Digital Medicine in Rheumatology

Challenges and Opportunities

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KEYWORDS

• Technology • Digital medicine • Social media • Virtual reality • Devices • Twitter • Rheumatology

KEY POINTS

- Digital medicine is poised to revolutionize the practice of medicine and field of rheumatology.
- Social media use is gaining traction with rheumatology professionals increasingly engaging in social media for purposes of education, research dissemination, and career advancement.
- Virtual reality is gaining traction as a tool for behavioral modification, movement-based therapies, pain management, and simulation training.
- The authors highlight some of the technology tools currently available and being used in the clinic.

INTRODUCTION

Over the last 2 decades, advances in technology have had a transforming effect on everyday life. Who could have imagined that we would have instant access to a computer in our pockets, with the same processing power of a room full of computers from a couple of decades ago? Technology has influenced all walks of life including how we shop, eat, travel, and communicate.

In the same time period, medicine has made relatively modest strides in how we deliver care. We still rely on providing care to our patients in the same way that we did 3 decades ago with enormous effort and energy going into the documentation of care and increasingly less time being spent in actually providing care and counseling.

Disclosure Statement: Research support Applied VR- R.S. Venuturupalli. Cofounder of RheumJC on Twitter – P. Sufka. Cofounder of RheumJC on Twitter- S. Bhana.

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Rheum Dis Clin N Am 45 (2019) 113–126

https://doi.org/10.1016/j.rdc.2018.09.010

rheumatic.theclinics.com

0889-857X/19/Published by Elsevier Inc.

Just like technology has disrupted several industries such as the hospitality, transportation, and merchandising sectors, medicine stands to be transformed as well. This transformation will be facilitated by the digitization of the health record, which is nearly complete at this point in time. By some estimates in 2008, only 1 out of 10 US physicians was on an electronic medical record (EMR) but by 2018 only 1 out of 10 US physicians is not on an EMR system.[1] Other examples of significant infrastructure changes are that most patients are now connected to smartphones and a significant portion are engaged in social media. However, the single-most monumental change is in the attitude of the payers, who are now demanding an increase in the quality of care with demonstrably better outcomes obtained at a lower cost. A new field of digital medicine loosely defined as the field of medicine that uses digital tools to upgrade the practice of medicine to one that is high-definition and far more individualized has emerged.[2] Based on these observations, it seems that the complete incorporation of technology in the clinic is not only inevitable but also absolutely necessary to provide quality care to masses of people.

In this article, the authors highlight some of the promising technology trends and discuss future opportunities and challenges posed by these technologies. To comprehensively list or predict all of the important advances in technology that will likely transform medicine is not possible. However, based on the interests and experiences of the investigators, the authors have chosen to highlight the use of social media in rheumatology, virtual medicine in rheumatology, and some tech tools that are currently available to rheumatologists.

Section I: What Does Social Media Mean to Rheumatology?

The pace of electronic communication has increased rapidly, coinciding with the rapid adoption of the smartphone[3] and social media throughout the United States, with almost 7 in 10 Americans currently using at least one social media platform.[4]

Access to medical information has also become nearly instantaneous through the form of online journals, allowing for innovative methods of information sharing such as videos, slide shows, and other interactive media,[5] such as the visual abstract,[6] that can be more easily shared through social media by allowing readers a quick visual overview of an article.

Limited data suggest a trend toward increasing use of social media among rheumatology trainees. In 2014, a survey of rheumatology fellows attending the American College of Rheumatology annual meeting suggested that 40.9% of respondents were using social media for professional purposes.[7] Subsequently, a 2015 survey of European rheumatology fellows and basic scientists was conducted by the Emerging European League Against Rheumatism (EULAR) Network (EMEUNET), and found more substantial use of social media networks, with 68% using it for professional reasons such as professional networking, finding new resources, learning new skills, and establishing an online presence.[8]

Popular uses of Twitter in rheumatology include online journal clubs and discussions during medical meetings. The Rheumatology Journal Club on Twitter (#RheumJC),[7] established in January 2015, observed a total of 646 individuals from 36 different countries participate in 23 online journal club sessions over a 36-month period, with 86% indicating they were either satisfied or very satisfied with the experience.[9] Data from the 2016 ACR annual meeting also show significant use of social media, with about 20% out of more than 16,000 attendees active on Twitter during the meeting using the hashtag #ACR16.[10] Thus, the use of social media is not widespread amongst rheumatologists but seems to be increasing rapidly.

