WHITE PAPER

Mark Nadeski
Global director of marketing,
Medical Imaging Group
Texas Instruments
m-nadeski@ti.com

Gene Frantz
Principal fellow
Texas Instruments
genf@ti.com

Texas Instruments

The future of medical imaging

Making healthcare personal

The 19th century poet Emily Dickinson was reclusive to the point that she would allow a doctor to examine her only from a distance of several feet as she walked past an open door.

If she were alive today, it's likely that she would benefit from advances in medical imaging that could accommodate her standoffishness while still diagnosing the Bright's disease that ended her life at age 55.

One example of our technologically enabled future is a bathroom mirror with a retinal scanner behind the glass that looks for retinopathy or collects vital signs. In the case of Dickinson, that mirror could have noticed a gradual increase in the puffiness of her face, a symptom of Bright's disease, and alerted her physician.

This technology also could be a viable way to improve care for patients who are too busy to schedule routine doctor visits. For latrophobics – whose fear of doctors has them putting off regular checkups – advances in medical imaging enable a wide variety of noninvasive diagnostic options.

For health care providers and their patients, these and other advances in medical technology make health care increasingly personal in terms of managing chronic diseases, predicting catastrophic ones and enabling patients to live out their final months or years in the comfort of their homes. These advances also allow health care to become a routine part of daily life.

Some examples:

- Bathroom fixtures with embedded devices that can detect potential problems, such as a toilet that analyzes urine to identify kidney infections or the progression of chronic conditions such as diabetes and hypertension. Another example is a bathroom scale that detects sudden changes in weight or body fat. These devices could automatically upload data to the patient's physician and schedule appointments based on the physician's predetermined criteria.
- Connected diagnostic devices such as retinal scanners could be coupled with patients' existing consumer electroics products, such as digital cameras, to provide additional diagnostic and treatment options and make information available to proper medical personnel.
- Sensors in the home could measure how a person is walking to determine if he or she may be a candidate for a medical episode, such as a seizure. This is another example of how health care can be preventative and move deeper into the home without significant trade-offs in quality of care.
- An alarm clock that tells the person it's waking that it's scheduled a doctor's appointment, perhaps based on information collected from other health care devices around the home, such as the retinal scanner embedded in the bathroom mirror. This example brings new meaning to the term "personal area network" (PAN), where multiple devices throughout a home regularly and noninvasively monitor and record a person's vital signs.
- Equipment can be brought into the home and be remotely connected to a caregiver's network. One example of a product in development is a gyroscope-based device worn by elderly patients to detect whether they've fallen.[1] This device could then connect to the patient's PAN to send for help. Near-falls, as well as extended sedentary periods (which could be a sign of a developing physical or psychological problem) could also be documented and reported to the patient's physician.
- Remote surgery, where a world-renowned specialist operates on a hologram that's used to control a surgical robot thousands of miles away. This approach spreads the best care around the world, allowing patients to be treated by world-renowned specialists without requiring them to travel thousands of miles.

- Virtual house calls, where physicians use videoconferencing – a service that many telecom operators plan to offer for the consumer market – and home-based diagnostic equipment such as portable ultrasound systems. Virtual house calls may be particularly attractive to patients in rural areas[2] or those in major cities with chronic traffic jams. Virtual house calls are also a way to bring health care to patients who otherwise wouldn't be able to see a physician, perhaps because they're bedridden, suffering from Iatrophobia or have limited means of transportation. Whatever the hurdle, virtual house calls are yet another example of how advances in medical technology are increasingly bringing care to the patient, instead of the other way around.

All of these examples improve patient care by making it a round-the-clock service rather than something that occurs infrequently and requires a disruption of daily routines. They enable earlier identification of health problems before a condition becomes irreversible. As a result, patients may receive care that's more thorough than if they had to find time for an office visit every week or month.

Automatic monitoring also eliminates the need for patients to remember to record information. As health care becomes a round-the-clock service, the cost of delivering care is reduced by automating processes.

For some patients, these technologies can enable care that they otherwise wouldn't receive for reasons such as finances or distance. A prime example is Dr. Devi Prasad Shetty, a cardiologist who has combined digital X-rays with satellite broadband to bring health care to residents of India's remote, rural villages.[3] Shetty's telemedicine program has had a major impact in India, where an average of four people have a heart attack every minute,[4] by bringing cardiac care to people who otherwise wouldn't receive it simply because of where they live.

