CHAPTER

# 4

# Technology considerations

*Gunnar Hartvigsen*

**University of Tromsø—The Arctic University of Norway, Tromso, Norway**

## Overview: Infrastructure requirement

*Gunnar Hartvigsen*

Patient's care requires healthcare professionals sharing information and interacting with each other in a coordinated way, such to provide an appropriate continuity of care, as decisions are made based on available information and knowledge. Indeed, healthcare is a communication industry,[41] and ICT is changing the way information and knowledge are retrieved, recorded, created, and managed, posing not only new opportunities but also new challenges.

Communication links are the key to creation of telesystems, but telehealth requires extra considerations. Here, medical data is obtained through a variety of sources. It has to be collected with ease, processed into information and knowledge, stored (if S&F), and then transferred as required to the right location. The target personnel have to have privileged access, and information should not wander into prying eyes. It is going to be used by clinicians, public health personnel, and patients for direct or indirect health support with each having their own sociocultural milieu and related preferences, choices, and comfort levels. Input could be manual or from body-mounted (wearables), stationary sensors and other devices that detect activity and state of residence. For such systems to succeed, there is a need for integration of patient data from these different sources. Following that, data and information has to be interpreted properly—a process called interoperability—and further discussed under the section on standards.



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The following restrictions on deployment of telehealth may apply:

- **Ease of use**: The equipment/solutions must be simple to use.
- **Reliability**: The system must be stable and safe, run without interruptions, and provide reliable measured values.
- **Security**: Data security has to be safeguarded.
- **Availability**: There needs to be a responsive system at all times of need.

**Hardware** used for telecare is not much different from other computer systems, except that access to others through networking is mandatory. An add-on to the hardware could be additional devices, that is, probes and sensors that connect directly with patients or input seamless health-related data. Whenever present, these can add much to the cost not only for the probe but also for the requisite training. The exact value preposition they offer depends on how much these will be used. Tailoring will be required obviously, depending on local availability, not only of the initial cost of hardware, but also of maintenance, repair, and service. A good system will ensure backup methods and needs to allow a variety of choices especially of the nonfixed components like software and connectivity.

**Connectivity** just means communication or how various devices and systems talk to each other. Many forms exist, wired or wireless, and as stated earlier there is little or no difference between telehealth systems as compared to other computer systems. Most telehealth systems, though not all, do require high bandwidth. However, with rising data speed consequent to wider penetration of 3G/4G/5G and fiberoptic as well as wired broadband, lately, this has become less of a constraint.

**Video conferencing** may possibly be considered as a relatively essential component of any telecare platform, unless only indirect benefits are being sought.

## Bringing it altogether is challenging

Telecare can and does take place without special equipment. For example, requirements for telecommunication-based supervision within a private home include diseases that do not require the permanent presence of health or life-critical monitoring equipment. Mostly, only a phone call, WhatsApp, or email is used. More savvy patients can sometimes use a video link using Skype and, increasingly, Facetime, other video callers, etc. These need a certain familiarity with not only the technology behind it but also the related security issues. Hence these are frowned up by clinicians and experts, who recommend specialized apps or equipment.

The specialized and high-end tools need deeper discussion. It is important that the communication, technical, and power infrastructure meets the necessary medical and security requirements. There is also the consideration that even if we can do monitoring for possible life-threatening problems, the same without an ability to correct the issue immediately will be a reason for frustration. More so if one remembers that there is an added cost of retaining such a system. An example would be the vital sign monitor previously considered an essential component of a comprehensive telemedicine system in India.[a] However, there was no possibility of anyone being able to start an intravenous drip for a precipitous drop in the blood pressure!

Telehealth-enabled diseases include chronic diseases that are "under control," such as COPD/asthma, heart disease/cardiopathy, diabetes, high blood pressure/hypertension, rheumatologic disorders, ulcers, and lymphedema. These are suitable for home care enabling requests for remote care and support from the patient end. There are more wherein the patients benefit indirectly. Here the personnel engaged are health providers of various capabilities like remote counselling, mentoring, and helping in emergencies and disasters, ICU care, etc.

Because of structural changes in the healthcare sector in the last decade(s), our understanding of healthcare has been challenged (see Table 1). The treatment has changed, or is about to change, from episodic care to continuous care and from individual providers to a team of healthcare workers.[42] Instead of focusing on the caregiver, the focus is shifting toward the well-informed patient (patient empowerment). The healthcare workers (will) have access to shared distributed electronic health records, in accordance with his/her level of authorization. In addition to "advanced telemedicine," we now see the emergence of "super advanced telemedicine," which includes outsourced hospital services and virtual care centers like Mercy Health Virtual Care Center in St. Louis, MO, which can be described as the world's first hospital without any patients: "We have the medical team here, but with technology like highly-sensitive cameras and real-time vital signs, our providers can 'see' patients where they are.

**TABLE 1** Simple and advanced telehealth.[44]

| | Simple telehealth | | Advanced telehealth |
|---|---|---|---|
| | **Telemedicine** | **Telehomecare** | **Telemedicine** |
| Where | Ward ↔ hospital | Patient's home ↔ Homecare central/general practitioner | Ward ↔ Hospital<br>\|<br>Patient's home ↔ Homecare central / general practitioner |
| How | Broadband (optical, IP, 4G/5G) | Broadband (optical, IP, 4G/5G) | Broadband (optical, IP, 5G) |
| Who | Clinician ↔ Clinician | Patient ↔ Nurse/doctor | Clinician ↔ Clinician<br>\|<br>Patient ↔ Nurse / Clinician |

[a]It used to be, but not any longer—see budgeting section in Chapter 7.

That may be in one of Mercy's traditional hospitals, a physician office or in some cases, the patient's home."[43]

Healthcare service is characterized by the following new advances[42]:

- The welfare state will not be able to meet upcoming increases in healthcare based on today's solutions, when it comes to both financing and personnel—we must rethink our healthcare service.
- Healthcare personnel have, or are about to have, a complete overview of patients' treatment workflow in most developed countries.
- Patients have access to their health data.
- Patients have, more and more control of their own health. This requires that the patients have more knowledge of their own health—diseases, treatment, alternatives, etc.
- Healthcare has somewhat become a global merchandise.
- Technology is the driving force in the development of healthcare services (Table 2)[42].

Part of this development is visible today. A revolution is brewing of sorts. Doctors and other healthcare personnel are returning to people's homes through telemedicine solutions. A Fortune article from 2017 argues as follows[45]:

> At the turn of the 20th century, getting a checkup in America frequently meant your doctor came to you. Armed with a modest black bag of tools and old-fashioned medical know-how, physicians of yore would often take care of you, right at your bedside. As quaint as that image may seem today, it is in some ways, a vision of the future. New technologies are bringing back the house call—or a digital version of it, anyway.

**TABLE 2** Current and expected structural changes in healthcare mostly related with changes in technology.

| Yesterday/today | Today/tomorrow |
|---|---|
| Episodic care | Continuing care |
| Focus in service provider | Focus on the well-informed patient |
| Individual approach | Team-based approach |
| Disease treatment | Health promotion—how to stay healthy |
| Institutionalized care | Community-oriented care |
| Each healthcare worker has his/her own journal system | Shared distributed electronic health record |
| Department/hospital focus | Enterprise focus—health as merchandise |

*Source: Yellowlees P. Telemedicine Enabled Homecare. Phoenix, AZ: American Telemedicine Association 2000: Pragmatic Approaches & Emerging Applications; May 22, 2000.*

There are changing roles for patients/clients/consumers leading to the previously mentioned as follows:

- Longer life span with a rising number of aged people
- Concomitant increase in chronic diseases
- Most people want to spend their old age in their own homes
- Dissolution of extended families
- Development of intelligent/smart houses
- Service providers must find new ways to spend less time with the patients

In summary, most patients are at home and being taken care of by self or other people in their homes. With that, we get the following:

- access to care from different groups (caring personnel, family, and friends)
- increased cost-effectiveness (in those cases that transport is eliminated and compared with the cost of a caring home)
- shorter time for access to treatment
- increased contact with health personnel (including through electronic media)
- increased safety through frequent monitoring of vital body functions
- early detection of health problems

The most important argument favoring telehomecare for the elderly is increased safety and sense of comfort for the patient and their relatives. This can be implemented through smart home devices like timers on the kitchen stove and coffee machine, or there can be more advanced solutions like fall sensors and advanced safety sensors. Such intelligent systems may be standalone, or used in combination with telehomecare systems. For people with dementia, we can use alarms that alert when they leave their house. In this way, smart house technology will function as a sort of invisible servant that looks after the resident(s) on a 24/7 basis.

