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Digital health: a new dimension in rheumatology patient care

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Abstract
The new digital health innovations have opened up several opportunities to help the clinicians, patients and other caregivers of rheumatology healthcare system in maximizing efficiencies resulting in better patient outcomes. In the global context, digital health technology has the potential to bridge the distance gap between all the key stakeholders involved in rheumatology health care. In this review, we update on the recent advances in the field of digital health and highlight unique features of these technologies which would help in routine care. Application of technology in any form to enable, facilitate or enhance the quality of care is the foundation of digitised care. The components could be smartphone apps, sensors, video, social media platforms or messenger platforms, wearables or a combination of these enabling healthcare delivery and overcoming the constraints of distance, location and time. Digital therapeutics have started evolving and an important step in this direction is the involvement of FDA in the approval process. Speciality specific apps, personalised patient education as per disease status, remote specialist consultations or virtual health coach to guide on lifestyle modifications are some of the developments which have been facilitated by increased digitization in all walks of life. Assisted care with the help of robots rendering care in the hospitals or an intelligent robot guiding a patient by voice and visual sense at home are already at the threshold of entering the mainstream of patient care. Wearable devices equipped with powerful sensors are coming handy in keeping a watch on patient symptoms all the time and providing useful insights on disease progression, clinical response or complications. In chronic care such as rheumatology the implications, possibilities and benefits seem unprecedented. Real time data analytics and artificial intelligence are helping the clinicians, healthcare systems and policy makers optimise the resources and improve patient outcomes. Digitization of healthcare has gained momentum in the recent years and it is envisaged that it could be a catalyst to change, bridge the quality of care and most important democratise the healthcare access across the globe. However, more data, efficacy and objective results are needed which would be fulfilled by ongoing observational studies, clinical trials, systematic review and meta-analysis to further establish the role of digital health in the realms of patient care.

Keywords Digital health · Digital therapeutics · Telemedicine · Synergistic app · Mobile devices · Smart phones · Algorithms · Artificial intelligence · Wearables · Virtual health · Health technology

Introduction

Digital health has emerged as one of the important advancements encompassing all the stakeholders in the healthcare ecosystem. One of the important offshoots of this has been digital therapeutics which essentially deploys technology to support or replace the clinical therapy. Unlike the usual health apps, digital therapeutics are approved by FDA and are prescribed by a doctor after being tested for efficacy. For instance, a reSET app developed by Pear Therapeutics treats various disorders which involves substance abuse of alcohol, cocaine and various stimulants. The app system is meant to train the patients in recognizing daily triggers, cravings, monitor and track them constantly besides sharing these with the treating clinician. The operating mechanism could be to complement the prescribed therapy through a smartphone application which prompts to take medication in time, modify the dietary intake or plans a customized exercise plan as per physical status of a patient. Alternatively,

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capture the physical or mental status through wearable and relay to the healthcare professional in real time remotely or through external stimuli in disorders such as depression. Researchers world over are experimenting with "closed loop system" which intends to offer personalised brain stimulation to treat Parkinson's disorders, cognitive training and mood disorders, etc [1]. All of these approaches are still evolving and are not part of mainstream therapy as yet. However, these are a paradigm shift from the pill based interventional approach followed for decades. Akili interactive has completed a trial demonstrating that the digital game it has developed to treat children with ADHD can improve attention and inhibitory controls in them [2]. If approved this would be another option besides drugs for the patients and it will be fist digital therapy for ADHD patients.

In this review, we intend to highlight and showcase different digital health models which a rheumatologist can apply in enhancing patient care. A patient's disease symptoms, severity, family settings, support infrastructure, technology savviness, acceptability, etc are some of the factors which differ vastly across the world and these play an important role in using technology as an ingredient in care delivery. However, the authors are not making any recommendations in favour of or against any digital intervention. Instead, the endeavour is to let the rheumatologist decide which individual solution or a combination of various solutions maybe useful in improving the outcomes.

