Horizon Scanning Series

The Internet of Things

The Internet of Things: Impact and Implications for Health Care Delivery

This input paper was prepared by Jaimon T Kelly, Katrina L Campbell, Enying Gong and Paul Scuffham

Suggested Citation

Kelly JT, Campbell KL, Gong E, Scuffham P. The Internet of Things: Impact and Implications for Health Care Delivery. J Med Internet Res 2020; 22 (11): e20135. DOI 10.2196/20135

The state of Internet of Things in healthcare: implications for integration into health service delivery

Jaimon T. Kelly, Postdoctoral Research Fellow, Menzies Health Institute, Griffith University

Katrina L. Campbell, Associate Professor of Applied Health Economics, Centre for Applied Health Economics, Griffith University

Paul Scuffham, Professor and Director of the Centre of Applied Health Economics and Menzies Health Institute, Griffith University

1.0 Overview of current technology in healthcare

The internet of things (IoT) devices are widely used in smart health services. These services make use of context aware intelligent agents, which can include anything from computing devices, mobile phones, Fitbit smart bands, in-home monitoring systems, electronic hospital records with “atomised data”, surgical devices such as implantable cardioverter defibrillators, devices to measure your blood chemistry, or devices to measure brainwaves.

The utility of these connected devices is widespread and can include the ability to track and monitor health progress remotely by health care professionals, improve self-management of chronic conditions, assist in the early detection of abnormalities, fast-track symptom identification and clinical diagnoses, deliver early intervention and improve adherence to prescriptions.(1)

Some care previously provided in hospitals may be transferred to the home. Wearables and other interactive devices can allow for remote monitoring of vital signs or even the administration of medicine. IoT can also be used in hospital settings to improve inventory management and can aid in the management of chronic diseases through remote monitoring and analytics.(2)

Current developments in information computer technologies such as the IoT have allowed the development of healthcare solutions with more intelligent and prediction capabilities both in- and out-of-hospital care. Utilising IoT technologies in current healthcare practice offers the opportunity to provide quality and low-cost medical care through the automation of tasks previously performed by humans. As such, IoT enables Electronic Health (eHealth), Mobile Health (mHealth) and Ambient Assisted Living (AAL) that allow remote review and monitoring of patients in their homes or treated in hospitals and creates a continuum among these through cloud access.(3)

2.0 IoT-based healthcare paradigm

The paradigm of IoT for healthcare essentially consists of three parts: 1) Master (the registered users of the devices, such as healthcare professionals and patients); 2) Server (the central part of the entire healthcare system which is responsible for prescription, data management, data analysis, subsystem construction and knowledge base management); and 3) Things (all the physical objects, including human resources, that are connected to the server through the master.(1)

2.1 Sensing systems is pivotable to IoT-based healthcare

Sensing systems are most commonly linked with a smart device. A smart healthcare device or system usually integrates sensing technologies with IoT, which enables the healthcare system to monitor patients.

Bluetooth- and WIFI-enabled devices allow smart devices that 'sense' clinical data (e.g. body composition, blood pressure, pulse pressure, oxygen saturation, temperature, glucose monitoring, muscle contraction, motion analysis, skin conductance and respiration) to be sent directly to health professionals in a way that causes minimal disruption to patients' lives and health professional's daily routines.(4)

Sensing technologies allow for treatments to be monitored in real-time and are pivotal to the acquisition of the multitude of physiological parameters about a patient, so that diagnosis and high-quality treatment can be fast-tracked. The careful design and utility of sensing technologies can allow for continual data acquisition from patients, facilitating the improvement of treatment outcomes and the reduction of healthcare costs.

2.2 Cloud-based healthcare

The majority of healthcare organisations host their data and associated applications on-site. The cloud can be thought of as 'the internet'. Specifically, storing information on the internet, which is accessible anywhere – permitting there is access to the internet. Cloud-based computing is ubiquitous, flexible and scalable in terms of data acquisition, storage and transmission between devices connected to the cloud.(5) Cloud storage can allow health care systems to better access and share information regardless of a patient's geographic location.