Advances in medical imaging

Medical imaging is continually evolving and advancing, all with the goal of improving patient care. Here are some examples.

- **The migration of X-rays from film to digital files.** In India, this migration has revolutionized health care by streamlining the process to the point that one of Dr. Shetty's clinics now handles 3,000 X-rays every 24 hours. Through the use of digital signal processing (DSP), X-ray signals now can be converted to digital images at the point of acquisition, with no trade-offs in image clarity. Digital files have a variety of benefits, including eliminating the time and cost of processing film, as well as more reliable storage. The ability to render digital images in real time has led to the use of digital X-ray machines in surgical procedures, allowing doctors to view a precise image at the exact time of surgery.

- **The evolution of MRIs from slow and fuzzy to fast and highly detailed.** Today's magnetic resonance imagers (MRIs) can provide higher quality images in a fraction of the time that it took machines that were state-of-the-art just a few years ago. Today's MRIs are also highly flexible, with the ability to take images of the spine while it's in a natural, weight-bearing, standing position.

Today's MRIs are also enabling tomorrow's breakthroughs. For example, with diffusion MRIs, researchers can create brain maps to study the relationships between disparate brain regions via tractography. Functional MRIs, meanwhile, rapidly scan the brain to measure signal changes caused by changing neural activity. These highly detailed images provide researchers with deeper insights into how the brain works – insights that can improve treatment.

- **The portability of ultrasound.** Over the past several years, ultrasound equipment has become more compact, with cart-based systems increasingly complemented or replaced by portable and handheld ultrasound machines. This reduction in size is enabling a wide variety of health care applications that illustrate how advances in medical technology are bringing care to patients instead of forcing them to travel. Portable and handheld ultrasound systems are also instrumental in bringing health care to rural and remote areas, disaster sites, patient rooms in hospitals, assisted-living facilities and even ambulances.
- **Retinal implants become reality.** Researchers at the University of Southern California's Doheny Eye Institute[5] are refining artificial retina technology that could restore some vision for patients with retinitis pigmentosa and macular degeneration.

A common theme flows through all of these examples: the use of digital signal processing. DSPs are used in multiple application areas that affect the world of medicine and our lives every day. More importantly, the technology is still in the early stages of its impact on medicine and health.

How telecom complements medical imaging

Advances in medical imaging are frequently complemented by advances in communications networks. Together, they have significantly improved patient care while also reducing costs for health care providers and insurance companies.

One example is NightHawk Radiology Services.[6] Instead of maintaining a full radiological staff overnight, a hospital emergency room can send an X-ray via broadband Internet link to NightHawk facilities in Sydney, Australia, or Zurich, Switzerland. NightHawk's staff then reads the X-ray and returns a diagnosis to the ER doctors.

Telemedicine is another example of how medical imaging and telecom technologies complement each other. Videoconferencing and a new, immersive version called telepresence[7] are increasingly used in both developed and developing countries for health care. Videoconferencing and telepresence systems are often paired with medical imaging systems such as ultrasound machines to enable telemedicine applications, which often enjoy government subsidies simply because they bring health care to areas where it's expensive, scarce or both.

The Missouri Telehealth Network[8] services include teledermatology, where a patient at a rural health clinic can put his scalp under a video camera for viewing and diagnosis by a dermatologist hundreds of miles away, providing a videoconference that mimics a face-to-face meeting. If the patient has limited time or transportation options, telemedicine could mean the difference between treatment and suffering. In the case of someone with stage 1 melanoma, early detection through telemedicine could mean the difference between life and death.

DSPs play a key role in telemedicine. For example, DSPs provide the processing power and flexibility necessary for videoconferencing and telepresence systems to support a variety of codecs. Some of these codecs compress video to the point that a TV-quality image can be transported across low-bandwidth wired or wireless networks. This ability extends telemedicine to remote, rural areas and developing countries where telecom infrastructure has limited bandwidth. In the future, compression will also help extend telemedicine to patient's homes over cable and DSL connections.

DSPs also provide the processing power necessary to support the lossless codecs required for medical imaging, where little or no compression could impact image quality and affect the diagnosis. The programmability of DSPs allows them to be upgraded in the field to support new codecs as they become available, thereby providing a degree of futureproofing for end users such as hospitals and physicians groups.

The future of health care

As impressive as some of the aforementioned advances might sound, there's ample research underway that likely will improve health care even further over the next decade.

