Alaska Native Tribal Health Consortium (ANTHC)
National Telehealth Technology Assessment Center (TTAC)

Crystal Ball Project:

What Technology will most impact Healthcare in the next 3-5 years

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Abstract:

The Objective of the Crystal Ball Project is to examine digital healthcare technologies and applications that will have the most impact in the next three to five years and provide credible vision and examples of near-term advancements in Health related technology. Deliverables of the project include providing tools to assist in the assessment of such technology to streamline decisions and results.

The technologies discussed will solve urgent needs at a critical time for healthcare by bringing remote diagnostic abilities, automation, and scalability to a market struggling with supply and demand challenges; including, but not limited to:

- a growing patient population which is living longer, but with more chronic comorbidities
- escalating provider shortages
- an increasingly complex and sub-specialized healthcare
- ballooning costs
- healthcare access and equity issues

The Crystal Ball team identified six major topic areas:

1. Artificial Intelligence including machine learning and natural language processing
2. Expanded applications and use of telehealth/telemedicine
3. Solution platforms: APPs, electronic health record (EHR) integration/data management, bioWare/bioSensors
4. Virtual and augmented reality
5. Drones
6. Robotics
7. Hearables

It was concluded that artificial intelligence (AI) and machine learning (ML) are essential components of the topic areas.

Materials and Methods: The results of this paper were accomplished by assembling a multi-disciplinary team of recognized experts in key healthcare technology areas and persons known as visionaries in telemedicine, digital health, hospital administration, consumer services, consumer products, chronic disease management, technology and the elderly, and technology trends. In addition, speakers were invited from key market segments in healthcare delivery to address specific areas of expertise. The content of this document represents the opinions and conclusions of the team based on their professional experiences, inputs of the speakers, and current literature.

Conclusions: Healthcare is in a period of profound change. These changes are driven by technology, staff shortages, the need for outcome and cost improvement, and, to an increasing extent, by consumer demand. The COVID-19 pandemic continues to stimulate accelerating change in healthcare. Our panel identified six technologies that will have a significant impact on healthcare delivery over the next three to five years. All six are mutually threaded by the application of artificial intelligence and machine learning. Many of these will be driven by market changes and consumer demand. All six will allow new models and relationships (example: care at scale for a flat-fee can disconnect patients from the payor system).

Summary Conclusions for each subject area:

1. Artificial Intelligence, Machine Learning & Natural Language Processing

- AI-driven medical knowledge and guidance systems will inform providers of current and up-to-date research, treatment, and processes of care. Provider's knowledge will be enhanced by the best and most current knowledge available.

- AI-driven medical knowledge and guidance systems will further enable and drive the expanded use of non-physician practitioners and allied health professionals.

- AI will enable the use of patient data, genomics, current condition, known allergies, and even digital twinning (the creation of virtual, digital copies of the patient and the state of their health using biophysiological data models created by algorithms) for personalized targeting and testing of care. This will optimize, and anticipate the responses to, treatments.

- Behavioral analysis AI and other tools that predict a decline in health, or other health status changes that may emerge.

- Applying AI will create greater value in patient and home originated data, as well as environmental factors. AI tools that access and assess consumer health data and provide alerts and added value decision support. This will further enhance the healthcare consumer's relationship with providers. Examples:

    - Smart sensors with AI data analytics will allow better management of Congestive Heart Failure (CHF) patients. These products are available or are coming online now.[1] [2] [3])
    - AI assisted heart rate, Photoplethysmography (PPG) PPG analysis and other non-invasive technologies will take signals from Smart watches to anticipate changes in CHF patients.

- To serve underserved populations, disparity data will be acquired, fused, and understood in a meaningful way, in order to improve health outcomes. This will include AI, mapping, drones, sensors, and other resources. This will drive a robust effort around affordable housing, food security, behavioral health, neighborhood safety, and other equity factors.[4]

- Differential diagnosis systems will continue to improve efficiency and outcomes across healthcare.

- AI will guide treatment and treatment planning. AI-guided surgical planning and surgery delivery will improve outcomes, reduce cost, while being widely available and accepted.

- AI applications for Intensive Care Units (ICU) and tele-stroke – long with expanded image analysis and decision support in teleradiology, dermatology, ophthalmology – will be available to every hospital in the US. This will enhance decision making to reduce mortality, improve outcomes and allow faster recovery.

- On-demand chatbots are already integrated with telemedicine by leading healthcare systems in the US and abroad. They will continue to grow in contextual capability and become more widely adopted in healthcare environments. Chatbots combined with on-demand telemedicine will provide rapid access to care advice, and reduce demand on current providers.

- AI will be used to optimize workflows and revenue cycles, as well as for streamlining tasks such as licensing and credentialing.

[1] https://www.nature.com/articles/s41569-020-00445-9 3-14-2022
[2] https://www.hindawi.com/journals/misy/2018/1546210/ 3-14-2022
[3] https://biofourmis.com/ 3-14-2022
[4] https://governmentciomedia.com/cms-depending-data-drive-health-equity 2-15-2022

- AI will begin to identify approaches to care, pharmaceuticals, and treatments.

2. Expanded Application of Telemedicine -

- The COVID-19 pandemic drove the use of telemedicine over a prolonged period. This disrupted the myth that providers and patients would not accept telemedicine or be able to use it. It has also shown the consumer a new level of access and convenience. Just as electronic banking revolutionized financial services, and online sales are revolutionizing almost every form of consumer buying patterns, telemedicine is making health care convenient.

- Continued strong growth in telemedicine and home monitoring – as well as the integration of patient originated data in the next five years – will result in better outcomes.

- Telemedicine will improve access and equity in ways that were not possible prior to the pandemic, and before the broad-based consumer and provider acceptance of this service and its capabilities.

- Primary Care will move toward a “virtual first” strategy, where many initial primary care provider encounters will be via telemedicine. Likewise, second opinion services will be used to improve patient outcomes.

- On-demand telemedicine will be a growing sector in telehealth driven by consumer demand. These services will replace some brick-and-mortar urgent care services.

- The use of telemedicine will leverage existing clinical resources and establish efficient approaches in surge capacity. Hybrid practices (a mix of in-person and virtual) will become the norm. Providers have an opportunity to adjust their practices so that telemedicine consults are scheduled when overhead resource demands and costs are reduced.

- All hospitals will have access to tele-ICU, allowing even small hospitals to have ICU beds providing local care. Tele-ICU will allow greater capacity and flexibility when future emergencies, or pandemics emerge.

- All hospitals will have access to tele-stroke. This is becoming the standard of care – improving outcomes and reducing the cost of long-term care and rehabilitation.

- Tele-stroke and tele-ICU will provide a change in the business plans for small rural hospitals, as they will be able to retain the patients and associated revenues locally.

- Tele-mental health (including crisis intervention) will be available to every Emergency Department (ED), urgent care and primary care practice.

- Care at home including “Hospital to Home” will grow exponentially. This will create a continuum of care that results in fewer acute care demands, better compliance with more frequent patient touchpoints, improved outcomes, and reduced cost.

- Healthcare market drivers will continue to change rapidly:
    - Consumer demand and preferences
    - New competitors and models
    - Disruption will likely come from outside the current healthcare infrastructure.

3. Solution platforms: APPs, EHRs and Wearable Sensors

- On-demand care will integrate decision support applications widely to improve response time, reduce costs and improve diagnosis and treatment.

- Chatbots will become more intuitive for consumers to help identify issues and direct them to appropriate care.

- Increased automation in the clinical workspace will reduce the need for administrative staffing in physician offices and hospitals.

- Remote patient management (RPM), chronic care management (CCM), virtual access, and integration of wearable sensors will provide a more complete relationship with a patient.

- Increased utility of wearables will create more demand for practitioners to prescribe them.
    - Organizations that provide care for older adults will apply health-related wearables for care recipients that have specific health conditions.
    - Medicare Advantage plans are already reimbursing the cost of a wearable for certain patient groups.

- Health equity and health disparity information will become an essential element in understanding how best to deliver effective care to patients.

4. Virtual and Augmented Reality

- Virtual Reality (VR) and Augmented Reality (AR) will drive a complete re-evaluation of current training methods.

    - VR and AR will enable standard approaches to care to be implemented more effectively and quickly.

    - VR and AR will provide better training at lower cost compared to current on-site training centers.

    - VR training will expand from educating providers to educating patients and better preparing them for their procedures and recovery. VR and AR tools combined with AI guided surgical planning and surgery will improve outcomes and reduce cost.

    - VR and AR tools will be used regularly to address mental health conditions and opioid recovery.

5. Drones

- Drones will be integrated into the national flight control systems for improved safety and simplified logistics.

- Drone use will expand in the US military healthcare.
    - Drones will be used for casualty transport on the battlefield.
    - Drones will be used for delivery of emergency supplies, plasma, and high-cost drugs.

- Drone use within the US for the delivery of critical and high-cost supplies will accelerate to match usage rates outside of the United States (US).

- Rapid, on-demand delivery of Automated External Defibrillator (AED)s to the patient is available in a few countries outside the US improving the survivability and outcomes for heart attack victims. Drone use for AEDs within the US will grow to match usage outside the US.

- In the next five years, drone use will remain a nascent application in the US due to regulatory restrictions, but these restrictions will be resolved and drone use will grow beyond five years.

6. Robotics

- Robotic prosthetics will significantly improve the lives of people. Amputation surgery will change to adapt to the needs and capabilities of modern robotic prosthetic technology.

- Physical therapy robot assistants will become common, reducing demands on therapists, and improving outcomes.

- Robotic surgery will continue to expand with enhanced capabilities and increasing autonomy. Specific areas of acceptance and growth will include catheter placement, tele-proctoring, and tele-surgery.

- Robots in the home will become more commonplace including:
    - Companion and assistive robots
    - Therapy robots
- 3D (robotic) printing will become more established for production of:
    - Dental appliances
    - Prosthetics
    - Joints and tissues

- Use of robots for physical assistance in moving patients and materials will expand especially in Nursing homes and Skilled Nursing Facilities (SNF)s.

7. Hearables

- Over the Counter (OTC) hearing devices are disrupting the established hearing aid marketspace.

- Costs for prescribed hearing devices will be reduced significantly.

- The market population will expand significantly to millions of people who are left out of the current solutions market.

- Consumers will be able to self-assess for hearing loss, as well as tune and adjust their hearable to preference.

- Increased consumer functionality and audio aesthetics will make this technology more desirable to consumers.

Disclaimers:

The contents of this document represent the thoughts and opinions of the authors. It does not necessarily represent the thoughts and opinions of the Office for the Advancement of Telehealth (OAT), the National Telehealth Technology Assessment Center (TTAC) or the Alaska Native Tribal Health Consortium (ANTHC).

Lists and any reference to vendors are provided for illustrative purposes only. This document does not endorse any of the vendors and lists are not intended to be comprehensive lists of all viable vendors. As known industry experts, some team members may or may not have any affiliation with companies or organizations. All the thoughts and opinions expressed represent the team member's personal and professional experience. They are not the opinions of these companies or organizations.

Topics

1. Artificial Intelligence, Machine Learning, Natural Language Processing

Artificial intelligence (AI) is intelligence demonstrated by machines, as opposed to intelligence of humans and other animals. Example tasks in which this is done include speech recognition, computer vision, translation between (natural) languages, as well as other mappings of inputs. AI applications include advanced web search engines (e.g., Google Search), recommendation systems (used by YouTube, Amazon, and Netflix), understanding human speech (such as Siri and Alexa), self-driving cars (e.g., Waymo), generative or creative tools (ChatGPT and AI art), and automated decision-making[5]

Machine Learning (ML) (the study of computer algorithms that improve automatically through experience) and Natural Language Processing (NLP) (computer communication with humans in their own language and scales other language-related tasks making it possible for computers to read text, hear speech, interpret it, measure sentiment, and determine which parts are important) are subsets if AI.[6]

The use of AI in healthcare has been increasing in healthcare for twenty years.[7] The use and applications is accelerating rapidly and will accelerate further in the next three to five years, and beyond.

