), culminated as the deep-learning boom so far away, due to the tremendous computational requirement, was only foreseen as viable for the wealthiest tech giants, effectively reshaping the healthcare sector by replacing repetitive works like pathological image reading or signal denoising. As digital health grows rapidly, especially over the past few years, medical big data and computational power start to settle, making it possible for the ordinary physician to tap the benefits left behind by the cutting edge medical service paradigms in the early stage of this era. The capabilities of digital clinics, empowered by scalable AI infrastructures, are multidimensional. The most intuitive and practical utilities are the advantages in diagnostics and health monitoring, setting up a phase distinction to filter out idiosyncrasies and irregularities. Analyses the symptoms for the generation of the reminder or advises via mobile devices so that the much-needed guidance could rope in promptly and prevent casualties from happening. The shared analysis and diagnosed data in the cloud empowers the physicians to map out a better-organized visiting group with the efficient allocation of the medical resources. Another innovative aspect is the establishment of the one-stop service for those orphans and isolates who have migrated from rural to urban without the ability to recruit public health services, prospective safeguarding the quality of the population released by the economic increase.

12.6. Conclusion

Officine Nobel devices and services – and potential tie-ins with their hospital's operations – are expected to ensure "such value that it competes with other strategic acquisitions," while others are entreated to "reflect if the [investment] truly mediates long term gain vs the risks from Chinese backlash". Four main concerns emerged in the original submission: healthcare construction share prices crashing, fresh lockdowns, broader consequences of the trade war with China, and requests for insight into potential collaboration arrangements between Officine Nobel and pharmaceutical groups. Officine Nobel's interlocutor underscores the company's commitment to "a broad and diversified consumer market across Europe and expanding into developing states," comprising the establishment of a local CE-mark tendering stream to "foster growth in the public purchase field". Concerning the matter of potential collaboration arrangements with pharmaceutical companies, Officine Nobel has already begun forging partnerships with these firms by opening clinics within large Italian pharmacy chains and enlisting 70 such companies – including counterparties concerned regarding generics – as onboarding partners "for wide-ranging promotional operations".

Moreover, Officine Nobel's liaison manifests openness to a joint project that would see a European hospital warehouse's supply chain "entirely restructured from the ground up," though it also confides "no comparable arrangement is foreseen with the US" due to concerns about the inability to trace conflict-of-interest exemptions. Officine Nobel's representative further insists that quicker vaccine safety authorizations will become increasingly common "now that safety has become a national political issue in myriad European states and Italy" and subtly contrasts Officine Nobel's guardrails against malicious interference with the "prototype system undermined by a complete reliance on traditional safety measures" that would be adopted by China's government.

12.6.1. Future Trends

Smart hospitals and digital clinics are regarded as promising health care settings, which are anticipated to be better prepared to meet future societal and technological expectations. However, their implementation presents significant challenges, particularly concerning the real-time processing of the vast amounts of data generated, continuous adaptation of the provided health care services and ensuring minimum quality and safety levels of services across multiple clinics. This paper discusses the aforementioned challenges and presents an ongoing initiative aimed at addressing those challenges. Motivated by the particular needs and settings of hospital health care providers, the forefront topics of smart hospitals and digital clinics equipped with digitalized and automated health care services developed within an artificial intelligence infrastructure that scales along hospital capacities and provides services to individual clinicians and asthma patients are analyzed.

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