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# The virtual physical exam in the 21st century

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## Abstract

The modern Western medical encounter follows a strict framework that weaves subjective and objective components into a unifying diagnosis. As health care changes to incorporate new technology, such as virtual health care, the components that lead to diagnosis must likewise evolve. The virtual physical exam has limitations compared with the traditional exam. Despite this limitation, every year more patients are seen virtually with high satisfaction. Data have shown that supplementary real-time patient–provider video telemedicine increases access and extends established patient–physician relationships which will likely fuel increased telemedicine adoption even further. However, to date, there are limited data regarding the validity of the virtual examination compared with the traditional physical exam. In this paper, we review the use of developing technology related to the virtual physical exam.


**Keywords**
Telemedicine, virtual, physical exam, diagnosis

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## Introduction

Before the modern advancement of technology, the physical exam was the gold standard for medical diagnosis. Galen, building upon the philosophical foundations of medicine laid by Hippocrates and Aristotle developed the scientific disciplines of anatomy and physiology. In the 11th century, Ibn Sina challenged inductive thinking by developing some of the first methods for physical examination and experimentation.[1] Leopold Auenbrugger continued this trend by percussing the patient's abdomen and thoracic cavity to determine the density of an organ or fluid collection, a technique improvised after observing his father tapping on casks of wine to establish how much fluid remained.[1] Later, Rene Laennec created the stethoscope by listening to one end of a rolled piece of paper attached to a patient's chest.[1] These proximal technologies enhanced the ability of a physician to make a physical diagnosis based on how a patient looks and sounds. By the late 20th century, remote diagnostic tests such as urinalysis, imaging and blood analysis became more integrated with physical exam techniques to support diagnostic decision making. Combining these new tests with the physical exam separated medical diagnosis away from home visits to doctor's offices and tertiary care centers.[1] This combination (physical exam with remote diagnostic tests) outlined the first shift in physical diagnosis.

New technologies have allowed telemedicine and digital instruments to change how physicians connect with patients. A natural result of a telemedicine visit compared with an in-office or in-hospital medical diagnosis is that clinical context is rooted within the patient's everyday life. For example, ambulatory blood pressure measurements are more indicative of cardiovascular risk compared with in-office blood pressure measurements – a finding that challenges the universality of the traditional in-office diagnosis of hypertension.[2] Use of medical apps, remote monitoring and wearable technology provides an opportunity to capture improved clinical information about a patient's behaviour outside the clinician's office.

Moreover, the convenience of these instruments has established a new paradigm for a successful physician–patient relationship. The American Hospital

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Association estimates that more than 60% of all health-care institutions and 79% of all hospitals in the USA use some form of virtual health care, from telemedicine to mobile applications, to improve patient access.[3,4] In one study, 96% of patients focused on issues such as inadequate communication, wait times and disorganised operations over medical expertise and clinical skill when rating their health-care experience, identifying systematic challenges potentially addressable via telemedicine.[5] Additionally, these instruments are more versatile and provide timely information when in-person examination is unnecessary or unfeasible. For example, dermatological conditions such as burns, retinopathy and minor orthopaedic injuries have been shown to be reliable via simple telemedicine assessments.[6,7] In a teledermatology review, Bashshur et al. described several studies showing high diagnostic ($k = 0.80$–$0.95$) and treatment concordance ($k = 0.83$–$0.95$) between in-person and virtual diagnosis among dermatologists.[8] One study argued that still images could substitute for the dermatologic physical exam in 83% of cases, resulting in improved diagnosis and treatment of skin disorders in a primary-care setting while extending specialty availability to underserved populations.[7]

It has been argued that a virtual physical exam lacks certain components which affect the willingness of payers to reimburse at comparable rates to traditional in-office visits, despite many states having parity laws. Every year, the Centers for Medicare Services (CMS) increase telemedicine coverage, although previous restrictions around its use have limited adoption to date. As state Medicaid programmes, the Veterans Health Administration and private payers increase telemedicine coverage, further expansion will continue to diversify the clinical perspective.[9] To date, there are limited data regarding the validity of the virtual examination compared with the traditional physical exam. In this paper, we review the reliability of the virtual physical exam, describe new technology and, where possible, highlight the clinical validity of these technologies.

## Understanding the virtual exam

Telemedicine allows increased clinical access to patients. Although the x-ray machine and laboratory may spatially and temporally separate the patient and physician, telemedicine and advances in technology have, somewhat paradoxically, created a closer bond between the patient and physician.[10] Telemedicine appointments are unique in that in some instances, a visit can be conducted in a patient's home where they are alone or with their spouse/children and/or caretaker. During other visits, there can be a care team present to help with the examination. Telemedicine challenges the current model requiring that patients travel to the clinic. With telemedicine, clinicians are virtually welcomed into a patient's home office, kitchen or even living room using their mobile device, tablet or desktop video camera. This access allows clinicians to access data during any activity (asleep, physical activity) and expands the clinical context that was previously unavailable to modern medicine. Furthermore, virtual data will likely catalyse more frequent visits without patients missing work, dealing with traffic or paying for parking fees. For example, wireless diagnostic tools such as the AliveCor (Mountain View, CA) enabled electrocardiogram (ECG), pocket ultrasounds (Butterfly Network, Guilford, CT) and smartphone-based otoscopes (Cellscope, San Francisco, CA) have disrupted point-of-care diagnostics. Despite not requiring an in-person visit, new point-of-care technologies may still increase encounters for data interpretation if the information impacts clinical decision making.[7]

In our own clinical practice, we have observed less reliance on the physical exam for clinical decision making. Part of this shift may be a result of decreased time spent in teaching the physical exam during training, and part may be a perception of the increased accuracy of advanced imaging and laboratory diagnostics. Fundamentally, telemedicine is another modality to connect with patients. As telemedical care evolves, clinicians will decide which patients require in-person evaluations and what data contribute to clinical decision making. Obtaining a baseline in-person exam and setting expectations prior to beginning a virtual encounter should improve diagnostic accuracy. Before initiating a virtual visit, the clinician should obtain consent from the patient, set expectations and address any limitations on the proceeding appointment. With a thorough history and objective findings, clinicians can obtain information to achieve a comprehensive virtual exam.