The organizational problems will be central in the development of smart house solutions. Appropriate modes of communication between the smart house and the traditional care service, however, need to be found or created, for example, an alarm has no value in the absence of existing mechanisms to take actions based on the alarm. There is also the issue of false alarms, which are likely to occur. Through the integration of smart house technology with the rest of the healthcare service, the foundation for many new and existing services can be made. Examples are remote supervision of the medical condition for patients with chronic diseases and those with special needs like infants (see Case study 1). It may also be possible to find new ways of communication between patients and the care service—in particular if the user interface is adapted to the user's need and level of interaction.

### CASE STUDY 1

*Your baby's safety is your responsibility…*

'call me picky, but is'nt keeping babies safe is what parents were designed for'..that comes from a Mom who was destined to monitor her baby's heart rate and oxygen levels from early infancy...that was how she came to use the 'Owlet', a sensor built into a baby bootie. The problems of procurement and import were solved with persistence but the larger issue however was how would she use the data on her baby's heart rate & oxygen levels to keep her safe..not to talk about the false alarms which the Owlet gave and which quite often than not panicked her..inspite of all this that any alarm from the gizmo-false or otherwise, would atleast make her to check on her baby and make her responsible for its safety..though how often with all those alarms she would call up her doc is a moot point.

*Courtsey Dr AJ, a pediatrician. His daughter was the child's mother who required long-term monitoring for possible recurrence of a viral cardiomyopathy. The baby is now 4 years and without monitor.*

The experience from the former Norwegian Centre for Telemedicine has shown that progress from pilot systems and stand-alone experiments with telemedicine systems to the final implementation in the health service may be long-winded. The equipment must be certified, operational routines must be made, the infrastructure must be in place, the market/receiver must be prepared, the health authorities must be convinced that the system will work, cost-benefit must be studied, etc. This is a cumbersome process, which again requires that the complete, or at least the relevant, part of the infrastructure must be in place.

It might be important to have an active and open relationship to the possible ethical problems such systems imply. In these kinds of systems, it is important that the users and/or their relatives decide by themselves to what extent they want to use these new possibilities.

A prerequisite for the use of telemedicine equipment and telemedicine-based monitoring is that there is a communication infrastructure both in the home and from the home and to the respective departments as well as to the healthcare workers that need to be kept informed about the patient's condition. Intelligent systems in the home may reduce the need for personnel. Such systems generally focus on increased security, safety, and comfort.

## Some solutions and devices

More and more companies are providing healthcare services to people's homes. We provide some current examples in the United States, where companies like American Well and Doctor on Demand are providing people for staying in remote locations.

An important driver behind this development is national health authorities' approval of telemedicine devices. Many of these are managed through peoples' smartphones. The devices are classified into two groups: those serving ordinary people and those for people with chronic conditions. We present a few, more or less randomly chosen examples of devices and application representing these two groups.

For people with cardiac problems, the company InfoBionic has developed a remote patient monitoring system, MoMe Kardia, to discover cardiac arrhythmias in patients by sensing ECG, respiration, and motion. The lightweight monitoring device can be carried as a necklace or an attachment to the belt. MoMe communicates data via a person's smartphone to a cloud-based platform where the data is evaluated. According to InfoBionic, the device works as a Holter, Event, and Mobile Cardiac Telemetry (MCT) monitor. This means, if a physician gets to feel that the patient's cardiac symptoms require another type of monitoring technology, he/she can change the device remotely to any one of three main monitoring modes.

A physician can access the patient's data via the web or through iOS and Android apps. His dashboard will provide views of patient monitoring progress and generates automated reporting in multiple parameters and data displays.

For people with diabetes, there are many alternatives. One system is Medtronic's Guardian Connect mobile continuous glucose monitor (CGM) and app. Medtronic also deliver a CGM called MiniMed Connect for users of both a Medtronic CGM and the company's insulin pump. Both systems show diabetes data on the mobile app. MiniMed Connect system is used by people who are on Medtronic's insulin pumps integrated with CGM, while the Guardian Connect system is a standalone CGM system used by people on insulin injections. The Guardian Connect system lets people record diabetes-related activities, like meals, exercise, and insulin intakes. They can also have the device to send text message alerts about high or low blood glucose to a care partner or upload the data into Medtronic's CareLink diabetes therapy management platform.

For people with asthma and other respiratory conditions, such as COPD and cystic fibrosis, Sparo Labs app-connected spirometer Wing helps them to track their lung function and manage their condition. Wing works by connecting the sensor to a smartphone and then measuring the fastest speed (forced exhalation) and maximum volume (peak flow volume) a person can exhale in one second. The scores are presented on the smartphone display with a "stoplight zone" system (green, yellow, or red) and a description of how the lungs are currently doing. The idea behind it is to allow the patient to learn how to anticipate an attack and adjust medication(s) and/or avoid particular triggers. By using metadata, for example, geographical location, the patient might get warnings about the different weather conditions like heat, cold air, and humidity. Patients are the primary Wing target audience for the next few months, as Sparo currently has no formal partnerships with healthcare providers or pharmaceutical companies.

One major player in telemedicine is American Well. According to their web site, the company "offers software, services, and access to clinical services – everything you need to offer a complete telehealth service – whether you are a health plan, an employer, or a delivery network. Our mobile and web service connects doctors with patients for live, on-demand video visits over the internet and handles all the administration, security, and record keeping that modern healthcare requires."[46]

American Well's mission is to connect patients with doctors, using a secure video system. The company offers patients immediate urgent care web visits in most of the US states. Their telehealth service runs on computers and Android- and iOS-based smartphones, which lets "a doctor or nurse to tap into a pool of on-call specialists and connect for an immediate video consult in any setting, from the office to the patient's bedside to the ER. Equip any point of care with specialists, without the cost of full-time onsite staff or travel."

American Well offers a lot of different services and functionalities, both for patients and clinicians (see Box 1). American Well is a good representative for a growing number of companies and health institutions—the doctors are returning to people's homes, although not physically but virtually.

Twine Health represents, in many ways, the new type of healthcare services in which the clinicians and patients plan the treatment together. The company was founded by the former physician John Moore, who felt that the lack of contact with his patients outside his office hours was problematic: "I was very frustrated and embarrassed with my inability to provide care outside of the office. I made many diagnoses, yet there was no way to support my patients after they left my office."

In Twine Health, which has now been taken over by Fitbit, patients worked with their doctors to create action plans with goals that mattered to them, then use devices and apps to track their progress, and to build self-efficacy and create new behaviors. In this way, patients and doctors got to mutually agree on how to proceed with their treatment. For example, if the goal was to lower the patient's blood pressure, the plan helped ensure it is reached. A combination of exercise, diet, and medicine was offered, with appropriate support through tightly integrated communication tools. After the mandatory first interview, patients communicate with the care team through a tablet application that displays their daily schedules, like intake of medication, measurement of blood pressure using a smart blood pressure cuff, and dissemination of information to patients regarding necessary certain actions as required. Simple measurements like pulse, blood pressure, and glucose are

BOX 1

## American Well product features
(from americanwell.com)

### American Well offerings for patients:

- Live video visits on web and mobile
- Telephone visits via the concierge service
- Co-pay management
- Apple Health integration
- Patient PHR/visit record
- Ability to review provider profiles
- Real-time insurance eligibility
- Ability to choose the provider you already see
- Image sharing
- Google Maps pharmacy selection
- Access to practices and service lines like medical, behavioral health, and diet/nutrition
- All-new web experience
- Enhanced medical history intake
- Self-scheduling—by preferred date or doctor
- Invite caregivers and family to a visit with multiway video
- Previsit chat in the app
- Share your visit summary with your PCP

### For clinicians, the company offers the following:

- Live video visits on mobile and web
- EMR integration
- eRX and medication history through Surescripts
- Real-time patient data
- iPhone provider mobile app
- Secure messaging
- Provider-initiated visits
- Enhanced availability modes—AskMe mode makes doctors potentially available without committing to an appointment
- Accept/decline visits on mobile
- Mobile previsit review and postvisit wrap-up
- Mobile secure messaging
- Enhanced scheduling tools—on demand or scheduled
- Telephone visits via the concierge service
- Guidelines to treat entire populations through Insight API
- Invite additional participants to a visit with multiway video
- Sidekick app to snap photos and send to consulting providers

communicated to the physician's office. The tablet allows patients to discuss with a health coach and get appreciation for keeping up with the treatment plan. Hence, patients get to take charge of their own treatment.