Delivering healthcare while overcoming the constraints of distance, location and time by deploying technology—smartphone apps, sensors, video, social media platforms or messenger platforms is the core of virtual health care (Table 1). Similarly, smartphones, wearables and other digital assistants are now considered more than an accessory and have been repurposed in various ways to facilitate remote diagnosis, treatment enabler to compliance driver or a remote healthcare provider. The possibilities are far too many as new digital health innovations get introduced each day to help the clinicians, patients and healthcare system with the potential of maximizing efficiencies and result in better patient outcomes (Fig. 1). Accenture estimates that by applying virtual health to annual ambulatory patient encounters could result in saving of 5 min per encounter for each US PCP (United States Primary Care Physician) translating into an economic value of more than $7 billion annually across the US health system [3]. If we extrapolate this to worldwide opportunity, resultant effect on cost savings to the healthcare systems would be in gargantuan proportions.

Telemedicine

Telemedicine has the potential to bridge the gap between the key stakeholders involved in rheumatology health care. The patient, patient caregiver, GP (general practitioner) and the rheumatologist can be brought together in one eco-system through various mechanisms besides a simple voice, text or video-based apps. For example; recently a Seattle based company Wellpepper won the Alexa Diabetes Challenge for their voice-enabled diabetes support platform Sugarpod [4]. It comprises of a scale, foot scanner, and mobile interface along with an Amazon Alexa voice functionality. Sugarpod is designed to support type 2 diabetes care plans by integrating regular screening into a patient's daily routine and remote engagement via SMS (short message service), email, web, mobile app, and voice. The user steps on the scale in the morning which takes the weight and then asks if it can take pictures of the feet. The obtained images are then put through a machine-learning image classifier looking for problems. Besides gathering this data, Sugarpod asks the user questions about their habits and provides diabetes management tips, relevant educational material, and messages from their healthcare professional. If voice prompts are not convenient, patients can also access all of this information on their devices through the accompanying mobile app. This concept could be very well adapted for a patient whose images of lesion/affected areas with reduction or increase in pain, inflammation could be shared with the rheumatologist in real time. Instead of making a visit to the clinic on a regular basis, this remote assistant will cut down the travel to clinic, waiting and clogging the clinic/hospital. In addition, the clinician gets more crystallized information to suggest appropriate intervention to the patient.

Personalized care with biomarkers data and synergistic app

Crescendo Bioscience has undertaken a more comprehensive approach to go to the molecular level by creating comprehensive models of disease biology in patients with rheumatoid arthritis (RA) through the application of genetics, gene expression, and quantitative protein analysis [5]. Currently, RA does not have a definite cure and out of the available multiple therapies the efficacy differs from patient to patient with significant variable toxicities. Vectra DA (Multibiomarker Disease Activity test) is an advanced blood test which measures serum concentration of 12 markers and combines them in a validated algorithm to produce an individualized score from 1 to 100 indicating disease activity and treatment response for RA patient [6–8]. The current database has pooled data from 357,000 unique patients [9]. By combining advanced analytics of data points with clinical insights through close collaboration with rheumatologists it is understood that age, gender, and adiposity (body fat) may influence a patient's test score. Two additional components; MyRA, a free mobile app and myVectra portal not only help the patients track their symptoms of RA on an ongoing basis but also help obtain disease activity status through the portal

Table 1 Snapshot of digital health models and their key attributes

Digital health system	Type/description	Key attributes
reSET app by Pear Therapeutics	Digital therapeutics	Treats various disorders which involve substance abuse of alcohol, cocaine and various stimulants Trains the patients in recognizing daily triggers, cravings, monitoring and tracking
Digital game by Akili interactive	Digital therapeutics	Improve attention and inhibitory controls in children with ADHD
Diabetes support platform Sugarpod by Wellpepper	Telemedicine	Support type 2 diabetes care plans by integrating engagement and regular screening remotely and engagement/patient education via SMS (short message service), email, web, mobile app, and voice support Remote image based scrutiny to look for neuropathy, foot ulcers, etc
Vectra DA (Multibiomarker Disease Activity Test), MyRA app and myVectra portal by Crescendo Bioscience	Virtual personalised care	Multibiomarker Disease Activity test to indicate disease activity and treatment response in RA patients Track and tabulate joint pain, morning stiffness, and fatigue besides daily functioning activity
Wellness4U	Health and wellness platform	Measure daily steps and sleep in patients with immunological disorders Access data, educational materials and social support, through a Wellness4U online community platform
Vidscrip	Personalised digital engagement	Personalised video content creation explaining prescriptions, conditions, and therapies for individual patient by treating physician
Expert manipulative massage automation (Emma)	Digitised care with robotics	Robot equipped with sensors and diagnostics measures the stiffness of a patient's muscle or tendon By applying artificial intelligence exact pressure to be delivered through massage by robot for a patient
Pillo	Home-based health robot	Uses artificial intelligence to assist the patients of all ages Answer health queries of a patient or family member through voice, connects directly with the clinician, and securely manages medications besides storing, dispensing, and ordering refills
Aldoc	Remote monitoring	Simplify the radiologist and clinician interaction Created algorithms in analysing imaging and clinical data more effectively
Zebra medical vision	Image analytics	Image-based artificial intelligence algorithm
Tempo by CarePredict	Wearable	Activities of Daily Living tracker and analyser Predictive analytics of impending declines in health or functional status in a patient
Molly by Sensely	Virtual assistant	Virtual and remote patient monitoring tool Personalised to handle different treatment and recovery regimens
SetPoint Medical	Bioelectronics	Applies digital doses—targeted pulses of electricity to activate the Inflammatory Reflex Demonstrated that stimulation of the Inflammatory Reflex produces a potent systemic anti-inflammatory effect

