White Paper

Technological Advancements and Trends of Interoperability in the Operating Room

ADVANTECH iHealthcare

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SUMMERY

Surgery is consistently subject to innovations in both medical and technological fields, as this is the core unit of the patient care system. Improvement in patient outcomes is not just the result of successful surgeries performed in the operating room, but a product of a close collaboration of actions executed pre-, intra- and post-operatively across multiple disciplines.

To improve patient outcomes, it takes breakthroughs in technology to move forward in intraoperative care. Seamless integration may be achieved through the facilitation of automation in imaging techniques, advanced surgical tools, accurate navigation, and patient monitoring systems in surgical processes and operating rooms. However, technological advancement alone does not cover the entire workflow process. The absence of synchronization within the surgical team may also impede workflow, resulting in stress and frequent misunderstanding, leading to risks, delays, and low efficiency.

Thereby, distributed team planning is inherent to the successful integration and cooperative functionality of multiple devices and systems within a complex set of surgical procedures. Here again, information technology could play a role to ease the routine complex processes occurring in surgery by providing contextual support.

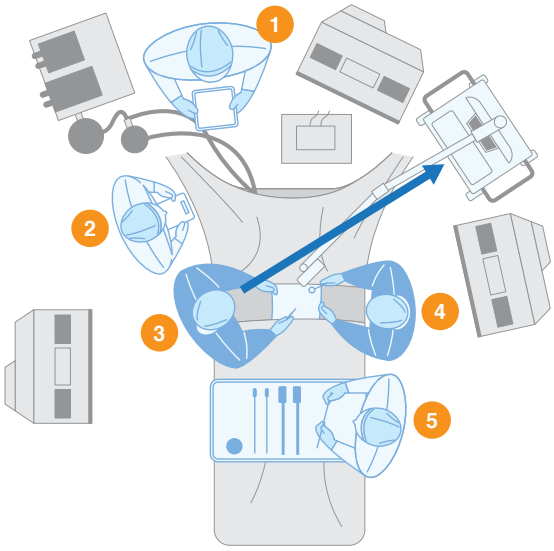
Through context awareness, the operating room (OR) staff can be ready with the available information displayed in the most suitable way at each time point during the surgical procedure. This may assist with more difficult tasks by eliminating simple but time-consuming tasks. Contextual support is achieved in an OR by tracking events and activities through automatic signal recognition available from different OR tools and systems. These revolutionized advancements in the OR have turned conventional ORs into the smart ORs we have today.

Introduction

Decisions involving OR management require the collaboration of interdisciplinary personnel and key players committed to taking on collective responsibility to achieve team goals. While one decision may lead to multiple effects within a dynamic setting, it is of paramount importance that well-coordinated and concerted decisions are made. Yet it is evident that often sporadic or partial information results in making inappropriate decisions that may further fallout as an aftermath. Such incidences may occur anytime during the course of the OR lifecycle, which includes:

1. OR setup
2. Anesthesia induction
3. Pre-surgery preparations
4. Opening and exposure by the surgeon
5. Necessary intervention
6. Closing the incision
7. Preparing for removal of anesthesia
8. Waking the patient from anesthesia
9. Debriefing
10. Cleanup and turnover of the OR

As surgery requires high situational sentience and tools laid ahead of time, communication and a strong understanding within the multidisciplinary team play a vital role to get through the course of events without facing inaccuracies. For a more customized operation, the team's shared awareness should be maintained, as miscommunication will possibly lead to loss of focus.



1. **Anesthesiologist**
2. **Circulating nurse**
3. **Chief surgeon**
4. **Assistant surgeon**
5. **Scrub nurse**

Automation and information technology corresponds with the potential to augment group decision-making, upsurge efficiency, attain staff satisfaction, and ensure safe patient care in a time and cost-effective manner. Evolution in machine learning and computing systems has enabled the transformation of complex OR structures into hybrid or integrated ORs that accomplish decision-making and personalized care via data analysis.

