



# Clinical Examination Component of Telemedicine, Telehealth, mHealth, and Connected Health Medical Practices

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## KEYWORDS

- Telemedicine • Telehealth • mHealth • eHealth • Connected health
- Direct-to-consumer telehealth care

## KEY POINTS

- Telemedicine and telehealth involves performing several clinical tests on patients at a distance.
- Video conferencing is often used for telemedicine clinical examinations.
- Many clinical tests are performed at a distance using special medical devices referred to as telemedicine peripherals (eg, electronic stethoscopes, tele-ophthalmoscopes, video-otoscopes, and so forth).
- Telemedicine peripherals can expand and enhance some clinical examinations and, in the future, may even become the standard of care for in-person clinical encounters.
- Some conventional clinical examination tests, such as palpation of the liver, are not currently amenable to telemedicine.

## INTRODUCTION

A century ago, the great academic physicians of the day achieved fame based on their remarkable bedside diagnostic skills.<sup>1</sup> These observation-based clinical examination

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tests (or signs) often bore the names of their creators<sup>2(P650)</sup> and became standard components of in-person clinical examinations. In the twenty-first century, many of these tests can be performed at a distance through telemedicine.<sup>3-7</sup>

Traditional in-person clinical examination tests and their telemedicine counterparts have similar performance characteristics.<sup>3-10</sup> In some clinical settings, the conventional examination's performance might even be improved by integrating a telemedicine peripheral, such as an electronic stethoscope, to aid in data acquisition and interpretation.

### ***Evolution of Telemedicine, Telehealth, eHealth, and Direct-to-Consumer Telehealth Clinical Practices***

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Teleradiology and tele-psychiatry were among the earliest telemedicine applications. Although the roots of telemedicine date quite far back, the modern era of telemedicine<sup>11</sup> started in 1968, when the Massachusetts General Hospital (MGH) bundled these and other services together into the first hospital-based multispecialty telemedicine practice that offered remote clinical examinations to travelers and airport workers at Logan International Airport. An assortment of ill airline passengers in transit and largely healthy airport workers needing annual physical examinations entered the MGH telemedicine system near gate 23 at the airport. The MGH tele-physicians were stationed 2.7 miles away near the MGH side of the Callahan Tunnel that linked the airport to downtown Boston.<sup>12</sup> Over the next decade, more than 1000 patients received telemedicine clinical examinations through the MGH service. This effort was a high-profile endeavor that had visibility in popular US magazines (Fig. 1) and inspired dozens of telemedicine programs around the world.<sup>12</sup>

For unclear reasons, most of these programs disappeared by 1980, leading to a decade hiatus in telemedicine activities. The telemedicine industry was jump-started again in the early 1990s and has undergone continuous growth and refinement in terms of implementation and practice as well as development of a taxonomy framework for research.<sup>12,13</sup> The reasons for this rebound are multidimensional; but some of the key factors include the development and rapid expansion of the Internet, increase in digital communication technologies (especially the smartphone), and, more recently, the reduction in the cost of technologies that drive telemedicine innovations.

Millions of patients around the world have received telemedicine and telehealth services from thousands of providers. In recent years, investments in start-up telemedicine service companies have skyrocketed. Thousands of hospitals are outsourcing selected gap services (eg, nighttime and weekend coverage by teleradiology) and urgent services (eg, tele-stroke services).<sup>4</sup> Direct-to-consumer telemedicine and telehealth services are a more recent entrant into the marketplace. The direct-to-consumer market includes in-store telehealth-enabled primary care services, typically delivered at pharmacies or big box stores; walk-in clinics; as well as services delivered directly to patients through the Internet or mobile devices. Typically, these patient-targeted services deliver a defined set of primary care services directly to patients, at the venue of their choice, and at low, fixed prices. Some evidence suggests that direct-to-consumer telehealth may increase utilization and health care spending by increasing access and convenience. A recent review<sup>14</sup> analyzed commercial claims data from more than 300,000 patients over a 3-year period on direct-to-consumer utilization and spending for acute respiratory illnesses. Ironically, the actual per-episode cost of a telehealth visit was lower than a comparable in-person visit; but the overall convenience resulted in greater use of care, thus, overall making telemedicine potentially more costly. It is important to note that this study did not examine the long-term impact of telemedicine, which might, for example, reduce more expensive health care