Table 1 (continued)

Digital health system	Type/description	Key attributes
Medilogos	Patient data analytics and artificial intelligence	Integration of patient data in real time and applies clinical knowledge in analysis of single- and multiple-patient data Provides clinical data analysis and visualization, evidence-based recommendations, and long-term knowledge-based monitoring capabilities to improve clinical decision-making
Healthbee	Crowdsourcing search engine platform for drug side effects	Patients vote on the severity of the most common side effects of the drugs they are being administered and provide feedback on individual experiences
Pack health	Virtual health coach	Personalized self-management program for the patients of various chronic diseases including RA

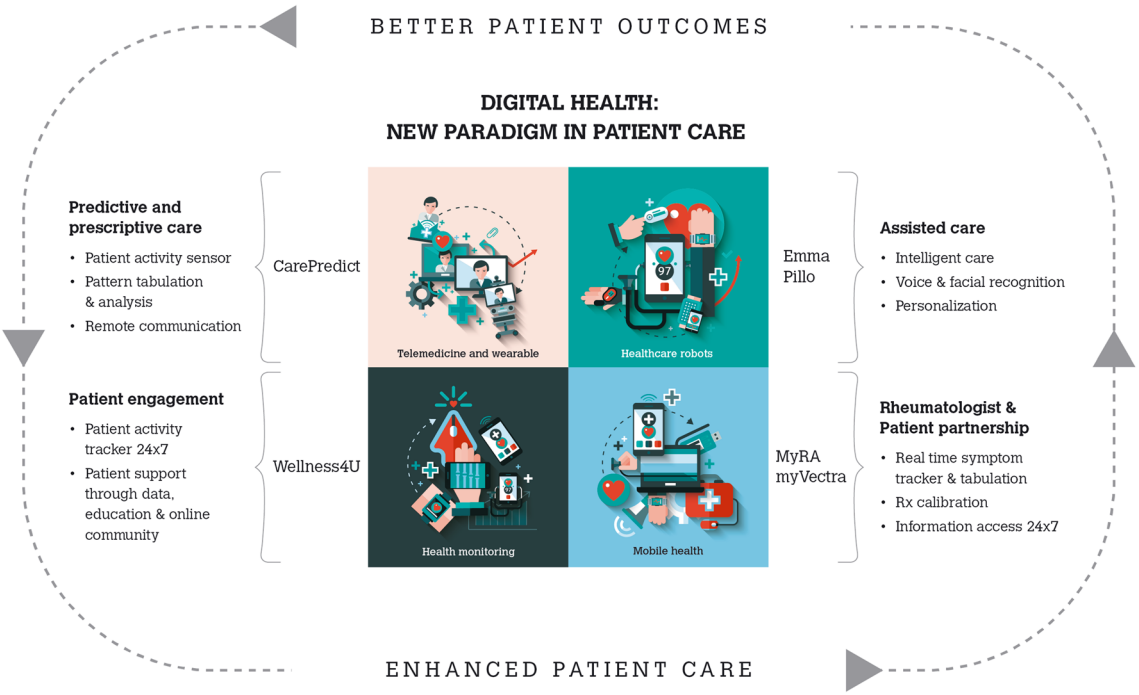

Fig. 1 Conceptual model of virtual health with some of the available tools (Used and modified with permission from http://www.shutterstock.com)

and keep the entire information saved on the cloud [10, 11]. The app helps to track and tabulate joint pain, morning stiffness, and fatigue besides daily functioning activity (Fig. 2). The visual summary provides synergy in patient involvement and helps rheumatologist to calibrate the treatment responses with various drugs (Fig. 3) [10].