AI is widely recognized as a transformative innovation in almost all industries. It is difficult to overestimate the potential impact. The impact on healthcare is already considerable and continues to grow. AI has already proven capable of outperforming human clinicians in the diagnosis of specific medical conditions, especially in image analysis. These abilities are enhanced by the capacity of AI systems to learn from patient records, genomic information, and real-time patient data.[8]

AI and ML is integrated into – and an essential component of - each of the topic areas of this document. They are all mutually threaded by the application of artificial intelligence (AI) and machine learning (ML). AI, ML and NLP continue to have growing pains and reasonable criticisms as they mature and algorithms improve. Regardless of

[5] https://en.wikipedia.org/wiki/Artificial_intelligence 8-28-2023
[6] https://en.wikipedia.org/wiki/Natural_language_processing 8-28-2023
[7] https://pubmed.ncbi.nlm.nih.gov/32565184/ 8-28-2023
[8] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7455610/ 8-2822023

these challenges, AI and the capabilities and applications of AI, will continue to accelerate over the next three-five years. In addition to – and in concert with – the other topics discussed in this document, areas that will be significantly advanced include:

- **Personalized-targeted medicine** - *"The convergence of artificial intelligence (AI) and precision medicine promises to revolutionize health care. Precision medicine methods identify phenotypes of patients with less common responses to treatment or unique healthcare needs. AI leverages sophisticated computation and inference to generate insights, enables the system to reason and learn, and empowers clinician decision making through augmented intelligence. Recent literature suggests that translational research exploring this convergence will help solve the most difficult challenges facing precision medicine, especially those in which nongenomic and genomic determinants, combined with information from patient symptoms, clinical history, and lifestyles, will facilitate personalized diagnosis and prognostication"*[9]

- **Differential Diagnosis** systems provide individualized and weighted diagnosis options for the provider or patient. The selection of differential diagnosis tools and applications are being developed and implemented rapidly. This can be used in a clinical setting, as screening tools and as "chatbot" front ends for virtual medicine. The accuracy of these AI tools is approaching (and in some cases exceeding) the accuracy of providers. *"There are countless cases where a digital personal assistant or a chatbot can help physicians, nurses, patients, or their families. Better organization of patient pathways, medication management, help in emergency situations or with first aid, offering a solution for simpler medical issues: these are all possible situations for chatbots to step in and ease the burden on medical professionals."*[10] Differential diagnosis tools also offer significant promise in identifying uncommon diseases.

- **Treatment planning** - Provide individualized and weighted treatment options for the provider or patient. For example: *"Artificial intelligence in oncology is no longer hypothetical, and its US Food and Drug Administration–approved use is expanding in several clinical scenarios, most prominently involving cancer diagnostics and computer vision … The application of AI in cancer practice includes providing clinical decision support for cancer diagnosis and screening, processing medical data for cancer detection or characterization of patient prognosis, and optimizing care delivery and clinical operations by increasing*

[9] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7877825/ 8-28-2023
[10] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6779111/ 8-28-3023

system capacity and allocating resources".[11] This will also include modeling or "digital twinning" of a patient where a digital model (digital twin) of a patient is created allowing a provider to digitally test the results of treatments and anticipated outcomes.

- **Workflow optimization** - Streamline sequences of tasks into automatic processes and automate some problem-solving processes. Example: automate administrative tasks, like pre-authorizing insurance, following-up on unpaid bills, and maintaining records, to ease the workload of healthcare professionals and ultimately save them money.[12]

- **Revenue Cycle Optimization** - Use AI tools to optimize coding, reduce their cost to collect are being implemented now at a rapid rate with the result of optimizing net revenue while reducing cost and improving the patient financial experience. Example: Tools are in place for the automation of the Prior Authorization which offers substantial financial, user-experience, and care benefits as well as labor savings.[13] AI applications in revenue cycle will accelerate rapidly. Within three to five years, most revenue cycle operations will imbed AI.

- ***Image analysis*** *- It is well established that by using AI in medical imaging, physicians can identify conditions much quicker, promoting early intervention.*[14] *Current and expanding application examples*[15]*:*
    - *Identifying cardiovascular abnormalities*
    - *Detecting fractures and other musculoskeletal injuries*
    - *Aiding in the diagnosis of neurological diseases*
    - *Flagging thoracic complications and conditions*
    - *Screening for common cancers*
    - *Screening and flagging conditions from retinal imaging*
    - *Screening and flagging conditions in dermatology*

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11 https://ascopubs.org/doi/full/10.1200/EDBK_350652#:~:text=The%20application%20of%20AI%20in,system%20capacity%20and%20allocating%20resources 8-28-2023

12 https://www.forbes.com/sites/tomdavenport/2021/06/14/improving-the-healthcare-revenue-cycle-with-ai-and-rpa/?sh=555213ef122c 3-29-23

13 https://www.mckinsey.com/industries/healthcare/our-insights/ai-ushers-in-next-gen-prior-authorization-in-healthcare 3-29-23

14 https://healthitanalytics.com/features/how-can-artificial-intelligence-change-medical-imaging#:~:text=By%20using%20AI%20in%20medical,well%20or%20better%20than%20pathologists. 8-28-2023

15 https://healthitanalytics.com/news/top-5-use-cases-for-artificial-intelligence-in-medical-imaging 3-23-23

- **The potential for new and original concepts** that humans have not yet discovered or may have otherwise dismissed. For example: DeepMind AlphaGo was able to beat the world's leading player at the complex game "Go" by playing not just mathematically but "intuitively". In game two AlphaGo's "Move 37" was a surprising move that was considered highly unconventional and even "a mistake" by the "Go" community. However, this unconventional move proved an innovation that won the game. In this way, AI promises potential for novel inventions / insights in healthcare as well. Additionally, AI is proving nothing less than a revolution for the pharmaceutical industry. New drugs have already been invented by AI and the first of which has entered clinical trials.[16][17] In the next three to five years we will look to AI for novel inventions and insight into drug development, patient care, treatments and public health.

Things to Consider:

- Quality and size of data sets
- Use of the term "AI" as a catch all for general algorithms or other technologies
- Bias in data sets due to general societal and data collection issues
- "Black Box" –lack of transparency into how AI arrives at a decisions-systems are to complex- not de-buggable
- How AI technology effects existing jobs and workflow structures

Current examples of the technologies and/or technology vendors

- Consumer-facing care and assistants
  - Youper - youper.ai/
  - Woebot Health - https://woebothealth.com/
  - Florence - https://florence.chat/
  - Babylon Health - https://www.babylonhealth.com/en-us
  - Bouy Health - https://www.buoyhealth.com/
  - Infermedica - https://infermedica.com/
  - Bright MD - https://bright.md/
  - Ada Health - https://ada.com/
  - Gyant - https://gyant.com/

- Clinical facing analytics
  - DocBox - docboxmed.com/
  - Philips - philips.com/a-w/about/artificial-intelligence.html
  - ScreenPoint Medical - https://screenpoint-medical.com/
  - Enlitic - https://enlitic.com/

[16] https://www.politico.com/newsletters/future-pulse/2023/03/13/your-new-medicine-brought-to-you-by-ai-00086702 3-23-23
[17] https://www.forbes.com/sites/calumchace/2022/02/25/first-wholly-ai-developed-drug-enters-phase-1-trials/?sh=9aa70eb26806 3-22-23

    - Butterfly Network - https://www.butterflynetwork.com/
    - Qure - https://qure.ai/
    - 4Quant - https://4quant.com/
- EHR performance enhancement
    - GE Healthcare Edison - https://www.gehealthcare.com/products/edison
    - Epic/Microsoft - https://www.epic.com/epic/post/epic-and-microsoft-bring-gpt-4-to-ehrs
    - Cerner Enviza - https://www.cernerenviza.com/

2. Expanded Applications and Use of Telemedicine

Current State

Remote healthcare delivery (virtual health/telemedicine) began to establish itself in the 1990s in various forms. Telemedicine started as a method to provide or share expertise in challenging and underserved environments and was initially limited to provider-to-provider consultations. Its applications have expanded significantly in the last thirty years. Increased access to broadband and the availability of lower cost and easy to use hardware have contributed to this, including the use of applications for smartphones. The combination of AI and telehealth is extending the healthcare clinician's capabilities, as well as efficiency. New diagnostic abilities, smart recommendations, and augmented AI tools will empower physicians to perform clinical care like never before.

Beginning this century, virtual health care delivery has become part of the digital transformation of healthcare. The COVID-19 pandemic accelerated this substantially by shifting the delivery of healthcare from an in-person first to a virtual first model for many organizations and practices.

Currently virtual care appears to fall into one or more of the following categories:

1. **Specialty acute applications** including, Tele-ICU, Tele-stroke and tele-crisis intervention. These applications leverage central resources to provide acute services where they were not previously financially viable. They also reduced the resources and costs of providing these services in small and rural hospitals and EDs, and in most cases showed significant improvements in services and outcomes.

2. **Enhanced existing care via virtual services** to current patients to replace or augment in-person visits. These included almost all specialties but are currently most applicable to mental health, primary and urgent care. The demands of COVID-19 pandemic forced most healthcare organizations to offer remote appointments because clinics were closed and to protect both the provider and patient from infection. These services are continuing as both providers and patients realize the advantages and convenience of virtual care. We are in a transition where providers are realizing that a practice that

has a balance of both virtual and in-person encounters may have opportunities to offer improved services at a reduced cost as well as to retain current, and attract new, patients. For example: post pandemic, the number of virtual-first players keeps growing, and physicians who do not offer virtual visits may struggle to attract and refrain patients.[18]

3. **Remote patient management and chronic disease management.** This provides monitoring for patients with chronic conditions in their home. The objective is to provide a greater level of care in the home, assist the patient and their caregiver to manage their condition, and avoid exacerbations and resulting hospitalization. Results have shown improved outcomes and a significant reduction in hospitalizations due to improved patient compliance and reduced anxiety for the patient and caregiver.

4. **Hospital-to-home** enables some patients who need acute-level care to receive care in their homes rather than in a hospital through more advanced, hospital quality monitoring and scheduled virtual and in-person visits[19]. This care delivery model has been shown to reduce costs, improve outcomes and enhance the patient experience. The demands of the pandemic and recent new reimbursement codes have accelerated growth in these services. This also offers added, and more flexible, capacity for a hospital.

5. **Direct-to-Consumer Telemedicine** - Perhaps the highest profile expansion has been in services offered by companies like Teledoc, AmWell, SOC Telemed, MDLive and many others. These on-demand services allow patients to directly access a provider through a website or an APP. These services offer convenience to the consumer, and access is available from almost anywhere at any time. The cost to the consumer is known up front offering exception transparency and usually a much lower cost to the consumer or payer. It is a convenient consumer facing alternative to urgent care and like urgent care, it has been shown that these services accurately diagnose and define treatment in over 80% of interactions. The provider prescribes and sends it to a pharmacy convenient to the consumer. Direct-to-consumer telemedicine provides quality care and equity to persons who might not otherwise be able to conveniently access care due to location, physical impairment, geography or other economic barriers. (see the TTAC Direct-to-Consumer toolkit - https://telehealthtechnology.org/toolkit/direct-to-consumer/). Healthcare systems and insurers are providing these services often in partnership with direct-to-consumer companies.

COVID-19 drove a disruptive event in the use of telemedicine which has changed the use of and attitudes toward telemedicine. Before the COVID-19 pandemic, the use of virtual care (with the partial exception of direct-to-consumer where the encounters were

[18] https://www.mckinsey.com/industries/healthcare/our-insights/patients-love-telehealth-physicians-are-not-so-sure 7-7-2023
[19] https://www.aha.org/hospitalathome - 5-20-2023

patient paid or paid by the employee's healthcare plan) was severely constrained by a number of factors including:

- Comparatively low or no reimbursement.
- Uncertainty and complexity of reimbursement rules including limitations of what providers and services qualified, as well as geographic and provider type limitations.
- Long accepted assumptions by providers, payers and regulators patients would not use them.
- Real and assumed provider resistance and a perception that providers would not, or could not, use it.

COVID restrictions, which forced offices and clinics to close, drove a marked shift in practice patterns. Providers were forced to provide consultation via telemedicine and patients had little option but to accept services via telemedicine or receive no care. CMS's decision to implement waivers to restrictions and to pay at the same rate as in-person proved very prudent and was a significant enabler for this to take place. The number of telemedicine consultations exploded 80x between February and April 2020. In mid -2021 this settled back to about 38x the levels just prior to the pandemic.[20]

Providers and patients experienced virtual care delivery as a viable alternative to in-person in their normal workflow and for the first time, telemedicine was used in consequential volumes. After initial growing pains, current surveys have shown that both groups found the experience effective. Over 80% of providers now say that they plan to have mixed practices (a mixture of in-person and virtual visits). Over 85% of patients now want their providers to offer virtual visits and plan to use them citing a high level of satisfaction and convenience.[21][22]

In addition to convenience and necessity, telehealth visits avoided potential exposure to infection for providers, patients, and staff by eliminating bringing people into healthcare facilities, in-person waiting rooms and in-person contact.

