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News & Highlights

Handheld Ultrasound Advances Diagnosis

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In March 2021, Chicago, IL, USA-based medical imaging giant GE Healthcare launched the Vscan Air [1], a self-contained, handheld ultrasound probe, its latest and first wireless version of the increasingly sophisticated "pocket" ultrasound systems now marketed by multiple vendors. Like with advances in other medical technology [2,3], the devices are smaller, smarter, and leverage smartphone capabilities.

Once limited to bulky and expensive cart-based machines, ultrasound systems in the last decade have been transformed by a technological and commercial race to miniaturization and making them much more affordable, and easier and more intuitive to use. The resulting generation of handheld ultrasound probes plug directly into a smartphone or tablet—or connect wirelessly as with the Vscan Air—and employ artificial intelligence (AI)-powered apps to boost image quality and diagnostic confidence.

Ultrasound technology has long served as a key tool in medicine because it offers healthcare professionals a dynamic window to the inner workings of patients' bodies, with no known side effects. It has countless established diagnostic and monitoring uses, from assessing pregnancies to checking heart function, guiding needle placement, and—most recently—spotting the signs of the coronavirus disease 2019 (COVID-19) infection in the lungs.

The growing affordability of the handheld devices—ranging from a few thousand to about 10 000 USD [4]—combined with ultrasound's sheer versatility, has led some physician experts to call for "insonation" (the use of ultrasound) to become a "fifth pillar" of clinical examination, joining inspection, palpation, percussion, and auscultation (listening with a stethoscope) [5]. Besides GE Healthcare, the ultra-portable systems are available from a range of manufacturers, including Philips, Siemens, and a cadre of smaller companies.

"You are looking into the body as opposed to listening, feeling, and making educated guesses," said Jonny Wilkinson, consultant in intensive care and anaesthesia at Northampton General Hospital in Northampton, UK. The COVID-19 pandemic has highlighted the usefulness of these highly portable systems, said Wilkinson, who trains others to use the devices and posts internet reviews of the latest models [6]. "COVID-19 caused an explosion in interest in handheld ultrasound."

Being able to see inside a patient's body from the bedside is being embraced across the medical spectrum, said Anjali Bhagra, a clinical investigative internist and professor of medicine at the Mayo Clinic in Rochester, MN, USA. "When I am a patient, I do not want my physician to guess. I want them to get the best possible information they need to make a good decision for my treatment. Handheld ultrasound really allows for that."

Engineered to connect wirelessly to an Apple or Android smartphone or tablet, GE Healthcare's Vscan Air is dual headed, with a linear probe on one end and a curvilinear probe on the other (Fig. 1) [1]. Each end meets a different set of imaging needs, thereby providing broad clinical utility in a single device. As with most ultrasound systems, including the more expensive cart-based systems, the probes use vibrating piezoelectric crystals to turn electricity into sound waves. A notable exception to this piezoelectric-based engineering is the iQ+ ultrasound handheld system, made by Guilford, CT, USA-based Butterfly Network. The iQ+, a

(a) (b)

Fig. 1. (a) Able to scan continuously for 50 min on a 90 min charge, the Vscan Air, GE Heathcare's latest model handheld ultrasound system pairs wirelessly with a smartphone or tablet. The curvilinear probe on the top of the device can scan (2–5 MHz) to a depth of 24 cm, while the linear probe at its base is for shallower scanning (3–12 MHz), up to 8 cm. The probe measures 131 mm × 64 mm × 31 mm, and weighs about 205 g. (b) For size/portability comparison, the high-end, cart-based system is a GE Healthcare Voluson ultrasound unit. Credit: (a) GE Healthcare, with permission; (b) public domain.

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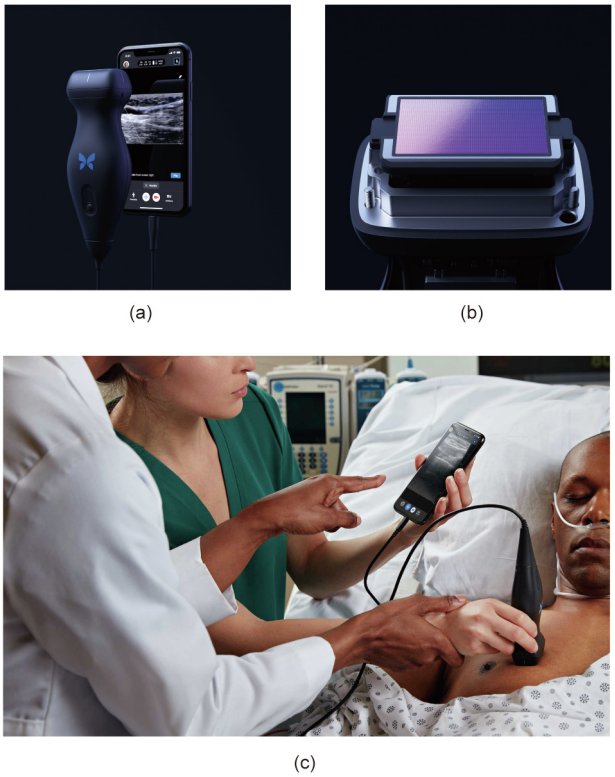

Fig. 2. (a) A wired handheld device, the Butterfly Network iQ+ ultrasound system is connected to a smartphone by a wire. (b) Within its head, the device contains an ultrasound-generating silicon chip comprising a two-dimensional array of 9000 micro-machined sensors (shown with the probe's upper casing removed). This technology allows the unit to emulate both a linear and curvilinear probe with a single head. (c) A physician uses the iQ+ on a patient. Credit: Butterfly Network, with permission.

wired handheld probe, uses a proprietary silicon chip technology ("Ultrasound-on-Chip") to create its high-frequency output (Fig. 2) [7].