New technologies and devices are consistently introduced to ease out the already complex environment of intra-operative visualizations. One of the advancements includes minimally-invasive image-guided surgeries, in contrast to open surgeries, wherein direct access to the anatomical region of interest is attained with minor incisions accompanied by faster recovery time. Endoscopy is one of the techniques used for minimally-invasive procedures. Other modalities equipped in the OR for navigation in intra-operative usage include X-rays, fluoroscopy, ultrasound, computed tomography (CT), magnetic resonance, and positron emission tomography. These techniques help the surgeon to project a roadmap while navigating through bodily structures and tissues. Likewise, robotic assistance has also extended the surgeon's hand while performing fine surgeries with improved precision. Operating rooms that are furnished with advanced electronic tools, patient monitoring systems, treatment delivery systems, hospital information systems, and high-resolution imaging devices indeed advance the surgical field.

Researchers believe that if all the data generated through these independent systems are pooled through a common communication platform, then all components of a procedure could be controlled and modeled within the operating room[1], as fragmentation of the data among several displays divides the attention of the working staff. In the OR, anesthesiologists, surgeons, and nurses monitor and interact with separate displays to track events such as physiologic monitoring, automated anesthesia records, patient warnings, access to hospital information systems, order entry, drug/supply chain management, surgical instrument control, and clinical documentation. In this case, each individual holding critical information about the patient's case can pass on partially overlapped information. In addition, logging in separate display systems wastes time and effort that could be spent attending to the patient.

Hence, a synchronized collaboration of medical devices and systems facilitating the flow of data exchange amongst the surgical staff, systems, departments, and hospitals cultivates a better design of user interfaces and an overview of the OR. Lemke and Berliner proposed the conditioning of specialized extensions of Digital Imaging and Communications in Medicine (DICOM) in ORs, which allow data interchange between surgical systems and enables image-guided therapy, referred to as Picture Archiving and Communication Systems (PACS) or Therapy Imaging and Model Management Systems (TIMMS)[2].

In simpler words, PACS is the computerized way of replacing the roles of conventional radiological film, wherein images are assimilated, stored, transmitted, and presented digitally - creating filmless clinical environment results. Once acquired, images in PACS would no longer be subject to loss or misfile, therefore preventing related events such as cancellation of patient appointments, delay in deferring clinical decisions, and image repetition due to missing films.

The ORs are thus integrated with a communication platform that ranges from images and signals to the visualization devices, including the procedure's workflow and knowledge databases. The adoption of integrated ORs improves surgical efficiency by allowing smooth interactions, communications, and decision-making. Improvements result in inpatient treatment, process workflow acquisition, data navigation and handling, system integration, user-friendliness, communications, time and cost-effectiveness.

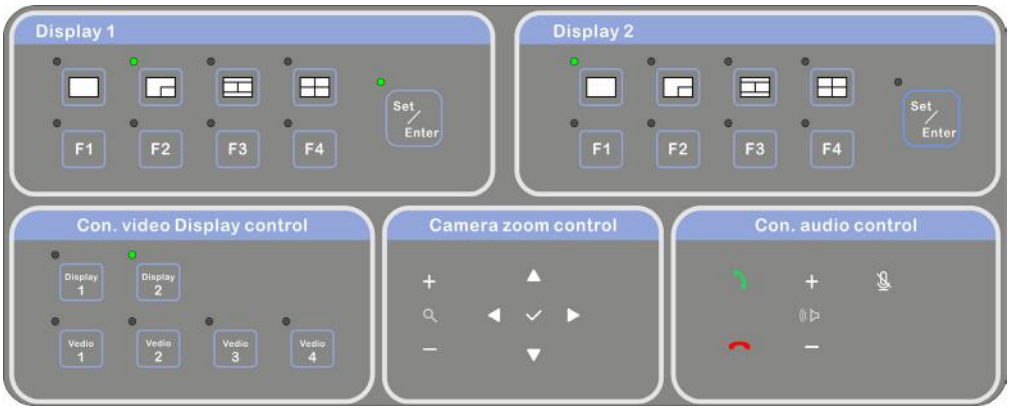
How Does Digitalization Aid a Conventional OR?

Aside from aiding and expediting the surgical procedure, today's digital ORs have the potential for wider integration via live streaming of the medical treatment. A surgeon in the sterile field can connect to the wider world through video streaming and arrange for online consultation with pathology and intensive care units (ICUs). Through these online consultations, prescribed medicines and treatments can be assessed, opinions are attained on the diagnosis, and other medical records such as CT scans and X-rays can be evaluated. Hence, this feature offers medical assistance at your doorstep in real-time, cutting down the patient wait time. Live streaming also provides e-learning facilities that offer the medical community virtual live feeds to conference rooms and auditoriums for training and demonstration purposes. This step has widened the window for medical education, when in the past an entire video crew was required in the OR to capture videos, adding stress on the surgical staff to carry out activities and threatening the surgeon's sterile surgical environment.

