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The hospital of the future

How digital technologies can change hospitals globally

Executive summary

The hospital of the future may look quite different than the hospital of today. Rapidly-evolving technologies and growing consumerism, along with demographic and economic changes, are expected to disrupt hospitals worldwide. Already, a growing number of inpatient health care services are being pushed to the home and outpatient ambulatory facilities; however, many complex and very ill patients will continue to need acute inpatient services.

With aging infrastructure in some countries and demand for more beds in others, hospital executives and governments should consider rethinking how to optimize inpatient and outpatient settings, how to best connect with consumers, and how to integrate digital technologies into traditional hospital services to truly create a health system without walls.

To learn what this hospital of the future may look like, the Deloitte Center for Health Solutions conducted a crowdsourcing simulation with 33 experts from across the globe. Participants included health care CXOs, physician and nurse leaders, public policy leaders, technologists, and futurists. Their charge was to come up with specific use cases for the design of digital hospitals globally in 10 years (a period that can offer hospital leaders and boards time to prepare).

The crowdsourcing simulation developed use cases in five categories, which are accessible and clickable along the bottom of this report:

- **Redefined care delivery:** Emerging features including centralized digital centers to enable decision-making, continuous clinical monitoring, targeted treatments (such as 3-D printing for surgeries), and the use of smaller, portable devices will help characterize acute care hospitals.
- **Digital patient experience:** Digital and artificial intelligence (AI) technologies can help enable on-demand interaction and seamless processes through a choice of devices to improve patient experience.
- **Enhanced talent development:** Robotic process automation (RPA) and AI can allow caregivers to spend more time providing care and less time documenting it; as well as help enhance development and learning among caregivers.
- **Operational efficiencies through technology:** Digital supply chains, automation, robotics, and next-generation interoperability can drive operations management and back-office efficiencies.
- **Healing and well-being designs:** The well-being of patients and staff members—with an emphasis on the importance of environment and experience in healing—will likely be important in future hospital designs.

Technology will likely underlie most aspects of future hospital care, but care delivery—especially for complex patients and procedures—may still require hands-on human expertise. Many future technologies can supplement and extend human interaction.

Many of these use case concepts and technologies already are in play. Hospital executives should be planning how to integrate technology into newly built facilities and retrofit it into older ones. A well-crafted strategy can lay the foundation for future investments in care delivery, talent, data management, and cyber security.

Introduction

What might hospital care look like globally 10 years from now? The following scenario offers a preview:

Remy is visiting his hometown to accompany his father, John, to the hospital. A heart patient, John is being admitted for a 3-D printed mitral valve replacement at Metropolis Hospital. Remy is surprised: the facility looks nothing like it did when Remy had his appendix removed in his youth. A digital console nicknamed *Welcome Packet* is waiting for John at the entrance. It directs him to his room, and helps orient him to the hospital and his schedule. (John's admission was automatically processed prior to his arrival.) Remy notices the hospital's smart ergonomic layout, bright lighting, and noise-free rooms. With AI built into his securely stored, cloud-based health records, John can access information on anything related to his care—such as the risks and benefits of the 3-D printed-enabled surgery—by using the monitor in his room or his own smartphone.

A wristwatch provided upon John's arrival remotely monitors his vital signs, analyzes them, and alerts caregivers to any significant patterns. Remy notes the absence of nurse stations, and watches robots deliver supplies and medications to patients' rooms. His father's hospital records are automatically populated through digital uploads, voice-capture sensors, and information from caregivers. Most of the routine charting and orders are entered through RPA and supported by AI. Discharge and post-discharge care are planned in advance using predictive analytics based on John's medical history, how well he is responding to his initial treatment, and his potential health related social factors (such as housing and family support).

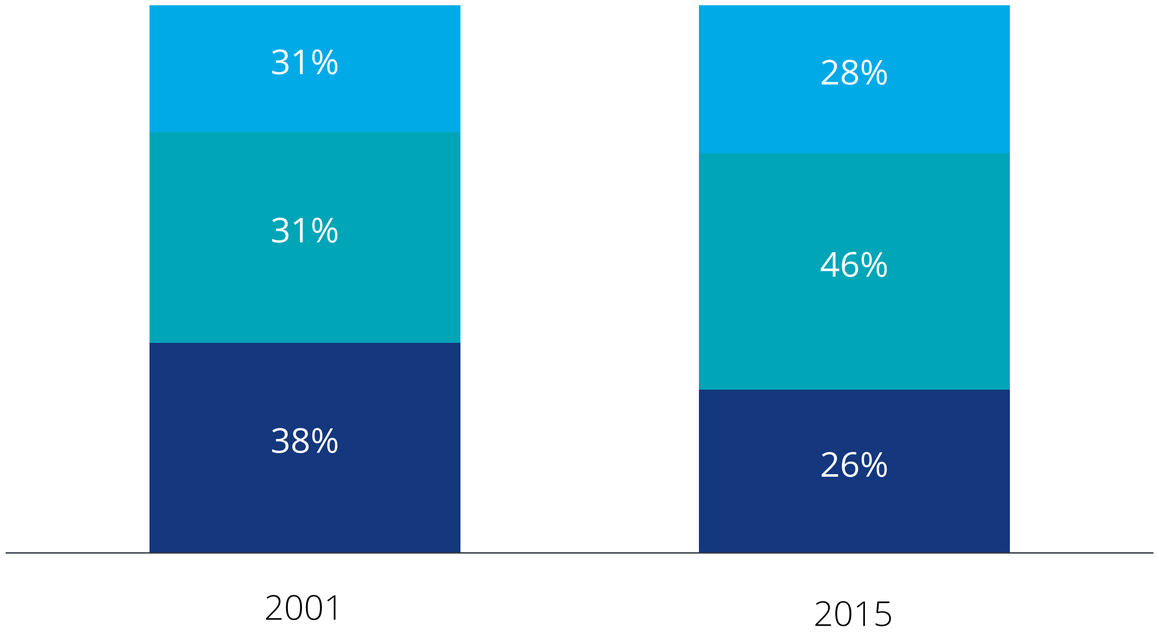
During a pre-op visit with the surgeon, Dr. Mace, Remy, and John are able to visualize the procedure in 3-D. The essential elements of this meeting are extracted by a listening device in Dr. Mace's wristwatch, and entered into John's hospital record—including the time and date: *5:43 p.m., October 1, 2027*.