**Fig. 1.** Pioneering telemedicine programs in the United States. First telemedicine application, a tele-psychiatry service, was established in 1959 by Cecil L. Wittson, MD, the future Dean of the University of Nebraska College of Medicine, in Omaha, Nebraska. (A) It linked the Norfolk State Hospital (*television monitor*) to the Nebraska Psychiatric Institute (*foreground*) in Omaha, 112 miles away. The program was in operation for a decade when federal funding ended. Telemedicine was also used to facilitate the transfer of mentally challenged patients. The first complete prototype telemedicine system became operational between the MGH and Logan International Airport in Boston in 1968. (B) Historical telemedicine magazine article. Cover of the January 11, 1969 *TV Guide*, "Bob Hope's 65th Birthday" issue: *TV Guide* telemedicine article. (C) 2-page spread in 1969 *TV Guide*. Dr. Kenneth Bird, at the MGH (*lower right*) is remotely controlling, with his right hand, the large movable and

utilization, such as emergency department visits and hospitalizations, because of earlier recognition and treatment of disease.

### ***Telehealth Facilities***

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In the more recent decades of the modern telemedicine era (1995–2015), many telemedicine clinical encounters originated in dual-purpose outpatient telemedicine clinics operated within rural hospitals, community health centers, or correctional facilities. In order to create these telemedicine clinics, a standard outpatient clinic was often retrofitted into a hybrid standard clinic/telemedicine clinic by outfitting the clinic with a standard videoconferencing setup and adding a mobile telemedicine cart designed to help manage an array of telemedicine peripherals that are plugged into the cart (Fig. 2). These mobile carts support 1 or 2 adjustable eye-level video monitors attached to a vertical support post. The carts are ergonomically designed for comfortable face-to-face videoconferencing between the tele-consultant, the patients, and their local case presenter. In addition, there are plug-in ports and lockable storage compartments for telemedicine peripherals.<sup>15</sup>

### ***Telehealth and the Personal Health Care Space***

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The telemedicine landscape may be shifting away from dedicated telemedicine clinics to individual patient's mobile health and personal health care space at work or at home. The widespread availability of the Internet, ready access to Internet-enabled computing devices, and evolving computer literacy in the general population have facilitated the transition to Web 2.0 technologies.

Smartphones are becoming the next-generation telehealth workstations.<sup>16</sup> Several medical and laboratory services use smartphones attached to relatively inexpensive telehealth accessories, such as blood glucose monitors and electrocardiogram devices.<sup>16</sup> Uses of these technologies are accompanied by an increase in patients' self-performed clinical examinations. Such clinical examinations may be carried out synchronously, under the direct supervision of a distant physician or nurse practitioner, or asynchronously, with the test results reviewed offline at a later time. Often, call support centers are staffed with advanced practice nurses, under the supervision of a physician. In addition to remote health consultations, many health systems post medical results on personalized Web-based portals, which may include some dashboard metrics and analytics to help patients understand their health challenges and potential solutions and to visualize trends in their health status.

### ***Telemedicine Examination Medical Devices (Peripherals)***

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The special medical examination tools used to conduct a clinical examination at a distance were traditionally called *telemedicine peripherals* (Fig. 3A and 3C). This term is a carryover from earlier times when the data streams from telemedicine peripherals were outside the main stream of telecommunications data generated during ordinary videoconferencing. Each of these medical devices now pushes a data stream through a shared digital interface for review by the distant provider.

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adjustable television camera (*upper left photo*) in the Logan Airport telemedicine clinic, 2.7 miles away. Dr. Bird is focusing the TV camera on the remote patient's left foot's hemorrhagic lesions. The patient's left leg was edited out by the magazine. (*Courtesy of [A] the McGovern Historical Center, Texas Medical Center Library, IC077 Medical World News Photograph Collection; and [B, C] Sai Saha, TV Guide magazine.*)



**Fig. 2.** The White House's telemedicine videoconferencing setup demonstration for President Donald J. Trump by the Secretary of Veterans Affairs (VA), David J. Shulkin, MD (center), on August 3, 2017. The light gray mobile telemedicine cart (equipped with 2 video monitors) is designed to help manage an array of telemedicine peripherals (eg, telemedicine clinical examination devices) that are plugged into, and tethered by, the cart. This same model of telemedicine cart is being deployed at VA hospitals and many VA clinics throughout the United States. The president is conversing with a tele-dermatology patient (video screen, seated) at a VA clinic in Grants Pass, Oregon. The White House, Air Force One, and Camp David are all equipped for telemedicine. A briefcase-sized miniaturized telemedicine workstation, the type of portable telemedicine workstation carried on both the President's Air Force One and Marine One aircrafts, is visible on the table behind the President and the Secretary of Veterans Affairs. (Photo courtesy of GlobalMed and the White House.)