In addition to educational benefits, a surgeon can collaborate or supervise his or her team in real-time with another surgeon located remotely. Therefore, conducting surgeries under the surveillance of an expert in rural areas is now doable - improving the quality of results. Through the live streaming of surgical procedures, surgeons can outsource the time-consuming yet essential documentation of medical records to external staff. Video streaming has integrated the ORs by making it possible to receive data exchanged through an electronic medical record system, radiological PACS, and network-enabled devices in other ORs.

The design and specifications of the integrated OR, network, and remote audio-visual technology should be coordinated to achieve effective and integrated communication. The ORs should be equipped with central equipment that connects multiple rooms together via shared video conferencing and streaming; endoscopes or other image-guided modalities; subsystems for display, control and archival; and cabling that links the medical devices and image-guided equipment. The central equipment collects large amounts of complex data, which is evaluated in the context of domain-specific information derived from existing evidence, clinical guidance, current interventional practices, caregiver skillsets, and patient preferences. This data progressively integrates multiple data sources to connect all systems with the surgical team. This real-time context awareness keeps track of all the surgical procedures, actions performed, events taking place, and the current state of the patient.

Most suitable display subsystems currently available are comprised of high-definition flat panels with adjustable arms positioned in close vicinity to the surgical site. Large, wall-mounted options are also available. Display sources include high-definition cameras attached to endoscopes, radiological images from PACS, hemodynamic monitor, CT images output, ultrasound, and video archiving subsystem for viewing the procedure or editing and review later. The control subsystems consist of a touch-sensitive control panel with graphic menus and buttons to direct different sources to several displays and control the archiving system. Other advanced features include voice command; foot-pedal control; control of selected medical devices for example endoscope settings, or the positioning of the operating table; and room lighting, temperature, and sound system control, etc.



Touch-sensitive Control Panels

High-speed bandwidth of data networks support the installation work as the video and audio streaming is only possible with good network coverage. Webinars or webcasts are shared through internet streaming. Colleagues or students can view live surgical procedures only if a high broadband internet facility is available. Thereby, this is an essential requirement for entry or exit pathways for audio-video streaming systems. Internet Protocol (IP) video conferencing is a step ahead of webcasts and webinars, as it has a two-way audio-video communication facility with high definition image resolution. Internet Protocol is the way in which data transfers through computers via the internet. Hence, building a foundation for all of the smart developments, IP is variably used for voice, video, and information exchange between devices. Device sensors comprise an IP interface to connect to other devices. Currently, IP video conferencing is considered the standard method of connection and is frequently used for consultation purposes with the pathology, ICU, radiology, and fellow surgeons.

What Are the Challenges in Video Management?

Video and live streaming has bridged the gap between patients and medical fraternity. However, it takes a lot of effort and collaboration to make it work effectively. For example, consider a well-equipped integrated OR that is connected to other wider systems of a hospital where lack of collaboration occurs, resulting in the isolation of the integrated OR. Or for instance, on a smaller scale, what if an OR sends high definition video to a remote location that lacks sufficient network coverage and thereby is incapable of displaying the video content? Data network connections play an important role in video management across ORs as live streaming is an interactive session. A slow network connection may render the video streaming images useless. Delay in a download of radiological PACS images or pathology slide images can occur. A power outage is another factor that may take the entire network down, completely isolating the operating room from the network.

The network planning should not miss single points of failure by including physically isolated backbone pathways, power supplies, and emergency generator power. Quality of service (QoS) parameters and virtual networks (VLANs) that segregate and prioritize data traffic by allocating bandwidth based on data type is preferable to configure. This may assist in preventing delay of radiological images sent because of routine e-mail traffic.

Security is another important factor that should be a priority since medical data carry sensitive and confidential information. Breach or leak of any such information can result in legal implications for the healthcare facility. Prevention of unauthorized access can be done by incorporating firewall traversal measures, which only allow access to authorized users. Other security measures working across firewalls are border controllers and gatekeepers that effectively prevent hackers from entry.