Impetus for change

Several macro trends could have significant implications for how hospitals of the future are staffed, sized, and designed. Demographic and economic trends, coupled with advancing technologies and growing consumerism, are allowing more health care services to take place in outpatient settings and in the home (see Figure 1 on the following page), although some types of patients—for example, complex cases and the very ill—likely will still require inpatient hospital care. Around the world, health care leaders should consider how to address these trends by planning for appropriate investments in people, processes, and premises enabled by digital technologies.

The Deloitte Center for Health Solutions conducted a crowdsourcing simulation with 33 experts from diverse fields across the globe. The goal was to develop specific use cases to illustrate how hospitals, enabled by digital technologies, might look in 10 years. (See sidebar for methodology and simulation details.)

Figure 1: Average health care expenditure by service area: Organization for economic cooperation and development (OECD) countries



Source: *Health at a Glance 2001-2017*, Organization for Economic Cooperation and Development

Crowdsourcing ideas for the global digital hospital of the future

The Deloitte Center for Health Solutions conducted a crowdsourcing simulation in May 2017. Participants included 33 experts from all regions around the world—North America, South America, Europe, Asia, and Middle-East—with backgrounds in health care, policy, and technology.

By crowdsourcing use cases, the experts developed a vision for a hospital 10 years from now—a period that offers hospital leaders and boards time to prepare. The simulation was divided into three phases:

- **Phase 1**—The experts ideated, created, and collaborated on specific use cases—examples of what a hospital may look like in 10 years that could impact clinical care, patient experience, staffing, and physical plant. The participants created 53 use cases.
- **Phase 2**—The participants then voted on the 53 use cases to prioritize their impact on the status quo.
- **Phase 3**—The top 20 use cases were organized into five master themes: (1) refined care delivery, (2) digital patient experience, (3) enhanced talent development, (4) operational efficiencies through technology, (5) healing and well-being designs. An interdisciplinary group of participants sketched scenarios and potential implementation impacts for each theme based on the top use cases.

The transformed, digital hospital of the future

The digital hospital of the future can leverage technologies that transform care delivery, patient experience, staff management, operations management, and hospital design.

Redefined care delivery

Our crowdsourcing experts focused on how emerging technologies can help reduce inefficiencies and improve care outcomes.

Centralized clinical command centers and digital continuous monitoring

What happens if an airplane loses an engine, or if two flights cross each other's paths while taking off? The nearest airport's air traffic control (ATC) system will quickly plot a new course. In the future, hospitals could have similar command centers that equip decision makers with real-time support tools to help them make quicker clinical and operational decisions.

ATC-like command centers already exist in some hospitals and industries including aerospace and aviation, oil and gas, and broadcasting. Why not more broadly at hospitals? First, digital data are the foundation of such centers, and many hospitals are late adopters of digital technologies. Second, hospital functional units tend to work in siloes. They produce large but discreet data, which can be difficult to collect, collate, and use for making actionable decisions.

This situation is expected to change as emerging digital technologies help hospitals move from episodic to collaborative and longitudinal care. These technologies can create new ways to continually monitor patients and to integrate the data to chart the "flight paths" of individual patients and operational units.

For example, wearables and microfluidic sensors can be placed near patients and at locations frequented by patients (such as washrooms) where there is a fall risk or other hazards. The real-time data from such devices can form the clinical command center's foundation. AI can constantly monitor the data to alert hospital operators and caregivers, which can enable more efficient care and better outcomes. Through big-data analytics, machine learning, and AI, patient harm—or unintended consequences—can be predicted before they occur and suggested interventions can be fed to caregivers. Such command centers exist in some hospitals today (see sidebar on the following page) but wider adoption is expected in the coming years.

The digital hospital of the future includes an air traffic-like control system to continually monitor patients and integrate data to chart the "flight paths" of patients.

Clinical command center in action[1]

In 2014, Cleveland Clinic launched a clinical command center named Bunker on the hospital's main campus under its eHospital program. At the bunker, a team of physicians, critical-care nurses, and technical staff monitors data on a digital wall—an image of a patient's vital signs—in real time at the intensive care units (ICUs) of the main campus and community hospitals.

Each patient has a tile on the wall that provides their name, age, hospital location, and vital signs trend line. The risk status is a simple dot—green for low risk and red for high risk—that beeps intermittently. The team monitors red dots closely and alerts the unit staff about possible interventions.