## Virtual physical exam by system

The CMS recognises two standards to document an in-person physical exam based on the year in which the protocol was introduced (1995 vs. 1997). Clinicians may use either rule to document exams properly but not both. Twelve organ systems (OS) and seven body areas (BA) are defined, with a tiered system outlining the level of detail (i.e. problem focused, expanded problem focused, detailed and comprehensive). Here, we outline the OS and BA defined by the CMS rules based on current documentation guidelines as a spring-board for a virtual physical exam feasibility table as developed by the authors (Table 2).

The 12 OS are:

1. Constitutional (vital signs, general appearance)

2. Eyes
3. ENT (ear, nose, mouth, throat)
4. Cardiovascular
5. Respiratory
6. Gastrointestinal
7. Genitourinary
8. Musculoskeletal
9. Skin
10. Neurological
11. Psychiatric
12. Heme/lymphatic/immunologic

The seven BA are:

1. Head, including the face
2. Neck
3. Chest, including the breasts and axillae
4. Abdomen
5. Genitalia, groin, buttocks
6. Back, including the spine
7. Each extremity

## 1. Constitutional

Vital signs (blood pressure, respiration, temperature, pulse oximetry, weight, pulse rate and general appearance) are easily obtainable through over-the-counter devices that are connected to the Internet. The CMS requires three vital signs and a constitutional description that is purely based on initial impressions of the patient such as being in distress or appearing dishevelled.

Light-emitting diode (LED) sensors and smartphone cameras help to measure pulse. Data can be asynchronously uploaded over a period of time that is reviewed by the remote clinician. Technologies from NASA's Jet Propulsion Laboratory such as FINDER (Finding Individuals for Disaster and Emergency Response) is used to help detect a human heartbeat beneath 30 ft (9 m) of crushed material from a distance of almost 100 feet.[10] Though further studies are required to determine clinical reliability and accuracy, this same technology may be used for vital sign monitoring in many different forms, including smart watches which monitor an individual's heart rate and rhythm.

Although traditional vital signs (pulse, blood pressure, temperature and weight) have demonstrated success in ensuring a healthy population, new vital signs such as average steps taken or net daily calories can add another dimension to the physical examination.[11] As more objective data points are gathered about a patient, these data points allow clinicians to understand the overall health of a patient.

## 2. Eyes

Directing a patient to determine extraocular motion can be done seamlessly using cameras on available smartphones .[12] These cameras may also capture icteric sclera limited by camera resolution and lighting similar to the in-person exam. Structures such as the eyelids, sclera, cornea and epicanthic folds are all visible with normal cameras on most updated laptops/tablets. New phones with multiple front-facing camera arrays capable of face detection and depth detection have the ability to scale a Snellen chart appropriately automatically, although mobile applications have yet to be validated.[13]

At the Veterans Affairs (VA) health-care system, retinal imaging has been utilised for more than a decade to screen for diabetic retinopathy.[12] With the prevalence of diabetic retinopathy, automated retinal image analysis can challenge a physician's exam with high sensitivity and workload reduction.[14] The IDx-DR device (IDx Technologies, Coralville, IA), approved by the Food and Drug Administration (FDA), is able to use automated grading for referable diabetic retinopathy.[15] Novel portable handheld smartphone-based retinal cameras are also capable of capturing high-quality, wide-field fundus images expanding the eye exam.[16]

In the UK, a study to monitor stable glaucoma found that virtual monitoring was a safe and logistically viable option for patients at low risk of progression to significant visual loss.[17] For patients who are remote, cameras and phones are now being used as parts of otoscopes, nasopharyngoscopes, ophthalmoscopes and dermatoscopes, and video cameras have even provided distant clinicians with high-resolution images of a particular body part.[18]

## 3. Ear, nose, mouth and throat

This part of the body can be the most challenging portion to examine, limited by camera resolution, ambient lighting and operator experience. Today, numerous companies have the technology to obtain images of the ear, mouth and nose with proprietary technology (TytoCare, New York, NY) coupled with an on-demand health-care business model. Additionally, hardware with LED lights/speculum to facilitate imaging is also available for less than $50 on Amazon (Seattle, WA).

In one study measuring parental use of an iPhone (Apple, Cupertino, CA) otoscope camera, the device was deemed unreliable when compared with images obtained by clinicians using the same software.[19] Likely a new set of skills will be required for widespread use and diagnostic reliability from parental images. Otolaryngologists may consider adding post-surgical evaluation via telemedicine based on data that it can be cost-effective for both the patient and the hospital system.[20,21]

New studies are demonstrating the use of speakers and microphones within existing smartphones to assess eardrum mobility.[22] By measuring for tympanometry and pneumatic otoscopy, researchers showed 85% sensitivity and 82% specificity for detecting the presence of middle ear fluid.

## 4. Cardiovascular

Blood pressure, pulse rate and ECGs can be obtained through devices that currently have FDA approval.[23,24] These devices can also be utilised for preventive screening, for example individuals with a resting heart rate of more than 80 bpm are more likely to have type II diabetes.[25] Another measure, heart-rate variability (HRV), indirectly measures autonomic tone and has a well-established role as a marker for cardiovascular risk.[26] Wearable technology, including the Apple watch, Fitbit (Fitbit, San Francisco, CA) and various smartphone applications (Elite HRV), can measure and share HRV with clinicians to improve diagnostic accuracy and provide avenues to measure preventative strategies and overall fitness.[27,28]

Electronic stethoscopes are incorporating artificial intelligence and machine learning to highlight murmurs, resulting in greater discovery of valvular issues at the same time that point-of-care ultrasounds are adopted into clinical practice.[29] Digital stethoscopes can record, analyse and send heart sounds to the clinician to diagnose heart murmurs or pulmonary hypertension.[30,31] Point-of-care ultrasounds are now connected to smartphones and are more accessible than ever with decreasing costs.