Professional uses of social media in rheumatology

Education Medical education tools and resources available on the web are collectively known as FOAMed (free open-access medical education)[11] and include sharing information and discussions on social media, as well as blog posts, videos, podcasts, and other interactive formats such as MOOCs (Massive Open Online Courses). The use of social media in medical education has also been shown to be valuable for medical students, patients, and physicians.[12]

For rheumatologists, the major intersection between FOAMed and social media can be found on Twitter. For example, the American College of Rheumatology (ACR) Twitter account, @ACRheum, currently manages a list of more than 1000 rheumatologists and health care professionals with an interest in rheumatology.[13]

Robust discussions of rheumatology-related topics can be found via networking directly with other rheumatologists on Twitter or by locating discussions using tools such as the Symplur Healthcare Hashtag Project,[14] which organizes ongoing Twitter conversations, communities, and events. Online journal clubs such as #RheumJC offer regular discussions of articles, allow participants an opportunity to develop their online network, and occasionally provide an opportunity to interact directly with authors.[15] Live-tweeting of curated information from medical conferences,[16] such as the ACR Annual Meeting or EULAR, allows for rapid sharing and dissemination to a global audience and invites discussion with those who are unable to attend the meeting in person.

Academic medicine and career advancement In the academic realm, the use of social media, especially Twitter, has been called "an essential tool"[17] that has the "potential to revolutionize academic medicine" given the "vast arrays of possibilities in which professionals, societies, and institutions can engage in conferences, education, research, and networking that extend far beyond traditional social network boundaries"[18] and its uses in allowing widely inclusive discussions, development of leadership influence, cross-disciplinary innovative efforts, scholarly dissemination of research, and mentorship opportunities.[17] In addition, the use of scholarly work within a social media portfolio has been recognized by institutions such as the Mayo Clinic as an important metric for consideration for promotion and tenure.[19]

Dissemination of research Social media has affected how information is disseminated, which required the development of new tools to measure the influence of online information. The most widely used tool for this measurement is the Altmetric score,[20] which gives real-time data on the quantity and quality of online attention that an article is receiving through news outlets, social media, citations, and downloads.[21,22] Publishers have developed promotional toolkits for investigators[23] and have suggested tips[24] that the investigators can improve the reach of their articles by promoting it on blogs, Twitter, news outlets, conferences, and via other tools such as Mendley.[25]

Professional networking and career enhancement Social media provides an opportunity for rheumatologists to broaden their professional network globally by using social media platforms such as Twitter to develop relationships with other physicians and professionals with similar interests. When used proactively, social media can be used as a powerful career enhancement tool, which can lead to opportunities related to employment, research collaboration and funding, and scientific publications and presentations.[26] In addition, social media has been recognized as a powerful tool for overcoming barriers to professional advancement of women physicians.[27]

Pitfalls in the use of social media

The use of social media in medicine certainly comes with potential pitfalls, including the accuracy of medical information, professionalism, impact on reputation, and privacy issues.[8,11] These issues are largely overcome through increased scrutiny of online information, such as by directly accessing the primary literature, or by educating users of social media regarding these issues with guidelines from the American Medical Association[28] or online courses such as the Social for Healthcare Certificate from Mayo Clinic and Hootsuite.[29]

Future directions of social media in rheumatology

Social media networks will continue to evolve and mature to meet the needs of users.

For example, Twitter recently increased the character limit per tweet from 140 to 280[30] and allowed users to link together related tweets into a thread.[31] Improving this constrained format, as well as linking together related tweets into a thread has resulted in an increase in physician engagement and discussion online.[32]

Because one of the most formidable challenges in modern medicine is organizing and keeping up with the vast amount of information, we have seen the emergence of the visual abstract as a way to rapidly share relevant data from articles via social media.

As we progress, we should expect more rheumatology professionals to engage in social media, while developing novel ways to meet their professional needs.

Section II: The Case of Incorporating Virtual Reality into the Rheumatology Clinic

Virtual reality (VR) is a technology that creates a sense of presence in an immersive, computer-generated, 3-dimensional (3D), interactive environment through head-mounted displays, body tracking sensors, and direct user inputs.[33] The promise of VR lies in the ability of this technology to transform a patient's experience almost instantaneously in a powerful way. Although initially used in the gaming world, VR has become increasingly recognized as a viable alternative for the management of pain, psychological conditions as well as simulation training in medicine.