The team uses analytical algorithms and multidimensional data to stratify patients based on risk and demographic profiles. The team also uses data from electronic health records (EHRs) to provide advanced alerts for patients that display higher risk levels. In the first half of 2015 alone, the bunker team reviewed data on more than 37,800 ICU patients.

With the visibility they provide into patient treatments and status, clinical command centers can help manage patient capacity and other operational processes. For example, using data on admissions, inter-facility transfers, and predictive analytics on possible days for discharge, command center analysts can help staff manage patient flow and improve care delivery, better manage lengths of stay, and enhance the discharge process. These command centers also can track social media for open feedback and identify any patterns in comments to generate alerts for rapid response from appropriate leaders.

Personal and portable care

An array of new technology advancements, including 3-D printing, robotics, nanotechnology, genetic coding, and therapeutic options can permit more personalized and accessible patient care. Many devices and equipment are getting smaller and more portable, and treatments will likely become more targeted—all of which can make future health care more mobile and precise. This, in turn, should increase staff and process efficacy and improve patient outcomes, as clinicians will be able to quickly find the best treatment option rather than try multiple interventions.[2] Personalization of medications, for instance, will be based on a patient's genetic profile and the use of precision medicine, whereas designs for 3-D-printed prostheses will be based largely on a patient's specific anatomy.

Furthermore, as medical equipment and sensors become smaller and more portable, clinicians may be able to perform various tests and procedures at a patient's bedside rather than transporting the patient to different areas of the hospital. Robots can be used to deliver medications to patients. Patient rooms can be built to include more equipment options, or the equipment can easily be moved to the patient. In certain countries, it is also possible that mobile hospitals may come to the patient. Additionally, medical interventions could become less invasive, resulting in better outcomes and faster recoveries.

Cloud-based, interoperable electronic health records

The long-elusive goal of EHRs populated by interoperable data from different sources will likely be a reality in the hospital of the future. Coupled with AI, this can create process efficiencies and improve decision-making necessary to boost quality. Data can be better integrated into daily care, and patients can play a role in curating their own data.

Comprehensive, real-time patient data at the point of care can improve patient outcomes,[3] which means that sharing standardized data is likely to be part of future care delivery. This data can include genetic, social, and behavioral patient information, as well as financial, clinical, and administrative records. Data can be securely stored in the cloud and accessed on an as-needed basis—perhaps on a blockchain (a distributed, immutable record ledger of digital transactions that is shared and editable by various stakeholders). This can offer easy and secure data access from multiple locations and devices, and maintain the data at a lower cost than today's storage options.

With an expected large, continuing influx of data, many hospitals will need cognitive analytics to sort through and find the most important personalized data points and trends. This information can be proactively presented to clinicians, patients, and caregivers in an easy-to-understand format that seamlessly fits into their daily activities. Patients can own their data, add to and edit their health records, and proactively communicate with their caregivers. Importantly, the data can be easily unidentified for research purposes.

Digital patient experience

The crowdsourcing simulation produced use cases to improve the patient experience. Hospitals of the future can better inform and educate patients, ease their anxiety, and empower them to actively participate in care before, during, and after the hospital stay.

Digital and artificial intelligence technologies

Across the globe, consumers have grown accustomed to getting information when, where, and how they want it, be it news, weather forecasts, traffic updates, or restaurant options. Many expect the same quick answers to their health care questions. Increasing numbers of consumers are going online to measure fitness improvement, seek information on treatments and medications, and monitor health issues, according to the *Deloitte 2016 Survey of US Health Care Consumers*.[4]

In the near future, digital technology may improve the patient experience by providing real-time access to medical knowledge. Imagine an AI-powered, bedside virtual care assistant for an impatient patient that can answer or direct queries to the most appropriate person at the hospital. This virtual assistant can answer the patient's routine questions about diagnoses, expected recovery experiences and times, and daily medication schedules. In addition, the virtual assistant can act as a data repository for the patient's medical history, test results, consultation times, appointment schedules, and even stories from other patients with a similar diagnosis. Such accessible AI technologies are starting to exist and can help empower patients and their families.

Virtual care assistant in action[5,6,7]

The Ohio State University's (OSU) Wexner Medical Center is a major US academic medical center. In 2012, in partnership with Epic Systems, researchers created OSUMyChart—a customized version of Epic's MyChart, which is an online portal solution for outpatients. OSUMyChart allows patients to see their health records, pose questions to physicians, view test results, and schedule appointments.

With growing interest in the application, OSU in 2013 extended OSUMyChart to inpatients in the form of bedside tablets. OSU piloted these tablets to patients in its James Cancer Hospital and Ross Heart Hospital. Patients could set medication alarms, directly schedule physician and relative visits, view test results, or read educational material pertaining to their diagnosis. Patients also could make minor requests for water, snacks, and even help going to the toilet without using a nurse call button.