Those managing hypertensives should look forward to the MASked-unconTrolled hypertension (MASTER) study. This is a four-year prospective randomised, open-label, blinded end-point investigation designed to determine whether using ambulatory blood pressure monitoring rather than office blood pressure measurements as a guide to antihypertensive treatment confers any benefit in terms of cardiovascular prevention.[2]

For heart failure patients, monitoring daily weights is fundamental. A history can provide information on dyspnoea, paroxysmal nocturnal dyspnoea, orthopnoea, cough or weight gain. A cardiac physical exam can be challenging when assessing for a jugular venous distention or hepatojugular reflex. Digital stethoscopes help with lung sounds to determine crackles, and remote monitoring devices provide insight into arrhythmias. Here, clinicians can also assess peripheral oedema and weight gain to help monitor heart failure.[32] Data such as cardiac filling pressure with implantable haemodynamic monitoring devices (e.g. CardioMEMS™; Abbott Laboratories, Atlanta, GA) have introduced new variables to take objectively into a patient's examination.[33]

Heart failure management remotely has been successful with cardiac-implanted electronic devices such as pacemakers and defibrillators. However, early studies have had mixed outcomes.[34–36] The Telemedical Interventional Management in Heart Failure II (TIM-HF2) was a prospective, randomised, controlled, parallel-group study to detect early signs and symptoms of cardiac decompensation with data monitoring for a well-defined population. It showed that remote management interventions can reduce the percentage of days lost due to unplanned hospital admissions and all-cause mortality.[37]

Finally, in a direct-to-participant randomised clinical trial and prospective matched observational cohort study, patients were selected to wear a self-applied continuous ECG monitor patch.[38] These patients had higher rate of atrial fibrillation diagnosis and greater initiation of anticoagulants. They also had increased utilisation of health-care resources at one year.

## 5. Respiratory

Management of asthma is complex, involving preventive, diagnostic and maintenance strategies. Telemedicine interventions are focusing on early detection of disease exacerbation for early symptom management. Although forced spirometry is important in the early diagnosis of chronic obstructive pulmonary disease (COPD) and asthma, web-based remote support demonstrated better quality of testing in the primary-care setting using smartphone applications for peak flow recordings.[39] A systematic review of telehealth in cystic fibrosis patients showed significant findings related to increased use of antibiotics and improved spirometry stability.[40]

Though pulmonologists are still trying to characterise the benefits of telemedicine better, instruments such as COPD Assessment Test questionnaires, telespirometry and teleoximetry have made it easier to determine patients who can benefit the most from telemedicine.[35] Through video, clinicians can comment on how many words patients are saying in a sentence or even the colour of their skin as part of the inspection of a physical exam. Electronic stethoscopes also perform as well in the respiratory exam as in the cardiac exam.

There are many additional measures that can be acquired from new devices that are able to track respiratory rate while sleeping for patient use, such as breath sounds for ruling out sleep apnoea. Data can also be shared with clinicians as needed. In addition, applications can also track temperature variation, resting heart rate and HRV and use this information to help give a readiness rating.[41,42]

## 6. Gastrointestinal

Gastroenterologists are among the few subspecialists to adopt telemedicine into their practice, with only 7–9% using telemedicine to interact with their patients.[43] While the field is driven by invasive diagnostic tests and treatments requiring face-to-face interactions, there is a big opportunity for clinicians to streamline and improve the quality of care they provide their patients with the help of telemedicine. Inspection and auscultation of bowel sounds alone can provide enough information to contribute to the physical exam.

Patients with diagnoses such as ulcerative colitis, irritable bowel syndrome and colorectal cancer fit well for telemedicine. Using rating scales or severity scores as indicators of disease activity can provide objective measures.[39] Concurrently, patients may be asked to report symptoms over a period of time utilising web-based self-management programmes.[44]

The gastrointestinal exam is not traditionally amenable to virtual inspection. Data such as protuberance and scarring can be readily assessed visually. However, positioning the patient would be limited by camera angle/room placement for accurate diagnosis. Despite these limitations, there are various new technologies that may increase diagnostic effectiveness.

Single-axis accelerometers have now changed how physicians can use a screen to triage abdominal pain. If palpation is needed, integrated micro-electromechanical accelerometers measure the motion of a smartphone application. Apps can measure the patient self-palpation, compare it with the physician palpation and provide feedback as to how to match the physician palpation: more or less depth, and shorter or longer compression.[45]

Although distant, screening and treatment of gastrointestinal diseases by a remote-controlled robotic capsule endoscope may play a greater role for gastroenterologists to implement new methods of providing care.[46]

For the general surgeon, telemedicine can provide important information such as ileostomy output or surgical drain output.[47] Studies demonstrate that clinical outcomes are comparable with the outcomes in the setting of traditional clinic follow-up for the postoperative care of patients.[48,49]

## 7. Genitourinary

Almost all urological conditions can be evaluated initially and followed up with telemedicine.[50] The most commonly managed conditions are lower urinary tract symptoms, elevated prostate specific antigen and prostate cancer. For men treated surgically for prostate cancer, video visits were equivalent in efficiency, with similar satisfaction and significantly lower patient costs compared with office visits.[51]

Given the sensitivity of this physical area of the patient, however, there can be limitations for images or examination of the genitalia. In general, an in-person exam would be recommended aside from typical rashes of balanitis and fungal rashes unless otherwise determined by a patient's comfort level. Machine learning algorithms are also becoming more robust, such as the XGBoost, which has demonstrated an ability to diagnose positive urine cultures accurately, as urinary tract infections are generally one of the top issues for many virtual urgent care programmes.[52,53]

## 8. Skin

Success in teledermatology is highly dependent on the quality of an image. It is one of the main subspecialties that has been able to thrive, not only as direct services for patients, but also for primary-care clinicians requesting triage.[54]

While there are benefits to using a dermatoscope, smartphones are now providing images clear enough for diagnosing lesions. With skin cancer being one of the most common malignancies diagnosed, automated classification of skin lesions using artificial intelligence and images from mobile devices can extend the reach of dermatologists.[55] Concurrently, these deep convolutional neural networks outperformed an international group of expert dermatologists.[56] It is worth noting that patients cannot see their scalp or back, and this may limit the comprehensive skin exam.