Telemedicine peripherals are evaluated as medical devices and classified as such by the US Food and Drug Administration (FDA), following rigorous evaluation. Generally, the methodological quality of studies of diagnostic tests lags behind the quality of studies of therapeutic interventions.<sup>17,18</sup> This circumstance is due, in part, to the rapid development of technologies and perpetual software upgrades.

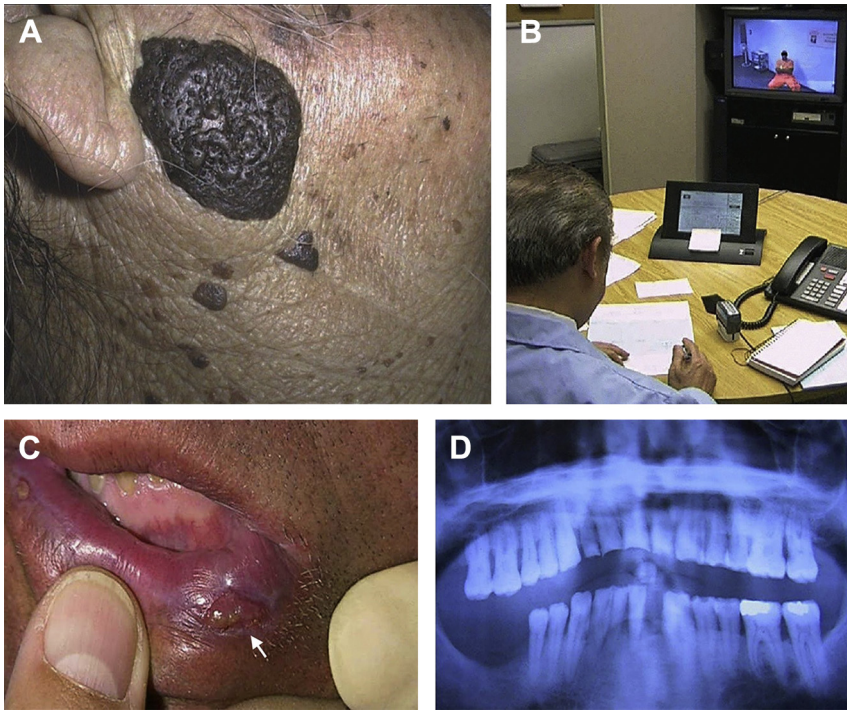
The following sections briefly summarize the telemedicine and telehealth patient examination tools most frequently used for telemedicine clinical examinations today.

### ***Videoconference system-based patient clinical examinations***

Many telemedicine cases can be handled by standard secure videoconferencing, without using any telemedicine peripherals (Fig. 3B).<sup>19,20</sup> In fact, one of the most common telemedicine applications, tele-psychiatry, is typically done by videoconferencing alone.

At the other end of the spectrum, there are clinical settings in which telemedicine workups are technically more complex and require a coordinated team effort at both ends of the encounter in order to be successful. For example, patients with Parkinson disease are ordinarily assessed using a set of neurologic tests that are performed by an experienced provider at the bedside.<sup>21,22</sup> The Unified Parkinson's Disease Rating Scale (UPDRS) was created specifically for telemedicine.<sup>22</sup> The





**Fig. 3.** Telemedicine applications. (A) Teledermatology. Digital photography of the right side of a patient's face, with multiple pigmented seborrheic keratosis lesions. (B) Corrections telemedicine. A deidentified patient (*on screen*) is shown on the video monitor. The telephysician is in the foreground noting the patient's history in his medical chart. (C) Example of an image captured with a handheld patient examination camera. There is a small nodular lesion of the buccal mucosa (*white arrow*) and adjacent hyperemia. (D) Oral telerradiology. Tele-dentistry has been successfully used in Arizona corrections facilities.

UPDRS is a rating tool that follows the longitudinal course of Parkinson disease. It is based on visual impressions only and has been shown to be reliable and valid. This approach to protocol development may be applicable to other disease assessments, but such applications will require validation on a disease-by-disease basis.