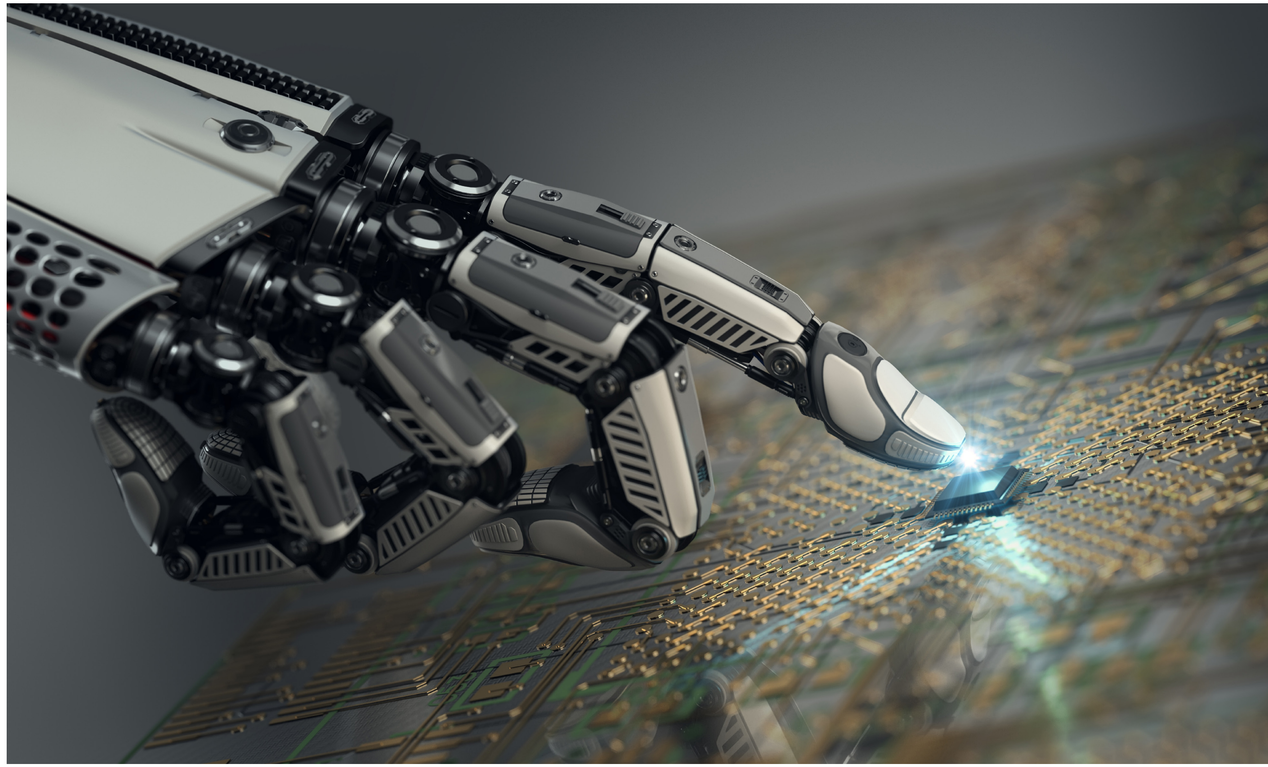
OSU reported that patients using OSUMyChart "loved it," "felt more confident," and said they better understood their health care experience. Returning patients requested these tablets upon admission. The pilot's overall patient satisfaction was 95 percent, compared to 85 percent for those who did not have access to a tablet. Today, OSU has a bedside tablet in almost all of its patient rooms.

Simplifying admission, discharge, and other processes

Hospitals frequently stumble in their admission and discharge processes, particularly when it comes to efficiency and patient satisfaction. Patients often complain about filling out multiple forms that ask for similar data, or receiving conflicting discharge instructions. As hospital processes go digital, staff can use AI to learn from and improve these processes.

In the near future, there will likely be no discrete patient registration process. Once a patient's physician advises admission, they can receive a personalized welcome package—an application on their own or a hospital device that helps to direct their experience. Clinical, financial, and demographic information can be pre-populated from the patient's records. As discussed earlier, these records can be cloud-based and easily accessible to key stakeholders. AI incorporated into the application can help physicians, medical staff, and patients converge on decisions such as modulating staffing needs, selecting room type, stocking required medication, determining diagnostic choices, and meeting non-medical support based on the patient's socio-demographic profile.

AI algorithms can be integrated into the discharge workflow, as well. Today, typically a nurse delivers tailored instructions that are based on the patient's condition, medical history, behavior, and attitude. Some patients require more time to understand and acknowledge the instructions than others. Nurses, often working on multiple priorities, sometimes are not able to provide enough time for such patients. With all information in a single location, AI algorithms can create customized discharge guidelines that can be integrated into the virtual care assistant and delivered to the patient at discharge and throughout recovery. Patients can take as long as they need to understand the instructions, ask questions, and talk to nurses or other medical staff if human intervention is needed.



How are newly planned hospitals envisioning patient experience?[8]

When Ireland's New Children's Hospital (NCH) opens in 2021, it will be one of the country's first digital hospitals. Construction of the government-sponsored hospital began in 2017, with a vision of elevating the patient experience through digital technologies.

The hospital board produced a short video showcasing how digitally integrated technologies can help patients throughout the care process—from admission to discharge—and post-discharge activities. The video follows the mother of a 10-year-old child, and highlights the role digital technology can play in future care and the patient experience. Consider these features:

- Physicians can use their own device to access the patient's secure, integrated EHR. It can include information about the patient's condition, medical history, family medical history, allergies, and current medications.
- During the admission process, the EHR can automatically capture details from the primary care physician; neither the patient nor family will be asked to fill out forms with redundant questions.
- All diagnostic and lab tests can be ordered directly from the physician's device, and results can be automatically captured by the EHR, with the physician receiving real-time notifications.
- Inpatient rooms, including beds and bedside devices, can be prepared based on patient demographics and preferences, as well as physician and nurse input.
- All patients can have bedside consoles that provide education, entertainment, and social media services along with pertinent medical information.
- Based on patient history, the EHR can automatically determine if the patient is a candidate for new treatments or clinical research that might improve outcomes.
- Post-discharge, patients can use a personal device to schedule appointments with various caregivers such as nutritionists, eye specialists, and pharmacists. The EHR can automatically capture results of these visits.

