DISCOVER — ENGAGE — IMPACT

COUGH A LOT? NO, *COUGHALYTICS*!

UQ researchers are working with hospitals, NGOs and industry to develop non-invasive technology for diagnosing illness, to boost mass health screening and minimise disease.

The saying "Cover your mouth when you cough!" may soon become "Get out your phone when you cough!" if Associate Professor Udantha Abeyratne from the School of Information Technology and Electrical Engineering has his way.

That's because he and his team of researchers have developed a diagnostic tool that uses smartphone technology to instantly identify respiratory diseases such as asthma, pneumonia and chronic obstructive pulmonary disease (COPD) – just by listening to the sound of a person's cough.

"Using a smartphone as a measurement, computing and display device, we have created a specially designed app that can mathematically analyse coughs and other respiratory sounds and so determine what type of disease a person has," says Associate Professor Abeyratne.

And all through coughing in the direction of a mobile phone!

With respiratory disease the third leading cause of death worldwide (after heart disease and cancer), the potential global health and economic impact of this technology that allows early and accurate intervention is phenomenal. For example, somewhere in the world a child dies every 30 seconds from pneumonia, and the cost of COPD in Australia alone is estimated to be around $98 billion per year.

So how did Associate Professor Abeyratne come up with this idea? After all, doctors have traditionally considered coughing as a symptom rather than a descriptor of disease. And a cough is a cough is a cough, right?

Wrong. Coughs can be wet or dry, brassy or raspy, ringing or barking. They can whistle, whoop or wheeze. But experts cannot always agree on what these descriptions mean, which is why Associate Professor Abeyratne wanted to create a simple way to remove the subjective element for describing coughs using modern signal processing and machine classification/learning technologies.

"My original aim was to develop a smartphone-based cough analysis technique that could diagnose childhood pneumonia in economically poor, geographically remote regions of the world where access to healthcare facilities is scarce or non-existent," he says, "but our *PneumoFone (Coughalytics)* technology has exceeded our wildest expectations.

"We now envisage our technology being used by people of all ages throughout the world, from resource-poor sub-Saharan Africa to resource-rich New York city, in a variety of contexts such as hospital emergency centres, airport screening, healthcare delivery in remote and disaster-stricken areas, telehealth, elderly care, and home-based personalised management of chronic diseases like COPD and asthma."

So how does the technology work?

First, the diagnostic tool allows the recording of a sound stream using the phone. It then automatically extracts the cough sound, analyses it using mathematical algorithms and then makes a diagnosis about which disease the sound most closely resembles. The technology can also use other measurements and disease symptoms (such as fever and runny nose) if and when available.

In its simplest form, the technology is available on a smartphone without the need for accessories, sensor attachments or a network connection; is automated and easy to use; and runs in real time with performance approaching that of a hospital-based diagnosis. It can also be made available for cloud computing applications and as an instrument in hospital lung-function laboratories.

But how did the research process begin?

"I strongly believed that cough sounds carry vital information on the state of the respiratory system but was surprised to find out it was heavily under-used for diagnosing pneumonia," says Associate Professor Abeyratne.

During a cough event, lungs are connected to the atmosphere via a column of air, which can support a much higher bandwidth than the traditional pathway across chest musculature. Stethoscopes measure sounds up to 3kHz, whereas coughs may consist of frequencies up to 60kHz – way beyond human hearing range. This 'cough information superhighway' is now what's being used to diagnose respiratory illnesses.

"Physics dictates that sounds generated inside the lungs and airways, including disease-specific ones, should propagate

outside through the air column at the speed of sound. Cough sounds also carry information on airflow rates, chest consolidations and constrictions. For instance, in asthma – which, incidentally, affects ten per cent of the population at any given time – constricted bronchioles limit the airflow rate in a cough and also generate characteristic resonances," he continues.

"In pneumonia, isolated multiple nodules or large sections of contiguous lung tissues can get infected, resulting in an accumulation of secretions in bronchial areas and in the tiny elastic air sacs (alveoli), which limit the total airflow volume/rate, as well as propagate particular sound characteristics. And in croup and pertussis, specific cough sounds can provide the earliest and best way to diagnose the disease."

