Acoustic AI as a scalable tool for diagnostics & monitoring: Hyfe's impact vision

The Hyfe Team[1]*

Our vision: a healthier world, in which smartphones and acoustic epidemiology identify illness and track health, transforming healthcare systems for good.

Our strategy: to create evidence-based, AI-driven, scalable, acoustic tools for diagnostics and monitoring that help save lives, eradicate disease, and stop the next pandemic.

[1] *www.hyfe.ai*
***Correspondence**: research@hyfe.ai

Fundamental change to healthcare is long overdue.

Rapidly evolving tech has transformed nearly every aspect of our lives. And yet healthcare, as a system, has resisted fundamental change. Even in instances in which health services do embrace new tech, innovations are based upon the same established and imperfect patterns that have been in place for centuries.

Smartphones are a case in point. To date, the health applications for smartphones have primarily been appointment reminders (e.g., [1–5], medication reminders [6–9], health education [7], and fitness goals [7]. But these uses, while valuable, serve to entrench healthcare in the practices of an outdated system. Smartphones are highly sophisticated, multi-sensor devices, carried in billions of pockets and purses worldwide [10], and interconnected to each other and to health service providers [11]. Surely they can do more for global health than push notifications and tracking steps.

Systems of healthcare are facing a critical moment. Two global events have converged to expose the latencies in our collective approach to healthcare:

1. **Digital natives, meet healthcare.**
   The first generation of digital natives is about to engage with healthcare as adults, both as patients and as doctors [12]. This global community of youth expects their healthcare experience to be just like every other experience in their lives: real-time, frictionless, and available on their smartphones.

2. **The pandemic: a pressure-cooker for change at the digital interface.** Like everyone, digital natives have endured tragedy, disruption, and social trauma at the hands of COVID-19. They have witnessed the failures of global healthcare, and they have watched as schools, businesses, and healthcare providers have struggled to conform to a new digital interface [13]. This generation will emerge from the pandemic with a higher standard for digital healthcare, and with the conviction that the system that allowed for a pandemic of such proportions is overdue for an overhaul.

Change is needed now if we are to meet the demands of the years to come.

That change is coming.

Regardless of the preparedness of healthcare systems, global health is quickly tilting toward revolution. The prevalence of respiratory, cardiovascular, and mental illnesses continues to rise globally [4, 14, 15]. Emerging pathogens have demonstrated their ability to take millions of lives and cripple global economies, uncovering catastrophic gaps in pandemic preparedness [16–18]. Meanwhile, developing nations in the global south are establishing a new middle class, billions-strong, with unprecedented resources for medical care [19]. But even in the wealthiest nations, where populations are aging across the board [20], the costs of care are rising unsustainably [21]. This is the shifting picture of global health.

Emerging from this reality are three related trends, which together can revolutionize and re-shape our fundamental approach to health:

1. **The rise of mobile health and patient empowerment.**
   Mobile tech has changed the way people interact with

their health [22–24]. Half of the world population now owns a smartphone [10], and the wealthiest nations now have more smartphones in use than users [10, 25]. A growing portion of these users – more than half in high-income areas – use their devices to manage personal health [26–28].

Mobile health (mHealth) and telehealth interfaces have increased patient-doctor engagement [1–5], improved adherence to treatments [6–9], and fostered health-minded living [6, 7]. The mHealth industry has been growing for years [22, 23], but the COVID-19 pandemic has accelerated its influence dramatically [13].

Most importantly, mHealth is improving access to care for billions living in remote and low-income settings [5, 24, 29–31]. Smartphones have distributed high-quality optical and acoustic sensors to at-risk populations, generating unprecedented opportunities for remote patient monitoring and diagnostic assessment.

2. **The rise of data-driven care.** For decades, medical technologies have been shifting patient care away from subjective assessments towards objective and quantitative metrics [32, 33]. Instead of an isolated snapshot of health gathered during a single consultation, remote patient monitoring can be used to provide physicians with detail and context [34–36].

The shift to device- and sensor-based monitoring has generated a vast ocean of medical data. As these data stores have grown, machine learning has risen as a means of unlocking its secrets. AI tools could yield enormous value for improving medical diagnostics, reducing the costs of care, and saving lives [37–40]. As AI penetrates systems of care and upends past approaches to diagnostics, every dimension of global healthcare is going to change [41].

3. **The shift from treatment to prevention.** Modern healthcare economics are focused almost exclusively upon treatment, but the future of health systems will feature proactive care [42]. Preventive, lifestyle focused, risk-based approaches to primary care will improve health, reduce costs, and fosters attitudes of agency in personal health [43]. As evidence of these benefits streams in [44], lawmakers and insurers have shown growing interest in preventive systems of care [45–47].

Proactive health services will emphasize patient monitoring, risk assessment, and early diagnostic interventions [43, 47]. The global preventative technology healthcare market is growing at a furious pace, projected to reach $240 B - $430 B by 2025, growing at a CAGR of 9.5% - 12.0% [48, 49]. Similarly, the global diagnostics market is expected to surpass $85 B by 2027 [50]. These markets are sure to be disrupted and redirected by the rise of mobile, AI-based diagnostics.

The next era of healthcare will be unlocked by acoustic AI.