A number of Cloud Computing platforms are already available for the management of user data, either free (for example, iCloud, Google Drive and DropBox) or commercial. There are many options for commercial cloud-platforms, however, only seven are certified 'protected' by the Information Security Registered Assessors Program,(6) including Microsoft Azure and Office 365, Amazon Web Services, NTT Australia Protected Government Cloud, Macquarie Government GovZone, Sliced Tech Gov Cloud Package Gov, and Vault Systems Cloud Package.(6)

Advancing healthcare through IoT will see more and more cloud platforms enter the market and so the protection and security of patient data will be paramount. Guaranteed protection will enable healthcare systems to consider utilising the cloud, which is essential to IoT-based health care. Utilisation of the cloud can be foreseen to support data intensive electronic medical records (EMR), patient portals, smart phone Apps, medical devices with IoT technology, and the big data analytics behind improved decision support systems and therapeutic strategies.(4)

2.3 Smart healthcare systems

Smart healthcare systems use the cloud. Smart healthcare essentially refers to the automation and connecting of health processes. Smart connected healthcare systems offer the opportunity to improve current information computer systems currently utilised by the healthcare system, as well as integrate IoT devices to complement health service delivery.(7)

Electronic medical records (EMRs) are purported tools for documenting and sharing medical care information which are upkept and accessed solely by health professionals. Australia is in a unique position in its opportunity for growth in technology-assisted healthcare, transitioning from paper records, EMRs and other ICT health systems into the one integrated EMR which houses all healthcare information relating to a patient under the one system. Current EMR challenges include lack of interoperability across technology platforms over time, and its unstructured data elements. Advancing healthcare through IoT needs to consider how the roll out of the integrated EMR and emerging health innovations and health-tech start-ups can enable interaction with IoT devices and harness data the analytic potential this roll out is capable of providing. IoT-based health care would ideally see smart

IoT devices and medical record data from the integrated EMR transmit data to the cloud, enabling data analytics to identify patterns within and across individuals to improve healthcare planning and budget allocations. Developing analytical methods to harness the data being generated from the integrated EMR is a major challenge, as well as data storage solutions (for example, one tertiary hospital in Brisbane with the integrated EMR generates more than 1 million “atomised” data points daily).

To realise this potential that IoT and EMR integration can provide, consider being able to predict future illness trajectories and medical outcomes, confidently predicting interventions and readmissions. For example, one study has already demonstrated that deep learning of EMR data can predicts future medical outcomes in diabetes and mental health, which both exert substantial economic burden on the healthcare system.(8)

The My Health Record is another electronic, cloud based EMR which is managed and upkept by patients, and they can share information with their healthcare providers. While the roll out of the My Health Record has been successful, many Australians are not aware how they can use the information or even access it. The My Health Record is a unique tool which could see a patient-viewable analysis of health risks, patterns and advice, all derived and generated through IoT-based healthcare. This approach is a way to ensure patient autonomy of data, advancing patient-centred care and empowering self-management. Linking IoT-devices into the My Health Record is also a way of facilitating this idea of a ‘connected’ ‘smart healthcare’ system but is particularly promising in improving patient-clinician communication, involvement of patient’s wider support/care network and facilitating shared decision making.

3.0 How smart cloud based IoT devices are improving health service delivery today

Sensing systems are most commonly linked with smart (cloud-based) devices. A smart healthcare system can integrate sensing technologies with the IoT, enabling real-time monitoring of patients by the healthcare system.

The current market continues to grow and there are many examples of potentially lifesaving IoT sensor devices, however, not all are clinically tested and proved to be safe or effective. Some of these emerging smart devices are discussed below.

Bluetooth-enabled inhalers for asthma sufferers use a sensor, mobile App, predictive analytics and feedback to help patients and providers better understand and control asthma and other respiratory diseases. Propeller Health drives the majority of research and development in this area and have shown these IoT devices to improve healthcare utilisation and reduction in inhaler uses through better self-management and symptom identification (9, 10).

Vital sign patches have been designed, primarily to wirelessly track and monitor patients heart rate, respiration, temperature, steps taken, sleep cycle, stress levels, and whether the user has fallen or otherwise become incapacitated. One pilot clinical trial conducted in discharged patients from emergency (with infection or exacerbation of heart failure, chronic obstructive pulmonary disease, or asthma) demonstrated fewer adverse events in the intervention (compared to usual care) and 67% lower healthcare costs through using the device.(11) Vital sign patches are still being tested for their effectiveness and until wider adoption of IoT and cloud-based computing becomes business as usual, their full potential will not be realised. However, the premise is exciting, consider a simple low-cost patch which can detect the risks of expensive and health-resource intensive conditions such as hypertension, Type 2 Diabetes Mellitus, sleep apnoea, asthma and exacerbation of chronic obstructive pulmonary disease or heart failure).