#### **General patient examination camera**

The telemedicine general patient examination camera is a handheld digital camera plugged into the telemedicine cart. It is equipped with special features designed to augment patient examinations. The general patient examination camera includes specialized lenses, selectable light sources, distance gauges, and built-in digital image capture and video signal outputs. General examination cameras can be used in combination with either asynchronous or synchronous videoconferencing. These general examination cameras provide distant clinicians with optimally illuminated, high-resolution views of selected fields of interest of patients' bodies (Fig. 3C). High-end models of these digital cameras can function as an otoscope, nasopharyngoscope, ophthalmoscope, dermatoscope, and a video camera.

#### **Electronic stethoscope**

Electronic stethoscopes have several innovative features previously unavailable on conventional acoustic stethoscopes. These features include electronic sound

amplification, recording, playback, and even graphic visualization of auscultated sounds. Digitized auscultation data can be transmitted to specialists for interpretation. Live and recorded auscultations can also be streamed simultaneously across multiple wireless stethoscopes for group clinical decision-making and didactics.<sup>23,24</sup> An additional benefit is the high-quality amplification of faint or difficult-to-interpret sounds, which is an especially valuable feature for hearing-impaired physicians.

### ***Tele-ophthalmoscope***

Tele-ophthalmoscopes offer features beyond those of traditional ophthalmoscopes. The optics make it easier for the examiner to view intraocular structures at higher magnifications and through an undilated pupil. The integrated digital camera captures high-resolution images at 30 frames per second for real-time imaging. Digital images can be used for immediate diagnosis or stored for asynchronous diagnosis and digital analysis. The wider field of view allows the examiner to more easily explore and document intraocular conditions, including papilledema, diabetic retinopathy, and hypertension.<sup>25–27</sup>

A second category of the ophthalmoscope is the freestanding retinal digital imaging device. These devices are most frequently used for screening of patients for diabetic retinopathy.

### ***Video-otoscope***

A standard otoscope provides clinicians with an illuminated and magnified view of the ear canal. A video-otoscope reproduces the otoscope visual field with enhanced viewing capabilities for the nonexpert and at high resolution for the expert. The video-otoscope's visual fields are seen on a local video display as well as at the distant telemedicine consultant's site. Today, some video-otoscopes include built-in digital image capture as well as video recording and playback capabilities.<sup>28,29</sup>

### ***Electronic dermatoscope***

Tele-dermatoscopes have integral light sources and magnification lenses to aid visual examination of patients' skin lesions (see [Fig. 3A](#)). Relatively inexpensive, single-purpose dermatoscopes, not adaptable to other functions, are also available.<sup>30–32</sup> Dermatoscope applications (apps) also exist to support patients and clinicians. The absence of a palpation feature (ie, the ability to assess the firmness or depth of a lesion) is a limitation in some cases.

### ***Digital-endoscope***

A digital endoscope is a capsule-size video camera that patients swallow. It images the interior of the bowel as it moves through the gastrointestinal track. The on-board digital camera wirelessly transmits a stream of images to a server for gastroenterologist interpretation.<sup>33</sup>

### ***Electronic scale***

A simple, high-yield, telemedicine encounter involves patients with congestive heart failure (CHF) at home, equipped with an electronic scale that transmits daily body weights to a call center. Typically, patients with CHF step on a wireless electronic scale, which measures and transmits their body weight to a nurse's dashboard at a telehealth center. An increase in body weight exceeding a predetermined critical value triggers an instruction to increase the dosage of a diuretic in a predetermined amount. Electronically tracking CHF patient's electronic body weights has reduced hospital readmissions for many patients, saving millions of dollars in health care expenses.<sup>23,34</sup>

### **Smartphone**

The smartphone is playing an increasing role in telemedicine and telehealth. The FDA is fast-tracking approval of both medical apps and mobile medical devices. Today, test-specific medical device-equipped smartphones can be used to perform and analyze an electrocardiogram, conduct an ultrasound scan on patients' hearts, perform clinical ophthalmic examinations, and even measure blood oxygen levels. With other relatively inexpensive accessories, smartphones can be used to evaluate pulmonary function, make breathalyzer measurements, and perform scans of the aorta. In the neurology arena, apps are being developed that may revolutionize migraine headache diagnostics and patient performances with Alzheimer disease or other dementias. The use of smartphones for diagnosing ischemic and hemorrhagic strokes has been validated.<sup>35–39</sup>

### **Wearables**

Wearable devices are widely used to monitor various body functions and activities.<sup>23,34,40(P8)</sup> It is important to note that many consumer-grade wearables may not yield data of clinical diagnostic value as compared with physician-prescribed medical-grade wearables.