During the pandemic, using tele-emergency services as an alternative to patients coming into the ED became a necessity to reduce infections and to reduce the pressure on EDs. This experience has proved both beneficial for the ED and the patient and recent studies conclude that tele-emergency has potential to increase rural hospital revenue and reduce ED costs.[23]

Acute applications like tele-ICU proved valuable well before COVID-19 delivering improved outcomes, decreased mortality and the more efficient use of scarce and

[20] https://www.mckinsey.com/industries/healthcare/our-insights/telehealth-a-quarter-trillion-dollar-post-covid-19-reality 5-25-2023
[21] https://www.mckinsey.com/industries/healthcare/our-insights/patients-love-telehealth-physicians-are-not-so-sure 5-25-2023
[22] https://www.ama-assn.org/system/files/telehealth-survey-report.pdf 5-25-2023
[23] https://www.emra.org/emresident/article/lit-review-telemedicine/

expensive resources. This became more essential during COVID. Tele-ICU allowed the expansion of ICU beds while remote intensivists and critical care nurses took pressure off local resources. The use of predictive analytics and artificial intelligence (AI) also allowed more effective intervention to improve outcomes and save lives. Tele-ICU allowed these services to be delivered into small, remote, and critical access hospitals where they would otherwise not be available. Tele-stroke service had similar results.

As of November 2021, the use of virtual visits rose again. While the initial explosive growth was due to necessity, this expansion appears to be driven by three items:

1. Apprehension around in-person visits due to the emerging new variants of COVID-19,
2. Expansion of available services being made available by providers,
3. Emerging trends in Consumer preference.

Additional analysis is needed to fully understand the drivers and sustainability of this new increase in use.

The key advantages of virtual care delivery are to provide access, equity, and reduced costs/risks.[24] Telehealth/telemedicine allows healthcare to be delivered regardless of location. It provides capabilities not currently available in both urban and rural underserved communities to improve outcomes, provide easier access to care when and where it is needed, and reduced hospitalizations decrease cost risks for “at-risk” providers.

The COVID-19 experience has also demonstrated the value of telemedicine in responding to other challenges. When snow storms crippled the Northeast US in 2021 and 2022, clinics that normally would have canceled appointments due to the weather were able to leverage the virtual technologies implemented for COVID-19 and shifted many of the clinical encounters to virtual care.[25]

The technology for the clinical encounters described above are well established and proven. Technology and clinical workflows have progressed to a point where telehealth is not merely a proxy for in-person care but incorporated into standard practices of care.

The cost advantages for telemedicine vary by application. All applications require up-front investment in software, platforms, diagnostic devices, training, and workflow change. This further requires understanding the ubiquity of mobile devices. Everyone has a phone and smartphones have become society’s preferred communications device.

[24] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8590973/ 2-25-2023
[25] https://www.healthcareitnews.com/news/when-next-storm-hits-telehealth-could-be-lifesaver 8-28-2023

Future State of Telemedicine/ Virtual Care

The Crystal Ball review indicated the potential for the following outcomes:

- Telemedicine/ virtual care will continue as a standard workflow of care after COVID-19. Most practices will proceed with a hybrid mix of in-person and virtual patient visits. This will encourage new business models and new competitors.

  > ***"A monumental shift is occurring across the industry as more and more organizations adopt digital health strategies that transform health and care,"*** *Russell P. Branzell, President and CEO, the College of Healthcare Information Management Executives (CHIME)*[26]*"*

- We believe consumers will continue to take a greater role in selecting and owning their healthcare. This will drive providers to offer more consumer-focused digital health including virtual visits. Consumer focus will drive disruptive methods of thinking. This will also encourage new business models and new competitors.

- Health systems will continue to invest in telehealth technologies as a cost-effective solution to expand their presence, better leverage their clinical teams, and provide easier and safer access to care for patients. AI and telemedicine will continue to proliferate at an increasing rate. The next five years will see continuing improvement and added applications of telemedicine along with deeper integration of telemedicine and analytics. There are very few, if any, technical barriers remaining. The key exception is access to broadband/ connectivity in both rural and urban environments especially in small clinics and consumer's homes. Expansion of connectivity through government and private sector infrastructure investments will continue and allow added health equity and access to these services.

- Tele-stroke and tele-ICU will allow a change in the business plans for small rural hospitals. These programs will enable small hospitals to better serve their community and allow them to treat and retain patients and keep the revenues in the home community.

- The merging of telehealth applications and AI will create the potential for a patient care journey that is better, safer, easier, and more cost effective.

[26] https://www.mobihealthnews.com/news/survey-telehealth-use-increases-overall-2021-growth-stabilizes 8-28-2023

The critical role of Policy and Reimbursement and a fresh look

Assessing, regulating, and setting policy and reimbursement for telemedicine as an alternative to an in-person visit is an obsolete view. Technical and market capabilities as well as patient capabilities and expectations have moved well beyond. A more productive view would be to consider that healthcare is being changed and improved by technology to a fundamental level just as the application of technology has fundamentally changed most other industries. Digital banking revolutionized financial services and how we access those services in almost every way, and companies like Amazon changed the way we shop and buy. Telemedicine should be seen as a set of tools that can and will significantly change healthcare. Regulation and reimbursement policy should encourage this opportunity to deliver care in new ways that address many of the major challenges that face healthcare in the US. Examples include:

- **Access, Equity and Fairness** - Telehealth enables us to move beyond the existing healthcare infrastructure; thus, creating opportunities for more equitable access to quality care. It allows the delivery of care in rural and underserved urban communities. Consumers (patients) can access care when it is needed wherever they are. On-demand (direct-to-consumer) services are delivered for a transparent, per visit, fee that is often not dependent on insurance. Tele-stroke, ICU and crisis intervention services can be provided at the highest quality even in small and remote locations. Chronic disease patients can be monitored in their home to provide an appropriate continuum of care, which increases compliance with treatment and avoids the need for disruptive and expensive acute interventions.

- **Resource and Expertise Shortages** - Through telemedicine, resources and expertise can be both shared and delivered from where it exists to where it is needed most. Examples:

    - Deliver expertise and care in areas where they may be most needed (rural and urban underserved communities).
    - Telemedicine allows access to new pools of resources. Telemedicine enables access to panels of providers who have excess capacity or are specifically focused on providing shared services. It also allows access to providers who may no longer have the physical ability for bedside care but have the expertise needed to deliver high quality care. Example:

        - Banner Health Tele-ICU supports ICUs in all their hospitals located in six states. Many of these hospitals are in rural areas where critical care nurses and intensivists are difficult to recruit and retain. To gain the proper resources, Banner Health's Tele-ICU can use critical nurses who no longer can, or are willing, to take on the physical requirements at the bedside. They also realized that there were not enough available intensivists in the area to staff their

Phoenix centered Tele-ICU bunker. Banner found that there are intensivists in the Santa Monica, California area that prefer this living location. Although Banner has no hospitals in southern California, they set up a remote tele-ICU bunker to capture this pool of resources.

- **Resource Retention** - Telemedicine creates an environment where expert resources can concentrate on cases at the top of their license often within a cohort of similar providers. Telemedicine also offers alternative work environments for providers that might otherwise have left healthcare due to physical limitations, burnout, or preferences on where they want to live.

- **Mental Health** - The increasing need for, and shortage of, mental health providers is well known. This is especially true in rural and underserved communities and schools. Tele-mental health makes better use of scarce resources and allows delivery of services when and where they are needed in a timely (often urgent) manner. Example:

    - Tele-crisis intervention programs deliver crisis intervention services to the patient when and where they are needed. Leading applications are in the ED and in primary care. This results in providing necessary care, reducing stress on (and diversion of) clinical resources, as well as radically reducing wait times and stress on the patients in crisis.
    - Tele-behavioral support and crisis intervention can be delivered in the schools and continued into the home.

- **Financial viability of small and rural healthcare providers** - Hospitals and clinics in small rural and underserved urban communities struggle to survive and are closing at an alarming rate. Their limited services are too often not competitive, and they often struggle to offer higher revenue services and retain patients. As a result, patients requiring acute or specialty care either do not get the services they need or must be transported. This is bad for patients, the community and for the small hospital. It is also costly for payers (who must pay for transportation and often higher cost services) and for the families of the patients. Example:

    - With telemedicine, almost every small hospital can offer tele-stroke services, which reduces the wait time until intervention, improving outcomes and reducing the cost of long-term hospitalization and care.
    - Tele-ICU service can allow small hospitals to support ICU services where traditional ICU services would be infeasible.
    - Consultative, specialist services, and second opinions can be obtained at the local facility.
    - Care management / chronic disease management keeps patients at home and out of the hospital while reducing cost and risk to payers or at-risk providers.

- Delivering these services locally also creates a more tenacious, long-term relationship between the local hospital and the community so that patients are more likely to stay in the community and not bypass the small hospital for their care.

- **Delayed Care** - Too often, people delay addressing health issues because of fear of the cost of care. Often the processes required to get care can be complex or inconvenient. This generates poorer outcomes and creates delay and worry for the patient/consumer. This often increases the acuity of the issue and increases the cost of care over time. As we focus more on keeping people healthy, it is critical that consumers access healthcare when appropriate. According to a December 2021 Gallop and West Health survey:

  "... about a third of Americans say they've skipped medical care that they needed in the past three months due to concerns about the cost … High medical costs are even impacting higher-income Americans, with one in five households earning more than $120,000 annually saying they also have bypassed care, the research shows. That's an almost seven-fold increase for higher-income families since March."[27]

  - **The Consumer/Patient Experience** - Patients and care decision makers are consumers inside the competitive business that is healthcare in the US. To stay competitive, any service organization must offer a competitive consumer experience. Banks and retailers that failed to offer digital services (tele-banking and on-line shopping) are, for the most part, out of business or restricted to niche markets. For many consumers, healthcare currently is a complex, inconvenient, high cost, frustrating and at times frightening marketspace. This makes healthcare a market ripe for disruption. Consumers (patients) today are changing. They are more willing to shop and compare. They have access to multiple sources of information on any number of topics. They want options that offer convenience, transparency, choice, and quality service. Healthcare providers that do not or cannot offer these benefits through telemedicine and digital health place themselves at a significant competitive disadvantage.

  - **Infection Control** - the COVID-19 pandemic placed in clear focus the infection risk to patients and staff. Bringing people (and their potential infections) into a facility raises the infection risk to patients and staff. The public health emergency caused every healthcare organization to rethink their work flow regarding patient care care. Telemedicine tools played an important part in reducing cross infection, and reducing a variety of costs (e.g., PPE, facilities, disinfection, resulting infections, etc.). Examples:
    - Remote patient encounters not only helped maintain care and revenue, but it also significantly reduced bringing the patient into care facilities.
    - Telemedicine and remote scheduling/check-in tools virtually eliminated the need for waiting rooms where patients would be exposed to each other. It

[27] https://www.cbsnews.com/news/health-care-costs-rising-americans/ 8-28-2023

also reduced the need for registrations staff, and most if not all the registration is still done in advance virtually. It begs the question: Why do we need waiting rooms and their related costs at all?

- Visitation is critical to engage patients and prevent the harm of social isolation. Tele-visitation using simple telemedicine tools like a tablet on a pole and general video platforms allowed patients, families, friends, caregivers, and providers to stay in touch. It also had the added benefit of reducing infection transmission risks, Personal Protective Equipment (PPE) costs and stress on staff.
- Virtual rounding using the same, simple pad on a pole and video platforms increased the safety of providers and patients and significantly reduced the demand for and cost of PPE. Nurses and physicians could complete many of their rotations virtually without having to enter the room and change PPE for every patient.

Adding telemedicine as an essential service to every healthcare organization's strategic pandemic/disaster plan was recommended[28]. The myriad of advantages during the recent pandemic include:

- Leveraging existing technology resources that may not be used full-time, thus increasing utilization and a better ROI.
- Bringing care and expertise where and when it is needed; reducing the need for and cost of transport.
- Reducing demand for resources (Examples: PPE, facilities (waiting rooms and staging facilities), hospital beds (by providing the capability to care for patients in their home).
- Allowing flexibility/conversion of beds (adding higher accurate beds via Tele-ICU and Tele-acute applications).
- Supplementing staff through similar systems.