Wellness4U is a health and wellness platform for people living with immunological disorder which includes an activity tracker pilot program [12]. In the activity tracker pilot patients receive a Garmin vivofit 2 activity tracker to measure daily steps and sleep. Patients can access the data, as well as educational materials and avail social support, through a Wellness4U online community platform. The pilot is aimed at patients with RA and currently is at an experimental stage. By tracking physical activity and sleeping habits through the Wellness 4U Activity Tracker patients can work with their clinicians to track the progress and be an active participant in the journey as opposed to a passive role.

Vidscrip, a Minneapolis-based patient engagement company offers an iPad app which helps clinicians to quickly and efficiently create video content explaining prescriptions, conditions, and therapies. Subsequently, the video content is

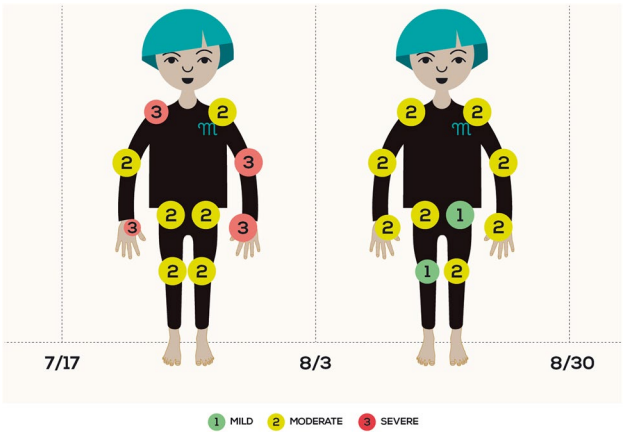

Fig. 2 Uniform colour scheme in the patient summary and app. Lower disease activity is represented by cooler colours such as green and blue and higher disease activity indicating more difficult days are represented by warmer colours such as yellow or red. (Source: http://www.trackmyra.com, with permission, [10])

relayed to the patients across a number of different possible channels [13]. Since the content is coming from a patient's own physician and is based on the patient's unique disease characteristics, it is, therefore, personalised for each patient. Since this dynamic content is coming from the treating physician, besides cementing the patient trust it empowers the patient to make essential lifestyle adjustments. The process of making the videos is automated as the software "interviews" the doctors, asking them questions which are then answered on camera. The software turns those clips into a sequential video series based on the questions, which serve as the topic heads. Patients can also share the videos on social media or any device of their choice.

Assisted care with intelligent robots

New age robotics equipped with multiple sensors, cameras, microphones, shape recognition software are being