In the rheumatology clinic, both acute and chronic pains are common presenting complaints. In addition, there are significant psychological overlays in patients suffering from the chronic diseases treated in rheumatology clinics. Coincident to the development of VR for pain is the current "opioid crisis" in the United States. From 1999 to 2014, drug overdose deaths nearly tripled in the United States[34] and the sale of opioid pain killers has nearly quadrupled from 1999 to 2010.[35] VR has the potential to provide a much-needed alternative to these agents and hence there has been increasing interest in studying this technology in patients with acute as well as chronic pain.

Mechanisms by which virtual reality potentially helps with pain

The power of VR-based interventions lies in the ability of lifelike VR gaming experiences to "hijack" the normal brain functioning and create a sense of disconnection with the patient's immediate surroundings (so-called distraction therapy). Distraction therapy has been used as a validated intervention for pain for several years,[36] and more recently, VR-based distraction therapy has also been validated in many clinical trials for pain.[37,38] Although the neurobiological mechanism by which VR acts on the brain remains unclear, researchers have hypothesized that VR can act as a nonpharmacologic form of analgesia that can unleash complex effects on the human body's pain modulation system.[39] One hypothesis states that VR may reduce the perception of pain through direct and indirect alterations in attention, emotion, concentration, memory, and other senses, which can change the body's pain modulation system.[40]

An illustrative study examined the effects of VR on the brain and showed that there was reduced activity in the insula and thalamus but other areas of pain circuitry did not seem to be affected.[41] The brain plays a complex role in the perception of pain and as such more research on the exact neurobiological effects of VR is needed to fully understand its role in pain reduction.

Utility of virtual reality in clinical medicine

Rheumatology patients present with both acute pain (osteoarthritis, crystal disease, rheumatoid arthritis [RA] flares) as well as chronic pain (fibromyalgia, osteoarthritis [OA], RA, SLE related pain). Several studies have shown that VR could reduce acute pain at least temporarily[37,42] although the literature on the effects of VR in chronic pain conditions is less robust. VR could have a wide range of uses in rheumatology. For example, rheumatologists often take care of patients with chronic lower back pain and the literature shows that VR simulations can enhance pain management by reducing pain perception and anxiety. Similarly, VR-based distraction therapy has shown to reduce the need for pain medication before burn dressing changes and in acute trauma care, where it could be used for patients with rheumatology presenting with acute pain. VR has already been shown to provide distraction therapy for diverse procedures such as lumbar punctures, cystoscopy, chemotherapy infusions, and blood draws in children. It would be easy to imagine rheumatology infusion patients using VR in a similar fashion. VR-based simulation has also shown significant utility in clinical training, particularly the mastery of procedural and interviewing skills. For a more comprehensive review of the literature supporting the use of VR in the medical clinic the authors direct the reader to an excellent recent clinical review.[43]

Rheumatologists often prescribe lifestyle modifications and physical therapy with varying results for a variety of conditions. VR has the potential of improving compliance with physical therapy programs by creating a fun gamelike environment. For example, in one study[44] patients with chronic low back pain and "kinesiophobia" were invited to participate in a VR-based dodgeball game environment over 3 days. The intervention was designed to improve lumbar spine flexibility by gradually increasing the levels of difficulty to achieve the game objective. Although this study did not reduce lower back pain (likely because the intervention was too short), the intervention was well tolerated and all patients had improved lumbar spine flexibility. The same group of investigators is planning a longer-term phase 2 randomized controlled trial, which will provide more definitive evidence for the use of VR gaming as a means to help patients with chronic low back pain.[44]

Several studies of VR have been conducted in fibromyalgia patients. A proof of concept study exposed patients with fibromyalgia to a VR-based exercise activity. In this study, when fibromyalgia patients were shown images of exercise in a virtual environment, functional MRI images demonstrated changes in brain areas associated with pain catastrophizing. Thus, interventions targeted toward pain catastrophizing using VR could be designed in the future to address chronic pain in fibromyalgia.[45] In another pilot study of 6 patients with fibromyalgia, VR was used as an adjunct to a cognitive behavioral therapy (CBT) program, primarily to help the patients develop relaxation and mindfulness skills. The intervention showed significant long-term benefits in these patients.[38] In another interesting study, investigators from Spain studied VR to enhance cognitive behavioral therapies to help patients with fibromyalgia. VR was used to improve the management of daily activities through the promotion of positive emotions, the so-called "positive technology." In this small study, the investigators demonstrated that VR-based intervention was helpful in reducing disability and also improved coping skills and perceived quality of life.[46]