See the TTAC sponsor Pandemic Response Action Plan for more information: https://telehealthtechnology.org/toolkit/pandemic-response-technology-response-plan/

- **Areas of Disruption and Potential Gaps**
  - Some level of Electronic Health Record (EHR) integration is offered with almost all current telemedicine platforms. Most Tele-ICU and hospital-to-home systems are fully integrated into the host's EHR out of necessity. The partnership between Cerner, Apache (now owned by Cerner) and Philips eICU is a good example. Epic has similar integration in place with a variety of providers. Cerner and Epic appear to be pursuing (through organic development, partnership and/or acquisition) the addition of a wide choice of telemedicine service capabilities directly from their EHR platforms. This trend is expected to continue for all EHR providers.

[28] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9058875/ March 12,2022

- These tools also contribute to and accelerate the “land grab” of large hospital systems looking to create a national brand and greater market share through acquisition, etc.
- A key point is that telemedicine and digital health applications have given rise to many new and non-traditional sources of healthcare which may increase competition with traditional healthcare business models (which are driven by proximity to patients). Telemedicine and digital health tools are enabling the opportunity to disrupt the healthcare market. Companies, including Microsoft, Apple, Amazon, CVS, Best Buy, Walmart, etc. are looking to compete with traditional primary care and urgent care providers. This has the potential to fundamentally change the delivery of care and substantially disrupt the business plans of all current health care providers.

Six critical areas of focus:

1. Moving away from the traditional assumption of in-person first to a virtual first strategy. This creates convenience for the patient, timely response to an issue and potential cost savings for the practice.
2. Changing the business process to take advantage of the cost savings potential. This might include reserving a part of the day for virtual only which requires no physical waiting rooms, front desk / registration staff, etc.
3. Technical literacy training and well as improving virtual care skills for providers and required staff.
4. Adapting to the technical literacy of patients and providing better consumer awareness
5. Assistance to ensuring the right size technology to serve specific clinical needs
6. Increases in technical support and level of service agreements.

Current examples of the technologies and/or technology vendors:

Direct to Consumer	Home (RPM, DCM, other)	TeleICU/Stoke/Platforms
Sesame Care	Accuhealth	Hicuity Health
PlushCare	CareClix	Cloudbreak Health
Teladoc	Caregility	Epic Telehealth
Teladoc	Cloud DX	Teledoc
MeMD	Current Health	Cloudbreak Health
iCliniq	Eko Health	GE - Virtual ICU
HealthTap	Lenovo Health	Caregility
Amwell	One Touch	Cerner Virtual Health
MDLIVE	Qardio	Phiips eICU
Doctor on Demand	ResMed	SOC Telehealth
LiveHealth Online	Validic	VSee
Virtuwell	Vivify	ViTel Net

3. Solution Platforms: Apps, EHR integration/Data Management, BioWare/BioSensors

There is an explosion in the availability of apps and biosensors in healthcare. Apps aimed at consumer health, patient engagement, patient health management and provider support are widely available. Generally, the market is moving from consumer-facing health and wellness devices to devices with increasingly recognized value as health management tools. Until recently most apps were developed to address “point solutions” or single use cases. Many of them have shown valuable results in narrowly defined applications (examples: urgent care, RPM, diabetes management). After years of point solutions, healthcare apps are now moving toward being a part of more comprehensive solutions covering multiple needs. Apps appear to fall into two categories: Stand-alone point solutions and integrated platform applications.

Healthcare apps generally fall into one or more of the following Categories

1. Patient Navigation and Engagement apps provided for patient use – Common functions include:
    - Make and manage appointments
    - Pre and post encounter engagement
    - Patient reminders
    - Replacing waiting rooms with virtual waiting rooms (queuing apps to eliminate/minimize waiting rooms)
    - Patient survey and form functions to gather data on condition, symptoms, social determinants of health, etc.
    - Messaging and data sharing directly between provider and patients
    - Community messaging
    - Weather warnings
    - Public health messaging
    - Air quality - allergy warnings
2. Therapeutic - Platforms and tools used in the direct support of a care provider interacting with a patient
    - Physical, occupational, speech, behavioral health
    - This can be physician aided, self-guided, and/or AI guided
3. Provider Support Apps
    - Access to publications - treatment protocols - drug facts and interactions
    - Decision making: Differential diagnosis - diagnosis and treatment guidance - AI
    - Peer to peer consultation and collaboration tools
4. Consumer focused Health and Wellness Apps
    - Activity and other health measurement tracking: measure performance to goals, maximize performance, reduce consumer stress and make them more in touch with their own health, might include environmental alerts
    - Self-selected or provider guided
    - Gamification - social group engagement
5. Care Access Apps_
    - On-demand care - Access to a provider
    - Intake, symptoms, forms
    - Differential diagnosis generation (chatbots / AI) as a screening tool to support the provider decision
    - Patient - provider interaction
    - Text chat/secure messaging
    - After hours support
    - follow up scheduling
    - reminders
6. “Do It Yourself” Apps
    - Access to consumer information (WebMD, etc.)
    - Guide for self-diagnosis and self-treatment
7. Apps to manage Apps

- Identify preferred apps to recommend to patients
- Approved app lists
- Apps that aggregate and track the data from other apps and devices
- Usage tracking: The use of apps and wearables by patents

Key Trends in the Healthcare Application Marketspace:

- The healthcare market is seeing a significant increase in new entrants and increasing competition. Consolidation of solution providers has already started, and this will accelerate in the near future.

- Point solutions are moving to platforms that address multiple points of care. Appropriate integration into the EHR as well as normalized workflow is essential and is becoming a necessary feature of solution platforms.

  "This pivot can empower providers to engage with health consumers on a much broader spectrum of interactions spanning acute medical issues to aspirational wellness goals and queries. With a wider scope of work, stakeholders can add further value to the experience by giving consumers timely and relevant health information at their fingertips and unparalleled access to experts—wherever they are—through their mobile devices. This access, information and dialogue can heighten the value of the interactions that build rapport and loyalty with consumers.[29]

- Example: Livongo[30] was designed and is accepted in the market as an effective diabetes management app. Livongo has moved to a chronic disease management application that can address the management of an expanding range of chronic diseases. Its workflows are increasingly designed to work within the standard workflows of care. Additionally, Livongo and InTouch[31] have both been acquired by Teledoc[32] (a virtual care platform). This is an example of the broad integration of multiple, former, point solutions into a more comprehensive platform for care delivery.

Trends in Healthcare Apps - From Applications to Solutions - Healthcare solutions are migrating to a new "future state"

[29] https://www.forbes.com/sites/forbestechcouncil/2022/06/08/the-platformization-of-healthcare-is-here/?sh=73967764145a 3 26, 2023
[30] https://www.livongo.com/ 8-28-2023
[31] https://intouchhealth.com/ 8-28-2023
[32] https://www.teladoc.com/ 8-28-2023

Current State	Future State
Skills and Actions	Services
Devices with stand-alone software and apps	Integrated systems
In-room only	Environmentally aware
Limited or no retained context	Context of prior statements, profile
Notifications and reminders	Conversations
Apps to apply context to conversations	Personalized relationship
Ad-hoc partner revenue	Partner segments deliver revenue

EHR Integration Trends - the trend is for these platforms to have some level of native integration into common EHR platforms. The role EHR systems play in data analysis and decision support is growing rapidly. Telehealth apps provide essential informational sources for EHR decision support. Critically, they can provide data to improve decision making using data from beyond the four walls of the hospital. As examples see:

- Teledoc/Livongo/InTouch/Epic/Microsoft CloudServices
- AmWell/Aligned Telehealth/Avisia/Cerner
- Cerner/American Well/Raxiel Health/Google

While many applications are still using the HL7 integration standard to move data between devices, applications and the EHR, we are noticing a strong trend towards the more robust HL7 FHIR integration standards. This is mainly because FHIR is a format that most developers, especially those that work in the mobile domain, are familiar with (based on JSON and REST, both are very commonly used in mobile development). Some common integration difficulties include: a) Variability in data granularity – how much detail that apps, sensors, etc., can send to the EHR while still making the information meaningful for care; and b) Clinicians trust in diagnostic quality of consumer grade health monitoring technologies.

- There is a push for easier and more standardized integration. For example: EPIC has created a “Connection Hub” to make integration easier and to provide a source for the selection of apps[33]

[33] https://www.fiercehealthcare.com/health-tech/epic-plans-overhaul-its-app-market-opens-new-connection-hub-developers-here-are-key 3-26-2023

We know consumer devices, applications, platforms, and data are converging with healthcare specific apps. It will be critical to know the overlaps and how to leverage the capabilities and data resources of consumer apps in the healthcare setting.

Bioware/Biosensors - Wearable Biosensors can take many forms including: wrist worn, rings, wearable patches, implantables and advanced hearables. Use of these technologies is expanding at a rapid rate led by demand for consumer-focused devices. It is inevitable that these consumer centric devices will be moving toward patient measurement and wellness. Device usage is prevalent in a variety of environments, age groups and clinical applications.

Trends in Apps/Wearables/Biometrics - Examples and expected use trends in the next five years in various category examples.

Use Cases	From	To
Mode of wear	Predominantly wrist, ear, device specific, user-integrated	Multiple body areas, patches, rings, data- integrated
Interaction method	Primarily touch	Touchless, voice
Chronic disease management	Condition specific tools	Integrated across diseases
Safety monitoring	Falls, user-signaled, with/without location	Multiple risks, location tracked
Intervention feedback	Episodic, when checked	Continuously available, alerted if out of range
Role of sleep	Device-specific monitoring	Multiple monitors, in combination
Hearing health	Hearing aid, audiologist serviced	Hearables centric, self service
Cost/availability	Consumer-paid	Insurance-covered
Physician input	Suggested	Prescribed
Privacy management	Default opt in assumed	Required opt in
Location of health monitoring	At healthcare provider location	At home, self-monitoring, alerting

Trends in Technology Categories – Expected changes in the next few years. This includes changes in who pays in some cases.

Tech Category	Current	Moving Forward
Telehealth, remote patient monitoring	**MD resistance, COVID-driven reimbursement**	**MDs embrace, CMS permanently reimburses**
Voice first technology	**Smart speakers, voice assistants**	**Touchless smart display, branded voice assistants**
Hearing technology	**High price hearing aids, sold by audiologists**	**DTC, hearables, low-cost hearing aids, self-service**
Caregiver technology	**Assisting care workers, time recording, PERS**	**In-home augmenting care, sensors, voice tech**
PERS, fall detection	**On body pendant, private pay**	**Add in-room sensing, insurance reimbursed**
Senior In-home fitness	**New post-COVID category**	**Telefitness, MD referral**
Virtual reality for seniors	**Experimental**	**Engagement, pain control, caregiver training**
Tech training for seniors	**Fragmented, senior center**	**Nationwide availability**

Current examples of the App/Biowearables/EHR integration technologies and/or technology vendors.

Example Integration Examples:

- Teledoc/Livongo/InTouch/Epic/Microsoft CloudServices
- AmWell/Aligned Telehealth/Avisia/Cerner
- Cerner/American Well/Raxiel Health/Google
- Alpha'et's/Verily/Google/Fitbit
- App–e - Apple Health/Apple Watch/FaceTime/
- Epic Mychart/Twilio

Example Technology Vendors:

- Microsoft/Nuance (Siri Voice and AI plus Teams)
- OneRemissio– - keenethics.com/
- FallCa–l - fallcall.com/
- Healthil– - livehealthily.com/
- Sensel– - sensely.com/
- Oura Ri–g - https://ouraring.com/
- App–e - https://www.apple.com/watch/
- Samsu–g - samsung.com/us/watches/
- Fitb–t - fitbit.com

4. Augmented and Virtual Reality

Augmented Reality "is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory. AR can be defined as a system that incorporates three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects."[34]

Virtual reality (VR) allows users to be transported into a 'virtual world.' Users are engaged in a fully immersive VR experience through a combination of technologies that may include a head-mounted display (HMD), headphones with sound/music and noise reduction, a rumble pad, joystick, or another device for manipulation/navigation of the virtual environment (VE). VR also includes head-tracking systems, which are often built into the HMD. These systems follow the user's head movements, giving them the illusion of being surrounded by a virtual world. Multimodal (visual, auditory, tactile, and olfactory) stimuli contribute to a sense of actual presence/ immersion in the virtual world, thus making the VR experience distinct from passively watching television or movies, or playing a 2D handheld video game or game console.[35]

Originally, VR technology was solely recognized for its entertainment value, such as shopping, video games and even pornography; however, in the past ten years, its application has been expanded to a variety of clinical areas, including pain management, surgical support, vision, rehabilitation and the treatment of psychiatric disorders (e.g., phobias, post-traumatic stress disorder and anxiety disorder).