Imagine the art of the possible: How can digitally integrated technologies help patients throughout the care process—from admission to discharge—and post-discharge activities?

Enhanced talent development

Our crowdsourcing participants focused on three aspects of staff management—recruitment, scheduling, and learning and development. Recruitment and scheduling can achieve efficiencies through analytics use. Staff development can focus on continuous learning through virtual simulations and online courses.

Intelligent staff recruitment and scheduling

Nurse and staff turnover—from 12 percent to as high as 50 percent at some hospitals—is a challenge in several countries.[9] Turnover results in caregiver shortages and cost overruns for most hospitals' single-largest cost center—labor. Digital technologies could help change this situation in the future.

Hospital recruitment increasingly can rely on cognitive analytics (CA) and RPA to help automate the candidate-selection process. Also, cloud-based capabilities can help filter resumes and profiles more quickly—both those that are submitted directly to an organization and those that are publicly available—so administrators can focus on choosing the best candidates. Analytics also could play a role in determining salary and benefits, automatically comparing a candidate's experience to the market rate and organizational structure.

Similarly, CA can continue to be used for staffing models and deployment. As the workforce moves toward a gig economy—an economy in which workers with short-term contracts are more common than traditional full-time workers—scheduling shifts can become more complicated. Also, with ongoing focus on improving patient outcomes globally, hospital executives will likely need to use acuity-based staffing analytics to study patient data and requirements to match them with the appropriate staffing competencies. This can help optimize staffing, reduce unplanned overtime, and eliminate last-minute scrambles for contract staff, which can be expensive.

Technology—specifically IoT, radio-frequency identification (RFID), and CA—also can track performance management. IoT and RFID devices can track when staff members arrive, determine how many patients they see, and determine the amount spent on patient care versus administrative tasks. CA can then review the data and determine where efficiencies can be improved. For instance, advanced-practice nurses might be able to delegate some of their activities to registered nurses, allowing them to practice at the top of their licenses. While some staff may feel that these technologies intrude on their work, if a level of trust is established between managers and employees, this barrier can be overcome.

Intelligent staff scheduling in action[10]

Allina Health, a nonprofit health system based in Minnesota, uses technology from AMN Healthcare to automate its staffing-management process. The software allows Allina to forgo manual scheduling and track staff hours and costs. After four years, Allina saved more than $4.8 million in staff-related costs. Automation saved 120 hours per week previously spent in-sourcing, reviewing, scheduling, on-boarding, and invoicing for supplemental staff.

Virtual learning and development

Virtual training will likely become more prevalent in the future. While hands-on, in-person medical training can never go away, virtual training can become more prevalent among students and seasoned clinicians. Virtual training can help surgeons map out their surgeries before conducting them—they can also share footage of the actual surgery with students and colleagues. Virtual training also can increase specialized expertise available to a larger audience, which can be particularly important when geography and costs are factors.

Continuing education credits for virtual training can be tracked with the help of applications or other programs, and can encourage health care professionals to keep up with training requirements. Furthermore, requirements can be tied to performance metrics based on objective criteria. Clinicians, for example, can be assigned courses in areas where they need additional training rather than just topics they want to learn more about. And to help retain staff and reduce burnout, clinicians also can be required—or at least, encouraged—to enroll in self-care classes that focus on mental and physical health. Some academic medical centers are currently developing VR programs to train surgeons.[11]

Operational efficiencies through technology

The crowdsourcing exercise led to the development of use cases to reduce costs and improve revenue by using robotics and automation to trim inefficient processes.

Automation and robotics for care and ancillary services

Within the walls of a typical 200-bed hospital, lab specimens, linens, materials, drugs, and other goods travel 371 miles a week.[12] In many ways, hospitals are mini-logistics companies that continuously move large volumes of material among labs, pharmacies, pantries, and administrative units. While this logistics function has cost, quality, and safety implications, it is not likely core to hospitals' mission of providing patient care. Consider this: Nurses typically spend less than two hours of a 12-hour shift on direct patient care. The remaining time, they are doing paperwork, searching for medications and supplies, coordinating lab results, and even helping deliver patient meals.[13]

Using robotics to automate hospital ancillary and back-office services can generate considerable cost and time efficiencies, and improve reliability. By simply touching a screen, nurses and other medical staff can summon robots for specific tasks. For instance, robots can deliver medications, transport blood samples, collect diagnostic results, and schedule linen and food deliveries—either as a prescheduled task or a real-time request. Robotic processes also can be used for certain hospital revenue cycle and accounting/finance functions, such as scheduling and claims processing.

Operations management robotics in action

Around the world, some hospitals are incorporating robots into their processes, starting with operations management.

Japan's Toyohashi University of Technology has developed *Terapio*, a robot that can carry out routine hospital tasks, such as making hospital rounds, delivering medications and other items, and collecting records. For now, the robot follows a nurse or other medical staff.[14]

Other hospitals are creating an ecosystem for autonomous robot operations. Hospitals of the future will likely have space overhead (such as heightened ceilings) or dedicated pathways for robots that allow for automated delivery of materials, supplies, and medications throughout the facility.