Digital (or smart) medications typically consists of an ingestible sensor (micro-fabricated sensor made from copper, magnesium, and silicon, in minute quantities), which communicates with an external body sensor such as a wearable sensor patch (as discussed above) (12). The patch detects the signals from the ingested sensor and wireless communicates this with a mobile App or Web portal (patient or provider). Information is stored on the cloud and is used to medication adherence, absorption, measure activity, and heart rate. The mobile device app also prompts the patient to take their medication doses as scheduled and allows family members or carers to know whether their loved ones are taking their prescribed medications. The potential of these sensors is vast, with one of the most promising being assisting appropriate treatment for uncontrolled hypertension (13) and diagnosing asymptomatic diseases. The ultimate goal of digital mediations are to improve clinical outcomes through better patient self-care, enhanced patient-provider dialog, and data-driven optimization of therapy.(14)

mHealth) and eHealth are examples of telehealth initiatives which utilise technology devices, such as mobile phones and tablets to deliver care programs. These programs are flexible in time and location, with the potential to offer intensive interventions that may not be feasible with traditional care models. For example, a telehealth lifestyle intervention may offer flexibility in delivery mode involving the provision of health education or counselling individuals or groups remotely using telephones, computers or the internet with video, email, and/or mobile applications including text and photo messaging (15). These initiatives are still in their infancy but are slowly seeing uptake into clinical systems (16, 17) and are particularly useful for facilitative behaviour change and improving chronic disease self-management (18, 19). The growth of IoT has the scope to realise the full potential of mHealth and telehealth programs, enabling seamless data collection and analysis to improve the remote delivery of patient-centred care.

IoT devices are growing beyond handheld devices to internet enabled and interconnected smart wearables. *Wearable IoT* can be defined as a technological infrastructure that interconnects wearable technology such as Bluetooth, used to exchange data with wearable sensors through wireless connections, such as WIFI and GSM, and used to send the data to the cloud (20). While wearable devices are vast and diverse and ever growing in a demanding market, the prudent question is will wearable devices just a peripheral for a smart phone, or is there a more important role for them as part of IoT-based healthcare? Examples of wearables currently used include continuous glucose monitors (which the Australian Government now provides subsidy to through the National Diabetes Services Scheme (NDSS), smart watches and Fitbits (to track activity, heart rate and sleep patterns), iFall (an wearable accelerometer which communications with a smart phone and the cloud) to detect and respond to patient falls,(21) smart insulin pens (which track dose, time and recommend correct type of insulin to use),(22) wireless ECG monitors(23) and wearable blood pressure monitors.(24)

Therapeutic virtual reality (VR) creates a sense of being transported into life-like, three-dimensional worlds and is an innovative treatment modality to manage a broad range of health conditions and is gaining considerable attention particularly in mental health and anxiety disorders, stroke and pain management (25-29). With the rapid improvement in technology, VR has become increasingly portable, immersive, and vivid, which has enabled the technology to be used in a broad range of inpatient and outpatient applications.(30)

4.0 The potential of IoT-based healthcare

4.1 Artificial intelligence streamlining medical practice

One of the most promising medical advancements IoT provides is through artificial intelligence (AI). AI's scientific applications have proliferated, including image analysis, text recognition with natural language processing, drug activity design, and prediction of gene mutation expression.(31) The IoT enables the computer (or 'artificial' robot learner) to be connected to the virtual world (to become 'intelligent'). AI has the capability to read available EMR data, including medical history, physical, laboratory, imaging, medications and contextualise it to generate treatment and/or diagnosis decisions and/or possibilities. For example, IBM Watson uses AI read both structured and unstructured text in EMR seconds, reads images to highlight primary and incidental findings, as well as compile relevant medical literature in response to clinical queries.(32)