Diabetic foot ulcer (DFU) monitoring utilises remote temperature to determine differences for high-risk patients. Case studies show that by having patients stand barefoot on mats for 20 seconds at the same time each day, persistent localised temperature exceeding 1.75°C between the left and right feet can result in early detection and treatment of uninfected DFUs.[57] These temperature-monitoring mats were able to detect 97% of impending DFUs correctly.[58]

In one study in a paediatric intensive care unit, patients had two physical assessments (face-to-face and telemedicine), one within 15 minutes of the other by two different clinicians.[59] The clinician practicing telemedicine had an assistant at the bedside to help with the placement of the electronic stethoscope, visual assessment of the desired body part and cycling of the automated blood pressure monitor. Assistants helped with depressing the skin, and a high-density peripheral camera was used to help determine pallor, mottling and skin colour with near-perfect concordance between the in-person and telemedical care clinicians.

In another study, an infrared thermal camera was useful for screening postoperative cellulitis.[60] With continued technological upgrades to peripheral cameras, we believe it is conceivable that an infrared filter can be utilised to diagnose cellulitis confidently over video.

## 9. Musculoskeletal

Range of motion, crepitus and local inflammation can be self-reported by patients. Gait assessment can be performed in an open space. Resistance would be difficult to assess except by utilising household items with a known weight to give an estimate of strength. However, traditional manoeuvres utilised to assess individual joints would be difficult to perform virtually (i.e. empty can test or the Hawkins/neer test which have been validated to assess for impingement syndrome).

Early trials are now testing the ability for postoperative care of patients via smartphone following carpal tunnel release. While 10/16 patients removed their sutures successfully, 14 patients captured a clinically adequate wound photo and range of motion video.[61]

## 10. Neurological

Clinicians using telemedicine can obtain an accurate and complete neurological history and physical exam, but clear communication and effective interpersonal skills are essential.[62] Standardised examinations, including the Mini-Mental Status Examination, National Institutes of Health Stroke Scale, Expanded Disability Status Scale and Full Outline of Unresponsiveness score, have also created reliable outcomes.[63,64] A neurology work group identified physical exams that are appropriate for teleneurology.[65,66] With virtual visits, it would be easy to have a range of motion to the upper limbs over the lower limbs. Telestroke has demonstrated huge success with addressing neurologist shortage in rural health care.[67]

## 11. Psychiatric

While telepsychiatry was among the earliest applications, understanding the mental health of a patient can be assessed through the strong observations of a clinician and the relationship that is built with the patient. Psychiatric disorders can be diagnosed through a detailed patient interview, and the physical exam is generally limited. Much like neurology, patients with post-traumatic stress disorders (PTSD), anxiety, schizophrenia, depression and alcohol disorders have demonstrated telemedicine to be as effective as in-person visits.[68] Psychiatric evaluation relies less on the traditional physical exam and more on a directed patient interview. As a result, psychiatry was an early adopter of telemedicine.[69,70] Consistently, with more than two million telehealth visits in the VA system, mental-health visits have been among the most common.[71]

## 12. Heme/lymphatic/immunologic

When considering this section, generally a clinician thinks about lymph nodes. Often, patients can accurately describe new lumps or bumps that they see on their body. In one study, in-person versus telemedicine-facilitated physical exams had moderate agreement on colouration of the palate and cervical lymphadenopathy for patients with pharyngitis.[72] However, further questions to help define mobility and firmness of a lymph node are important which would warrant further in-person evaluation.

## Discussion: Advances in 21st-century practice of medicine

During this paradigm shift in how telemedical care is provided and delivered, physicians are actively trying to master the virtual physical examination in order to provide an accurate informed diagnosis. Observing and listening are fundamental skills that clinicians hone early in their training to develop patient rapport. Informed patients are requesting that clinicians provide telemedical care. This consumer pressure creates a drive to examine a patient effectively and efficiently through untraditional methods. One of the greatest challenges physicians face is performing a relevant examination within the time constraints of a clinic visit. However, when it comes to telemedicine, many clinical questions still need to be answered. Which patients are best suited for this modality? What are the limitations of virtual health care? What are the advantages? And what does the future hold?

This article has shown that virtual health care has an established presence. Here at the University of Washington, courses on telemedicine are taught at the Law School, are integrated into medical school curriculums and are becoming rotations for physician residents to have protected time for practice. The authors believe an ongoing provider–patient relationship is fundamental to adopting virtual visits into practice. Furthermore, the level of skill and experience of a clinician can vary the extent of a physical exam. Many seasoned clinicians can piece together information in ways that can compensate for an incomplete physical