In the race for healthcare systems to keep pace with the changes coming to global health, medical AI will be a keystone tool [37]. Imaging AI has proven the value of AI in medical diagnostics [51]. The next – and much larger – frontier in the AI age of diagnostics and monitoring will be *acoustic epidemiology.*

Our health is communicated to others through sound: coughs, sneezes, wheezing, snoring, sniffles, hoarse speech, and more. These sounds were the original indicators of health, before thermometers and stethoscopes. They are also information-rich, containing essential diagnostic information for physicians [11, 52]. Equally informative is changes in these symptoms over time; such trends can indicate the onset of an illness, its convalescence, its long-term impacts, and the risk of future outcomes [53, 54].

The production of these sounds – particularly cough and sneeze – can also spread disease [55]. These explosive sounds transmit viruses and bacteria within aerosol droplets to new hosts, leading to super-spreader events and the exponential outbreak of illness [16]. The prevalence of these acoustic health indicators provides invaluable intelligence for public health authorities [11].

Cough is a uniquely valuable acoustic indicator of health. Coughing is ubiquitous, it is an efficient vector of disease, and the change in its characteristics and regularity is a common symptom of nearly all respiratory diseases – from tuberculosis and lung cancer to asthma, chronic cough, and COVID-19 – which altogether account for more than a quarter of all deaths worldwide [11, 56, 57].

This is the opportunity: Acoustic epidemiology using smartphones.

New acoustic diagnostic and monitoring tools will unlock a blue ocean of epidemiology and transform public health. For decades, cough has been recognized as an important data point in medical diagnoses and public health [11, 58, 59], but neither data science nor medical tech has been able to implement cough monitoring effectively or at scale [11]. Until now. AI algorithms have only recently learned how to detect tuberculosis, COVID-19, and other diseases based on cough [60, 61]. Meanwhile, sound detectors (i.e., smartphones) are proliferating throughout the world's most remote and high-risk communities [10].

The impact of acoustic healthcare tools will depend upon their scalability. If kept non-invasive, affordable, and small, these tools will be capable of remotely monitoring patients on a long-term, continuous basis [11]. And if kept simple, user-friendly, and app-based, these tools will be capable of swiftly penetrating communities all over the world.

This is Hyfe: Acoustic AI
for counting and diagnosing cough. Everywhere.

Hyfe was founded to transform healthcare systems and improve global health through acoustic epidemiology. To do so, Hyfe is creating acoustic tools for diagnostics and monitoring that are:

- simple to use,
- efficient to analyze,
- accessible to all,
- scalable without limits, and
- impactful everywhere.

These tools are built using the world's largest and fastest-growing cough dataset, improved upon continuously via machine learning, and vetted extensively through partnerships with clinical researchers around the world.

Our suite of diagnostic and monitoring tools is developed according to **three core principles of design:**

- Achieving global health will take collective effort and new solutions; it can only be done together, and not from within current systems.
- Acoustic epidemiology can help save lives, improve quality of life, eradicate disease, and stop the next pandemic.
- The key to unlocking this impact is already in our pockets.

Hyfe's products will pioneer the next era of patient care and public health:

Smart health at home

- **Smartphone apps** allow users to track their own coughs or the coughs of loved ones, fostering autonomy and agency in managing personal and family health.
- **Integration into smart home tech** allows cough monitoring to leverage the Internet of Things (IoT) for improving family health.
- **Real-time risk scores**, updated on a rolling basis, alert users to changes in their cough. These risk scores trigger earlier interventions by clinicians, reduce the exacerbation of symptoms, and improve treatment outcomes.
- This worldwide user base lays the groundwork for the **early detection of disease outbreaks.**
- Meanwhile, these users provide Hyfe's machine learning algorithms with new training data for **continuous refinement**.

Clinical screening

- Long-term, continuous monitoring provided by smartphone apps can be **used by physicians during consultations** to get a rich and complete picture of their patients' health.

- Screening apps can be used by physicians to analyze a patient's cough, returning **disease risk scores** that can guide subsequent diagnostics and triage the allocation of resources for high-risk patients.
- These apps will prove particularly impactful in **remote settings** where access to care is poor and front line workers are over-taxed.

Public screening

- **Cough screening stations** can be used in densely populated and high-risk facilities, such as airports and stadiums, to efficiently screen people for risk of infectious disease.
- Cough monitoring apps can be used at large facilities, such as **airports, convention centers and shopping malls**, to monitor the prevalence of cough in crowds.

Remote patient monitoring

- Smartphone- and IoT-based apps allow for remote patient monitoring to track cough as a **clinical endpoint during and after treatment.**
- Again, these apps will be particularly valuable in scenarios where in-patient care is not possible, or when symptoms require monitoring throughout the lifestyle of the patient in **out-patient settings.**

Disease control

- The **worldwide base of smartphone users** with the coughing app serves as a network of sentinels for disease control.
- By monitoring **syndrome prevalence at large scales** throughout this network, the spread of respiratory disease can be detected and tracked unlike ever before.
- Real-time and **early detection** of outbreaks will guide resource allocation, slow the spread of illness, and contribute to avoiding and containing epidemics.

In short, Hyfe is making cough count. But these are only the most obvious applications for this technology. We see no limit to the uses and adaptations of Hyfe's platform for diagnostics and monitoring.

Cough is just the beginning.

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