Another good representative of the development is TytoCare (Boxes 2 and 3). The company argues that it "provides *The Missing Link in Telehealth* – a complete virtual visit, including physical exam, designed to replicate a visit to the doctor's office. With TytoCare, doctors can diagnose more conditions more accurately, making the promise of telehealth a reality."[25]

The foundation of the company was inspired by one of the cofounders' experience with his own children who needed frequent visits to the

BOX 2

## TytoPro features
(from www.tytopro.com)

### TytoPro features

- TytoPro device with high resolution camera, no-touch infrared basal thermometer, digital stethoscope (with volume, bell, and diaphragm filters), digital otoscope and tongue depressor adaptors
- TytoVisit platform with Clinician Dashboard for conducting "exam and forward" and "live video telehealth exams," plus EHR integration
- TytoApp
- Earbuds

### TytoPro can be used in different ways

- Extend specialist services to remote locations when needed such as schools, nursing and home care facilities, clinics, employee work sites, urgent care and EMTs
- Get a quick and easy specialist consult
- Examine, capture and share images with patients to explain diagnosis and motivate treatment
- Send exam data to EHR for continuity of care

### Benefits of using TytoPro include:

- Extend the reach of your specialists
- Reduce readmission rates
- Recover patient visits and revenue lost to ER or urgent care
- Improve continuity of care
- Motivate treatment
- Improve patient satisfaction

BOX 3

**TytoHome features**
(from www.tytopro.com)

### TytoHome features include

- a device for examining the ears (otoscope), throat (camera), heart (stethoscope), lungs (stethoscope), abdomen(stethoscope), skin (camera), and capturing heart rate and temperature data (basal thermometer)
- TytoApp for live video telehealth exams with the patient's physician or "exam and forward" for later diagnosis

### TytoHome allows

- Enabling the doctor to remotely diagnose conditions such as ear infections, flu, upper respiratory infections, sinus infections, pink eye, rashes, bug bites, wounds, sore throat, and pneumonia
- Monitoring chronic conditions without leaving home
- Use from everywhere as long as there is a network connection. It could be at home, in the office, and even on vacation.

pediatrician. TytoCare's main product is a portable device for parents to inspect their own children and then consult a clinician to analyze the results. TytoCare essentially lets the ordinary user, who maybe without a medical background or training, to be in charge of the technical basics of a pediatrician's visit at home. The user then makes the images and recordings available for a clinician who takes care of the diagnostics via video chat.

There are many other companies offering different specific devices like Nokia Technologies Withings Thermo—a WiFi-enabled thermometer that measures temperature from the temporal artery on the user's forehead. Readings are displayed on the device's side. In addition, the measurement is automatically sent to a companion smartphone app, where users can allocate the number to a particular user and, if desired, make a note.

## How to ensure effective communication

*Shashi Gogia*

## Introduction

Effective telehealth requires a persons' absence physically to be replaced by an effective form of tele to allow the healthcare interaction to proceed smoothly. Human-to-human communication depends on voice along with gestures of the hand, face, and to a lesser extent even other parts of the body like shrugging of shoulders or rolling up of eyes. A final message is received in consideration of all the previously mentioned.

Tele is electronic communication beyond visible or hearing range. Telecommunication has constraints, which go beyond the technology, that is, a message may not be created, be incomplete, may not have been sent, not have been received, may have inadequate compliance to standards, and so on. The crux lies in proper transmission after the creation of an effectively readable message, though we may have failures even if the previously mentioned are perfectly in order. This subsection talks about the technology behind video-conferencing and software communication but also goes beyond the same on how to ensure that the right message goes across every time and not create communication gaps.

All forms of electronic communication, whether or not concerning telehealth, depend on a certain level of basics like input and output. Proper input is the first step of data creation. The same can be transmitted only if relevant data exist, else the adage *garbage in garbage out* or GIGO[47] applies. GIGO, in its strictest sense, applies to software systems wherein processes are in place to ensure that data entry and flow follow a certain standard methodology. But getting the right software with included ease-of-use features in the healthcare domain is a challenge. Such systems necessarily have to be designed and developed by ICT professionals, but their understanding of how healthcare operates is somewhat limited.

The most important at all times is the correct contextual information as to which patient is being sent by whom and to which doctor. Here a proper identification processes, for each, patient as well as the care provider(s) have to be made and with linkages to national level IDs like the Social Security Number in the United States and the Aadhar card in India for patients, medical license number for providers, and so on. However, these are restricted by national choices as well as related privacy and data security issues.

Ensuring accuracy also means that the data creation is easy and unambiguous. Some more examples:

**Gender**—A patient could be *male* (M) or *female* (F), with a third type—*transgender* (T) being officially recognized in most countries. Some systems will allow a fourth type—*not known* but can also be *not mentioned*. A good software will allow the possibility of all these four choices through processes called as data format, which means only these four choices exist. The storage or transfer could be of the full text or preferably only the first character.

When the entry is less restrictive, that is, not from a preexisting choice but a person physically typing the same, another rule to ensure correctness of entry is called upon. This is *data validatio*n wherein an inappropriate entry may be refused or there is a related message. This would happen if the person making the entry does not know the term transgender but instead prefers the term intersex or even hermaphrodite.

**Dates**—In the United States, which also happens to be the place where most software majors are based, the date format is month, date, year also known as *mm/dd/yyyy*—the year can be 4 digits (read 2018) or 2 digits when 18 will suffice. However, the format followed in most other countries is date, month, and then year or *dd/mm/yy*. A system following the latter will reject the entry 06/22/15, as no 22nd month exists. The system may not understand that these data originated in the United States or may just have been handled by an operating system made in the United States, which means almost all, that is, Windows, Mac, IoS, Android, etc. Standardized systems ensure that dates are transferred and processed only in the format of year → month → date (yyyy-mm-dd) whatever may be the entry format.

Displaying the date during output may occur differently. This is known as display format that can make a readable date as per the viewers' choice. For the date earlier (i.e., 06/22/15), it could be read as June 22, 2015 if date format is *mmm/dd/yyyy*, or it could be Sunday 22nd June 2015 (*dddd/mmmm/yyyy*). You will note that the actual date has not changed.

Display formats have little to do with how the entry is made or validation checks. They are only concerned with readability. In the gender example (earlier), an entry of F will be having a display format of female. That is only required at the client's end, that is, the person viewing the data. The control on entry is called Edit Format, and it ensures correctness at the time of data entry. For example, for the month of June, an entry of 31 as the day will generate an error—converting the sixth month to 00. With the US date format (*mm/dd/yy*), we enter the month first, so that makes it easier to work with. The standardized format of *yyyy-mm-dd* will even adjust the maximum dates for February to be 28 or 29 depending on whether it is a leap year.

Two-digit years (*yy*) used to be the norm during olden times—when computer memory used to be a constraint. Hence 19 automatically became 2019, while 45 would mean 1945. Now that people do survive beyond 100 years, there is a need for insisting on *yyyy* at least in the *date of birth* field.

Edit formats exist for numbers, including variants like whole numbers (integer) and those with decimal values (numeric, float, real, etc.), dates and datetimes, as well as certain types of text entries.

**Blood pressure**—Edit Format would be XXX/YYY wherein the number before "/" (XXX) is the systolic value in mmHg and the latter (YYY) would be diastolic. A validation check would ensure that there is always an entry of "/".