**Table 1.** Components appropriate for teleneurology.[62]

| Appropriate for teleneurology | Difficult but possible via teleneurology (variable and dependent on telepresenter) | Likely not appropriate via teleneurology |
|---|---|---|
| Functional strength testing and sensory examination (spinothalamic tests and vibration with the help of a telepresenter) | Detailed motor testing (reliant on the telepresenter to determine tone and specific grades of Medical Research Council grading scale) | Comprehensive vestibular testing (given current peripheral devices in existence) |
| Cerebellar and gait testing (movement disorder physicians have been some of the earlier and most successful adopters of telemedicine) | Testing of muscle stretch reflexes | Comprehensive neuro-ophthalmologic (without requisite peripherals) |
| Mental status examination, including MoCA or other cognitive measures | Proprioception | Comprehensive neuromuscular examination |
| Cranial nerve examination (the funduscopic examination currently requires peripheral devices that are not always available) | Functional testing for psychogenic examination components | Brain death examination |
| Various measurement scales including the NIHSS and UPDRS | | |

MoCA: Montreal Cognitive Assessment; NIHSS: National Institutes of Health Stroke Scale; UPDRS: Unified Parkinson's Disease Rating Scale.

exam.[50] Biases still exist, as clinicians can review prior notes which have physical exam findings. Training will need to be adopted earlier into residency programmes and medical schools in order to create a level of comfort in a structured training environment.[73,74]

Today, clinicians are spending twice as much time behind a computer as they do in front of their patients.[71] Much of this time is spent doing administrative work, but also includes interpretation of objective data points through ECGs, pulmonary function tests, laboratory tests and radiological exams. As telemedicine utilisation is further incorporated in health care, costs associated with time off from work, parking and travel will be eliminated.[75]

As a result, the virtual physical exam should be integrated into clinical practice if we accept certain basics principles: (a) a thorough review of systems has been obtained, (b) patients are actively involved in their own health care, (c) an appropriate follow-up plan is established and (d) care has ideally been established with a clinician.

Point-of-care treatment has previously improved diagnostic accuracy in measurable ways. Telemedicine allows a continuous in vivo perspective of a patient's life (such as data generated from wearable technology) rather than a single point of engagement (i.e. point-of-care haematocrit). How we understand the physical exam is now challenged as we collect more and varied data points about our patients. Data remotely provided to clinicians accelerate management decisions to facilitate improved outcomes. For example, multiple sclerosis patients with attached biosensors (accelerometers, gyroscopes, eye trackers and grip sensors) can provide daily use data to decipher interventional effectiveness and monitor disease progression.[76]

Fundamental to optimising telemedicine is identifying which aspects of clinical care are ideal use cases.[77] Early on, there will need to be a way to develop which patients are best suited for virtual clinics. We recommend specialty developed guidelines through telemedicine work groups as exemplified by the American Academy of Neurology (see Table 1). Despite ongoing studies to identify those most likely to adopt virtual visits, we believe clinical judgement will drive optimisation. Patients who require a procedure obviate an in-person visit, while other non-procedural visits may increasingly turn to virtual-care visits. Follow-up appointments, postoperative visits, surgical discussions, wound care and magnetic resonance imaging/lab review are all use-case scenarios that can develop telemedical niches. However, we must be cautious in our approach, as one prospective randomised controlled trial assessed individuals using multiple smartphone-enabled biosensors and demonstrated little evidence of differences in health-care costs or utilisation as a result of the intervention.[78] Aside from a few papers focusing on system-specific comparisons, there has not been a direct comparison of the validity of the virtual exam compared with the in person exam. For this reason, we and others recommend that the initial exam be done in person if at all possible.

Patients with more chronic unstable diseases traditionally require frequent face-to-face appointments. Medical devices and technologies are changing how we obtain information about a patient and may contextually challenge current guidelines in disease management.

**Table 2.** Virtual physical exam: brief overview of current feasibility.

| | |
|---|---|
| *Constitutional* | |
| Blood pressure | High[a] |
| Pulse | High[a] |
| Auscultation Korotkoff sounds | Low[b] |
| Respiratory rate | High |
| Temperature | High[a] |
| Weight | High[a] |
| Body mass index (BMI) | Medium[a] |
| *Head and neck* | |
| Size and shape | High |
| Symmetry, masses, trauma signs, lesions | High |
| Speech (stridor, hoarseness) | High |
| *Eyes* | |
| Visual acuity | Medium[b] |
| Visual fields | Low |
| Extraocular movements | High |
| Pupil size | Medium[b] |
| Scleral icterus | High |
| Conjunctival pallor | High |
| *Ears* | |
| Inspect auricle and mastoid | High |
| Otoscope | Medium[b] |
| *Nose* | |
| Inspect external nose | High |
| Nares, septum, cavities, and turbinate | Medium[b] |
| *Oral cavity* | |
| Inspection | Medium |
| Teeth/gums | Medium |
| *Neck* | |
| Asymmetry, tracheal deviation | Medium |
| *Respiratory* | |
| Accessory muscle use | High |
| Nasal flaring | High |
| Symmetry of chest movement | Medium |
| Breath sounds | Low to medium[b] |
| *Cardiovascular* | |
| Auscultation | Medium[b] |
| Jugular venous pressure | Low |
| Peripheral circulation/oedema | High |
| *Gastrointestinal* | |
| Patient distress | High |
| Abdominal distension | High |
| Scars | High |
| Masses, hernia | Medium |
| Auscultation (bowel sounds, bruits) | Medium[b] |
| Percussion (ascites) | Medium |
| *Genitourinary* | |
| Inspection | High |
| Costovertebral angle (CVA) tenderness | High |
| *Musculoskeletal (shoulder, hand, elbow, knee, back)* | |
| Inspect (swelling, deformity, rash) | High |
| Range of motion | High |
| *Skin* | |
| Inspection | High |
| *Neurological* | |
| Mental status | High |
| Consciousness | |
| Orientation | |
| Memory | |
| Language/speech | |
| Cerebellar: finger to nose, heel to shin | High |
| Gait | High |
| Romberg | High |
| Motor bulk/tone | Medium |
| Cranial nerves: | Low |
| II: visual acuity/fundoscopic | |
| II/III: pupillary reaction | |
| Cranial nerves: | High |
| III, IV and VI: extraocular movements | |
| V: mastication muscles | |
| VII: muscles of facial expression | |
| IX and X: phonation/coordinated swallow | |
| XI: sternocleidomastoid/trapezial bulk | |
| XII: tongue size and movement | |
| Asterixis | High |
| Tremors | High |
| *Psychiatric* | |
| All elements | High |
| *Heme/lymphatic/immunologic* | |
| Lymphadenopathy | High |
| Pallor | Medium |
| Petechia | High |
| Ecchymosis | High |
| OeEdema | High |

A broad overview on the ability to complete a physical exam through a telemedicine virtual exam and confidence-level rating based on a low, medium and high scale with the understanding that good lighting is available.
*Reportable by patient.
**Supported with device/mobile applications.