VR also has the potential to augment physical therapy treatments and rehabilitation care that form the backbone of therapeutic intervention in the rheumatology clinic. For example, 40 athletes who underwent anterior cruciate ligament repair were exposed to a VR-based exercise regimen and showed improved joint biomechanics when compared with a non-VR control group.[47] In 32 elderly patients, VR based simulation exercise program showed improved hip muscle strength and balance compared to a non-VR control group.[48]

Taken together, these data show that VR is a promising new technology that could be used in the rheumatology clinic in a variety of different ways to improve outcomes.

Challenges in implementing virtual reality in the rheumatology clinic

Although VR is a significant technological innovation, it is in an early stage of development. Patients raise issues related to tolerability including complaints of nausea and vertigo after an immersive experience. Hence, VR in its current form is contraindicated in patients with severe vertigo. In one of the authors' (RSV) Rheumatology Clinic, VR-based distraction and mindfulness therapies have been piloted in about 20 or so patients. The authors' personal experience is that rheumatology patients are enthusiastic about this technology, they seem to tolerate the VR experience, and are very interested in the mindfulness programs. Cost has been an issue, although with the launch of standalone VR headsets such as Oculus Go,[49] the cost of VR is becoming significantly lower. In addition, companies in the medical VR field are innovating with their pricing plans. For example, some companies have subscription plans whereby access to numerous programs is available to patients, without a need to invest in the hardware.

As VR is incorporated into the rheumatology clinic, several important questions need to be answered. Firstly, we need to understand which patients will benefit the most and what particular immersive experience will help a particular patient or problem. A big question is whether the clinician can afford to take time from their clinical responsibilities to administer VR to patient or will there be the development of a new specialist, the digitalist. Brennan Spiegel, a leading VR researcher based at Cedars Sinai Hospital, believes that the solution would be a form of "VR Pharmacy."[50,51] Here "virtualists" who will be professionally trained in clinical medicine and VR technology will be able to evaluate patients to administer the correct corresponding VR prescription.[52] Lastly, the question of where and how VR will be administered needs to be answered. Will it be at the patient's home or in the clinic setting with superior equipment and controlled prescriptions or adjunctive therapies such as CBT? These are questions for the next phase of research in VR.

Section III: Top Tech Tools for Enhancing a Rheumatology Practice

Readily available hardware and software technology tools can augment the physician and patient experience to deliver more focused and high-quality care. Although certain technology tools such as ultrasound are being implemented in rheumatology practices around the world, one could argue that device cost, training time, and strain on workflow can be prohibitive to widespread adoption.[53,54] The ideal implementation of particular technology products relies on the principals of cost, time, usability, and effect on patient outcomes. Although technology holds great promise in changing the way we practice, we are still in the early stages of implementing new technologies in the clinic. This point is well illustrated in a recent study that examined the utility of fitness trackers and apps and found that there was no significant change in health outcomes for patients by the use of these apps and devices.[55]

The popularity and power of the smartphone is a driving force in the implementation of personal and portable technology in the clinic. At its core, the smartphone is a

combination of a microcomputer, camera, contextual sensors, and constant internet connection for all applications. Each year, the smartphone models become increasingly more powerful. As of the end of 2017, the iPhone X processing benchmarks were equal to a 2017 Macbook Pro.[56] This unprecedented processing power could transform how the clinician patient interaction takes place. Although a comprehensive listing of portable technology in the clinic is not possible, in the following section, we highlight some of the most practical and accessible tools as of the time of this writing (June 2018) that could help rheumatologists in the care of their patients. These tools were chosen based on low entry price compared with medical device grade products, usability and design, and portability, and testing in the rheumatology clinic by one of the authors (SB). A summary of the tools and their applications is presented in **Table 1**.

Hardware tools

A variety of inexpensive hardware tools, which tend to focus on enhanced imaging techniques, can aid the diagnosis and management of a subset of rheumatic patients.