**Email** is text with numbers allowed, but the entire sequence has to have an "@" value followed by with one or more dots subsequently. This check can only be through data validation, and no Edit Format is possible.

Validation checks do slow down data entry and may even stall the system. Repeated messages appear asking the user to correct an error, but the location of the error may be confusing, as checks take place on exiting the relevant field where the incorrect entry had been made previously. But most probably, by now, the user is concentrating on the next input item!

Further, in many apps, validation checking is performed in bulk for an entire set of fields, during the save command (or what is called updating) which could be many inputs later.

Validation-related slowdowns are more for cloud-based servers. The reason for this is that it takes precious seconds for the information to reach the server—sometimes literally travelling across the globe—the user may be entering in Australia, but the server may be located (currently most are) in California. For a form with many fields, updates are best done en masse, rather than one by one as a refresh takes time. But this also means simultaneous but individual validation checks of each of the multitude of entries. Simultaneous validation checks for many fields together would also mean that there has to be a method of marking the incorrect entry; otherwise, there is much confusion. For example, you might find a red-colored note next to it "The entered email address is invalid." Sometimes an asterisk (*) is placed next to the field as a check for possible incorrect entries before initiating an update.

Understanding data formats and related validation issues means users have to be trained on how to tackle them. This is a slow learning curve. Clinicians are busy persons and do not have time for such training. They also face a paucity of time for making any entry, especially ones with complicated or less understood formats.

Data entry does interfere with patient time and is reflected in slow and poor usage of EHRs[48] in general, despite incentives being offered, in the United States for example. Some systems are more open-ended and allow free text, which would resemble writing the clinicians' notes. Even here, the time taken for typing is a challenge especially for those from the older generation. This can be shortened by many tools—being mentioned only in brief here:

- **Dropdown and Multiselect lists** (one can select more than one choice). For example, occupation may be driver, teacher, student, agricultural worker, etc.
- **Type ahead**. That is, when the entered data is matched to an expected value. Typing the URL in your browser or search engine is a typical example. Within a form—especially when using a smart mobile—the full and anticipated correct spelling(s) of a word occurs, but this means a high chance of mistyping.
- **Default entries**. That is, automation of most likely choice—<History of smoking>—is "None." If that hopeful instance is incorrect, that is a "Yes" choice, another field appears where the user can enter the number of cigarettes per day, duration, etc.—and even these may have default values. Date of first visit is normally defaulted to the current date, that is, when entry is being made.
- **Assumed data based on previous entries**. *Correspondence address is generally the permanent address* but can be changed—sometimes a checkbox is provided to confirm.

- **Conversion of audio notes to text is done through software**. Current technology promises around 90% accuracy, which means 10% inaccuracy—making it unsuitable for a health software as there are literally, life and death issues.
- Many persons like to type fast, and any smart mobile user would recognize the problems with the tools that correct misspelt text and type ahead. These are a reason many a time for incorrect entries and consequent misinformation. (A common one faced by the authors of this book was conversion of EHR to HER!) Remember that drug brand names (as also persons names), are among the more common ones to be (mis)corrected. Besides words in the local language which are used in day to day conversations - remembering that the spellchecker maybe in a different variant of English or may even not be English, which could replace correct words with jargon.

Despite all the earlier forms of assistance (exact provision depends on the software application being used), data input or entry time is a major challenge—it is literarily the slowest component of ICT usage, a human handiwork and executed at human speeds. Data processing and transfer, on the other hand, occur at electronic speeds. Transfer however also depends on the distance to the server. In a cloud-based system, it means the information travels once to the server and then back even if both locations for input and output are exactly the same. Cloud-based servers also have issues regarding the time allowed for a person to make the entry. This problem, called session expiry, is done to ensure security but is a reason for extreme frustration.

Besides the controls and challenges in the data entry and output, there are also other issues. Most need to be solved by the software developer but obviously need discussion with the user (generally the clinician). First is whether the entry should be open-ended, for example, history taking or subclassified like examination findings that could have fields for pulse, blood pressure, etc., with specific formats. Even history may be broken up into complaints (with/without duration of each), past and present and family history—some even have specifics for brother, sister, mother, father, etc.

Another is whether to allow the null (i.e., a blank field) or make it essential. For example, there cannot be a history without a single complaint! Higher number of essential fields will mean more checks, which are going to slow the entry time—remember a validation check will be invoked whenever an essential field has not been entered at all. There will be variations of what is essential and what is not, for specific situations and specialties. But telehealth is necessarily team based and cross specialty. Hence the developer maybe faced with a Hobson's choice. S&F data exchange has further issues of incomplete or incorrect interpretation at the other end that is better covered by the section on standards.

Real-time information fortunately is more automated as the entry, and output is more dependent on the system. That we discuss next.

## Video conferencing (VC)

*Shashi Gogia*

A video conference is a two-point or multipoint communication tool where face-to-face live communication takes place using multimedia. It utilizes audio and video inputs that are uploaded and downloaded at the requisite ends in a seamless manner. Older telemedicine systems used a camera with an inbuilt communication methodology. Sophisticated systems exist, like the camera focusing, and turn itself toward the speaker, automatic mixing into multipoint screens. However, such systems like by Polycom™ are expensive for day-to-day telehealth purposes. They also necessitate use of multiple screens. The VC screen would be separated from the EMR, and there was less chance of merging both, though one would argue that there is little need (of merging), as each and every point of the discussion—introductions of personnel, a welcome hello, etc.—would be irrelevant for the care provision. Also, such stored multimedia content generally consumes gigabytes of space with little or no possibility of analytics and becomes relatively useless later.

However, the simplicity and instant start with little user effort has resulted in VC, being described as the high point (and for some the only form) of telemedicine. Older VC methods used a direct connection either through satellite, VPN or ISDN, since the required bandwidth was not sufficient for two-way video streaming.

Proper telehealth should be a mixture of both real-time and S&F. VC allows the feel and satisfaction of the doctors' presence, while S&F is time saving, allowing relevant documentation like the patients' history, radiology, investigation reports, etc. for deeper analysis both immediate and in the long term.

Lately the scene has changed to allow cheaper home-based systems, with VC managed through personal computers; laptops; and mobiles, which is now the most common. Such development had its roots in systems that allowed text messaging via the Internet wherein voice was later added called Voice over Internet Protocol (VoIP). Later, sharing of live video became enabled over VoIP as a form of a multimedia message. Current tools allow additional inputs to be shared in the form of a white board, live chat, or messaging, sharing files and common viewing of the EMR.

There are many solutions that provide VC along with online meeting support; Skype is the oldest and best known. Originally point to point, it allows multipoint support and screen sharing. Other examples like Google plus, Yahoo! messenger, and AOL messenger are extensions of their email applications. Facebook also allows live chat, but security is a concern—highlighted by the election of US President Trump. One must remember that there are strict guidelines against sharing health data. One has also to understand that VC is data intensive, and many systems have failed because the provided connectivity was not enough. However, better systems currently adjust to lower clarity (of video) based on the amount of available connectivity.

Dedicated online meeting programs that require a license make for better security. Examples are Webex™, GotoMeeting (Citrix)™, Zoom™, Teamviewer™, and of late even Skype. All also allow mobile-based conferencing. These also provide an option of remote desktop control and sharing, which in turn allows online support and help for problems faced while working with any software—important since EHRs and telehealth apps need much learning. Such comprehensive solutions purely as a part of a telehealth solution are coming up but, not as yet commonplace.

Use of such meeting solutions in mobile phones, however, is challenging due to the small screen, and there are multiple components. The advantage however is that the phone number by itself is necessarily unique and allows easy passage through relevant security protocols. Pure VC on mobile includes Facetime (Apple) wherein iMessage is a separate application. WhatsApp, WeChat, Telegram, Slack, etc. allow both to run as part of the same application.

One has to remember that constant connectivity speed needs to be maintained right from (1) the starting point, then (2) to the local switch (i.e., network provider), and then (3) to the server and from there on (4,5,6,…) (traversing a similar path) to the other locations, which could be more than one. Mixing and displays depend on the application and can be at the server level (similar display at all ends) or at the client end—generally the latter, as that adjusts better to the local needs.