When video conferences are conducted with remote sites located outside the hospital network, a crossover from one interface to another is favorable to allow video conferencing traffic. For example, an IP interface is switched to integrated services digital network (ISDN) environment in a remote site with an ISDN connection only, so that both sites are able to connect.

What Are the Current Market Trends?

The global market of integrated ORs was valued at US$1721 million in 2017 and is projected to exceed more than US$1175 million between 2019-2024 at a Compound Annual Growth Rate (CAGR) of 13% in the given forecast period[3]. The integrated OR market is globally segmented based on the type of device, application, end-user, and geographical region. Based on the devices, subsystems include the audio and video management system, display system, documentation, recording system, etc. The audio and video management system are classified into simple, advanced, and data comparing IP-based. The display system is categorized into small and large format displays. Likewise, documentation & recording system branches into individual recording devices and embedded recording software.

By application, the OR market is categorized into diagnostic imaging and therapeutic regions. Diagnostic imaging comprises three-dimensional (3D) C-Arm computed tomography, fluoroscopy, and digital subtraction angiography. Surgical therapeutic areas are divided as cardiovascular, neurosurgery, thoracic surgery, endo-bronchial procedures, urological, laparoscopic, biopsy, orthopedic, emergency care, and others. Based on end-user, this market is bifurcated into hospitals, clinics, ambulatory surgical centers, and medical research organizations.

Regionally this market is segmented across North America, Europe, Asia-Pacific, and LAMEA (Brazil, South Africa, and other Middle East countries)[4].

What Factors Affect Integrated OR Market Expansion?

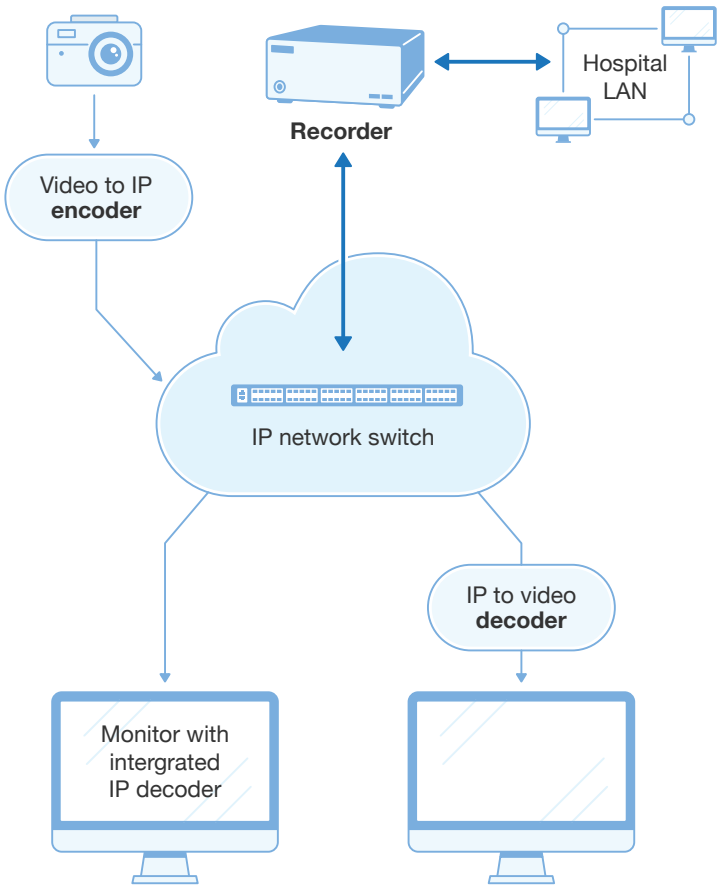
The growing acceptance of minimally-invasive surgery and advances made in imaging tools in recent years have resulted in an upsurge of market expansion of integrated ORs. Both patients and medical practitioners prefer these minimally-invasive surgeries to conventional surgeries, the former being safer and convenient with quicker recovery time. Another factor changing the market trends for integrated ORs is the increasingly high demand for surgeries. It was projected that by 2035, 8.5 million patients in the United States will require cardiovascular surgery that represents a 61% increase in the national caseload[5]. Hence, the cumulative increase in surgical procedures will drive the demand for integrated ORs. Nowadays, aesthetic surgeries have also gained traction, which will likely lead to a rise in integrated ORs.