IoT-based healthcare and utilising AI can assist health professionals see the unseeable and provide new and enhance current diagnostic capability. While diagnostic confidence never reaches 100%, combining machines plus physicians reliably enhances system performance. In a recent paper,(31) the improvements in elements of general chronic disease management was summarised. For example, Type 2 Diabetes Mellitus effects over 1.7 million Australians, and retinopathy is an extremely common complication. AI deep learning systems have been previously trained to detect and grade diabetic retinopathy and macular oedema achieved high specificities (98%) and sensitivities (90%), compared with 54 ophthalmologists and senior residents.(33) Similarly, AI has been trained (with 74% accuracy) at predicting major depressive disorder though applying deep learning to magnetic resonance image mapping of white matter neuronal water content.(34) Finally, AI has been shown to be a superior predictor of patient survival in heart failure, compared to traditional risk assessment methods.(35)

AI has given rise to the concept of chatbots (or AI doctors) which, for example, can deliver nutrition advice,(36) or provide medical advice, as seen through established AI doctor 'bots' (Woebot, Your.Md and HealthTap - where a patient can input their symptoms and advice is generated instantly). These use simple algorithms and require robust testing and the potential of AI bots to deliver medical and preventative advice would need to be monitored or at least stored in a patient EMR so medical override is always possible.

4.2 Primary (preventative) health care which is accessible and effective

As we move into the 2020 decade, more and more focus on disease prevention will become a priority, with the burden of disease attributable to modifiable risk factors is great than ever before.(37, 38) IoT-based healthcare has the potential to improve population health and transition our healthcare model to a true hybrid of primary, secondary and tertiary care – where the health system can utilise its existing workforce to deliver these services both in- and out-of hospital. Consider the benefit of taking the doctor out of the hospital and into the home, all made possible through IoT.

It is important to note the paucity of evidence underpinning the vast majority of health apps on the open market, which was estimated at less than 50% even among the highest 'rated' applications on the App store.(39) In the future, IoT-based health care should harness the most evidence-based Apps. To realise its potential, a core strategy is needed from a research and development perspective, and from a clinical implementation perspective. Increasing access to care does not guarantee more quality or even better care. An IoT strategy which collects and stores health information safely, with complete control of such data still in the hand of the individual, is paramount.

IoT to enhance primary care deliver offers the opportunity to link, and potentially learn from non-health IoT. See **Box 1** (below) for an example of how this might look for a patient using health-related and non-health related IoT-enabled devices.

BOX 1 – Smart homes for healthcare

Smart homes offer the master (user) to control anything that can communicate through a wireless internet network through their smart device, including lighting, power, appliances, security, entertainment and security. A person wearing a smart watch can wake up in the morning, their watch triggers the kettle to boil and the lights to turn on – the person takes milk out of the fridge and uses the remainder. The fridge notices the milk is not placed back in the fridge within 3 minutes which triggers the person's phone to inform it whether they are out of milk; alternatively, when the milk is placed back in the fridge a sensor detects the remainder and use rate. This is then added to an online shopping list, purchased online and delivered to the door that evening. Now picture an aged care setting, a frail man has been discharged from hospital back into his independent living unit. The patient wears a wearable smart device which detects his heart rate and respiratory rate, as he moves between rooms, lights are automatically turned on to avoid any risk of falling – this detail is captured and stored to assist in home assessments of activity of daily living, if required. If he has a fall, the app sends an SOS call to emergency and an ambulance is on scene within 20 minutes.

4.3 Secondary and tertiary health care which is proactive, continuous and coordinated (40)

An IoT-based healthcare system enables the overall healthcare systems to move past a traditional model of service delivery which is often reactive, intermittent and uncoordinated, to a more proactive, continuous and coordinated approach. Such an approach is favourable because:

- IoT connects the patient and their care provide, outside of the hospital and in the patient's home to 'treat' / 'monitor' – this can save health dollar spending and improve the delivery of patient-centred care.
- It encourages self-monitoring and data-driven health decision. For example, self-monitored data is uploaded to the cloud, and continuously fed back to the health service. No action is needed unless a 'trigger' alert (generated through data analysis) which can be used to prioritise review appointments in clinic.
- IoT encourages people to seek health support when they need it through continuous alerts and feedback provided at their fingertips – all enabled through IoT. A fully connected IoT-healthcare system could provide the patient with information on who, when and where health professional help is available.

5.0 Issues with IoT-based healthcare and barriers to address

Despite its many benefits, transitioning to a fully connected smart healthcare system through the IoT requires robust data management plans and clear codes of practice on the supply and use of IoT devices in healthcare. As discussed, IoT has ambiguity and technical challenges with regard to growing and deploying IoT in society. An intelligent IoT-based healthcare system which involves big data management with additional important safety and barriers to consider.