Macro lens for nailfold capillaroscopy Nailfold capillaroscopy (NC) is the most reliable way to distinguish between primary and secondary Raynaud phenomenon (RP).[4,57] NC is part of the ACR/EULAR classification for systemic sclerosis. In clinical studies 200x-magnification ophthalmoscope is typically used; however, a standard handheld ophthalmoscope only provides 2 to 3x magnification when repurposed for NC. Handheld lighted magnification devices used by dermatologists can provide 10x magnification but cost $500 or higher. Alternatively, the OlloClip Macro Pro Lens, a consumer external lens kit for iPhone can clip to the smartphone's camera and provide up to 21x optical magnification (**Fig. 1**). When combined with the smartphone's built-in digital zoom, up to 31x magnification can be achieved, as well as being able to capture pictures and live video without emersion oil or gel.

Thermal imaging Thermal imaging (TI) is a rapid, highly reproducible method of using infrared imaging to quantitate the degree of inflammation in animal models of RA.[58] Infrared imaging in RA can distinguish disease severity with a sensitivity and specificity of 96% and 92%, respectively compared with normal control.[59] TI can distinguish Raynaud temperature differences in a women's first toe with a sensitivity and specificity or 73% and 66%, respectively compared with healthy controls.[38] Other non-Raynaud vascular disorders can be assessed with TI (**Fig. 2**). Commercial grade TI cameras can be thousands of dollars per device. Alternatively, the forward-looking infrared ONE thermal imaging camera is a smartphone attachment that can be used for medical applications. This device attaches to a smartphone or tablet via the dataport and combines both a thermal camera and standard camera to composite a dual image with added detail. The manufacturer states the ability to detect temperature differences as small as 0.18°F (0.1°C) ($199 FLIR ONE).

Microscope imaging Synovial fluid microscopy is still the gold standard diagnostic modality for crystalline arthropathy.[60] Traditional image capture equipment for a tabletop microscope can exceed $1000, with added cost and complexity for captured and live streaming video. Alternatively, a mounting bracket for a smartphone can be attached to the left or right eye piece of a microscope for optical to digital image and video capture. One example is the Gosky Universal Cell Phone Adapter Mount ($24.99), which can capture still images plus video, and use digital zoom. In addition, the smartphone can stream to an external display or still use live video chat (eg, Skype or FaceTime).

Table 1
Emerging innovative tools for use in rheumatology

Device/Software	Description	Potential Use
OlloClip Macro Pro Lens (Hardware tool)	External lens kit for iPhone can clip to the smartphone camera and provide up to 21x – 31x optical magnification for nailfold capillaroscopy	Scleroderma, connective tissue disease monitoring
Forward-looking Infrared ONE Thermal Imaging Camera (Hardware tool)	Smartphone attachment that combines both a thermal camera and standard camera to composite a dual image with added detail. Could detect temperature differences as small as 0.18°F (0.1°C)	Inflammatory arthritis, CRPS, vasculitis monitoring
Gosky Universal Cell Phone Adapter Mount (Hardware tool)	Fits eyepiece of smartphone. Can be used as an alternative to traditional image capture equipment of synovial fluid microscopy	Synovial fluid analysis and other microscopy
3D4Medical Application (Software tool)	Software using 3-dimensional, real-time rendered images and video, based on MRI and CT reconstructions	Education of patients, practitioners
DAS Calc (Software tool)	Can calculate a variety of disease activity instruments such as DAS28 (3 or 4 Variable), Disease Activity Score C-Reactive Protein (DAS-CRP), Clinical Disease Activity Index (CDAI), Simple Disease Activity Index (SDAI), and Routine Assessment of Patient Index Data 3 (RAPID3)	Rheumatoid activity monitoring
Psoriasis Calc (Software tool)	Software application to calculate the PASI score	Psoriasis activity monitoring

Abbreviations: CRPS, complex regional pain syndrome; CT, computed tomography; PASI, Psoriasis Area and Severity Index.

These innovative hardware tools offer a low-cost alternative that can promote the integration of technology into rheumatology.

Software tools

There are several opportunities for the use of software tools in the medical office. Innovative software tools can assist with patient education, informing consent, improved compliance, education of trainees, and EMR workflows.