With new care models challenging the current fee-for-service structure, telemedicine tools can redesign chronic disease management to decrease in-person visits when patients are well and increase access for patients who need to be seen. These are the changes that can improve the patient experience and decrease costs while optimising health-care system resources. Limitations to adoption of telemedicine include reimbursement rates and state regulations. With few exceptions, providing care across state lines requires a clinician to obtain a licence in each individual state. Finally, the challenges of privacy, HIPAA compliance, data security and litigation will persist and will need to be updated as they pertain to virtual care.[79]

In the near future, we expect a new divergence in the clinical examination of a patient as data are interpreted and best practices established. The physical exam will evolve to keep up with the growing wealth of information. Artificial intelligent (AI) systems will provide meaningful diagnostic algorithms. AI is currently being developed to listen actively to a physician–patient interaction and format the conversation into meaningful clinical notes for review/approval immediately after the clinic visit. Technological advances may allow virtual/augmented reality interfaces to improve a limited physical or virtual exam. The challenge will rest on our medical team to master the data streams of these paradigm shifts effectively without sacrificing the patient–physician relationship.

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## References

1. Verghese A, Charlton B, Cotter B, et al. A history of physical examination texts and the conception of bedside diagnosis. *Trans Am Clin Climatol Assoc* 2011; 122: 290–311.
2. Parati G, Agabiti-Rosei E, Bakris GL, et al. MASked-unconTrolled hypERtension management based on office BP or on ambulatory blood pressure measurement (MASTER) Study: a randomised controlled trial protocol. *BMJ Open* 2018; 8: e021038.
3. American Hospital Association. Fact sheet: telehealth, https://www.aha.org/system/files/2019-02/fact-sheet-telehealth-2-4-19.pdf (accessed 18 September 2019).
4. Reed ME, Parikh R, Huang J, et al. Real-time patient–provider video telemedicine integrated with clinical care. *New Engl J Med* 2018; 379: 1478–1479.
5. King RH, Stanley J and Baum N. Hard Internet truths: 34,748 online reviews reveal what patients really want from doctors. *J Med Pract Manage* 2016; 31: 309–312.
6. Marin JR, Bilker W, Lautenbach E, et al. Reliability of clinical examinations for pediatric skin and soft-tissue infections. *Pediatrics* 2010; 126: 925–930.
7. Saffle JR, Edelman L, Theurer L, et al. Telemedicine evaluation of acute burns is accurate and cost-effective. *J Trauma* 2009; 67: 358–365.
8. Bashshur RL, Shannon GW, Tejasvi T, et al. The empirical foundations of teledermatology: a review of the research evidence. *Telemed J E Health* 2015; 21: 953–979.
9. Rajda J and Paz HL. The future of virtual care services: a payor's perspective. *Telemed J E Health*. Epub ahead of print May 6 2019. DOI: 10.1089/tmj.2019.0020.
10. Office of Technology Transfer at JPL. Office of Technology Transfer, https://ott.jpl.nasa.gov/ (accessed 18 September 2019).
11. Allouch SB and van Velsen L. Fit by bits: an explorative study of sports physiotherapists' perception of quantified self technologies. *Stud Health Technol Inform* 2018; 247: 296–300.
12. Conlin PR, Fisch BM, Orcutt JC, et al. Framework for a national teleretinal imaging program to screen for diabetic retinopathy in Veterans Health Administration patients. *J Rehabil Res Dev* 2006; 43: 741–748.
13. Perera C, Chakrabarti R, Islam FMA, et al. The Eye Phone Study: reliability and accuracy of assessing Snellen visual acuity using smartphone technology. *Eye (Lond)* 2015; 29: 888–894.
14. Nørgaard MF and Grauslund J. Automated screening for diabetic retinopathy – a systematic review. *Ophthalmic Res* 2018; 60: 9–17.
15. Van Der Heijden AA, Abramoff MD, Verbraak F, et al. Validation of automated screening for referable diabetic retinopathy with the IDx-DR device in the Hoorn Diabetes Care System. *Acta Ophthalmol* 2018; 96: 63–68.
16. Maamari RN, Keenan JD, Fletcher DA, et al. A mobile phone-based retinal camera for portable wide field imaging. *Br J Ophthalmol* 2014; 98: 438–441.
17. Clarke J, Puertas R, Kotecha A, et al. Virtual clinics in glaucoma care: face-to-face versus remote decision-making. *Br J Ophthalmol* 2017; 101: 892–895.
18. Weinstein RS, Krupinski EA and Doarn CR. Clinical examination component of telemedicine, telehealth, mHealth, and connected health medical practices. *Med Clin North Am* 2018; 102: 533–544.
19. Shah MU, Sohal M, Valdez TA, et al. iPhone otoscopes: currently available, but reliable for tele-otoscopy in the hands of parents? *Int J Pediatr Otorhinolaryngol* 2018; 106: 59–63.
20. Gunter R, Chouinard S, Fernandes-Taylor S, et al. Current use of telemedicine for post-discharge surgical care: a systematic review. *J Am Coll Surg* 2016; 222: 915–927.
21. Rubin JS and Sataloff RT. Telemedicine: Part II. *Ear Nose Throat J* 2018; 97: 226–228.
22. Chan J, Raju S, Nandakumar R, et al. Detecting middle ear fluid using smartphones. *Sci Transl Med* 2019; 11: eaav1102.
23. Cheung CC, Krahn AD and Andrade JG. The emerging role of wearable technologies in detection of arrhythmia. *Can J Cardiol* 2018; 34: 1083–1087.
24. Gropler MRF, Dalal AS, Van Hare GF, et al. Can smartphone wireless ECGs be used to accurately assess ECG intervals in pediatrics? A comparison of mobile health monitoring to standard 12-lead ECG. *PLoS One* 2018; 13: e0204403.
25. Carnethon MR, Yan L, Greenland P, et al. Resting heart rate in middle age and diabetes development in older age. *Diabetes Care* 2008; 31: 335–339.
26. Electrophysiology Task Force of the European Society of Cardiology the North American Society of Pacing. Heart rate variability. *Circulation* 1996; 93: 1043–1065.
27. Etiwy M, Akhrass Z, Gillinov L, et al. Accuracy of wearable heart rate monitors in cardiac rehabilitation. *Cardiovasc Diagn Ther* 2019; 9: 262–271.