Confidence and acceptability: A gap in awareness and understanding of data safety in cloud stored health information exists. This is of concern as it is the single biggest threat to the adoption of IoT from a societal perspective. The premise of IoT is clear to society, however, what is not clear to people is the actual value IoT delivers them personally from a healthcare perspective. The potential threat of breached confidentiality may never go away – as is with any health initiative – however the perceived value to consumers' needs to outweigh these concerns.(41) The Internet of Things Alliance Australia is reportedly developing an IoT product security certification program that will help consumers identify devices that do not meet the voluntary code of practice for suppliers of consumer IoT devices designed to keep insecure devices off the market guidelines. Government endorsement of these initiatives could improve consumer confidence in IoT-based healthcare.(42) Furthermore, future considerations could be made to enforce the voluntary certification program – making it mandatory for only certified IoT products being able to collect, store and communicate healthcare information with healthcare cloud servers.

Privacy & Security: The IoT provides opportunity for cyber-attacks and for personal data to be collected inappropriately. IoT-based applications are vulnerable to cyber-attacks for two basic reasons: (1) most of the communications are wireless, which makes eavesdropping very easy; (2) most of the IoT components are characterized by low energy and therefore they can hardly implement complex schemes on their own to ensure security. The National Institute of Standards and Technology (NIST) has recently released a draft security guide and recommendations for IoT devices which will see an emphasis on data security in IoT devices,(43) however whether such a guideline can or will be enforced across IoT health devices is unclear.

Cybersecurity-Focused Guidelines for Robust and Resilient Market Adoption. As discussed in Jalali and colleagues recent paper, cyber risk for buyers is a major obstacle to broad adoption of the IoT.(41) The privacy of patients must be ensured to prevent unauthorised identification and tracking. From this perspective, the higher the level of autonomy and intelligence of the things, the more challenges the protection of identities and privacy would arise. Four guidelines suggested by Jalali et al(41) include:

- Recommend investing in cybersecurity capabilities from product design to sales to ongoing support
- Measure and monitor your product's risk–reward ratio. Specifically, ensuring the risks of security and uncontrolled sharing of health data is mitigated and the benefit to consumers is realised.
- Capture data at the granularity level that shows measurable (and no lower) benefits for customers; and
- Take responsibility for security along your technology supply chain. Specifically, ensure you chose a reputable, high-security platform when developing health system IoT

Data storage, control and ownership. As mentioned previously, cloud-storage is a big industry, yet very few meet the 'protected' certification by the Information Security Registered Assessors Program.(6) One important consideration moving forward in IoT-based healthcare is transparency and enforced codes of practice regarding where cloud data is stored and who owns the data. For example, does the owner of the cloud have viewing rights to someone's data and is this data completely controlled by individuals or is it never deleted from the cloud, despite a user's request? Another important consideration is the sharing of data across states/territories and internationally. Privacy, security and confidentiality of data control and storage should be Federally enforced, but International hosts and suppliers may not be required to follow any such code and therefore the use of these platforms requires strategic planning and transparent guidelines to move forward.

6.0 Conclusion

The potential of IoT is growing in healthcare and these developments provide great opportunity for healthcare systems to proactively predict health issues, diagnose, treat and monitor patients both in- and out-of-hospital. Cloud-based computing allows smart devices to collect information through sensing systems, in the form of medical devices, medications, activity trackers, and vital sign wearables, to remotely store this information, which can enable complex data analysis and AI-driven health decisions. To transition the current potential of IoT in healthcare to a fully realised smart healthcare system, a clear code of practice on the management of data, privacy, confidentiality, and cyber security concerning the supply and use of IoT devices in healthcare is required. Investing in IoT-based health care (including the necessary security and community awareness) will advance our healthcare system, to a more proactive, continuous and coordinated approach which will save the health care dollar and improve patient-centred care.