Anatomic applications Anatomy software has been ubiquitous in medical education for decades. Besides education of trainees and practicing physicians, patient education can be enhanced with medical software.[61,62] 3D4Medical is a top rated anatomy software developer for the iOS, Android, and Mac operating systems using 3D, real-time rendered images, and video, based on MRI and computed tomography reconstructions. Newly added features include augmented reality mode to overlay 3D

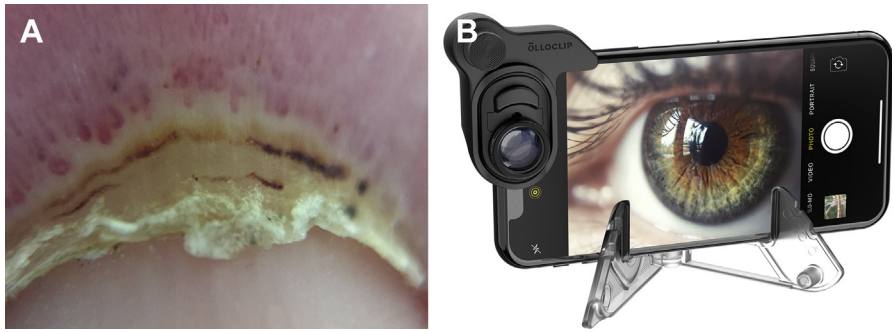

Fig. 1. (*A*) A patient with limited cutaneous systemic sclerosis, interstitial lung disease, and pulmonary hypertension. Image captured using an iPhone 7 and a 2016 OlloClip Macro Lens with 21x magnification. (*B*) Means of attachment of 2017 OlloClip to iPhone X.

reconstructions within the real world. Software from this developer is used in universities and physician offices throughout the world, with affordable costs of apps ranging from $7.99 to $59.99.

Clinical applications The Disease Activity Score 28 point joint count (DAS28) remains a ubiquitous disease activity instrument for inflammatory arthritis. There is a handful of rheumatology-dedicated EMRs that can calculate this but most multipurpose EMRs still do not contain this function. DAS Calc is an offline smartphone application for iOS devices that can calculate a variety of disease activity instruments as mentioned in **Table 1**.

Similarly, Psoriasis Calc is a free application for iOS and Android smartphones that enables quick calculation for body surface area involvement of psoriasis and has a visual guide and calculator to generate a Psoriasis Area and Severity Index score. Both of these applications are widely applicable in rheumatology practices due to the prevalence of these diseases with many of the patients encountered.

Patient applications Obesity is a common risk factor for rheumatic disease, with many patients struggling with even modest weight loss. Although there is no substitute for a regular exercise routine and formal dietary counseling, there are several smartphone applications designed to aid in weight loss. One example amongst many is Lose It! (free with premium features), a multiplatform smartphone and Web application that enables tailor-made calorie counting based on user-defined goals enhanced with gamification and a social component. Lose It! integrates with connected health devices such as fitness bands, smart watches, weight scales, and blood pressure cuffs. Fitness bands can also be used in clinical trials to gather data on the efficiency of different weight loss methods in research studies.

Chronic pain remains a leading cause of disability and it is a major contributor to health care costs, with one in every 4 Americans having suffered from pain that lasts longer than 24 hours.[63] Although this problem is extraordinarily complex in terms of long-term management, meditation and mindfulness-based stress reduction (MMBSR) has been shown to be effective in modulating through endogenous opioids.[64] In addition, MMBSR is associated with significant deactivation of regions of the default mode network, the region of the brain that is dysfunctional in chronic pain, fibromyalgia, mood, and cognitive disorders.[65] Along with several applications currently available, Calm (free with premium features) is a multiplatform app for MMBSR. Calm allows users to choose different mindfulness programs spanning 1