Associate Professor Abeyratne had already discovered that snoring sounds could provide enough information for diagnosing sleep apnea approaching the accuracy of standard sleep laboratory technology, but without the drawback of patients being hooked up to 20 different sensors, so the idea of listening to coughs without connecting patients to various instruments naturally evolved from there.

"I was convinced that WHO's crude method of diagnosing childhood pneumonia by counting breaths could be improved with the addition of mathematical analysis of cough sounds, and in my mind, it was not a matter of whether we could improve it, but by how much."

And he was right. He discovered that cough sounds alone could diagnose pneumonia at an accuracy well above that of the WHO method, as he and his team had already demonstrated that similar methods could be successfully used to diagnose diseases such as asthma, bronchiolitis, croup, viral wheeze and COPD.

Exceeding all expectations, the team recently discovered initial evidence that the basic technology may be adapted to identify the etiology of x-ray confirmed cases of pneumonia as bacterial, viral or atypical. If proven scalable, this should provide a unique tool for supporting the global efforts against antimicrobial resistance – a prime threat to modern civilisation, on par with the threat of terrorism according to top UK health officials.

Leading a team of biomedical engineers and experts in medical signal processing and machine learning at The University of Queensland, Associate Professor Abeyratne works with paediatricians at the Princess Margaret Hospital for Children in Perth, respiratory physicians at Princess Alexandra and Wesley Hospitals in Brisbane, as well as clinical practitioners at Joondalup Health campus in Western Australia.

"Respiratory nurses recruit subjects who satisfy our inclusion criteria and collect sounds from them by holding a mobile phone within a one-metre radius of their face," says Associate Professor Abeyratne.

"From young children, we collect spontaneous coughs; and from older children and adults, we collect both voluntary and spontaneous coughs from those with and without respiratory disease.

"Our analysis so far indicates that we can work equally well with either type."

Making use of the high-tech resources available in modern hospitals – radiology, pathology, laboratory, imaging facilities (x-rays and CT scans), microbiology and lung-function tests – the team has developed research protocols that satisfy medical ethics boards and validate the technology.

Associate Professor Abeyratne's idea was initially funded by a Grand Challenges in Global Health Explorations grant from the Bill & Melinda Gates Foundation. Later supported by a PathFinder grant from UniQuest and a CIEF grant from UQ, the project has culminated in a spin-off company ResApp Health Ltd (ASX:RAP), which has a market capitalisation of above $200 million.

With the boom in telehealth – currently the second fastest growing industry in the US with a predicted value of $6 billion in the next four years – the future for ResApp Health Ltd looks positive indeed. And the technology may even have impacts outside human health, for instance, in veterinary medicine for household pets, and in the livestock industry where non-invasive screening of animal illness would be a key feature for preventing mass outcrop of disease.

Another bonus would be the ability to limit the widespread administration of antibiotics for misdiagnosed respiratory diseases, therefore avoiding antimicrobial resistance within communities.

So, instead of covering your mouth when you cough in future, "getting out your phone" may save not just your social life, but possibly your real life too.

uq.edu.au/research/impact

Highlights to date:

2009: $100,000 Grand Challenges in Global Health Explorations Grant from the Bill & Melinda Gates Foundation received

2012: Australian provisional patent for cough extraction, dry/wet classification and diagnosis technology applied for

2013: $17,000 UniQuest Pty Ltd Pathfinder Grant received

2014: $60,000 University of Queensland CIEF Grant received

2015: Country-specific patents filed in the USA, Japan, European Union, Australia, South Korea and China

2015: Research spin-off company ResApp Health Ltd (RAP) listed on Australian Stock Exchange with $5 million capitalisation

2015: People's Choice Award for *Most Promising Childhood Pneumonia Innovation* received at Pneumonia Innovations Summit, New York

2016: Global Talent Unleashed Awards for Best Tech IPO/Venture Capital Raising in recognition of disruptive entrepreneurs who utilise innovative technology solutions to truly make an impact in their field received by ResApp Pty Ltd

2016: Associate Professor Udantha Abeyratne listed as one of Australia's most innovative engineers by Engineers Australia

2016: Partnership formed with Massachusetts General Hospital, USA, to run a clinical study of ResApp technology in support of the De novo application due to be submitted to the US Food and Drug Administration, with approval anticipated by early 2017

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