7.0 References

1. Yuehong Y, Zeng Y, Chen X, Fan Y. The internet of things in healthcare: An overview. Journal of Industrial Information Integration. 2016;1:3-13.
2. Qi J, Yang P, Min G, Amft O, Dong F, Xu L. Advanced internet of things for personalised healthcare systems: A survey. Pervasive and Mobile Computing. 2017;41:132-49.
3. Nazir S, Ali Y, Ullah N, García-Magariño I. Internet of Things for Healthcare Using Effects of Mobile Computing: A Systematic Literature Review. Wireless Communications and Mobile Computing. 2019;2019.
4. Dang LM, Piran M, Han D, Min K, Moon H. A Survey on Internet of Things and Cloud Computing for Healthcare. Electronics. 2019;8(7):768.
5. Darwish A, Hassanien AE, Elhoseny M, Sangaiah AK, Muhammad K. The impact of the hybrid platform of internet of things and cloud computing on healthcare systems: Opportunities, challenges, and open problems. Journal of Ambient Intelligence and Humanized Computing. 2019;10(10):4151-66.
6. Australian Signals Directorate. Anatomy of a Cloud Certification | March 2018. In: Division CaIS, editor. 2018.
7. Sundaravadivel P, Kougianos E, Mohanty SP, Ganapathiraju MK. Everything you wanted to know about smart health care: Evaluating the different technologies and components of the Internet of Things for better health. IEEE Consumer Electronics Magazine. 2017;7(1):18-28.
8. Pham T, Tran T, Phung D, Venkatesh S. Predicting healthcare trajectories from medical records: A deep learning approach. Journal of biomedical informatics. 2017;69:218-29.
9. Merchant RK, Inamdar R, Quade RC. Effectiveness of population health management using the propeller health asthma platform: a randomized clinical trial. The Journal of Allergy and Clinical Immunology: In Practice. 2016;4(3):455-63.
10. Merchant R, Szefler SJ, Bender BG, Tuffli M, Barrett MA, Gondalia R, et al. Impact of a digital health intervention on asthma resource utilization. World Allergy Organization Journal. 2018;11(1):28.
11. Levine DM, Ouchi K, Blanchfield B, Diamond K, Licurse A, Pu CT, et al. Hospital-Level Care at Home for Acutely Ill Adults: a Pilot Randomized Controlled Trial. (1525-1497 (Electronic)).
12. Plowman RS, Peters-Strickland T, Savage GM. Digital medicines: clinical review on the safety of tablets with sensors. Taylor & Francis; 2018.
13. Naik R, Macey N, West R, Godbehere P, Thurston S, Fox R, et al. First use of an ingestible sensor to manage uncontrolled blood pressure in primary practice: the UK hypertension registry. J Community Med Health Educ. 2017;7(1):1-5.
14. Frias J, Virdi N, Raja P, Kim Y, Savage G, Osterberg L. Effectiveness of digital medicines to improve clinical outcomes in patients with uncontrolled hypertension and type 2 diabetes: prospective, open-label, cluster-randomized pilot clinical trial. Journal of medical Internet research. 2017;19(7):e246.
15. Kelly JT, Reidlinger DP, Hoffmann TC, Campbell KL. Telehealth methods to deliver dietary interventions in adults with chronic disease: a systematic review and meta-analysis. The American journal of clinical nutrition. 2016;104(6):1693-702.
16. Goode A, Reeves M, Owen N, Eakin E. Results from the dissemination of an evidence-based telephone-delivered intervention for healthy lifestyle and weight loss: the Optimal Health Program. Translational behavioral medicine. 2013;3(4):340-50.