### **Telemedicine Presenter/Site Coordinator**

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The case coordinator and case presenter are critical members of the telemedicine team at rural sites and in community health centers. The same person may fill both professional roles. The case coordinator aggregates patient information, including the electronic health record, and submits it to the physician or nurse at the distant site. The case presenter serves as the distant clinician's proxy for hands-on examinations and could be a primary care physician, advanced practice nurse, physician assistant, or a nurse.

### **Limitations of Telemedicine**

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There are several limitations of telemedicine, some of which are amenable to workarounds. As mentioned earlier, certain clinical applications, such as performing a remote neurology examination, require the teaming of the health worker at the spoke site with the diagnosing physician or advanced nurse practitioner at the telemedicine diagnostic hub.

The telemedicine clinical examination is somewhat limited by the inability of the remote physician to palpate patients. Although imaging can substitute for palpation in certain instances, there are some parts of the physical examination that require direct touch. Technologies are being developed to allow the remote provider to sense palpation in a virtual-reality setting. Ultrasound is an alternative means to obtain the information that palpation provides.<sup>41</sup> Other types of remote palpation systems are being developed, such as wearable haptic systems for the hand and fingertips.<sup>42,43</sup> Tele-robotic surgery, although technically possible, is encumbered with ethical, communications, reliability, and delay issues.

### **Outcomes and Evidence**

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There is a large literature on telemedicine published in a select set of dedicated telemedicine journals. Publication of clinical telemedicine articles in leading journals, such as the *New England Journal of Medicine* and the *Journal of the American Medical Association*, is relatively uncommon but increasing each year. It should be noted that several trials are reported in the literature that incorporate new telemedicine technologies but do not directly refer to them as telemedicine or telehealth. Nevertheless,



there is a general perception in the health care industry that telemedicine is only beginning to enter the mainstream.

Published standards and guidelines represent expert consensus on the current state of medical diagnostic tests, procedures, and even therapies delivered via telemedicine techniques and technologies. The American Telemedicine Association posts authoritative clinical standards and guidelines that are valuable guides to some of the most important service areas in the telemedicine and telehealth industries.<sup>44</sup>

## FUTURE CONSIDERATIONS AND SUMMARY

Important factors driving the telemedicine sector forward at an accelerating rate are patient needs for access to care and cost savings at both the patient and health care system levels. There have been numerous studies on the issue of cost in telemedicine, with conflicting results. It is important when reviewing these studies to assess exactly what type of cost analysis was conducted (eg, cost-utility, cost-benefit, cost-effectiveness), what patient population was used, and what costs were included.<sup>45</sup>

Increasingly, hospitals are using commercial clinical service providers that handle a suite of telemedicine services. For example, a teleradiology service company can interpret plain film bone and chest radiographic images, ultrasound, mammography, computerized tomography, and MRI and provide video consultation. Telecardiology services include interpretation of cardiac rhythms and other studies, such as echocardiography, vascular, and nuclear medicine. They also include video consults. Many hospitals are also using tele-intensive-care-unit services that monitor patients 24 hours per day and alert on-site health care providers about emerging problems. These telemedicine services allow hospitals in rural areas to keep patients on-site and with their families, which can also reduce the overall cost.

Today, many private practices and health care systems are becoming hybrid health care providers, presenting their patients with the option to see their medical provider either by telemedicine or in person and scheduling their appointments on-line at the patients' convenience. These private practices will soon be competing with many commercial telehealth service providers that effectively and efficiently manage and transfer patients between physicians and advanced practice nurses and other contract providers who are housed in virtual call centers. Often, these companies have thousands of telehealth workers on-call who hold multiple state licenses and practice in multiple time zones every day.

In addition to legal, regulatory, and reimbursement issues, other significant issues include concerns over the increasing fragmentation of health care services, the slow (but increasing) rate of acceptance of telemedicine by physicians and other key decision makers, and the need for champions of telemedicine to drive acceptance forward. Several systematic reviews of the literature support the effectiveness of telemedicine in numerous clinical specialties.<sup>3-7,46-50</sup>

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