A totally VC-based teleconsult has many challenges, the biggest being the time of the doctor, aside from low connectivity speed. Teleconsultations may allow face-to-face meeting, but when one has to examine or view the leg or an X-ray or reports, a screen display makes for a difficult read—a moving frame necessary means that the pixel size is smaller to maintain the appropriate screen refresh rate.

The above-mentioned systems require voice and multimedia inputs through codecs and related standards, many of which have been described previously,[b] Codec H264 is the standard protocol for videos. In VC, a lossy image is allowed as constant communication is more important, while some reduction in clarity can be adjusted to. Compression is mostly the norm through reduction of frame size, that is, an image of dimensions 192×144 is one-fourth the size of a frame of 384×288, and hence it would require one-fourth of the bandwidth too for transfer. In case one is working with still images, for example, a document photo, screenshot (here the pixel rate of the remote screen may matter), or X-rays, the frame refresh rate can decreased. This allow for better clarity even if data speed is slow. A frame refresh only once every minute—adequate

[b]See Chapter 3—Acquiring Sound, Images, and Video.

for an X-ray—would allow an image 450 times the number of pixels in the same data speed of a routine VC—remembering that normal refresh should be 7.5 MHz (= frames per second) for the eye to discern movement.

VC can be on a one-to-one basis, that is point to point (P2P), wherein two people are talking to each other or as part of a multipoint conference wherein multiple persons participate. In the latter, most systems would allow for the video of each person to be visible in a side bar, while the main person speaking would be visible in an enlarged mode. The main screen could also be a presentation, originating from the speaker. Each participant has to set his individual sound and video upload settings beforehand. The sound can be though a normal phone call or through an accompanying VoIP. All the incoming calls, videos, etc. are finally laid out as a single multimedia stream by the provider company, and then the same is transmitted through appropriate connectivity to the participant's screen.

However, successful VC requires much effort. The general principles, with a focus on multipoint conferencing, are as follows:

1. At the hospital, a separate room should be set aside for the equipment, as it takes up a certain amount of space, and this also makes it available to more users. The setting should be "uncluttered," that is, with walls and curtains in soft and solid colors. Strong patterns in the background or the participants' clothing may be a distracting factor. It is wise to speak calmly and at an even rate. Sudden movement can create a disturbance and interference in the picture.[49]
2. For patients, single rooms are desirable so that they can talk to the doctor alone, or together with local healthcare staff. The optimal frequency for VC should be assessed (may not be needed every day). To ensure continuity, the same doctor should be responsible for contact with the satellite centers over a continuous period (e.g., 1 month).[49]
3. Make sure the appointment is at a time that is comfortable and convenient for all participants. This becomes a bigger challenge when there are going to be participants from across the global—meetings of authors and editors for this very book raised such challenges.
4. A dress code is similarly required including combing your hair (shoes maybe optional!). When one is sitting at home, one conveniently forgets that they are very visible to other participants (So forget about doing VC from your bedroom!)
5. Older systems allowed a separate camera that could be mounted at a particular place where they could ensure only what was required to be revealed of their home and office would be revealed. This is not possible any longer as current laptops and even desktops have a camera at the top of the screen that *does not move* to face the speaker. Mobile-based VC is simpler, better done with the mobile placed on a stand, but not without challenges (see Chapter 12).

6. It is important to have a round of introductions—the system normally allows for the name to be displayed while speaking.
7. Microphone and ear plugs are better than speakers for sound quality, but do not obviate the need for a soundproof closed room. The main convenience is in stopping an echo effect caused by 2-3-s delay of audio reaching across and coming back through the listeners' device as a fresh audio note. Any participant who does not have head mikes should remain muted at any time he/she is not speaking. Feedback (the loud crescendo-type tinny sound when the mike faces the speaker) is another problem best avoided thus. Also remember that noise cancelling headphones may not cut external noise for the audience at the other end!
8. Speaking out of turn is another frequent cause for confusion. Hence the conference organizer needs to have a moderator. Most systems allow a form of digital hand raising, but even better is that comments or questions be entered into the accompanying chat box.
9. Hybrid meetings are wherein there is a physical presence in a room but some of the members are connected online. If this room has multiple speakers, a tabletop multidirectional mike would be preferred.
10. Similarly, for the hybrid meeting, more sophisticated cameras with turning to face the speaker would be important.
11. The final speed and clarity depend on a calculated average bandwidth wherein some persons may lose the voice or video. During an ongoing conversation, it is even recommended that users switch off their video input to allow for better clarity all around.
12. When making a presentation or on-screen discussions, it is important to remember that only one screen is normally allowed for sharing with others. The choice could be the entire desktop or just a particular opened presentation or document—even a running EHR screen.
13. Special problems, mostly of noise and no sound, emanate when switching from external mike to internal sounds of the system (e.g., when one wants to run an onscreen explanatory video) during a conference call. Solving these tests the skills of even professional broadcasters.
14. A possibility of remote control of the screen being viewed may be allowed for annotations. However again not more than one remote entity should do that.

Now, we discuss some recommendations for VC as part of health support. We assume that the target is a possible teleconsultation, and the same is being done through a telemedicine app:

1. While the caller (a patient or preferably the local care provider) may use a mobile or desktop, for the clinician, a desktop will be better as he should be comfortable and not moving around.

2. Patient-related data—history, investigation reports, etc.—should be available through S&F for viewing in the same screen or sometimes a parallel side screen. The same depends on the system being used.
3. An ambient light source, preferably daylight from a window, should be behind the camera even if a desktop-mounted camera, that is, the speaker, faces the light. Many systems allow for a light to be switched on when the video is active, but such lighting is rarely adequate and if so may cause a glare or redeye of the speaker.
4. Provide an appointment roster; for example, *Dr A shall be ready and awaiting calls from 1600 to 1700 hours.*
5. A background screen or display board behind the caller and more importantly the clinician should reveal the identification and location of the consulting parties.
6. The display screens should allow all the desired components with large enough fonts to avoid discomfort and specially, squinting, which one must understand will be seen immediately on the other end, to allow and sometimes may be glaringly enlarged on two screens.
7. Special telemedicine apps include all the previously mentioned in an all-to-all inclusive system. They also support creation of ePrescriptions, which are made by the clinicians but can be printed remotely with digital signatures, etc.
8. Even though many now do all work through a mobile phone, the small screen is however a hindrance; hence tablet computers should be considered a minimum.
9. Most important is try to ensure eye-to-eye contact with the patient (you just need to keep viewing your own video box to see if that is what it appears) as that shows empathy and concern.

## Example of video-conference system for emergency care

*Gunnar Hartvigsen*

Telemedicine is a vital part of emergency care in Northern Norway. Emergency care is difficult in the high mountains and off shore, particularly during winter time. To make emergency medical knowledge available in emergency situations on the island of Spitsbergen (almost at 80 degrees north), the former Norwegian Centre for Telemedicine (NST), together with the Acute Unit at University Hospital of North Norway (UNN) and Longyearbyen hospital, developed a telemedicine system called videoconferencing acute medical conference (VAKe). VAKe connects the emergency treatment room at Longyearbyen Hospital to the Emergency Medical Communications Center (AMK)[50] at UNN, which in turn provides access to a wide range of medical specialists.

Clinicians at Longyearbyen hospital get in contact with UNN by pressing the button on the VAKe display named “Call AMK UNN.” The design idea is that in emergency situations, the device should be very simple to use. The acute ward at Svalbard hospital was, in addition to a camera on the wall, equipped with a ceiling mounted camera. This camera has motion and zoom functions that can be controlled from the UNN so that the medical specialists can study the desired areas of the injured patient. All vital signs measurements from the patient such as ECG, pulse, oxygen saturation, and temperature are sent to UNN so that both sites have access to the same patient information. It has also been emphasized that good, sensible placed microphones are needed to provide good conditions for dialogue between the two locations regardless of where they are positioned in the room.[13] VAKe has proved that access to images has improved understanding of the situation, resulted in correct advice, and thus had positive therapeutic consequences.