There are three primary categories of virtual reality simulations used today: non-immersive, semi-immersive, and fully immersive simulations.[36]

Augmented Reality (AR) is an enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli delivered via technology."[37]

The distinctions between VR and AR experiences come down to the differences between the devices they require and the nature of the experience itself.

[34] https://en.wikipedia.org/wiki/Augmented_reality 8-28-2023
[35] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138477/ 8-28-2023
[36] https://heizenrader.com/the-3-types-of-virtual-reality/ 8-28-2023
[37] https://www.investopedia.com/terms/a/augmented-reality.asp 8-28-2023

- *AR uses a real-world setting while VR is completely virtual*
- *AR users can be more aware of their real-world environment "*
- *AR users interact with real world objects and space, while VR users interact with simulated objects and spaces*
- *VR requires a headset device, while AR can often be accessed with a smartphone*
- *AR overlays can add digital information to the physical world, VR uses digital information to enhance a simulated environment* [38]

The key advantage to both is the ability to build and learn in an immersive digital environment that can adapt to, or be modified with software.

Application Examples:

- **Surgical planning and procedure support** - In the technical support and services industries, VR and AR are used to support customers and technicians with field assessment and repairs. This same technology has proven effective in supporting surgeries and other clinical interventions remotely. Surgeons and first responders can receive high level expertise remotely including situation assessments, and guidance on completing a procedure or treatment. These applications allow expert clinicians to virtually 'scrub in' to any operating room or catheter lab from anywhere in the world. These solutions are available and in use today with excellent results.[39] Benefits include:
  - Deliver an immersive experience that allows professionals to act quickly and consistently as well as improve decision through on-demand, voice-directed VR simulation, training, and haptics.
  - Provide educators with the ability to scale experience-based training to any sized population
  - Enable an affordable and efficient way to increase exposure to, and the frequency of, deliberate practice (to reduce skills decay), which has been shown to directly correlate with reduced readiness anxiety and improved retention, performance, and patient outcomes
  - Share high expertise, high-cost resources
  - Rapid, life-saving intervention capability
  - Reduce resource costs
  - Improve success outcomes

[38] https://sopa.tulane.edu/blog/whats-difference-between-ar-and-vr#:~:text=What's%20the%20Difference%20Between%20the,are%20controlled%20by%20the%20system 8-28-2023

[39] https://www.lifescienceindustrynews.com/future-watch/state-of-the-art-operating-theatre-to-feature-live-and-simulated-surgery-at-future-surgery-2022/ 5-4-2023

- **Provider training -** The same tools used for surgical planning, education, and procedure support (above) can be used to provide initial and ongoing training for providers at all levels.

- **Mental Health** - Significant evidence is showing that VR can be effective in treating a variety of mental health conditions[40]. Riding a wave of interest in mental health tech, companies creating VR content for therapeutic outcomes are receiving a deluge of attention and funding. And, while VR has been used successfully to treat post-traumatic stress disorder (PTSD) since the 1990s, these new programs address a much broader range of conditions. For instance, the library of Palo Alto–based company Limbix, includes VR content designed to treat issues ranging from alcohol addiction, claustrophobia, and teenage depression. Barcelona-based Psious offers treatments for eating disorders.

  Much of today's mental health VR content is designed to aid in exposure therapy, a treatment for anxiety disorders in which patients are exposed to anxiety-inducing stimuli in a safe, controlled environment, eventually learning that the "threats" they're worried about are not actually very dangerous. For example, someone who fears heights might visit progressively taller buildings under the guidance of their therapist (a therapeutic called *in vivo* exposure), while someone with PTSD might revisit traumatic memories in therapy sessions (imaginary exposure).

  In non-VR environments, exposure therapy mainly happens in carefully controlled real-world scenarios. However, VR allows therapists to create that safe, controlled environment inside a VR headset instead. This can be a far safer, quicker, and less expensive option.

  An added benefit of using VR is that it also gives therapists much more control over the intensity of their patients' experiences, which can lead to better treatment outcomes.[41] For example, studies show that patients with PTSD who also suffer from depression tend to respond much better to VR exposure therapy, compared to other treatment methods.

[40] https://www.forbes.com/health/mind/virtual-reality-therapy/#:~:text=Virtual%20reality%20therapy%20in%20the,relief%20in%20place%20of%20medications. 5-4-2023
[41] https://blogs.scientificamerican.com/observations/virtual-reality-might-be-the-next-big-thing-for-mental-health/ 8-28-2023

- **Pain Management** - Pain is a high-cost segment of healthcare. It is also problematic in the limited options to treat, and the effects of prescription drugs used in pain management. The National Academy of Sciences estimated in 2010 that more than 100 million American individuals experienced chronic unrelieved pain.[42] The estimated cost of this segment of healthcare was $560 billion to $635 billion per year, composed of direct health care costs ($261 billion to $300 billion), days of work missed ($11.6 billion to $12.7 billion), hours of work missed ($95.2 billion to $96.5 billion), and lower wages ($190.6 billion to $226.3 billion.) The cost of pain was more than either that of heart disease and cancer treatments.[43] AR and VR are being applied as a modality that improves pain and costs less.[44]

  Virtual reality (VR) has been shown in a variety of settings to effectively decrease pain and distress associated with a wide variety of known painful medical procedures. Participants immersed in VR experience reduced levels of pain, general distress/unpleasantness and report a desire to use VR again during painful medical procedures.[45]

  Most have assumed that the effectiveness of VR in managing pain is a simple distraction. However, investigators are now considered the neurobiological interplay of brain cortices and neurochemistry, as well as emotional, cognitive and attentional processes to understand the underlying mechanistic origin for VR analgesia (the inability to feel pain). Researchers have only recently begun to deconstruct patient and disease characteristics, specific aspects of VR technology, and to identify neurobiological mechanisms underlying VR.[46] This is a very fast moving area and the FDA has authorized marketing of a virtual reality system for chronic pain reduction.[47]

- **Physical rehabilitation** - Virtual reality is an emerging area of the therapeutic arts.[48] With the shortages of therapists and limits on the number of sessions covered by payers, there is significant interest in tools that make sessions more effective as well as tools that motivate patients to continue rehab activities at home between sessions. VR offers a more engaging and motivating and "fun"

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[42] https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2729797#zic190020r1 5-5-2023
[43] https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2729797 1-23-2023
[44] https://www.cedars-sinai.org/newsroom/new-study-shows-value-of-virtual-reality-for-pain-management/ 1-24-2023
[45] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138477/ 1-22-2023
[46] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138477/ 1-20-2023
[47] https://www.fda.gov/news-events/press-announcements/fda-authorizes-marketing-virtual-reality-system-chronic-pain-reduction 1-24-2023
[48] https://www.apta.org/patient-care/interventions/virtual-reality 8-29-2023

experience that combines physical and cognitive therapies at the same time. This application of VR/AR is emerging and may not have a significant effect in the next five years.

- **Surgical patient education pre-procedure, post procedure and treatment** - VR and AR are being used to educate patients about their clinical issues, the procedure they are about to receive, as well as post-procedure treatment protocols and the healing process. See surgical planning, education, and procedure support (above).
- **Medication and protocol adherence** - VR has proven to enable better compliance with care and drug treatment plans resulting in better compliance and outcomes.[49]See surgical planning, education, and procedure support (above).
- **Assistance for visually impaired** - Augmented reality and virtual reality are being used to radically improve patients' remaining sight by simulating human vision. It does this by using a camera to process incoming images and projecting the augmented feed onto the working part of a patient's retina.[50] The results have been excellent, and the use of this technology and treatment is expanding rapidly.

Current State of the VR/AR Industry

The VR/AR industry is often described as "in the middle of messy adolescence stage". However, these signs of maturation are evident in that 1) Products and services are available for a wide variety of use cases; 2) Efficacy has been proven; 3) There are current vendors in every sector we have discussed; and 4) Additional new vendors, products and services are expanding quickly.

Currently, VR is dependent on glasses or cave-like structures or desks which were initially costly and had limitations. However, capabilities are increasing, and costs are dropping. This is largely being driven by consumer gaming capabilities. Cell phone-based VR, where a cell phone is used in a low-cost VR headframe, is further dropping cost. The gaming and pornography industries are often leading the improvement of openly available software tools for content creation – therefore platforms to develop virtual environments are available today. A critical factor will be the integration of AR&VR into normalized training workflows of organizations. This technology can replace the millions spent on demonstration centers and can simplify onboarding, training on new technology, and protocol implementation. Widespread use of this technology will require the restructuring of current training approaches, greater technical literacy for trainers, and a higher level of technical support.

[49] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6610452/ 8-29-2023
[50] https://www.forbes.com/sites/nicholasfearn/2020/01/08/how-vr-is-helping-visually-impaired-patients-regain-close-to-normal-levels-of-sight/?sh=7a7b5e860277 8-28-2023

The Centers for Medicare and Medicaid Services (CMS) opened a pathway for reimbursement when it established a unique Healthcare Common Procedure Coding System (HCPCS) Level II code for a virtual reality program as durable medical equipment.[51]

Current examples of the technologies and/or technology vendors:

- Software platforms
  - Unity - https://unity.com/
  - Unreal - https://www.unrealengine.com/
  - Apple - https://www.apple.com/augmented-reality/
  - Microsoft - https://www.microsoft.com/en-us/mixed-reality/windows-mixed-reality
- Surgical planning, provider and patient training and remote expertise/guidance
  - ImmersiveTouch - https://www.immersivetouch.com/
  - Proximie - https://www.proximie.com/
  - Proprio - https://www.propriovision.com/
  - TrueVision - *www.truevisionsys.com*
  - EchoPixel - https://echopixeltech.com/
  - Osso VR - https://www.ossovr.com/
  - FundamentalVR - https://www.fundamentalvr.com/
  - SentiAR - https://sentiar.com/
  - Surgical Theater - https://surgicaltheater.com/
  - Proximie - https://www.proximie.com/
- Mental health
  - Limbix - https://www.limbix.com/
  - Psious - https://psious.com/
  - Oxford VR - https://ovrhealth.com/
  - MindCotine - https://mindcotine.com/
- Pain management
  - RelieVRx - https://www.easevrx.com/
- Vision assistance
  - GiveVision – https://www.givevision.net/
  - Irisvision – https://irisvision.com/
  - Samsung Relúmĭno – https://www.samsungrelumino.com

[51] https://mhealthintelligence.com/news/cms-establishes-reimbursement-pathway-for-virtual-reality-program 5-20-2023

5. Drones

Drones are unmanned aerial vehicles (UAVs), aircraft without any human pilot on board. UAVs are a component of an unmanned aircraft system (UAS), which includes a ground-based controller and a system of communications with the UAV. The flight of Drone may operate under remote control by a human operator, as remotely-piloted aircraft (RPA), or with various degrees of autonomy, such as autopilot assistance, up to fully autonomous aircraft that have no provision for human intervention. Drones can be fixed wing or rotary wing configurations depending on the application. While rotor drones demand less infrastructure and are more maneuverable in tight environs, fixed wing drones generally offer far greater range and endurance. Drones were originally developed through the twentieth century for military missions too "dull, dirty or dangerous" for humans. As control technologies improved and costs fell, their use expanded to many non-military applications. These include aerial photography, product deliveries, agriculture, policing and surveillance, infrastructure inspections, science, smuggling, and recreation.[52]

Drone applications are much broader than the recreational (toys) or military devices we may be familiar with, and applications for healthcare are emerging rapidly. Drones make it possible to deliver blood, vaccines, birth control, snake bite serum and other medical supplies to remote and rural areas. They offer the ability to reach victims who require immediate medical attention within minutes with essential tools (including Automated External Defibrillators - AEDs), which in some cases could mean the difference between life and death. They can transport medicine within hospital walls and courier blood between hospital buildings, as well as give elderly patients tools to support them as they age in place. Drones offer a variety of exciting possibilities to the healthcare industry that can help save money as well as lives.[53,54]

Drones are a promising technology for improving patient survival, outcomes, and quality of life, particularly for those in areas that are remote, are under-resourced, or that lack infrastructure. Their cost savings (when compared with ground transportation alone), speed, and convenience make them particularly applicable in the field of emergency medicine. Research to date suggests that use of drones in emergency medicine is feasible, will be accepted by the public, is cost-effective, and has broad

[52] https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle 1-31-2022
[53] https://www.dronesinhealthcare.com/ 1-31-2022
[54] https://healthcaretransformers.com/healthcare-business/drones-healthcare/ 1-31-2022

application.[5556] Drones have the capability to improve situational awareness and improve response related to environmental and airborne biotoxins.