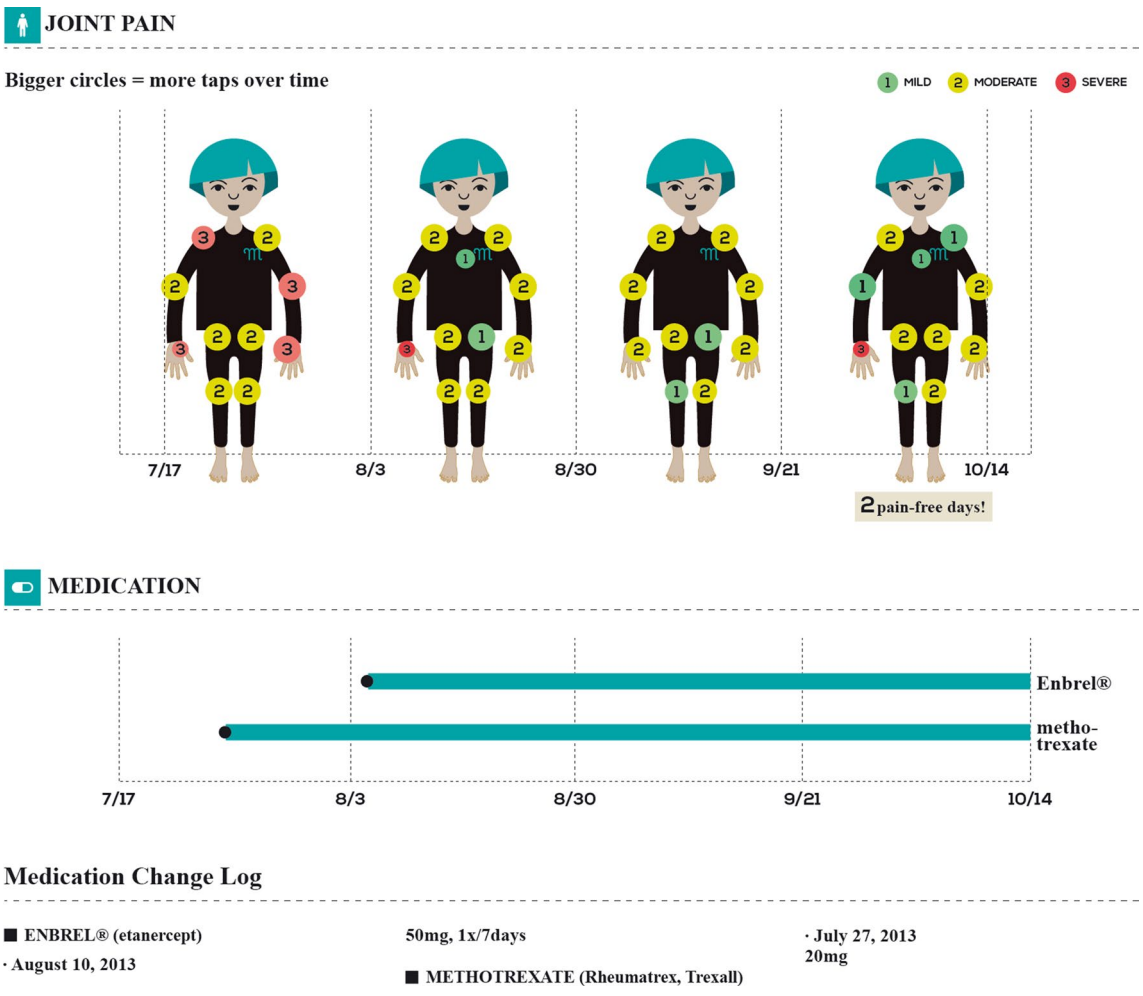

Fig. 3 Patient report sample. The patient can print or email the report for appointment with the doctor. A summary report of the tracked data allows the doctor to have a conversation and track the disease activity between different appointments. (Source: http://www.trackmyra.com, with permission, [10])

applied to bridge the existing gaps in patient care. For instance, in the UK, a robot called pepper is being developed to interact with the elderly, patrol care homes, decipher voice tones and expressions to determine how they are feeling. A separate British trial which started in October 2017 would use robots to bolster staff at homes in the UK, Poland and Greece. It is hoped that the robots will eventually be able to monitor pulses and signs of illness in order to alert staff when an intervention is required. In Japan, a bear-shaped robot is being used to lift people out of beds and into chairs. The robot can change its eye colour and the tone of its voice to match the mood of the person it is speaking to and the robot can also interact through touch sensors. Although experts argue that when it comes to providing care in any form, human touch is over and above any existing smart technology.

A robot masseuse called Expert Manipulative Massage Automation (Emma) has been commissioned recently in Singapore to treat patients [14]. The robot uses an articulated robot arm with silicon massage tips mimicking the human palm and thumb such that a massage session described by patients is almost indistinguishable from a professional human masseuse. The robot equipped with sensors and diagnostics also measures the stiffness of a patient's muscle or tendon specifically. The data collected for each patient is sent to the cloud where artificial intelligence (AI) computes the exact pressure to be delivered for a patient individualised to his or her needs. The AI also analyses a patient's progress enabling physicians to measure a patient's recovery. It is envisaged that the digital health assistants will reduce the institutional care cost in the medium to long term and enable consistent personalised care to the patients for any specific needs.