Handheld ultrasound systems have proved particularly useful during the COVID-19 pandemic because patients can have their lungs quickly assessed without moving them around the hospital, which reduces the risk of spreading infection, said Yale Tung-Chen, attending physician, chief of the Division of Ultrasound in Internal Medicine at Hospital Universitario Puerta de Hierro, and associate professor at Universidad Alfonso X El Sabio, in Madrid, Spain. "At the beginning of the pandemic, I performed all my lung examinations with a handheld device because it was easier to carry and decontaminate," Tung-Chen said. In a recently published study of 51 patients with suspected COVID-19, Tung-Chen and his collaborators found examinations with a Butterfly iQ handheld probe to be as effective as computed tomography scans for identifying abnormal changes in the lungs related to COVID-19 [8].

Additional research suggests that, for many medical procedures, handheld ultrasound can match standard practice using more sophisticated, expensive ultrasound machines. As far back as 2011, just a year after GE Healthcare launched their first handheld Vscan model, one emergency room study showed that assessment of trauma with the Vscan handheld device correlated well with scans performed by a radiologist with a standard machine [9]. Today, handheld ultrasound's value for patient triage and monitoring is widely recognized. "If I can arrive at a diagnosis earlier and start the required treatment, I might get someone out of the hospital in 6 h, rather than two days," said Bhagra. "I can potentially save lives that might be lost through delayed diagnoses."

Physicians using a variety of handheld probes and smartphone apps to treat patients does raise institutional-level concerns, however. For example, most makers of handheld ultrasound models offer secure cloud-based storage not always compatible with established hospital picture archiving and communication systems. And hospital administrators can be wary because physicians take their phones home with them at the end of the day. "There is more of a fear factor over the governance of handheld devices and what happens to the images on them than there is with centralized ultrasound systems that plug into the wall. That is a big issue," said Wilkinson.

In less connected, low-resource settings, the handheld devices have shown potential for extending the benefits of ultrasound to populations for whom access might otherwise be limited or absent. A recent trial of the Butterfly iQ device in a low-resource African emergency room found it to be effective and versatile [10]. However, the authors noted that, although all these issues were "surmountable," image quality was inferior to a cart-based system, the probe often overheated during continuous use, and the reliance on internet-based cloud storage was disadvantageous.

Despite their usefulness, the latest handheld systems can present difficulties when taking them into hostile or low-resource areas, said Pippa Letchworth, consultant in obstetrics and gynaecology at St. Mary's Hospital, part of Imperial College Healthcare NHS Trust, in London, UK, and Obstetric Lead for Hostile Environment Surgical Training at the David Nott Foundation. "Because it is so versatile, ultrasound has the potential to save lots of lives," said Letchworth, who has performed surgery all over the world with the non-profit Médecins Sans Frontières. "But ultimately, in low- and middle-income countries, the internet connectivity is often just not there. For my purposes, the probes need to be more rugged, a bit more droppable, and not reliant on good connectivity, just reliant on being charged every now and again."

The Vscan Air is marketed as meeting a military-grade drop test standard, designed to survive falls of 1 m. In terms of scan time per charge, the average for wireless handheld probes is around one hour. Overheating is frequently mentioned in reviews and research articles as an issue that can shorten a probe's continuous-use time. This is not surprising as the battery typically resides within the probe itself—always, in the case of wireless models.

It is broadly accepted that the image quality delivered by handheld devices is inferior to that obtained with more expensive cart-based systems, which can apply a great deal of computing power to image processing and performing a greater range of analytics in real time. Regardless, for many applications, the difference does not appear to matter. A 2018 policy statement from the American College of Emergency Physicians described the usefulness of handheld ultrasound images as "comparable" to cart-based machines [11]. In addition, a 2019 systematic review of research comparing handheld imaging to high-end ultrasound found "good overall agreement" between the two types of systems [12]. Bhagra emphasizes, however, that "with point-of-care handheld devices, I am interested in point-of-care decision-making that allows me to care for the patient at the bedside and triage the best care. We are not, for example, looking to replace sophisticated echocardiograms and being able to calculate complicated flow dynamics."

Another benefit of the handheld devices compared with cart-based systems, said Wilkinson, is that they boot up quickly and have no complex set-up procedures to deal with. User interfaces are broadly intuitive because they make use of the taps, swipes, and pinches of modern smartphones. And the latest systems use sophisticated software and AI-based capabilities that can automatically calculate important features such as bladder volume and ejection fraction (a measure of how well a ventricle pumps blood with each heartbeat) and indicate in real time the current quality of the image, increasing the ability of less experienced users to obtain diagnostically relevant images [13,14].

Even so, user experience is a key factor in making the most of handheld ultrasound, said Tung-Chen. "During COVID-19, handheld devices were used extensively, and now many more physicians are engaged and motivated to learn how to use them. The main limitation for the spread of this technology is not the devices, which are now widely available in most hospital departments, but the knowledge of how to use them effectively."

Part of Bhagra's work involves integrating ultrasound technology into medical training. She led a trial that provided all first-year medical students at the Mayo Clinic with access to personal handheld ultrasound devices [15]. "Getting point-of-care ultrasound into the hands of our students is fundamental to their comfort level with the technology and learning to use it to make good decisions."

Fortunately, these systems lend themselves to teaching, thanks to their accessibility and the ability to digitally stream the images, Bhagra said. "You can teach as you scan, incorporating point-of-care ultrasound with live tutorials." She anticipates handheld ultrasound becoming ever more central to patient care: "The increasing miniaturization and sophistication in technology, as well as the capacity for digital delivery of training; all that, along with the potential of combining AI diagnostic algorithms, is going to change how we learn and practice medicine."

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