The use of drones for many of the above applications is already proven and in operations today (mostly outside of the US). Regulatory standards are improving as is incorporating more Drone pilot license curriculums around the country.

Healthcare Applications include:

- **The delivery of time sensitive medical materials** (blood, plasma, vaccines, drugs, spare parts, instruments, etc.). This is already being used in remote or underserved areas where access is difficult and where infrastructure is limited (conflict zones, poor roads, urban congestion, etc.). This application allows centralized inventory of high cost and essential supplies, which reduces cost and the need for small clinics to store high-cost products "just in case".

- **Transport of specialty life-saving medical devices and equipment**. Examples include:

    - On-demand delivery of AEDs cutting the time to assist cardiac arrests and increase survivability. An AED can be delivered to the patient location in minutes – much faster than EMS vehicle response – especially in crowded cities or remote and rural areas.

    - The US Army's "hospital in a rucksack" which brings medical supplies, devices, guidance and even robotics to the location of medical need.[57]

- **On-demand delivery of telemedicine capability** – Deliver a telemedicine unit including: connectivity, screen, camera, and sound – allowing direct connection between the patients in need and providers, to help the patients and other responders at the scene.[5859]

[55] https://www.dovepress.com/impact-of-using-drones-in-emergency-medicine-what-does-the-future-hold-peer-reviewed-fulltext-article-OAEM 1-31-2022

[56] http://csohio.himsschapter.org/sites/himsschapter/files/ChapterContent/csohio/Drones%20in%20Healtcare%20Rise%20of%20the%20Machines.pdf 1-16-2022

[57] https://www.pitt.edu/pittwire/features-articles/trauma-care-rucksack 5-17-2023

[58] https://pubmed.ncbi.nlm.nih.gov/35678389/ 5-17-2023

[59] https://southerncrossdrones.com/cape-aerial-telepresence.html 5-17-2023

- **Emergency Transport of patients** – EMS transport drones are now available that can carry a patient in emergencies. These can include non-contact vital signs collection (using light, imaging, and AI to measure BP, temp, pulse, respiration, SpO2, motion and other vital signs) which allows continuous monitoring of the patient in flight. Using facial imaging to provide these measurements is well proven in various applications.[60],[61]
- **Transport of blood and other samples for routine testing** – Drones can deliver samples quickly even in rural areas with poor roads and long transit times, giving ritual providers quick access to tests. Samples can go directly from the home or other site of care to the lab.[62]
- **Delivery of food, medicine, shelter, and connectivity/communications in a natural or man-made disaster** – Drones can deliver critical supplies to the most remote locations even if essential infrastructure is unavailable to disaster sites, facilities, vehicles, ships or to the homes of people in need. Drones can also provide Wi-Fi and cellular communications platforms in disaster relief and emergency situations.[63]
- **Symptom identification and surveillance in crowds** – Drones have been developed to remotely detect people in crowds with infectious conditions such as COVID-19, using non-contact vital sign measurement.[64] [65]

Current state of the industry and uses:

- **Delivery** - Transportation of medical supplies, blood plasma, organs, and medical samples is already costly especially in crowded urban areas and remote or rural locations. Today the use of air ambulances and ground vehicles is expensive and time consuming and at times dangerous. Drones offer a very cost effective and rapid alternative.

  Examples:

- Drones are already in use in a normal workflow for many of the above applications.

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[60] https://news.mit.edu/2020/spot-robot-vital-signs-0831 1-16-2022
[61] https://www.forbes.com/sites/johnkoetsier/2020/08/19/ai-health-startup-can-get-15-vital-signs-via-your-phone-camera/?sh=65eee0c529b5 1-31-2022
[62] https://www.fiercehealthcare.com/healthcare/drones-can-help-transport-blood-samples-for-routine-tests 1-31-2022
[63] https://hdiac.org/articles/communicating-in-remote-areas-or-disaster-situations-using-unmanned-aerial-vehicles/ 5017-2023
[64] https://hitconsultant.net/2020/03/27/pandemic-drone-could-detect-virus-symptoms-like-covid-19-in-crowds/ 1-31-2022
[65] https://www.unicef.org/supply/media/5286/file/%20Rapid-guidance-how-can-drones-help-in-COVID-19-response.pdf.pdf 1-31-2022

- In Australia, Google drone delivery service has reached over 100,000 deliveries per weekend.

- In Rwanda, distribution of blood plasma, drugs and medical supplies is in place. This service has been operational since 2016 and has become an essential part of the daily distribution of medical supplies. In addition to rapid delivery, it also allows using centralized supply centers which reduces inventory costs.[66] The drone and supporting technology is supplied by California based Zipline.[67] Ziplines's drone flights are fully integrated into the Rwandan air traffic control system. In addition, Zipline has developed advanced accident- avoidance avionics for drones and is sharing this technology with other drone manufacturers. A similar program to Rwanda is in implementation in Malawi using drones from California based Flirtey (Skydrop).

  Zipline has expanded healthcare delivery operations into Nigeria and Ghana and is partnering with an ecommerce company in Rwanda to deliver household goods and electronics to homes.

- In Switzerland, Swiss Post is using drones to transport laboratory samples, also using drones from California based Flirtey (Skydrop).[68]

- In the US,
  - Air Methods is implementing a US wide drone medical delivery service.[69]
  - CVS/UPS - UPS announced a partnership with CVS to deliver drugs in Florida and is pairing with others to expand drone delivery of additional goods to other locations. First deliveries started in 2019.[70]
  - UPS has begun a new logistics program using unmanned drones to deliver medical samples at a North Carolina hospital. The pilot program is taking place at Wake Med Hospital in Raleigh, North Carolina, overseen by the FAA and North Carolina Department of Transportation.

- **AED delivery** - Approximately 350,000 individuals have an out-of-hospital cardiac arrest (OHCA) in the US each year, with survival at around only 10%, despite advances in emergency cardiac care. Survival probability doubles when

[66] https://www.youtube.com/watch?v=jEbRVNxL44c 1-28-2022
[67] https://flyzipline.com/ 1-27-2022
[68] https://www.post.ch/en/about-us/innovation/innovations-in-development/drones?shortcut=opp-en-about-us-company-innovation-swiss-post-s-innovations-for-you-drones 1-17-2022
[69] https://wingcopter.com/spright-deal 1-31-2022
[70] https://www.globenewswire.com/news-release/2020/04/27/2022615/0/en/UPS-Flight-Forward-CVS-To-Launch-Residential-Drone-Delivery-Service-In-Florida-Retirement-Community-To-Assist-In-Coronavirus-Response.html 1-16-2022

a bystander conducts defibrillation and cardiopulmonary resuscitation (CPR) prior to EMS arrival. However, time is of the essence. The likelihood of a neurologically intact survival outcome decreases by 10% for every minute without resuscitation, and is highest when CPR and defibrillation are conducted within five minutes of the OHCA. In rural areas, EMS arrival time is considerably more than the median US arrival time of eight minutes and can be more than thirty minutes. Bystander use of AEDs has the potential to improve survival, yet bystander AED use in the US remains at less than 2%, despite programs to increase their use in public areas. AEDs remain difficult to locate and are rarely available in homes or residential areas where approximately 70% of OHCA occur.[71] Drones offer an effective and cost effective alternative for rapid intervention.[72],[73],[74] Sweden has implemented drone AED delivery and European testing and implementation of drone AED delivery.[75] In Sweden, on-demand, drone delivery of AEDs is in place and is already credited with saving lives.[76,77] Studies in the US, UK and Canada have confirmed viability and benefit. Most large US AED manufacturers have had this capability in testing for years.

Key Regulatory barriers appear to be being resolved. The air traffic control regulations inside and outside the US have been largely resolved and flight approvals have been granted. The FAA has established programs to address drone delivery operations [78] and has granted authorization to a number of delivery services under this program. The EU aviation administrations are testing drone delivery applications.[79] Zipline's medical delivery drone operations are fully integrated into the Rwandan air traffic control. Relatedly, New Zealand approved the use of drones in delivery of a variety of goods (including Domino's pizza). The FAA approved drone delivery of medical supplies in Virginia and Kentucky. In August of 2020 Amazon received the Federal Aviation Administration's permission to begin conducting regular drone operations. Other applications are expected to be approved in 2023.

It is believed drone use will continue to expand quickly especially in logistics and emergency response. There are drone vendors available now who will supply and support these applications including full outsourcing.

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[71] https://www.dovepress.com/impact-of-using-drones-in-emergency-medicine-what-does-the-future-hold-peer-reviewed-fulltext-article-OAEM 1-29-2022
[72] https://www.nejm.org/doi/full/10.1056/NEJMc2200833 5-10-2023
[73] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8592459/ 5-10-2023
[74] https://www.ahajournals.org/doi/10.1161/JAHA.120.016687 5-10-2023
[75] https://healthcare-in-europe.com/en/news/aed-drone-delivery-shows-great-potential.html 1-16-2022

[76] https://dronelife.com/2022/01/06/for-the-first-time-in-medical-history-autonomous-drone-saves-heart-attack-patient-delivering-defibrillator/ 1-27-2022
[77] https://www.bbc.com/news/technology-59885656 5-10-2023
[78] https://www.faa.gov/uas/advanced_operations/package_delivery_drone 5-10-2023
[79] https://healthcare-in-europe.com/en/news/aed-drone-delivery-shows-great-potential.html 5-10-2123

- The US military and private companies are testing expanded applications in the battlefield and beyond.

Current examples of medical drone service and technologies include:

- Amazon - https://www.aboutamazon.com/news/transportation/
- Cape - https://southerncrossdrones.com/cape-aerial-telepresence.html
- Matternet - https://mttr.net/
- Ehang - https://www.ehang.com/news/732.html
- Flirtey - Skydrop - https://getskydrop.com/
- Flyrex - https://www.flytrex.com/
- Swoopaero - https://swoop.aero/
- Wingcopter - https://wingcopter.com/
- Spright - https://www.gospright.com/
- UPS - https://www.ups.com/
- Wing (division of Google parent Alphabet) - https://wing.com/
- Vayu - https://www.vayuaerospace.com/
- Zing - https://www.zingdrones.com/
- Zipline - https://www.flyzipline.com/
- Intelomed[80] https://intelomed.com/ (facial camera measurement of vital signs)

6. Robotics

A **robot** is a machine capable of carrying out a complex series of actions automatically. A robot can be guided by an external control device, or the control may be embedded within. Robots may be constructed to evoke human form, but most robots are task-performing machines, designed with an emphasis on stark functionality, rather than expressive aesthetics.

Robots can be autonomous or semi-autonomous and range from humanoids to industrial robots, medical operating robots, patient assist robots, pet therapy robots, collectively programmed *swarm* robots, and even microscopic nanobots. By mimicking a lifelike appearance or automating movements, a robot may convey a sense of intelligence or thought of its own. Autonomous machines are expected to proliferate in the future.

[80] https://intelomed.com/ 1-16-2022

The branch of technology that deals with the design, construction, operation, and the applications of robots, as well as computer systems for their control, sensory feedback, and information processing is robotics.[81]

Robots in the medical field are transforming how surgeries are performed, streamlining supply delivery and disinfection, assisting in physical therapy and rehabilitation, and freeing up time for providers to engage with patients.