For the specialists at UNN, who obviously have to evaluate the patient’s condition from remote, their ability to “recreate the patient” is crucial for the evaluation: What kind of data do you as a specialist need to give appropriate advice and/or make decision(s) about optimal treatment when you do not have the patient in front of you? A good approach is to establish good routines based on adequate data: audio, images, visual data, written data, and trained healthcare personnel remotely who the specialist can instruct to do what he/she obviously cannot do with the patient.

The typical setting with participants at Longyearbyen hospital and UNN in Tromsø includesthe following (Tables 3–5):

The VAKe system became immediately a success story after it was installed at Longyearbyen hospital. It very quickly turned out to be very useful to avoid unnecessary transportation by plane to the mainland or give support for stabilizing a patient. After the system became known among healthcare workers, other healthcare organizations on the mainland asked for the same service.

According to the project leader of VAKe, Oddvar Hagen, positive experiences with the VAKe system included the following[13]:

- The technology worked well.
- Better support and workflow.
- “Closer” teamwork.

**TABLE 3** Details of staff working at the Telemedicine facility.

| **Longyearbyen hospital** | **UNN** |
|---|---|
| • GP/surgeon | • AMK-doctor |
| • Anesthesia nurse | • AMK-nurse |
| • Surgical nurse | • Surgeon |
| | • Anesthesia specialist |
| | • Neurosurgeon |

TABLE 4 List of equipment at UNN Emergency unit (AMK).

| Equipment | Manufacturer | Model | Number |
|---|---|---|---|
| Codex | Tandberg | 6000 MXP | 1 |
| Ceiling mic | Tandberg | Audio Science | 1 |
| Headphones | AKG | HSD 200 SR/OC | 2 |
| Audio/video control unit | Crestron | Professional media processor MP2E | 1 |
| Touch panel | Crestron | Wired 5.7-inch tabletop touch panel CT-1550 | 2 |
| Mixer | Behringer | Eurorack UB802 1 | 1 |
| Distribution amplifier | Extron | P/2 DA 2PLUS | 1 |
| TV | ATEC | LCD 37″ HD ready | 2 |
| Camera | Sony | EVI D70 “robot camera” | 1 |
| TV | Hitachi | 37PD5200 | 2 |

TABLE 5 List of equipment at Longyearbyen hospital.

| Equipment | Manufacturer | Model | Number |
|---|---|---|---|
| Codex | Tandberg | 990 MXP | 1 |
| Ceiling mic | Tandberg | Audio Science | 1 |
| Headphones | AKG | HSD 200 SR/OC | 2 |
| Audio/video control unit | Crestron | Professional Media Processor MP2E | 1 |
| Touch panel | Crestron | Wired 5.7-inch tabletop touch panel CT 1550 | 1 |
| Camera | Sony | EVI D70 “robot camera” | 1 |
| TV (LCD 23″) | Hyundai | HLT2310 | 1 |
| Sound mixer | Behringer | Eurorack UB802 | 1 |
| Transformer | Noratel | IMED 300 | 1 |

- It saves time, tasks solved in parallel.
- The nurses felt safer in situations with severely injured patients.
- Reduced stress, especially after the first use.
- Specialists at the University Hospital had a better understanding of the condition of the remotely located patient.
- Positive impact on patient care.
- Improved team function.

Negative experiences included the following[13]:

- Monitoring and cooperation: If "they" help "us" or "see us in the cards"?
- Sensitive initial phase, vulnerable to interference
- Disruptive communications.
- "Keen" specialists.
- The communication was not well structured.
- No clear operational procedures.
- The need for the work routines and "rules."
- Need for more exercise.

The medical specialists at UNN argued that visual information gives a better platform for decision-making. They were more confident by giving advice base on visual information. Also, eye contact made it easier to get acceptance for the suggested treatment procedures.[13] Hence, the introduction of the VAKe system resulted in important organizational changes for the routines at UNN. Now, multidisciplinary medical teams sit together for both emergency teleconference and general emergency cases. Previous participation was mostly through a phone call from the different hospital departments.

## Standards and certification

*Maurizio Mattoli*

As per International Standards Organization (ISO), "A **standard** is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose."

The ability to exchange information safely and securely about the patient at a distance is the ultimate enabling factor in telehealth, and this applies to all forms: real-time, store and forward, remote monitoring, and more. Whenever we attempt to do telecare, we need to adopt the relevant and proper protocols and standards to enable the information exchange (transmission) through different systems and physical media.

We must also establish, as in any system, the distant participating parties' identity, privileges, and authorization. Alongside, there is a need to ensure the availability, integrity, and confidentiality of the information and ensure the exchange and transfer is secure, especially when this takes place through a third-party or public infrastructure. That's why interoperability and information security standards are even more critical in this case of care provision, as they contribute to reliability and safety. They form the prerequisites of any medical act, especially if carried out at a distance, since here the chances are higher.

But there is yet another—less obvious—safety issue related to it. We must also make sure we can preserve the meaning of information as it flows across different systems and different caregivers get access to it. In fact, as pointed out by Coiera,[51] besides others working on communication and information theory applied to healthcare, in practice, individuals do not know the same things, and the resulting issue is that the receiver's knowledge may alter the effectiveness of a message. So, let's say we succeed in making information about a patient reach the next patient's point of care (either physical or virtual) because we were able to manage what we call functional or syntactical interoperability.[c] Will this info still be clear enough to let the next care provider understand, interpret, and use it correctly? Someone who has different knowledge and in a different context and time from the one that generated the information. Will she/he still correctly understand, interpret, and make proper use of such information?

The following example may help understand this issue. This example may hold true for either a physical patient referral or a virtual patient referral to a specialist. Let's say the medical history summary of the patient comes with "MS" as one of the previous diagnoses for the patient. "MS" is an acronym that could either refer to the following:

- multiple sclerosis
- mitral stenosis

How should the specialist interpret that piece of information? He or she might need to remove this ambiguity somehow. In the case of an S&F teleconsultation, it could be even harder to clarify, as neither the patient nor other caregivers are immediately available to help as solving the puzzle would imply a need for further interactions and lead onto further latencies. Or—another example—let's say the medical history summary of the patient says "diabetes" only. "Diabetes" alone is ambiguous, as it does not specify what type of diabetes the patient is suffering. And so on, many other examples can be made where the use of acronyms, abbreviations,[52] and eponyms[53] may put at risk the meaning and interpretation of different kinds of clinical information about the patient.

So here comes the challenge we call semantic interoperability,[d] defined as the "*ability to exchange information* between different systems **and** to use the information transferred, i.e., *preserving the meaning of information*."

[c] Syntactic interoperability refers to the packaging and transmission mechanisms for data. It enables the information exchange, yet alone does not ensure data will be also always understood.

[d] Semantic interoperability is the ability of computer systems to exchange data with unambiguous, shared meaning. Semantic interoperability is a requirement to enable machine computable logic, inferencing, knowledge discovery, and data federation between information systems (definition from Wikipedia, accessed February 2018, https://en.wikipedia.org/wiki/Semantic_interoperability).

The latter is usually addressed by "coding" information versus what we call "controlled vocabularies" or standard terminologies, to ensure nonambiguous meaning, but this comes with a coding effort that may be low or high depending on several implementation aspects.

*Note*: To enable knowledge-based CDSS attached to an EHR, EHR information must be coded (i.e., made not ambiguous). Otherwise, CDSS "if-then" rules will not work correctly. For instance, a rule may say something like, "IF **drug_1** is taken AND **drug_2** is being prescribed/taken THEN send a warning to the user," that will not work safely and correctly if input drug information is ambiguous (i.e., not coded).

In this section, we will review several technology standards addressing interoperability in healthcare, both syntactical and semantic. We will briefly mention the challenges and the benefits that may arise from their adoption, their primary purpose, features of the most relevant ones, and some of the new and most promising ones. Still, in doing this, we should keep in mind that interoperability itself, in its broader definition, is still a challenge in most of the world.

## Messaging and data exchange standards

These standards define the structure and data content of electronic messages enabling information sharing. A message is a portion or unit of information sent from one system to another. For instance, a message from a laboratory information system (LIS) sending a patient's lab tests results to a clinical information system (CIS) or an EHR.