The South Glasgow University Hospital in Scotland, opened in 2015, is designed as a robot-friendly facility. The hospital has 26 robots that move medical equipment, linens, food, and waste. The robots have their own underground tunnel, through which they transport supplies, and a dedicated elevator. The robots are arranged in a line where they wait to be assigned tasks. As the first heads out, the next in line takes its place. The robot reaches the loading bay where materials, such as medical supplies, await pickup. After retrieving the supplies, the robot moves through the tunnel, calls the elevator, and heads to the appropriate floor. With continuous sensing, the robot can stop and call for help if an obstacle remains in place after a predefined time limit. Once it completes a task, the robot moves back to its "charging" pod. These robots now perform 10 percent of the hospital's operations tasks. As robots become more affordable, that figure could increase to 25 percent by 2025, resulting in additional cost and time efficiencies.[15]

How will robotics change operations management in the future design of hospitals across the world?

Blockchain and secure contracting through next-gen technologies

As discussed earlier, many hospitals have invested significantly in data and operations management systems for EHR, supply chain, and revenue cycle functions over the past few years. Yet, interoperability, data security, and inefficient processes continue to challenge efficient operations management for many.

In the United Kingdom, a survey conducted by the National Health Service (NHS) found that more than half of acute care hospital respondents faced patient record access issues.[16] In the United States, 78 percent of hospital executives say they use manual processes for their supply chain management, which can lead to inflated costs and data integrity issues.[17]

Blockchain technology has the potential to revolutionize many of these operations processes. Blockchain is a distributed, immutable—write once and read-only—record of digital transactions that is shared among established stakeholders. Blockchain's strength lies in its data integrity—each new piece of data must be validated by the majority of the users in the network. With no central intermediary, a malicious hacker must target many users, rather than one, to alter the data. Here are a few examples of how blockchain can improve hospital operations processes:

Data interoperability: Blockchain can help health information exchanges (HIEs) alleviate security concerns. For example, each time caregivers provide patients with a service, they update their patients' health data on a blockchain-enabled HIE. Each blockchain member has a private key, which is secure, and a public key that acts as a visible identifier. Because of these permission layers, patients can limit data access and share only the relevant parts of their medical records with their caregivers or other clinicians.

Supply chain management: Hospital materials management includes planning, purchasing, and tracking inventory of goods (such as medical supplies and drugs) across the supply chain—all areas where blockchain can create efficiencies and improve safety. Supply chain participants typically include retailers, wholesalers, distributors, and manufacturers, and they might be located around the globe. With such a complex chain, there may be low accountability in cases of delays or damage. Counterfeit products can be another risk. A blockchain-enabled supply chain management system can facilitate the transfer and ownership of material across the supply chain, and trace the process via a blockchain ledger over a peer-to-peer network.

Revenue cycle management: Blockchain can help improve the validity and efficiency of the hospital revenue cycle. Billing and payment errors are common, and can lead to payer denials and bad debt. Customers can lose trust in their hospitals if their bills are incorrectly coded. Implementing blockchain-based claims-adjudication and payment-process systems can eliminate the need for intermediaries between hospitals, physicians, insurers, and customers. It also can help reduce administrative costs. As more complex payment contracts become the norm, blockchain-based contracts will help automate calculations that are now done manually. For instance, a patient or an insurer can deposit currency guaranteeing that it is available, but not release it until the clinical outcome is achieved.

Healing and well-being designs

The crowdsourcing exercise led to the development of hospital design use cases that can enhance patient healing and increase staff productivity.

Hospitals will likely have prosocial designs for patient and staff well-being

Hospital stays can be frightening, stressful, and boring. Hospital executives increasingly acknowledge that a facility's design has the potential to promote good physical, spiritual, and mental health, and contribute to quicker patient recovery. Our crowdsourcing provided examples of a future hospital that incorporates a prosocial design with features such as:

- **Customized patient rooms:** People can get bored after a day of looking at the same smartphone wallpaper. Imagine how boring a hospital room looks to a patient after a week's stay—the dull environment could negatively impact the overall patient experience. Instead, imagine the walls of a hospital room pre-populated with pictures of the patient's family members, or photos from a recent trip. Along with these "picture" walls, a patient could customize music, make video calls with friends and family through the internet, or access entertainment through virtual reality headsets. The bed is customized to desired firmness, and the pillows are preselected to be feather, foam, or allergy-free. Bathrooms have integrated sensors that monitor unusual activities, such as patient falls, and trigger a call for immediate help. Customized patient rooms may be the new normal in hospitals of the future.

- **Smart, ergonomic premises:** A hospital that has attractive visitor lounges, dayrooms, and views of natural or green surroundings, such as healing gardens, can help reduce patient anxiety and expedite healing. Also, furniture that can be flexed to create space, smart table layouts (e.g., changing rectangular to radial), and offstage, staff-only spaces can reduce walking demands and employee stress.
- **Modular lighting and noise management:** Bright, ambient lighting that is non-intrusive and easily scalable to increase intensity when and where it's needed can bring about significant change in patient-centered care. Proper lighting can improve the patient experience, particularly in terms of mood and perception of pain. Also, hospital staff can benefit from innovations in lighting which, in turn, can contribute to improved patient care and alertness. Another environmental issue often considered a necessary evil is hospital noise; primarily staff conversation, alarms, and medical devices. There is a growing body of evidence that links hospital noise with sleep interruption, stress (e.g., increased blood pressure and heart rates), and re-admission for adults and children.[18,19] Hospitals in the future could have noiseless alarms on medical devices, soundscapes, noiseless paging, and health acoustic engineering to improve ambient noise.