Application Examples – types of medical robots include:

- **Surgical and surgical training robots**: allow surgical operations to be carried out with better precision than an unaided human surgeon, or allow remote surgery where a human surgeon is not physically present with the patient. Human factors such as age-related hand tremors or eye-hand coordination can be significantly improved with surgical robots.
- **Rehabilitation robots**: facilitate and support the lives of infirm, elderly people, or those with dysfunction of body parts affecting movement. These robots are also used for physical, occupational, and cognitive therapies and can guide the exercise of the patient autonomously.[82]
- **Telepresence robots**: allow off-site medical professionals to move, look around, engage the patient, communicate, and participate from remote locations.
- **Pharmacy automation**: robotic systems to dispense oral solids in a retail pharmacy or hospital setting or preparing sterile IV admixtures in a hospital pharmacy setting.
- **Companion/Support robots**: have the capability to engage emotionally and physically with users keeping them company, and alerting if there is a problem with their health.
- **Disinfection robot**: has the capability to disinfect a whole room in mere minutes, generally using pulsed ultraviolet light.[83]
- **3D Printing**: Also known as additive manufacturing, 3D printing is a method of creating a three-dimensional object layer-by-layer using a computer created design and a robotic printing device to lay down the layers. As a result, 3D printing can be used for creating one-off or custom items or production items.[84]

[81] https://en.wikipedia.org/wiki/Robot 1-30-2022
[82] https://ifr.org/news/robots-help-patients-recover-faster-from-stroke/ 5-17-2023
[83] https://en.wikipedia.org/wiki/Medical_robot 2-4-2022
[84] https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing 2-10-2022

Current state of the Industry and uses:

Robotics surround our everyday life. ATMs, coffee/drink-making vending machines, self-driving cars, autonomous vacuum cleaners and lawn mowers to name just a few. The introduction of robotics into healthcare has been proceeding for over two decades and continues to accelerate.

Robots are very capable of repetitive tasks and can be programmed or guided for very precise or complex tasks often beyond the capability of a human. Historically, robots have been used in specialties like surgery and pharmacy, where a great amount of accuracy and remote control are needed. New devices and robots for a wide variety of healthcare applications are being introduced and put into practice.[85]

- **Assistance tools for the home** – There is a significant need for the development, approval, and implementation of assistance tools for people in the home. Drivers for this need include increasing demand (an aging population), and an escalating shortage in available persons to provide this type of care. Robots are being used as companions and to provide support for dementia patients. They can also be used to help move the patient; move goods to the patient; assist with rehabilitation and exercise, complete basic home tasks, etc. Examples include:
    - **Smart wheelchairs** - this includes wheelchairs that support independent/autonomous movement and others that have smart cushions that inflate or deflate to adjust pressure to reduce pressure sores and muscle atrophy. Wheelchairs are available that use natural language processing to accept driving instructions.

    - **Devices that improve patient access and convenience –** Currently available robots that provide a variety of assistance task in the home include, cleaning, telepresence, security, fetch, and delivery, etc. [86]

    - **Devices that enhance performance** – Robotic exoskeletons are becoming more commonplace. These enable humans to lift greater loads or overcome injuries and other physical limitations.

    - **Companion/support** - The value of support robots for Alzheimer's is being recognized and acceptance is growing. Some healthcare payor entities are now paying for these types of devices (Aetna and others).

[85] https://www.nature.com/articles/s41598-022-12632-4 8-28-2023
[86] https://www.washingtonpost.com/technology/2021/11/10/home-robots-more-personal/ 5-17-2023

- **Surgical robots** have become increasingly common. There are now nearly 6000 da Vinci systems in operation that have performed 8.5 million procedures worldwide.[87] These are controlled in proximity to the patient in most applications.

  Our think tank members observed that we are entering what some call the "third phase of tele-surgery technology". This phase applies advances in the virtual transport of real time expertise (via telepresence, AI, and VR) to operate surgical robots remotely. Distant, remotely controlled surgical robots can suffer from technical limitations related to bandwidth and latency (a time delay of even a few milliseconds can be a problem in surgery). However, as bandwidth and reliability improve, truly remote surgery is in testing for viability.[88]

  The use of surgical robots is also being explored throughout the military. Carnegie Mellon is working with the University of Pittsburgh to develop completely autonomous remote surgery solutions for life saving interventions in the field. This has applications for the military as well as rural care and the growing market for wilderness medicine. Examples include:

- **Guidance robots** - Use of robots to guide the medic on the ground in acute life-saving actions. These might include needle insertion guidance (catheter insertion) or other guidance intended to save a soldier's life and stabilize for transport.
- **Pharmacy automation**: robotic systems to secure, sort, count, package, and dispense oral solids in both retail and clinical pharmacy settings. They can also be used to prepare sterile IV admixtures and in pharmacy compounding in a hospital pharmacy setting.[89]

- **3D printing** – In the last ten years, the use of 3D printing technology has increased dramatically in medicine. Engineers and medical professionals now routinely print 3D parts, tools, and appliances. This enables the ability to leverage digital workflows and other benefits of 3D printing, such as just in time, cost effective, small batch production capacity. The return on investment is supported by improved patient care and the ability to print appliances like splints, surgical

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87 https://wchh.onlinelibrary.wiley.com/doi/full/10.1002/tre.834#:~:text=There%20are%20now%20nearly%206000,performed%208.5%20million%20procedures%20worldwide. 5-10-2023

88 https://www.scmp.com/news/china/science/article/3210752/how-5g-and-remote-robot-arms-are-extending-chinas-surgical-reach 5-10-2023

89 https://www.healthtechmagazines.com/analyzing-compounding-pharmacy-robotics-what-to-expect/ 5-17-2023

guides, and dentures on site with rapid turn-around. We expect that 3D printing has only just begun to transform the field. Specific applications which are expanding quickly include:

- **Dentistry**. Advances in materials are beginning to allow the creation of permanent crowns and other appliances. Today, there are already 3D printers that can meet the high demand and strict requirements needed for permanent crowns, inlays, onlays, and veneers. [90],[91]
    - Current device suppliers include : Formlabs: www.formlabs.com

- **Surgery preparation** assisted by the use of 3D printed models. The on-demand creation of customized models, that enable surgeons to better visualize, practice, and perform surgeries while saving time and increasing precision.[92]

- **Prosthetics** and joint replacements are customized to suit and fit the wearer. It is common for amputees to wait weeks or months to receive prosthetics through the traditional route; however, 3D printing significantly speeds up the process. Additionally, these prints can be made using lower cost materials that offer patients the same functionality as traditionally manufactured prosthetics. The lower price point of these products makes them particularly applicable for use with children, who quickly outgrow their prosthetics. 3D printing can also allow the patient to design a prosthetic that corresponds directly to their specific needs.[93]

- **Bioprinting tissues and organoids** – Using specialized 3D printers and techniques we can now begin to fabricate biological and living tissue. The process creates three-dimensional structures of biological materials (from cells to biochemicals) through precise layer-by-layer positioning). The ultimate goal is to replicate functioning tissue and material, such as organs, which can then be transplanted into human beings. In reconstructive and plastic surgeries, implants can be specifically customized for patients using “biomodels” made possible by special software tools. Human heart valves[94], for instance, are now being 3D

[90] https://www.dentistrytoday.com/2021-the-year-of-3d-printing-in-dentistry/ 8-28-2023
[91] https://www.dentalnews.com/2020/08/20/5-ways-3d-printing-revolutionized-dental-industry/ 8-28-2023
[92] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7176764/ 5-18-2023
[93] https://www.medicaldevice-network.com/features/3d-printing-in-the-medical-field-applications/ 8-282023
[94] https://directorsblog.nih.gov/2019/10/10/3d-printing-a-human-heart-valve/ 5-17-2023

printed through several different processes although none have been transplanted into people yet. This is an area where regulations are only catching up with technology. This regulatory lag may result in restricted progress in the field.[95]

- **Surgical instruments** - Sterile surgical instruments, such as forceps, hemostats, scalpel handles and clamps, can be produced using 3D printers. Not only can 3D printing produce sterile tools but, using traditional origami like techniques, printed tools can be made small and precise. These instruments can be used to operate on tiny areas without causing unnecessary damage to patient tissues.

- **Spare Parts for Robotics and other medical devices** - Creating spare parts for robots, assistance devices, medical instruments, and other items can be valuable, especially in rural and remote locations where parts vendors are not available, and parts replacement is critical. Gears, housing, and other hard parts are good applications.

- **Nursing Homes, SNFs and other multi residential environments:**
  - **Lifting and moving assistance** - Robots are capable of great strength with the ability to augment human strength.[96] Back injuries are a leading source of workplace injury in healthcare staff and mechanical devices can help solve this challenge. Robots and robotic arms to assist caregivers and nurses to move patients have been around for years and are used to good effect today. In addition to stand-alone devices, these robots can also be wearable assist devices that augment the provider's strengths.[97]
  - **Companions/therapy assistants** - Robots are being used as companions and to provide support for dementia patients.[98]
  - **Telepresence** - using a mobile telepresence robot can enhance provider/patient connection[99] as well as connection to friends and family.[100] A side benefit is the reduction of infection exposure.

[95] https://theconversation.com/3d-printing-of-body-parts-is-coming-fast-but-regulations-are-not-ready-128691?utm_source=flipboard&utm_content=GedCoz%2Fmagazine%2FHealth%2C+Mind+%26+Biology1 8-28-2023
[96] https://fsi.stanford.edu/news/robots-may-be-right-prescription-struggling-nursing-homes 5-18-2023
[97] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8256590/ 5-18-2023
[98] https://www.npr.org/2022/05/24/1100985010/are-robots-the-solution-to-understaffed-nursing-homes 5-18-2023
[99] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8603033/ 5-18-2023
[100] https://journals.sagepub.com/doi/full/10.1177/23337214231166208 5-18-2023

- **Meds/supply delivery** - these are autonomous healthcare robots that navigate hallways and elevators around the clock, carrying medications, /ab samples, and other critical items boosting efficiency and throughput.[101]

Many of these robotic applications have shown compelling ROIs because of the scale and volume of work they can do for multiple patients and providers.

- **Life Saving** - In remote medicine (rural, military, humanitarian) patients with an acute life-threatening injury need expert intervention immediately. However, in these applications, high level expertise resources are often not available or will not be available within the time window needed to save the patient. As discussed in the surgical application above, Robots can provide the precision of an expert in an environment where these experts are not available. They are currently used with a "person in the loop" but are becoming more capable of autonomous operation. Current programs are moving these applications and capabilities out into the field. The Center for Military Medicine Research (CMMR) at the University of Pittsburgh along with Carnegie Mellon and others are among some of the institutions driving this trend forward. The objective is to engage the use of these tools for lifesaving procedures in remote and rural areas and to allow the far forward provider to act as effectively, safely, and autonomously as possible. This includes decision support systems as well as robotics. All that is needed would be delivered in a package the size of a rucksack that could be carried in or delivered by a drone to the point of need.

- **Rehabilitation** Therapy: facilitate and support the lives of infirm, elderly people, or those with dysfunction of body parts affecting movement. These robots are also used for rehabilitation and related procedures, such as training and therapy. Robots can be programmed to adapt to the individual, providing the correct motion and resistance (for example in stroke recovery). The same capabilities are applied to physical, occupational, and cognitive therapies and can guide the exercise of the patient autonomously. These products are available today and can improve therapy while increasing capacity of highly trained resources. Rehabilitation is moving to the home or to stand alone facilities and robotics are proving to be a very effective tool.[102],[103] ,[104]

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[101] https://nurse.org/articles/delivery-care-robots-launched-in-texas/ 5-18-2023
[102] https://pubmed.ncbi.nlm.nih.gov/36979997/ 5-18-2023
[103] https://link.springer.com/article/10.1007/s43154-020-00015-4 8-28-2023
[104] https://motusnova.com/?campaignID=9368895282&adgroupID=95756083395&targetID=kwd-355156969575&gclid=CjwKCAjw_L6LBhBbEiwA4c46uu0giUtmTmCmS9Dn-VexhpBDh34U23BGEBdlQyeUgstDKVVNUPHzXBoCtLAQAvD_BwE#what 8-28-2023

Note: It is important when setting expectations that we understand that the advancement of robotics is not the same as the advancement of computing or software. The advancements of robotics are impacted by the need for physical machine parts (frame, gears, motors, etc.) and other devices. This means that unlike computing devices, robotics is not subject to the exponential capacity growth indicated by Moore's Law[105]. Robotic capability growth is more linear.