As patients have access to the internet and social media, awareness is growing about the features and capabilities of technological advancements in surgery, which is drawing them to choose surgical procedures with integrated ORs due to safety and operational efficiency. The public is aware of the low efficiency of conventional procedures, resulting in loss of interest in the area. Comparatively, the effective decision support system of integrated ORs is driving patient's interests worldwide. In addition, developing countries such as India and China are the upcoming markets for integrated ORs with a rise in infrastructural developments.

What Is the Role of Video Integration Over IP?

High-resolution images and videos are essential for effective diagnosis and treatments. Analog or digital video connections have been totally replaced by an all-IP solution, empowering the surgical staff to plan, route, record, and share data in medical images without boundaries of the ORs. Instant digital image sharing across hospitals can do wonders on the efficiency of surgical procedures. Through video integration over IP, multiple imaging systems and devices can be managed centrally in the ORs with simplified installations and set-up times. Built on the IP network, the single universal cable can distribute audio, video, and data signals through this integration system. This integration system distributes videos for surgical imaging in a preferable raw, uncompressed format without latency - delivering high-image quality and transmission speed.

The flowchart above shows the steps of video-over-IP solutions, wherein the video-over-IP encoder converts video or audio signals to IP streams; video-over-IP decoders extend video and audio over any IP network; video-over-IP transmitters and receivers allow the extension of audio-visual connections setup via LAN.



What is Integrated OR and How is it Beneficial?

An integrated OR stands for a functionally connected centralized system having access and control over all the activities of an OR, such as patient information systems, audio, video, lighting (surgical and room), medical equipment, and building automation. An operator can manipulate all the associated technological activities through a central command in an integrated OR. There are many variations of ORs available - from simple visualization of images on displays to a complex centralized system that is capable of automatic audio-video routing, image capture, and surgical equipment control.

An integrated OR is comprised of the complex automatic control system so that surgical staff can collaborate in real-time using video streaming, and supports visualization in 4K ultra-high definition. It works by connecting to several other facility areas such as radiology and laboratories. PACS images, desktop images, data images with laboratory results can be routed to display systems within the OR suite. To organize the surgery and monitor its functional progress, a specialized information system collects case-specific information and presents on a large display. This improves safety while recording progress and maintaining staff orientation. While surgery is in progress, if a surgeon requests a real-time laboratory analysis of a specimen, images from the pathology microscope can be sent back to the integrated OR as soon as the analysis is complete. This avoids delays and prevents the need for additional surgeries.

As integrated ORs consolidate patient information, streamline workflows, and centralize information from multiple platforms, several routine activities of surgical staff are dispersed. These include examining and writing down patient information, controlling OR lighting, stepping into the surgical field to display or change the video, and more. The time and energy saved by skipping these time-consuming activities can be constructively utilized in attending to the patient and procedure. The integration of ORs often extends beyond the operating room, as it connects and supports teams, processes, and information across the operative workflow. For example, through real-time surgical video streaming, surgical teams can coordinate or provide supervision with remote specialists, or demonstrate a surgical procedure to train and educate students and colleagues virtually. Clinicians can show and share high-definition images of the procedure on a tablet or cellphone during a post-operative consultation with the patient and family. These images and videos automatically associate with the patient record for documentation.

What Are Advantech iHealthcare Video Archiving and Streaming (AVAS) Solutions?

AVAS solutions are designed to offer an infrastructure of an integrated OR inclusive of facilities with:

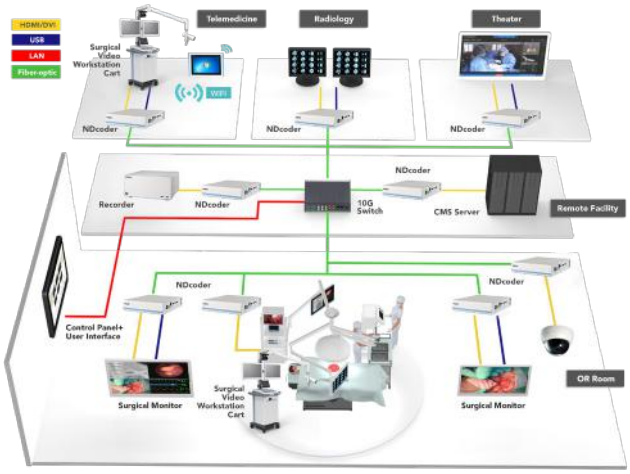
- Real-time medical image integration
- Zero-latency video streaming
- High-definition broadcasts
- Centralized control
- Remote teaching and consultation
- Cloud-based management to streamline OR workflows

With AVAS, integrated surgery and patient data are accessible via switchable displays, enabling convenient management of medical surgery records and enhanced workflow efficiency.