Prosocial design in action[20,21,22,23]

Sweden's state-owned Karolinska University Hospital began planning for a new facility in 2010—New Karolinska Solna (NKS)—to "meet the health care needs of the future." NKS opened its doors to patients in late 2016.

The hospital is proud of its state-of-the-art, prosocial design, which supports the healing process and stimulates both patients and staff. All inpatient rooms are private rooms and have modern designs, colors, and materials that create a feeling of comfort and help patients, visitors, and staff members navigate the facility.

The hospital's glass structure maximizes natural light and is intended to aid healing. NKS is also designed to be much quieter and calmer than a typical city hospital. The staff carries discreet buzzers instead of relying on alarms, pagers, or loudspeakers. **"During the NKS project, we have prioritized human needs. The buildings and rooms have been designed with health care in mind, but they also provide a sense of well-being."—Charlotte Ruben, NKS architect.**

The NKS hospital also features one of the largest-ever art investments for a hospital. There is $13.2 million worth of paintings, sculptures, and design objects installed at strategic locations—staff facilities, staircases, and waiting rooms. **"Art and culture in all its forms has both preventive and healing effects. At the new hospital, art will play its part in the medical toolbox," according to Gunnar Bjursell, professor emeritus, Karolinska Institute.**

Many hospitals will focus on safety and security—by design

Hospitals handle a large flow of people every day, and they are accountable for everyone's safety. Hospital employees need to be prepared for anything: theft, vandalism, physical assault, or even aggravated behavior by patients and relatives. Three-out-of-four surveyed US hospital security executives said security has become more challenging over the past few years.[24] And the United States is not alone. In Canada, hospital executives reported an assault rate of 20 incidents per 100 beds in 2015, according to a survey from the International Association for Healthcare Security and Safety.[25]

Many hospitals now have access to digital technologies to supplement on-premises physical security. They can systematically tag patient wristbands and employee and visitor badges with RFID tags that allow appropriate levels of access. The intent of RFID tracking is to be able to respond appropriately to an urgent situation, and to locate people in real time. The same tagging system can be extended to certain pieces of equipment, including any robotic helpers within the hospital.

Additionally, security cameras monitored by AI—using facial recognition and empathic expression detection—can identify dangerous situations as—or even before—they occur. For instance, a camera viewing an altercation between a visitor and a nurse will know where to focus its recording attention and to notify security immediately. Imagine, though, if that camera reads the expression and vital signs of the upset visitor before anything happens. The AI notifies a counselor, gives a general outline of the situation, and the counselor de-escalates the confrontation. The system can work best when monitored by AI with human back-up for interpreting events that are too complex, and too human, for the AI to decipher.

Digital hospital in action[26,27,28]

What does a hospital look like when it combines all of the elements we've discussed in this paper? Opened in April 2017, Sunshine Coast University Hospital in Queensland, Australia, is an example. What sets the hospital apart is how it knitted digital technologies together to help hospital operations, clinicians, nurses, and other caregivers bring "new age" health care to the region.

Patients are directed via digital way-finder kiosks to their clinicians. RFID tags are used for equipment, devices, and patients. For instance, newborns will be fitted with skin-sensitive tags that emit a pleasant beep as mother and baby bond. An unfriendly beep sounds if someone other than the mother picks up the baby, or if there is an attempt to remove the tag. Motion detectors and easy-to-use touch pads are mounted on patient beds to alert staff, especially in the elderly care and dementia wards, to prevent falls or alert staff that a patient needs assistance with the toilet. Doctors use an application on their devices to dictate notes; the application employs enhanced voice recognition software to produce transcriptions, eliminating the need for medical administration staff to type notes.

The hospital prioritizes staff training and development. The facility houses a 20-room simulation suite that has fully equipped operating and ICU rooms with simulation patients and devices capable of running realistic scenarios for clinical staff.

Traveling through dedicated tunnels and elevators, robots assist with logistics tasks such as delivering linens, meals, and medical supplies; this gives staff more time for patient care.

More than 30,000 comments from hospital users, clinicians, and staff guided the 14-month design process. The result is a hospital infrastructure that enhances patient healing and staff productivity. And even though the facility's size is massive—it is equivalent to 100 football fields and has about 6,300 doors—the hospital is designed to help visitors, both first-time and repeat, feel at ease. In addition to user-friendly physical and digital maps, color-coded wards and strips on the floors orient visitors and identify the shortest routes to their destinations. All patient rooms have tall windows that oversee landscaped gardens with 30,535 trees and shrubs. Inside, the bright, ambient lighting is sensitive to movement; there are no manual switches. To check on patients without disturbing them, nurses use a magnet-like device to open blinds, rather than opening the room door.

The hospital was built to be scalable from a physical and a digital perspective. It currently has a 450-bed capacity but can double to 900 beds in the future. The hospital also has the capacity for 40,000 IT touchpoints to scale up digital capabilities, if needed.