Examples of technology vendors in the above described, include

- Home
  - Sony's Aibo - https://us.aibo.com/
  - Joy for All - https://joyforall.com/
- Rehabilitation and prosthetics
  - Ekso Bionics - https://eksobionics.com/
  - Interactive Motion Technologies - https://bioniklabs.com/
  - Bioxtreme Robotics Rehabilitation - https://bio-xtreme.com/
  - MediTouch - https://meditouch.co.il/
  - Touch Bionics - https://www.ossur.com/en-us
  - Motus Nova - https://motusnova.com/
- Surgical
  - Conformis - www.conformmis.com
  - Intuitive Surgical - https://www.intuitive.com/
  - Stryker Mako - https://www.stryker.com/us/en/portfolios/orthopaedics/joint-replacement/mako-robotic-arm-assisted-surgery.html
  - Accuray - https://www.accuray.com/
  - Smith & Nephew CORI - https://www.smith-nephew.com/en-us/health-care-professionals/products/orthopaedics/cori
  - Medtronic Mazor and Hugo - https://www.medtronic.com/
  - Johnson & Johnson Ethicon Monarch - https://www.jnjmedtech.com/
  - Globus Medical Excelsius - https://www.globusmedical.com/
  - Zimmer Biomet ROSA - https://www.zimmerbiomet.com/
  - Stereotaxis - https://www.stereotaxis.com/
- Delivery - Logistics
  - Aethon - https://aethon.com/
  - Locus Robotics - https://locusrobotics.com/
  - Ramoll - https://ramboll.com/

[105] https://en.wikipedia.org/wiki/Moore's_law 2-4-2022

7. Hearables

Hearing aids are entering a fundamental change in technology and regulations that will bring solutions to millions of the hearing impaired.[106] Approximately 15% of American adults (37.5 million) aged 18 and over report some trouble hearing and about 28.8 million US adults could benefit from using hearing aids.[107] Of adults aged 70 and older with hearing loss who could benefit from hearing aids, fewer than one in three (30 percent) has ever used them. Even fewer adults aged 20 to 69 (approximately 16 percent) who could benefit from wearing hearing aids have ever used them.[108] A significant barrier to hearing aid use is cost, with the average cost for a pair of hearing aids being approximately $5,000.[109]

The US alone spends about $2.65 Billion per year and this amount is expected to double by 2028.[110] Unfortunately, even among the people who have received hearing aids, approximately 20% of adults currently do not use them at all, 30% use them some of the time and only about 50% most of the time.[111]

Current state of the industry

The hearing aid market space is entering a time of significant changes related to regulatory policy, access, and cost. [112]

In October 2021, the Food and Drug Administration (FDA) proposed to establish a regulatory category for over the counter (OTC) hearing aids. This category was implemented in October 2022 enabling consumers with perceived mild to moderate hearing impairment to purchase hearing aids directly from stores or online retailers

[106] https://www.npr.org/2022/08/17/1117934920/hearing-aids-over-the-counter-paying 5-18-2023
[107] https://www.nidcd.nih.gov/health/age-related-hearing-loss#:~:text=Approximately%2015%25%20of%20American%20adults,than%2075%20have%20difficulty%20hearing. 5-11-2023
[108] https://www.nidcd.nih.gov/health/statistics/quick-statistics-hearing 5-11-2023
[109] https://www.hearingtracker.com/how-much-do-hearing-aids-cost 8-282023
[110] https://www.globenewswire.com/news-release/2021/11/03/2326062/0/en/US-Hearing-Aids-Market-size-is-Projected-to-Grow-USD-4-48-Billion-in-2028-Market-Projection-By-Technology-Major-key-players-Growth-Revenue-CAGR-Regional-Analysis-Industry-Forecast.html 8-28-2023
[111] https://www.manchester.ac.uk/discover/news/20-of-people-with-hearing-aids-do-not-use-them/#:~:text=The%20study%20showed%20that%20approximately,50%25%20most%20of%20the%20time. 5-18-2023
[112] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9149229/ 5-18-2023

without the need for a medical exam, prescription, or a fitting adjustment by an audiologist.[113]

The capabilities of hearing aids and earbuds have been converging for years. This convergence has created a new product category of "Hearables" which are essentially "smart" earbuds. Wikipedia defines hearables and smart earbuds as "technically advanced, electronic in-ear-devices designed for multiple purposes ranging from wireless transmission to communication objectives, medical monitoring and fitness tracking." There are currently five main categories of hearables:[114],[115],[116]

- Sports true wireless earbuds
- Voice-focused true wireless earbuds
- Commodity true wireless earbuds
- Hearing enhancement earbuds
- Hearing aid hearables

For purposes of this document, we focus specifically on hearing enhancement earbuds / hearing aid hearables.[117]

Companies like Bose and Apple are adding amplification features to their wireless earbuds to provide hearing assistance in difficult listening situations (like restaurants). Active noise cancellation, feedback cancellation, and directional microphones are all traditional hearing aid technologies that are now being made available in direct-to-consumer hearing-enhancement earbuds and general consumer products.

Hearables offer a meaningful alternative for those who are not quite ready for the cost and stigma attached to traditional hearing aids. The cost is significantly less than the average hearing aid. Most hearables are priced under $1,000 per pair (80% less than today's average hearing aid cost). Hearables also help to alleviate any potential stigma attached to hearing aids because a majority of them look like ordinary wireless earbuds. They also offer controls that allow the consumer to tune the hearable to their preferences.

To enhance hearing, hearing aids and hearables collect sound using a microphone, amplify and process it using advanced digital signal processing technologies, and then

[113] https://www.fda.gov/news-events/press-announcements/fda-finalizes-historic-rule-enabling-access-over-counter-hearing-aids-millions-americans 5-11-2023
[114] https://www.hearingtracker.com/hearables 8-28-2023
[115] https://en.wikipedia.org/wiki/Hearables?utm_source=hearingtracker.com 8-28-2023
[116] https://www.forbes.com/sites/forbestechcouncil/2020/05/21/2020-and-the-future-of-hearables?utm_source=hearingtracker.com 8-28-2023
[117] https://audioxpress.com/article/true-wireless-designs-a-case-of-loose-fit-earbuds?utm_source=hearingtracker.com 8-28-2023

provide amplified/processed sound to the ear through a tiny speaker. The sound processing components of hearables are made up of four primary parts:

1. The microphone - The microphone picks up acoustic sounds from the environment and converts those sounds into an electronic signal. The electronic signal from the microphone is sent to the sound processor.
2. The sound processor - The sound processor takes the analog electronic signal from the microphone and converts it to a digital format. Digitally represented sound is enhanced and amplified by the processor and converted back to an analog signal before being sent to the speaker.
3. The speaker - Sometimes referred to as the "receiver," the speaker is the part that creates the sound waves that enter your ear and vibrate your eardrum.
4. The battery - A power source of some kind is required to enable the functionality of the microphone, sound processor, and speaker.

Additionally, hearables often feature additional components for Bluetooth connectivity, tap-touch controls, noise cancellation technologies, movement, and health sensors (see below), and more.

Hearing-enhancement earbuds offer similar technology and performance at a substantially lower "consumer product" price, often comparably priced with premium wireless earbuds. Industry-leading hearing-enhancement devices from companies such as Nuheara, Olive Union, BOSE, Alango, typically cost anywhere from $200 to $500 a pair.

A self-guided smartphone app is typically used to assess hearing issues and personalize the sound amplification provided by hearables. In the wake of COVID-19 and a growing need for in-home and affordable hearing solutions, the self-fitting aspect of hearables has become increasingly appealing.[118]

These built-in or online hearing assessments, while not as thorough as a professionally administered audiogram, can be adequate for many uses. Having more individuals develop awareness of their hearing health challenges at an earlier stage is also a clear benefit of the emerging hearables sector.

Impact on healthcare and the hearing aid industry

The FDA's creation of OTC clearance for hearing aids removed the key regulatory barrier. Also, resistance and competitive messaging by hearing aid manufacturers will be overcome by the significant cost and services advantages of OTC products. These

[118] https://www.hearingtracker.com/services/remote-care 8-28-2023

and other changes close the industry's largest gaps by providing a lower cost, easy to use, easy to adjust in an off-the-shelf consumer environment.

- **Current consumer earbud** manufacturers are aggressively entering the market. They will offer self-assessment, a radically lower price point, self-tuning from a smartphone, and consumer level services. This will allow significantly more people to be able to afford hearing aids, and to be able to adjust them to meet their needs. This should lead to greater use and compliance. In the not-too-distant future, we expect to see increased competition in this market.
- **Current hearing aid manufacturers** will attempt to differentiate their products and maintain their price point by adding functionality and perceived value through added or improved functionality. Competition from consumer ear-bud providers may also drive price reductions.
- **The Near Future?** - The ear has long been known as a good location for measurements of human biometrics. Hearing aids and hearing enhancement earbuds are moving toward "biometric hearables" that measure and capture multiple biometrics at once. This takes their scope beyond that of conventional health and fitness trackers and even hearing aids.[119] The ear is a site to measure various vital signs[120] which include:
    - Heart rate
    - Blood pressure
    - Movement
    - Temperature
    - Eye movements
    - Skin resistance
    - Stress hormone levels
    - Brain electrical activity

These new wearables are expected to be integrated with other technologies including machine learning/AI and cloud computing to discern the physiological, physical, and emotional status of wearers and then trigger actions in response. In this scenario, the hearable might be able to 'know' how stressed the wearer is, how best to calm them down (example: prompting their smart speaker to play a favorite music track). Hearables with voice recognition tech will 'inform' the hearable how often the wearer is speaking, in what tone, and even with what emotion.[121]

[119] https://www.idtechex.com/en/research-report/hearables-2020-2030-technology-players-and-forecasts/727 8-28-2023
[120] https://hearingassociatesofnova.com/2018/01/29/future-tech-hearing-aids-that-can-monitor-vital-signs/ 5-18-2023
[121] https://futurism.com/stanford-scientist-ear-gadgets-monitor-brains 5-18-2023

Current examples of the technologies and/or technology vendors

- SONY - https://electronics.sony.com/otc-hearing-aids
- Bose / Lexie - https://lexiehearing.com/us
- Jabra Enhance - https://www.jabraenhance.com/
- Horizon AX - https://www.hear.com/hearing-aids/horizon/
- Audicus - https://www.audicus.com/
- Eargo - https://get.eargo.com/
- MDHearing - https://www.mdhearingaid.com/
- Widex Moment - https://www.widex.com/en-us/hearing-aids/moment/
- Oticon More - https://www.oticon.com/
- ReSound One - https://www.resound.com/en-us/
- Phonak Virto P-Titanium - https://www.phonak.com/en-us

Challenges:

Broadband access and technical literacy - 40% of the population over 65 do not have broadband (22 million people). This population continues to lack broadband access at home, severely limiting their access to digital health tools and social connectedness. 12% of those over 65 are aging alone. Lack of broadband access and technical literacy will leave these people isolated from services and society. In addition to being harmful to consumers and patients, this will put a constraint on healthcare delivery as providers and payers will not be able to provide the same level of care improvements or cost savings to people isolated from society. Every effort should be made to guarantee affordable, accessible broadband access; which is essential to providing healthcare services.

Over-restrictive privacy protections - Consumers appear more willing to share data if it shows a benefit. Regulators should respond accordingly. The ability to protect privacy – requiring an explicit opt-in permission for data or Amazon network sharing – means that information protection principles known as Privacy by Design, should and will be expected by users, even where it is not mandated by law. And changes in terms about privacy will be communicated in easy-to-understand terms, requiring the user to again acknowledge that they have seen the change.

Obsolete work rules and healthcare's resistance to change continue to be an obstacle. Despite workflow disruption during, and advancement made due to the COVID-19 pandemic, there is a risk of losing the realized improvements. This requires incentives for modernization and the application of technology

FAA clearance for widespread drone use - Although initial limited clearances have been granted, the FAA will need to define new rules for medical drones before widespread adoption.

Drones have the potential to reduce the cost, complexity, and investment in transportation; however, it will require a redesign of delivery strategies as well as technical literacy and technical support.

The COVID-19 pandemic has driven the use of telemedicine over a prolonged period. This long use dissolved most assumptions that providers and patients would not accept telemedicine or be able to use it. It has also shown the consumer a level of access and convenience. Just as electronic banking revolutionized financial services and online sales are revolutionizing almost every form of consumer buying patterns, telemedicine is changing healthcare.

In Closing:

The technology used to deliver healthcare is in a period of rapid and fundamental change. The evidence shows that the technologies discussed in this paper will aid patients and providers in obtaining and providing care with better outcomes at reduced costs. Each of these benefit from the power of AI. AI is a rapidly improving technology, underpinned with growing data sets, and improving algorithms. Additional technologies beyond the scope of this study (examples: genomics, gene splicing, pharma, etc.) will also deliver significant improvements in care and will further harness the power of improving AI to accomplish this. These technologies are being implemented and have momentum, but there are real and serious concerns that need to be considered before we are able to see the full benefit. Leaders and decision makers must think strategically about how the use of (or the failure to use) emerging technologies will impact their organizations and patients. In many cases, policy work needs to be done to get ahead of the technology to provide appropriate regulatory guidance. We hope this document aids in these processes. For further information and support, contact the Telemedicine Technology Assessment Resource Center or the lead authors of this document.

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