Besides the hospital care robots, personalized health robots are also coming to the fore in assisting elderly patients who are not so conversant with technology. Pillo Health has developed a small home based personalized / family robot called Pillo (Fig. 4), which uses artificial intelligence (AI) to assist the patients of all ages [15]. Pillo can answer health queries of a patient or family member through voice, connects directly with the clinician, and securely manages medications besides storing, dispensing, and even ordering refills with the pharmacy when required. It informs the other family members if the patient at home skips the medication through app-enabled interface. Pillo is powered by state of the art voice and facial recognition technology which wirelessly syncs with wearables and smart home devices. The reminders, alerts and mobile notifications are delivered through Pillo mobile app.

Fig. 4 Home health robot—Pillo. (Source: http://www.pillohealth.com with permission, [15])

Remote monitoring

Many believe that with developing technologies the patient may be required to visit a clinic in specific situations only. The tiny wearables fitted with sensors would send real time data to the cloud, which in turns processes the information and alerts the care provider if there is a deviation calling for intervention. The diagnostics could be done remotely to cut down on time and any human error in interpreting the reports. Aldoc—an Israeli healthtech company is working to combine technological streams—computer vision, deep learning and natural language processing algorithms to simplify the radiologist and clinician interaction. The company has utilized deep machine learning to create algorithms in analysing imaging and clinical data more effectively. Highly accurate scan upon combining with patient data creates comprehensive, intuitive, and holistic patient view for the busy clinician. Zebra medical vision is another image analytics company that has analysed over a million patient scans at more than 50 centres worldwide over past few years to create artificial intelligence algorithm product AI1 (All-In-1) [16]. This new way of delivering the algorithms which Zebra has developed will allow healthcare providers anywhere in the world to access any of its algorithms for $1 USD per scan. Transparent and flat pricing are virtually non-existent in the healthcare industry and this potentially lifesaving technology to diagnose and treat the patients is now in everybody's reach. Patients who are constrained by the limitation of advanced diagnostics, interpretations and affordability hurdles will benefit by this service in not only rheumatology settings but also in other clinical areas.

Activities of daily living (ADLs) such as eating, walking, sleeping and toileting patterns provide plenty of insights as the changes set in before the health or functional problems start manifesting. CarePredict has developed an array of sensors within a wrist-worn wearable called Tempo (Fig. 5)

Fig. 5 CarePredict app. (Source: http://www.carepredict.com, with permission, [17])

for patients to detect these changes and has a touch-button call system for real-time communication with caregivers [17]. Using the data from the Tempo wearable, coupled with smart indoor location tracking, deep machine learning and predictive data analytics each individual's pattern is charted. By applying deep understanding of ADL patterns and subsequent changes for each individual, CarePredict provides powerful predictive analytics of impending declines in health or functional status. Additional feature in development is a two-way audio communication between the caregiver and the patient for special support.

A health technology firm Sensely has developed virtual assistant platform and a virtual nurse called "Molly" which works as a patient monitoring tool. Molly can be personalised to handle different treatment and recovery regimens. The patient interacts with the virtual nurse which alerts the treating doctor if it senses any anomaly or deviation. The doctor then follows up with the patient through video consulting or face to face appointment. Sensely's platform supports more than 20 chronic conditions and in partnership with Mayo clinic it intends to combine the clinical expertise and algorithms with its existing platform to be able to predict best possible resources for patient care remotely.

Bio-electronics

Bioelectronics is an amalgamation of molecular medicine, neuroscience and medical engineering to modulate nerve signals and alter biological response during the disease process. The underlying rationale is the ability to manoeuvre the neural signals will empower rheumatologists in managing chronic and crippling disorders which impact the quality of patient's life.

SetPoint Medical has developed a proprietary platform based on the Inflammatory Reflex—the natural mechanism by which the central nervous system regulates the immune system [18]. This approach applies digital doses—targeted pulses of electricity to activate the Inflammatory Reflex. Published literature has demonstrated that stimulation of the Inflammatory Reflex produces a potent systemic anti-inflammatory effect. SetPoint successfully completed a first-in-human proof-of-concept trial in RA and is currently conducting human trials in Crohn's disease at multiple European centres [19]. The phase 2 trials in RA are being rolled out which will provide further insights on the patient outcomes.