The digital hospital of the future: Putting it all together

In the past, typically every major hospital design project started with the same discussion: How many beds do we need? This conversation is changing and bed count is no longer the primary design driver for many hospitals of the future. Many health systems are shifting their efforts to improve care quality, create more efficient processes, and enhance the patient and staff experience.

Health care executives with an aging hospital facility may have to decide whether to retrofit the structure or build something new. Building can offer greater flexibility to embed all of the digital elements discussed in this paper. Retrofitting an outdated facility could pose challenges due to limited space and flow options, and make it more difficult to fully embrace the hospital-of-the-future concept. Unfortunately, not all hospital leaders have the option to build something new; they should consider, therefore, prioritizing retrofitting elements based on their organizational strategy.

Whether building or retrofitting, a comprehensive, enterprise-wide digital strategy can be essential for creating the hospital of the future. Some hospitals, finding their operations disrupted by technology advances and economic trends, jump on the bandwagon by *going digital*—introducing digital technologies into their existing processes. However, over time, they may experience challenges—discreet implementation, issues with scalability and interoperability, lower staff knowledge and motivation—which lower the return on their digital investments.

Instead, hospital executives should consider *becoming digital*—building an enterprise wide digital strategy and weaving it into their organizational strategy, operations, and processes.

Suggested next steps

In the coming decade, many US and European hospital executives plan to renovate or rebuild their aging infrastructure.[29,30,31] Similarly, increasing health care demand in emerging economies could drive considerable hospital planning and construction. For instance, spending on new hospital infrastructure in India is expected to reach $200 billion by 2024, and China plans to add 89,000 new hospital beds by 2020.[32,33]

But there is no need to wait for a building boom to integrate emerging technologies into hospital operations. A number of digital solutions do not require new bricks and mortar or major facility redesign; they can be implemented in the near future to improve operational efficiencies and clinical outcomes. Among the solutions for hospital executives to consider:

Care delivered digitally. To improve cost, quality, and outcomes, hospitals can use digital technologies to engage differently with patients. Remote patient monitoring, telehealth, advanced analytics, and wearables can transform an existing hospital into a cost-efficient delivery system that engages more with patients for improved quality and outcomes.

Digitally enabled customer experience: Hospitals can elevate the customer experience by using digital solutions to aid omni-channel patient access, including customer apps, patient portals, personalized digital kits, and self-check-in kiosks. Additionally, digital technologies, such as IoT, augmented reality, and virtual reality can help customize patient needs during a hospital stay.

Digitized operations: Many back-office functions—finance, supply chain, human resources, and revenue cycle, among them—can benefit from robotics, advanced analytics, sensors, and automation to drive cost efficiencies. These functions also can be digitally improved by using cloud-based enterprise resource planning solutions to make them shorter, faster, and more responsive.

Organizational capabilities for long-term success

Hospitals that integrate digital solutions into broader organizational capabilities can improve the potential for long-term integration success. The core elements of an enterprise digital strategy are:

Create a culture for digital transformation. It is essential that senior management understands the importance of a digital future and drives support for its implementation at all organizational levels.

Consider technology that communicates. Digital implementation is complex. Connecting disparate applications, devices, and technologies—all highly interdependent—and making certain that they talk to each other can be critical to a successful digital implementation.

Make needed investments manageable. Consider subscribing to certain technologies and services to help avoid significant upfront capital investments.

Play the long game. Since digital technologies are ever-evolving, flexibility and scalability during implementation can be critical. The planning team should confirm that project scope includes adding, modifying, or replacing technology at lower costs.

Remember, data are core. While the requirements of data interoperability, scalability, productivity, and flexibility are important, they should be built upon a solid foundation of capturing, storing, securing, and analyzing data. Organizations should create a strong, system-wide data infrastructure.

Prepare for Talent 2.0. As hospitals invest in exponential technologies, they should provide employees ample opportunities to develop corresponding digital skills. An augmented workforce and use of new technologies requires current staff to learn new skills to manage and work alongside the robots and AI processes.

Maintain cyber security. With the proliferation of digital technologies, cyber breaches can be a major threat to hospitals of the future. Executives should understand that cyber security is the other half of digital implementation and allocate resources appropriately.

Many hospital executives have little choice today—maintaining antiquated assets is really not an option. Building a digital hospital of the future can require investments in people, technology, processes, and premises. Most of these investments will likely be upfront. In the short term, hospital leadership may not see immediate returns on these investments. In the longer term, however—as digital technologies improve care delivery, create operational efficiencies, and enhance patient and staff experience—the returns can result in higher quality care, improved operational efficiencies and increased patient satisfaction.

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Acknowledgements

The authors would like to thank Christopher Harris and Anthony Coccarelli for their help with the research design and the interpretation of the simulation findings. They would also like to thank Sarah Thomas, Terri Cooper, Josh Lee, Adam Sandlin, Balaji Bondili, Melissa Schwarz, Violette Zhu, and Janine Leger (Deloitte US); Stephanie Allen, Luke Baxby, Andy Lane, and Rohan Hammett (Deloitte Australia); Gary Comiskey and Brian Griffin (Deloitte Ireland); and Enrico De Vettori (Deloitte Brazil) for their expertise and guidance.

The authors would also like to thank Samantha Gordon, Steve Davis, Lauren Wallace, Amy Hoffmaster, Jessica McCann, Terry Koch, and the many others who contributed to this project.

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