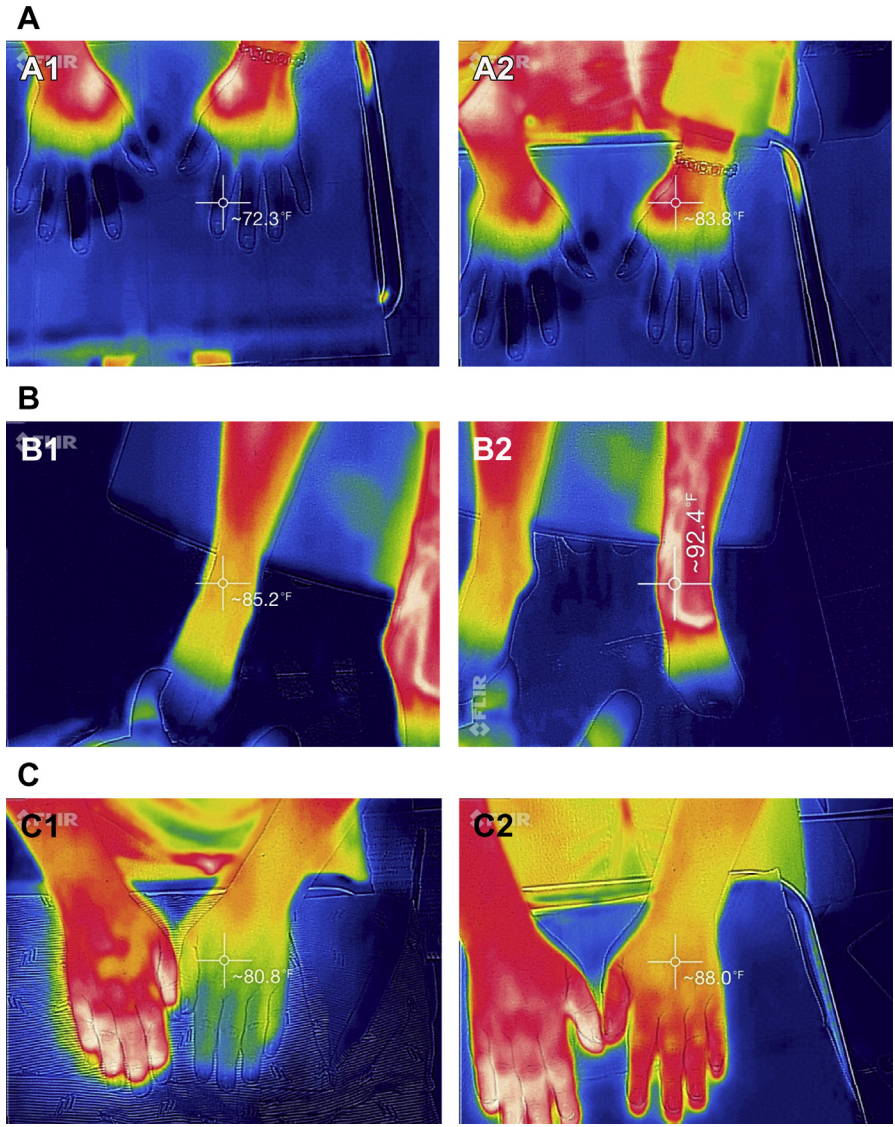

Fig. 2. (*A*) Secondary Raynaud syndrome and Lupus with 11.5°F difference between proximal hand (*A1*) (*left image*) and distal digits (*A2*) (*right image*). (*B*) Pseudogout attack in left ankle (*left image*) (*B1*), 7.2°F difference with right ankle (*B2*). (*C*) Takayasu arteritis and left subclavian artery stenosis with sedimentation rate of 113 mm/h (*left image*) (*C1*), after 2 months of high-dose corticosteroids, 7.2°F difference with sedimentation rate, reduced to 13 mm/h (*right image*) (*C2*).

to 3 weeks, requiring users to engage 10 to 15 minutes per day for audio-based sessions.

Technology adoption for the office-based physician is (and continues) to be driven by the smartphone. The ideal office technology needs to be affordable, usable, fast, and aid patient outcomes. More research is needed to see if additional technology products can significantly affect diagnosis and management. Along with hardware,

software can be used for productivity, education, informed consent, and to manage comorbidities. Increasingly, patients are using data and technology to help manage their illness but welcome physician guidance.

SUMMARY

Although the advent of digital medicine has been slow to take hold, the pace of adaptation of digital medicine will accelerate over the next several years. Advances in biosensors, artificial intelligence, telemedicine, VR, smart monitors etc. are going to transform the way that medicine will be practiced. Digital medicine provides rheumatology many opportunities to innovate and redefine the way we practice medicine. In addition, tools that help us achieve these goals will become more pervasive. Although change is inevitable, it will require us as rheumatologists to define the basic questions of who these interventions will be helpful for, when they are worth using, where interventions should be administered, and perhaps most importantly, will these new technologies help provide better, safer, and cheaper care for our patients.

ACKNOWLEDGEMENTS

We would like to acknowledge Timothy Chu, BS for writing assistance, final proofreading, and organization of cited sources which contributed to the overall quality of the final paper.

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