28. Perrotta AS, Jeklin AT, Hives BA, et al. Validity of the elite HRV smartphone application for examining heart rate variability in a field-based settings. *J Strength Cond Res* 2017; 31: 2296–2302.
29. Leng S, Tan RS, Chai KTC, et al. The electronic stethoscope. *Biomed Eng Online* 2015; 14: 66.
30. Behere S, Baffa JM, Penfil S, et al. Real-world evaluation of the Eko electronic teleauscultation system. *Pediatr Cardiol* 2019; 40: 154–160.
31. Kaddoura T, Vadlamudi K, Kumar S, et al. Acoustic diagnosis of pulmonary hypertension: automated speech- recognition-inspired classification algorithm outperforms physicians. *Sci Rep* 2016; 6: 33182.
32. Kataoka H. Clinical significance of bilateral leg edema and added value of monitoring weight gain during follow-up of patients with established heart failure. *ESC Heart Fail* 2015; 2: 106–115.
33. Mangi MA, Rehman H, Rafique M, et al. Ambulatory heart failure monitoring: a systemic review. *Cureus* 2017; 9: e1174.
34. Morgan JM, Kitt S, Gill J, et al. Remote management of heart failure using implantable electronic devices. *Eur Heart J* 2017; 38: 2352–2360.
35. Dickinson MG, Allen LA, Albert NA, et al. Remote monitoring of patients with heart failure: a white paper from the Heart Failure Society of America Scientific Statements Committee. *J Card Fail* 2018; 24: 682–694.
36. Dorsch MP, Farris KB, Bleske BE, et al. A web application for self-monitoring improves symptoms in chronic systolic heart failure. *Telemed J E Health* 2015; 21: 267–270.
37. Koehler F, Koehler K, Deckwart O, et al. Efficacy of telemedical interventional management in patients with heart failure (TIM-HF2): a randomised, controlled, parallel-group, unmasked trial. *Lancet* 2018; 392: 1047–1057.
38. Steinhubl SR, Waalen J, Edwards AM, et al. Effect of a home-based wearable continuous ECG monitoring patch on detection of undiagnosed atrial fibrillation: the mSToPS randomized clinical trial. *JAMA* 2018; 320: 146–155.
39. Mikalsen IB, Nassehi D and Øymar K. Vortex whistle and smart phone application for peak flow recordings in asthmatic children: a feasibility study. *Telemed J E Health*. Epub ahead of print 20 December 2018. DOI: 10.1089/tmj.2018.0270.
40. Hernandez C, Mallow J and Narsavage GL. Delivering telemedicine interventions in chronic respiratory disease. *Breathe (Sheff)* 2014; 10: 198–212.
41. De Zambotti M, Rosas L, Colrain IM, et al. The sleep of the ring: comparison of the ŌURA Sleep Tracker against polysomnography. *Behav Sleep Med*. Epub ahead of print 21 March 2017. DOI: 10.1080/15402002.2017.1300587.
42. Hamilton JL and Alloy LB. Atypical reactivity of heart rate variability to stress and depression across development: systematic review of the literature and directions for future research. *Clin Psychol Rev* 2016; 50: 67–79.
43. The potential of telemedicine in digestive diseases. *Lancet Gastroenterol Hepatol* 2019; 4: 185.
44. Dorn SD, Palsson OS, Woldeghebriel M, et al. Development and pilot testing of an integrated, web-based self-management program for irritable bowel syndrome (IBS). *Neurogastroenterol Motil* 2015; 27: 128–134.
45. Myers DR, Weiss A, Rollins MR, et al. Towards remote assessment and screening of acute abdominal pain using only a smartphone with native accelerometers. *Sci Rep* 2017; 7: 12750.
46. Ohta H and Kawashima M. Technical feasibility of patient-friendly screening and treatment of digestive disease by remote control robotic capsule endoscopes via the Internet. *Conf Proc IEEE Eng Med Biol Soc* 2014; 2014: 7001–7004.
47. Bednarski BK, Slack RS, Katz M, et al. Assessment of ileostomy output using telemedicine: a feasibility trial. *Dis Colon Rectum* 2018; 61: 77–83.
48. Gunter RL, Chouinard S, Fernandes-Taylor S, et al. Current use of telemedicine for post-discharge surgical care: a systematic review. *J Am Coll Surg* 2016; 222: 915–927.
49. Williams AM, Bhatti UF, Alam HB, et al. The role of telemedicine in postoperative care. *MHealth* 2018; 4: 11.
50. American Urological Association. Telemedicine in urology, https://www.auanet.org/guidelines/telemedicine-in-urology (accessed 18 September 2019).
51. Viers BR, Lightner DJ, Rivera ME, et al. Efficiency, satisfaction, and costs for remote video visits following radical prostatectomy: a randomized controlled trial. *Eur Urol* 2015; 68: 729–735.
52. Taylor RA, Moore CL, Cheung K-H, et al. Predicting urinary tract infections in the emergency department with machine learning. *PLoS One* 2018; 13: e0194085.
53. Gordon AS, Adamson WC and DeVries AR. Virtual visits for acute, nonurgent care: a claims analysis of episode-level utilization. *J Med Internet Res* 2017; 19: e35.
54. Done N, Oh DH, Weinstock MA, et al. VA Telederm study: protocol for a stepped-wedge cluster randomised trial to compare access to care for a mobile app versus a workstation-based store-and-forward teledermatology process. *BMJ Open* 2018; 8: e022218.
55. Esteva A, Kuprel B, Novoa RA, et al. Dermatologist-level classification of skin cancer with deep neural networks. *Nature* 2017; 542: 115–118.
56. Haenssle HA, Fink C, Schneiderbauer R, et al. Man against machine: diagnostic performance of a deep learning convolutional neural network for dermoscopic melanoma recognition in comparison to 58 dermatologists. *Ann Oncol* 2018; 29: 1836–1842.
57. Killeen AL and Walters JL. Remote temperature monitoring in diabetic foot ulcer detection. *Wounds* 2018; 30: E44–48.
58. Frykberg RG, Gordon IL, Reyzelman AM, et al. Feasibility and efficacy of a smart mat technology to predict development of diabetic plantar ulcers. *Diabetes Care* 2017; 40: 973–980.