17. Khanal S, Lloyd B, Rissel Cs, Portors C, Grunseit A, Indig D, et al. Evaluation of the implementation of Get Healthy at Work, a workplace health promotion program in New South Wales, Australia. Health Promotion Journal of Australia. 2016;27(3):243-50.
18. Burke LE, Ma JZ, Azar KMJ, Bennett GG, Peterson ED, Zheng Y, et al. Current science on consumer use of mobile health for cardiovascular disease prevention a scientific statement from the American Heart Association. Circulation. 2015:CIR. 0000000000000232.
19. Beratarrechea A, Lee AG, Willner JM, Jahangir E, Ciapponi A, Rubinstein A. The impact of mobile health interventions on chronic disease outcomes in developing countries: a systematic review. Telemed J E Health. 2014;20(1):75-82.
20. Bhatt Y, Bhatt C. Internet of things in healthcare. Internet of things and big data technologies for next generation HealthCare: Springer; 2017. p. 13-33.
21. Sposaro F, Tyson G. iFall: an Android application for fall monitoring and response. (1557-170X (Print)).
22. Sangave NA, Aungst TD, Patel DK. Smart Connected Insulin Pens, Caps, and Attachments: A Review of the Future of Diabetes Technology. Diabetes Spectrum. 2019:ds180069.
23. Majumder S, Chen L, Marinov O, Chen C-H, Mondal T, Deen MJ. Noncontact wearable wireless ECG systems for long-term monitoring. IEEE reviews in biomedical engineering. 2018;11:306-21.
24. Kakria P, Tripathi N, Kitipawang P. A real-time health monitoring system for remote cardiac patients using smartphone and wearable sensors. International journal of telemedicine and applications. 2015;2015:8.
25. Tashjian VC, Mosadeghi S, Howard AR, Lopez M, Dupuy T, Reid M, et al. Virtual reality for management of pain in hospitalized patients: results of a controlled trial. JMIR mental health. 2017;4(1):e9.
26. Chirico A, Lucidi F, De Laurentiis M, Milanese C, Napoli A, Giordano A. Virtual reality in health system: beyond entertainment. a mini-review on the efficacy of VR during cancer treatment. Journal of cellular physiology. 2016;231(2):275-87.
27. De Carvalho MR, Dias TRdS, Duchesne M, Nardi AE, Appolinario JC. Virtual reality as a promising strategy in the assessment and treatment of bulimia nervosa and binge eating disorder: a systematic review. Behavioral Sciences. 2017;7(3):43.
28. Lohse KR, Hilderman CG, Cheung KL, Tatla S, Van der Loos HM. Virtual reality therapy for adults post-stroke: a systematic review and meta-analysis exploring virtual environments and commercial games in therapy. PloS one. 2014;9(3):e93318.
29. Valmaggia LR, Latif L, Kempton MJ, Rus-Calafell M. Virtual reality in the psychological treatment for mental health problems: an systematic review of recent evidence. Psychiatry research. 2016;236:189-95.
30. Birckhead B, Khalil C, Liu X, Conovitz S, Rizzo A, Danovitch I, et al. Recommendations for methodology of virtual reality clinical trials in health care by an international working group: iterative study. JMIR mental health. 2019;6(1):e11973.
31. Miller DD, Brown EW. Artificial intelligence in medical practice: the question to the answer? The American journal of medicine. 2018;131(2):129-33.
32. IBM Watson Health. Artificial Intelligence in medicine 2018 [Available from: https://www.ibm.com/watson-health/learn/artificial-intelligence-medicine.
33. Gulshan V, Peng L, Coram M, Stumpe MC, Wu D, Narayanaswamy A, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. Jama. 2016;316(22):2402-10.
34. Schnyer DM, Clasen PC, Gonzalez C, Beevers CG. Evaluating the diagnostic utility of applying a machine learning algorithm to diffusion tensor MRI measures in individuals with major depressive disorder. Psychiatry Research: Neuroimaging. 2017;264:1-9.
35. Deo RC. Machine learning in medicine. Circulation. 2015;132(20):1920-30.

36. Fadhil A. Can a chatbot determine my diet?: Addressing challenges of chatbot application for meal recommendation. arXiv preprint arXiv:180209100. 2018.
37. Australian Institute of Health and Welfare. Australian Burden of Disease Study: impact and causes of illness and death in Australia 2015. In: AIHW. ABoDsnCnBC, editor. 2019.
38. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018;392(10159):1789-858.
39. Wisniewski H, Liu G, Henson P, Vaidyam A, Hajratalli NK, Onnela J-P, et al. Understanding the quality, effectiveness and attributes of top-rated smartphone health apps. Evidence-based mental health. 2019;22(1):4-9.
40. Korzun D. Internet of things meets mobile health systems in smart spaces: An overview. Internet of Things and Big Data Technologies for Next Generation Healthcare: Springer; 2017. p. 111-29.
41. Jalali MS, Kaiser JP, Siegel M, Madnick S. The Internet of Things Promises New Benefits and Risks: A Systematic Analysis of Adoption Dynamics of IoT Products. IEEE Security & Privacy. 2019;17(2):39-48.
42. Internet of Things Alliance Australia. Strategic Plan to Strengthen IoT Security in Australia In: IoTAA SaNRo, editor. 2017.
43. National Institute of Standards and Technology. NIST Releases Draft Security Feature Recommendations for IoT Devices 2019 [Available from: https://www.nist.gov/news-events/news/2019/08/nist-releases-draft-security-feature-recommendations-iot-devices.