For example, CNOGA[9] is an Israeli company whose technology uses video cameras to noninvasively measure vital signs such as blood pressure, pulse rate, and blood oxygen and carbon dioxide levels simply by focusing on the person's skin. Future applications of this technology can lead to noninvasively identifying biomarkers for diseases such as cancer and chronic obstructive pulmonary disease.

As medical imaging advances, it becomes increasingly possible to conduct more tests in the patient's home. This benefits insurance companies by reducing the amount paid for office visits, while patients benefit by having to schedule less time for office visits and not enduring the inconvenience of seeing a doctor. For those with transportation issues or inflexible work schedules, telemedicine can help identify and treat conditions before they become debilitating or life-threatening.

Other research includes:

- **Single-chip ultrasound.** Shrinking an octal ultrasound receiver down to a single chip enables portable designs, but has historically also required a trade-off in image quality, which limited the unit's usefulness as a diagnostic tool. However, recent advances in integration have minimized that trade-off by reducing the signal path's size, as well as noise levels. The goal is to create a single-chip design that allows the probe, receive, transmit and processing chains to be integrated. That in turn allows all of the ultrasound machine electronics to reside in the probe head, which then can use a wireless link to transmit information to the display. Single-chip designs also complement 3-D probes, which have significantly more transducer elements and thus require more cabling to the machine.
- **High-intensity focused ultrasound (HIFU).** This technology is part of a trend in health care toward reducing the impact of procedures in terms of incision size, recovery time, hospital stays and infection risk. But unlike many other parts of this trend, such as robot-assisted surgery, HIFU goes a step further to enable a noninvasive option for many procedures currently done invasively.

One example is using transrectal ultrasound[10] to destroy prostate cancer cells without damaging the healthy, surrounding tissue. HIFU can also be used to cauterize bleeding and melt fat, so it's a potential fit for a wide variety of procedures, including cosmetic ones.

- **Beyond MRIs.** Researchers at the University of Missouri[11] are using 3-D images rather than MRI slices to identify correlations between children's facial features and brain structures. Those correlations may allow physicians to diagnose autism earlier, as well as provide genetic insights to help future research into the disorder.

This research dovetails with at least two trends in health care: a preference for noninvasive diagnostics and the quest for early diagnosis. The latter is particularly important because the sooner autism is diagnosed, the sooner parents and physicians can begin treatment and therapy.

Conclusion: toward more personal, effective health care

With all of the technological advances in health care technology, it's easy to forget what they're really all about: the patient. But whether it's a retinal scanner in a bathroom mirror or a home ultrasound machine, it's the patient who is the greatest beneficiary.

For Iatrophobics such as Emily Dickinson, new, noninvasive techniques that are increasingly available in the comfort of one's home can make all the difference in diagnosing and treating diseases before they become debilitating or life-threatening.

These advances enable health care to become more personal and, for lack of a better term, user-friendly, with patients interacting with physicians through videoconferences from their homes or nearby clinics. They also help make health care more effective by providing ways to identify diseases and other conditions before they become untreatable.

At the same time, these advances also allow health care to fade into the background and become a part of daily life: being scanned each morning while brushing one's teeth instead of only during an annual checkup. That's particularly valuable for patients with chronic or end-stage diseases because it may keep them from having to move into a hospice. In that sense, health care revolves around the patient, as it should.

Someday soon, technology will be able to manage our chronic diseases, predict our catastrophic diseases and allow us to live out the last days of our lives comfortably.

[1] *http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=1019448&isnumber=21925*
[2] *www.columbiamissourian.com/stories/2007/05/12/improving-care-rural-diabetics*
[3] *www.financialexpress.com/news/everyone-must-have-access-to-healthcare-facilities-Devi-Prasad-Shetty/42099/*
[4] *www.abc.net.au/foreign/stories/s785987.htm*
[5] *www.usc.edu/uscnews/stories/13442.html*
[6] *www.nighthawkrad.net*
[7] *www.telepresenceworld.com/ind-medical.php*
[8] *www.proavmagazine.com/industry-news.asp?sectionID=0&articleID=596571*
[9] *www.cnoga.com*
[10] *www.prostate-cancer.org/education/novelthr/Chinn_TransrectalHIFU.html*
[11] *http://munews.missouri.edu/news-releases/2008/0818-duan-autism-research.php*