*Examples of messaging and data exchange standards used in healthcare systems*:

**HL7 v2.x and v3**: messaging standard to exchange clinical, administrative, and financial information in the context of healthcare. v2 is one of the most common and worldwide used standards in healthcare systems. It is used to exchange messages triggered by events between many different hospital systems within a healthcare provider. For instance, messages/events about patient admission, transfer and discharge, scheduling, laboratory orders/results, patient information updates, and many more; "x" stands for several of the subversions of the v2 standard (e.g., v2.7, v2.7.1, and v2.8). On the other hand, v3 represents a new approach to clinical information exchange based on a model-driven methodology (see HL7's Reference Information Model, http://www.hl7.org/implement/standards/rim.cfm). It has a higher information representation power and several benefits compared with the previous version. However, that comes at price in the form of higher complexity and implementation costs. There is also no backward compatibility with the previous version. So far, v3 has not seen broad adoption, despite the fact that countries like Canada and Australia officially embraced it. The standard is developed and maintained by Health

Level Seven (HL7). See www.hl7.org. To some extent, the newer and interestingly, open-source FHIR (see later) makes it likely that the same will never be used.

**Digital Imaging and Communications in Medicine (DICOM)**: is an international standard to transmit, store, retrieve, print, process, and display medical imaging information. This is almost the most universally used standard in the context of medical imaging, for example, radiology information systems (RIS), picture archive and communications systems (PACS), and medical imaging viewers. Developed by National Electronics Manufacturers Association (NEMA). See www.nema.org and www.dicomstandard.org/. There used to be many proprietary versions, in the past disallowing information exchange; now, this is less of an issue. Open-source versions allow easy adoption by any one.

**Clinical Data Interchange Standards Consortium (CDISC)** standards suite: data structure format for reporting data collected in clinical research studies; it evolved into a broader suite of data standards, enhancing the quality, efficiency, and cost-effectiveness of clinical research processes. Developed and maintained by CISC. See www.cdisc.org/.

**National Council for Prescription Drug Programs (NCPDP)**: data interchange standards for the pharmacy domain (prescriptions transfers, billing, and more). See http://www.ncpdp.org/.

**Accredited Standards Committee (ASC) X12**: electronic messaging standards for transactions, eligibility, and payments. Developed and maintained by X12, chartered by the American National Standards Institute (ANSI). See www.x12.org/x12org/index.cfm.

**Institute of Electrical and Electronics Engineers Standard 1073 (IEEE 1073)**: messaging standard for communication between medical devices. Developed and maintained by IEEE. See http://ieeexplore.ieee.org/document/713466/.

### *Terminology standards*

Terminology or vocabulary standards are directly related to the meaning (semantics) of the information exchanged. By assigning unique codes to the information, they allow the receiver to relate it to the corresponding concepts managed within the controlled vocabularies (in the form of either classifications or ontologies) where the meaning is defined by the standard vocabulary itself, which means that the information is understood the same way by all participating parties. This aspect is key not only in the context of information exchange but also whenever you want to harness the benefits from knowledge-based clinical decision support systems or CDSS (as already mentioned, they direly need nonambiguous information). Standards enhance research and knowledge discovery capabilities in healthcare. Ensuring precise meaning of any "input" information improves many of related processes and allows information reuse. It allows the principle "capture once, use many times."

*Examples of messaging and data exchange standards used in healthcare systems:*

**WHO ICD-9, ICD-10, ICD-O, and ICD-11***: International Classification of Diseases (ICD) is the standard diagnostic classifications for epidemiology, health management, quality, and clinical purposes. Translated into 43 languages and used by 117 countries to monitor incidence and prevalence of diseases. Also used to monitor outcomes and allocate resources in healthcare. Developed and maintained by the World Health Organization (WHO).[e] (http://www.who.int/classifications/icd/en).

**Logical Observation Identifiers, Names, and Codes (LOINC)**: a universal code system standard for the electronic exchange and gathering of clinical results (e.g., laboratory tests, clinical observations, outcomes management, and research). Often implemented into laboratory information systems (LIS) interfaces and related software. Developed and maintained by the Regenstrief Institute. See http://www.regenstrief.org/resources/loinc/.

**Systematized Nomenclature in Medicine—Clinical Terms (SNOMED CT)**: a controlled coded clinical terminology for use in electronic health records (EHRs). SNOMED CT represents clinical information meaningfully with adequate detail for clinical recording (e.g., clinical findings, procedures, body structures, organisms, specimens, substances, and pharmaceutical), facilitating EHR guidelines implementation, decision support systems integration, and clinical research among several benefits. It is one of the most comprehensive reference terminology standards for semantic interoperability together with LOINC. SNOMED CT has several mappings toward ICD10 (WHO), and ICD 11 has been made in close coordination. But it is much more as it can represent clinical ideas in more detail than any other standard classifications. SNOMED CT is used by more than 5000 affiliate licensees worldwide, maintained and distributed by SNOMED International (a trade name of the International Health Terminology Standards Development Organization, IHTSDO), a not-for-profit organization having currently 30 member countries. See https://www.snomed.org.

**RxNorm** provides normalized names for clinical drugs, linking its names to several drug vocabularies commonly used in pharmacy management and drug interaction software (see CDSS). It has two main components: a normalized naming system for generic and branded drugs and a tool for supporting semantic interoperability between drug terminologies and pharmacy knowledge base systems. Developed by the US National Library of Medicine (NLM). See https://www.nlm.nih.gov/research/umls/rxnorm/.

**ICD-10 Procedure Coding System (ICD-10-PCS)**: it is a procedure classification for classifying procedures performed in hospital inpatient healthcare settings in the United States that is intended for use by

[e] ICD-11 was released in June 2018, but adoption will take time.

healthcare professionals, healthcare organizations, and insurance programs. Developed by 3M Health Information Sys. for the Centers for Medicare and Medicaid Services (CMS), the latter is the US government agency responsible for overseeing all changes and modifications to the ICD-10-PCS. See https://www.cms.gov.

**Unified Medical Language System (UMLS)**: it is a set of files and software tools that bring together many health and biomedical vocabularies and standards to enable interoperability between computer systems. It has a metathesaurus, containing terms and codes from many vocabularies (including CPT, ICD-10-CM, LOINC, MeSH, RxNorm, and SNOMED CT). A semantic network made of broad categories (semantic types) and their relationships (semantic relations) and a set of natural language processing tools called SPECIALIST Lexicon and Lexical Tools. Developed by the US National Library of Medicine (NLM). See https://www.nlm.nih.gov/research/umls/.

### *Document standards*

**Continuity of Care Record (CCR)**: it is a patient health summary record specification containing the most timely and relevant core health information about a patient that can be sent (electronically) from one caregiver to another, also aimed at creating a standard of health information needed when a patient is transferred or referred or seen by another healthcare professional or caregiver, expressed in the standard data interchange language extensible markup language (XML). Developed and maintained by ASTM Subcommittee E31.25 and other organizations. See https://www.astm.org/COMMIT/SUBCOMMIT/E3125.htm.

**Clinical Document Architecture (CDA)**: is a document markup standard that specifies the structure and semantics of clinical documents for exchange between healthcare providers and patients. It ensures the following characteristics within a clinical document: persistence, stewardship, potential for authentication, context, wholeness, and human readability. A CDA can contain any clinical content; for instance, a CDA document could be a discharge summary, imaging report, admission and physical, pathology report, and more.

**Continuity of Care Document (CCD)**: combines the benefits of ASTM Continuity of Care Record (CCR) and the HL7 Clinical Document Architecture (CDA) to specify the encoding, structure, and semantics of a patient summary clinical document for exchange. It defines a set of templates representing the typical sections of a summary record and expresses these templates as constraints on CDA.

## Coordination, harmonization, and convergence of standards

We just had a review of many standards related to interoperability in healthcare. Let's see a practical example of how some of those standards we mentioned may "work together" into some implementation.