Artificial intelligence and predictive analytics

Rheumatic disorders are chronic in nature and clinical response usually follows a variable course. Owing to the involvement of multiple factors, predictability for each patient is extremely difficult. But with latest advancements in big data analysis, statistical modelling, artificial intelligence and predictive analytics it is now possible to draw some defining conclusions. Deploying historical and real-time unstructured patient data sets rationalized comprehensive dataset are obtained. Deep machine learning synthesizes clinical histories, historical clinical and administrative decisions, patient demographics, laboratory and biomarkers, applied clinical knowledge, guidelines and best practices. Data streams and their subsequent analysis uncover trends, patterns and correlations which are at times missed. Artificial intelligence (AI) provides real-time clinical decision making and optimizes patient health outcomes with relevant individual choices thereby eliminating unnecessary investigations or treatment interventions or eliminate the agents which have not worked at all in the past. Medilogos provides seamless integration of patient data in real time and applies clinical knowledge to resolve physicians' cognitive overload resulting in analysis of single- and multiple-patient data in shorter time span [20]. A combination of twin systems—one which summarizes medical information into clinically meaningful concepts, resulting in saving of clinician's decision-making time, and another which recommends appropriate medical treatment tries to restrict the errors to minimum. The platform provides clinical data analysis and visualization, evidence-based recommendations, and long-term knowledge-based monitoring capabilities to improve clinical decision-making. This enhances the quality of care and optimises the clinician's time simultaneously.

Healthbee is a crowdsourcing search engine platform for drug side effects [21]. The patients vote on the severity of the most common side effects for the drugs they are being administered and provide feedback on individual experiences. Since lot of patients requiring rheumatology care are on drugs such as glucocorticoids, DMARDs and biological agents, deeper perspective and insights on side effects specific to patients would be an important guide in evaluating various drugs.

Hospitalization puts heavy cost burden on the healthcare system as well as the family. There is an involvement of medical, non-medical professionals besides the full-time engagement of direct family members. Using predictive analytics towards forecasting the chances of hospitalization risk for a patient in between the hospital visits would be a big boon to all the stakeholders in the healthcare system. Care At Hand—an American company applies evidence-based smart surveys to identify early medical and psychosocial warning signs in patients at various levels of risk for hospitalization [22]. Evidence-based algorithms assign risk score and trigger alerts while the dashboards and reports provide unique insights, predicting who is most "at-risk". The programmed decision support is based on risk score (high, moderate and low) which provides recommendations, frequency, and duration of care. With further improvement in specificity and sensitivity of outcome prediction, the practical utility of such a tool would be very useful t*o* all the stakeholders.

Lifestyle modifications

It is an established fact that exercise has an anti-inflammatory effect and lifestyle modification is equally important in any chronic inflammatory disorder such as RA [23]. Majority of the patients lead a physically inactive and sedentary lifestyle solely dependent on the medications for altering the course of disease. A virtual health coach which helps the patient with appropriate guidance at each step and acts as a sounding board on day to day basis results in significant lifestyle modification adoption. Pack Health designs and structures a personalized self-management program for the patients of various chronic diseases including RA through a dedicated health advisor. The patient engagement involves a combination of text messages, phone calls and personal meetings. The reported outcomes have resulted in better medication adherence, increase in exercise duration, improvement in the eating habits and cost savings. A recent study on the patients' acceptance of a virtual health coach (VHC) who emulates medical staff to activate the patient to engage in a conversation with their physician about healthy lifestyles even before entering the physician's office demonstrated that patients were very much acceptable to the usage of technology and improved the quality of interactions [24]. The authors identified that VHC has immense potential to improve quality, efficiency, health outcomes, cost, and patient satisfaction with further refinement of the medium and its wider application.

Conclusion

Digital applications are not the panacea to all the shortcomings in patient care as the human touch can never be replaced by any means. Technology is evolving constantly and with that newer approaches in digital health will keep emerging. The patients are now more informed due to the accessibility of information and are taking self-responsibility in managing the disease better. Regardless of the barriers of variable access, costs and language, rheumatologists will be the most important drivers to digital health movement in applying new advancements for the betterment of patients and easing the workload. More observational studies, randomized controlled trials, systematic review and meta-analysis of digital health efficacy in rheumatology health care are the need of the hour. The outcomes of these studies will help identify limitations, applications and ensure wider acceptability of the technologies discussed in the paper. International and national rheumatology societies across the globe may identify key thrust areas for digital interventions and commission pilot projects to measure the resultant impact in a structured manner.

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Compliance with ethical standards

Conflict of interest Suchitra Kataria declares that he has no conflict of interest. Vinod Ravindran declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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