The AVAS surgical video station integrates all medical equipment in the OR. An IP central hub connects all the systems together to operate through a common command. It comprises of NDcoder to enable video over IP for streaming lossless videos with zero latency; a recorder for video and video management system console server; diverse display systems including surgical with high precision required during surgery and video display management; and accessories such as the 4k ultra-high-definition (4k-UHD) camera for high-quality recording.

AVAS NDcoder is an IP-based data transmission system with a single-cable distribution architecture designed for installation in ORs. Video, audio, and control signal streaming are provided with zero latency. Rapid switching between streams is supported through this system. It transmits high-definition image quality with superior color distinctions. AVAS recorder is a powerful integrated imaging hub equipped with software development APIs for customizing video and imaging streams according to specific application requirements. Through this capability, images and video signals can be collected from multiple sources and integrated for simultaneous display on monitors with diverse configurations. Both AVAS NDcoder and recorder together deliver enhanced imaging for surgical precision and enable cloud-based centralized management, while also streamlining OR workflows for improved efficiency.

The 4k-UHD technology is extremely important for video streaming in surgeries, as it provides an unprecedented level of detail, allowing the surgeon to distinguish between tissues, nerves, blood vessels, and other anatomical structures. Advantech iHealthcare's display system comprises of products from the PAX series - offering diverse systems for every necessary requirement within or outside the OR. PAX series offer products with surgical monitors for flexible (darkroom operations) and rigid (bright room under surgical light) scope surgeries, diagnostic displays, X-ray modality display, ultrasound imaging, open frame solutions, and special modality imaging. These monitors provide ideal luminance to see detail of a tissue structure; offer most comfortable ratio (16:10 Golden ratio) preventing eye fatigue and high pixel density for more sharp images; more vertical spaces for vertical and horizontal alignment for images; equipped with various analog and digital interfaces offering a wide range of connectivity; dual-modality display of color and monochrome images on the same screen; capable of displaying accurate shades of grayscale enabling accurate imaging performance and precision diagnosis.



In June 2019, during the endoscopy medical seminar held in Cheng Hsin General Hospital, Advantech iHealthcare's AVAS system was connected with medical equipment from Cypress technology to successfully transmit post-integrated OR images to the seminar venue. The uncompressed images were displayed with 4k ultra HD quality with no delay in transmission. Through this live streaming, bilateral dialog inside and outside the OR was made possible.

Attending physician, Meng-Ting Wu from the division of neurosurgery explained how AVAS helps reduce surgical staff movement around the ORs during surgery, and instead focuses on the medical procedure and reports important decisions such as X-ray navigation or endoscopic images. This has a great impact on the success rate of surgery with fewer errors on the part of the surgeon. When-Shin Song, Chief of Division of Neurosurgery, elaborated on how AVAS fulfills the requirement of an integrated device that collects medical images from various sources and presents integrated images with non-distorted high resolution on the same operating platform. He explained that this way, the surgeon and the staff could track surgical status in real-time, which increases surgical efficiency.

Jin-Yu Lu, a clinical nurse specialist from Cheng Hsin General Hospital, explained how the direct drop and drag approach is intuitive to decide which way the image could be best displayed. It helps to know if the nurse received a correct signal given by the surgeon. Hence, there was less possibility to be misunderstood.

With this image integration technique, processed images can be uploaded online for a webcast. One can even watch the surgery on cellphones, computers, and tablets.

About Advantech iHealthcare

With decades of proven experience, Advantech iHealthcare is a leading player in the global healthcare market. Advantech iHealthcare has developed its core competencies and collaborated with international medical equipment manufacturers and system integrators, to assist hospitals with advancing patient-centered healthcare.

Starting with high-performance as well as medical-grade products, Advantech iHealthcare branches out into integrated platforms and services aimed at mission-critical healthcare applications.

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