For instance, we might want to further send an ECG report already received from a remote ECG system to the corresponding patient's record in the GP's local EHR system. We could use a *messaging standard* like HL7 v2.x to provide the transport and message specification format. Then, "inside" the v2 message itself, we could pack, as part of its payload, the clinical document we want to send, the ECG report in this case. The document structure and semantics of the "embedded" ECG report could make use of a *document standard* like the CDA, which would define the document structure and also establish a *terminology standard*, like SNOMED CT, for instance, which might have been used to code the ECG finding information that comes within such ECG report. This way we get transportation, structure, and coding of information. So, this could be an example of how three different types of standards cooperate to make information transport possible and to ensure univocal information meaning. The following diagram (Fig. 1) will try to represent this example in a simplified view.

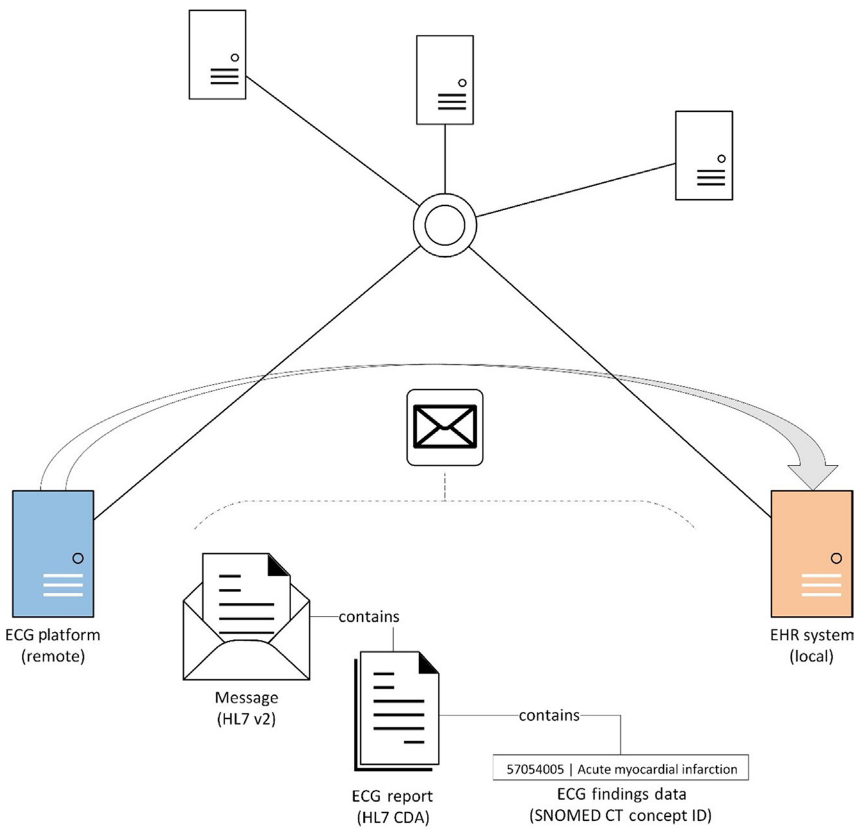


**FIG. 1** A didactical diagram illustrating the coordinated use of standards in document exchange.

The previous is just a very rough example since many other additional aspects need to be addressed. For instance, how should we establish correct and consistent patient and physician identification included in the ECG report document? Is there some common "source of truth" that would be consistent both for sending and receiving systems, even in the case of exchange between different organizations caring for the same patient? These and many other aspects must be "agreed upon" to achieve interoperability in a broader sense. In the next subsections, we are going to mention some of the more relevant initiatives aiming at establishing a coordinate use of standards to achieve interoperability in healthcare.

## Integrating the healthcare enterprise—IHE

As shown in the previous example, to accomplish some goals related to an information exchange context, we had to choose some of the many different available standards related to interoperability (both syntactical and semantical). It means that every time we want to address some information exchange involving different systems developed, managed, or maintained by different parties, we have to agree with all participating parties on what standards should be used (or find some way to translate them to make exchange possible between different systems).

The organization called Integrating the Healthcare Enterprise (IHE) has been established precisely to address such coordination needs. As IHE itself states, "IHE is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical needs in support of optimal patient care. Systems developed in accordance with IHE communicate with one another better, are easier to implement, and enable care providers to use information more effectively."[54]

IHE collects case requirements, identifies available standards, and develops technical guidelines which manufacturers can implement. The main result of this process is a set of "integration profiles" that describe specific solutions to integration challenge within different domains (e.g., radiology, cardiology, eye care). An integration profile establishes standards used by each system's actors, allowing cooperation to address specified needs. So, for instance, the "scheduled workflow" within the radiology domain establishes the flow of information that supports efficient patient care workflow in a typical imaging encounter. It specifies transactions that keep the consistency of patient information from registration through ordering, scheduling, imaging acquisition, storage, and viewing. The specification also establishes the underlying standards to be used in such transactions (DICOM and HL7 in this case).

IHE also organizes what are called Connectathon(s). These are interoperability testing events gathering hundreds of industry developers and vendors to collaborate and test implementations through test scenarios, which are called IHE profiles—the ECG example is one of them. In this, disparate vendors gather in separate cubicles, a clinical scenario—like the ECG and report as earlier is provided to one who in turn sends to another vendor's system. The receipt accuracy is checked. And if successful, developers and vendors are issued "IHE Integration Statements" related to their products. This helps prospective purchasers to gain confidence of product integration capabilities. More recent, IHE integration profiles also make use of other promising and emerging standards like openEHR and FHIR (see next section). For more information, see https://www.ihe.net/.

## Emerging interoperability standards

### *HL7 Fast Healthcare Interoperability Resources—FHIR*

A standard specifying data formats and elements called "resources" (e.g., patient, practitioner, encounter, CarePlan), together with an application programming interface (API) for exchanging the resources using modern web-based technology and standards (e.g., XML, JSON, HTTP, and OAuth). It defines a simple framework for extending and adapting the existing resources. All systems can read these extensions, and their definitions can be retrieved using the same framework. So, it is both flexible and easy to implement, particularly suitable for mobile devices. FHIR is very promising, it has reached version 4 (i.e., first Normative Content + Trial Use Developments) as of December 2018 and was incorporated into several IHE integration profiles related to mobile access and more. The specification is free to use. See https://www.hl7.org/fhir/.

## Standard development organizations

Technical standard development is a systematic process requiring coordinating, producing, releasing, revising, amending, and reissuing those standards among other activities. Those organizations primarily engaging in such activities are called standard development organizations (SDO). Usually, most standards are voluntary, while some of them may become mandatory if regulators define them as a legal requirement. Here is a list of some of the most relevant SDOs related to interoperability for health information systems.

### *International Standards Organisation (ISO)/TC 215 health informatics*

ISO is an international standard development and accreditation organization, established as a worldwide federation of national standard bodies. The ISO Technical Committee (TC) 215 Health Informatics covers health information and communication technology (ICT) to promote interoperability and compatibility between systems. ISO TC 215 has several working groups. Many of the already mentioned above standards have also been incorporated as ISO standards. ISO/TC 215 has direct responsibility on more than 180 published ISO standards, ranging from medical devices to personal and electronic healthcare record standards. See https://www.iso.org/committee/54960.html.

**Health Level Seven (HL7) International**: it is a not-for-profit standard development organization (SDO) accredited by the American National Standards Institute (ANSI) for developing healthcare-related standards. It has responsibility for a broad suite of standards larger than those we already mentioned (v2, v3, or CDA). Among others, HL7 also manages the Arden Syntax and HL7 EHR Functional Model (FM). It is probably the most well-known SDO related to health information systems. See http://www.hl7.org/. FHIR is an open-source project supported by HL7.

**openEHR Foundation**: a not-for-profit company of University College London, the United Kingdom. Owner of openEHR trademark and standard, licensing and making available openEHR artifacts at no cost, openEHR is also a virtual community working to enable semantic interoperability, mainly focused on clinical information systems and electronic healthcare records. So far, openEHR is not regarded as a formal (*de jure*) SDO. See https://www.openehr.org

**International Health Terminology Standards Development Organisation (IHTSDO) or SNOMED International**: See section under SNOMED.

**WHO**: it has developed the entire range of ICD.