59. Yager PH, Clark ME, Dapul HR, et al. Reliability of circulatory and neurologic examination by telemedicine in a pediatric intensive care unit. *J Pediatr* 2014; 165: 962–966.
60. Fujita K, Noguchi M, Yuzuriha S, et al. Usefulness of infrared thermal imaging camera for screening of postoperative surgical site infection after the nuss procedure. *Case Rep Surg* 2013;2013:946156.
61. Tofte JN, Anthony CA, Polgreen PM, et al. Postoperative care via smartphone following carpal tunnel release. *J Telemed Telecare*. Epub ahead of print 14 November 2018. DOI: 10.1177/1357633X18807606.
62. Govindarajan R, Anderson ER, Hesselbrock RR, et al. Developing an outline for teleneurology curriculum: AAN Telemedicine Work Group recommendations. *Neurology* 2017; 89: 951–959.
63. Kane RL, Bever CT, Ehrmantraut M, et al. Teleneurology in patients with multiple sclerosis: EDSS ratings derived remotely and from hands-on examination. *J Telemed Telecare* 2008; 14: 190–194.
64. Loh PK, Ramesh P, Maher S, et al. Can patients with dementia be assessed at a distance? The use of telehealth and standardised assessments. *Intern Med J* 2004; 34: 239–242.
65. Craig JJ, Mcconville JP, Patterson VH, et al. Neurological examination is possible using telemedicine. *J Telemed Telecare* 1999; 5: 177–181.
66. Huston JL. Telemedical record documentation. *Top Health Inf Manage* 1999; 19: 59–65.
67. Schwamm LH, Audebert HJ, Amarenco P, et al. Recommendations for the Implementation of telemedicine within stroke systems of care. *Stroke* 2009; 40: 2635–2660.
68. Hyler SE, Gangure DP and Batchelder ST. Can telepsychiatry replace in-person psychiatric assessments? A review and meta-analysis of comparison studies. *CNS Spectr* 2005; 10: 403–413.
69. Adams JL, Tarolli CG and Dorsey ER. Next generation house call. *Cerebrum* 2017 Jan 1; eCollection 2017 Jan–Feb.
70. Brenes GA, Danhauer SC, Lyles MF, et al. Telephone-delivered cognitive behavioral therapy and telephone-delivered nondirective supportive therapy for rural older adults with generalized anxiety disorder. *JAMA Psychiatry* 2015; 72: 1012–1020.
71. Office of Public and Intergovernmental. VA telehealth services served over 690,000 veterans in fiscal year 2014, https://www.va.gov/opa/pressrel/pressrelease.cfm?id = 2646 (accessed 18 September 2019).
72. Akhtar M, Van Heukelom PG, Ahmed A, et al. Telemedicine physical examination utilizing a consumer device demonstrates poor concordance with in-person physical examination in emergency department patients with sore throat: a prospective blinded study. *Telemed J E Health* 2018; 24: 790–796.
73. Pathipati AS, Azad TD and Jethwani K. Telemedical education: training digital natives in telemedicine. *J Med Internet Res* 2016; 18: e193.
74. Demaerschalk BM, Miley ML, Kiernan T-EJ, et al. Stroke telemedicine. *Mayo Clin Proc* 2009; 84: 53–64.
75. Ray KN, Chari AV, Engberg J, et al. Disparities in time spent seeking medical care in the United States. *JAMA Intern Med* 2015; 175: 1983–1986.
76. Yousef A, Jonzzon S, Suleiman L, et al. Biosensing in multiple sclerosis. *Expert Rev Med Devices* 2017; 14: 901–912.
77. Vitacca M, Montini A and Comini L. How will telemedicine change clinical practice in chronic obstructive pulmonary disease? *Ther Adv Respir Dis* 2018; 12: 1753465818754778.
78. Bloss CS, Wineinger NE, Peters M, et al. A prospective randomized trial examining health care utilization in individuals using multiple smartphone-enabled biosensors. *PeerJ* 2016; 4: e1554.
79. Rajan JP and Rajan SE. An Internet of Things based physiological signal monitoring and receiving system for virtual enhanced health care network. *Technol Health Care* 2018; 26: 379–385.