

A bathroom scale could monitor millions with heart failure

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An experimental scale that monitors heart failure has successfully gone through proof-of-concept testing. Credit: University of California, San Francisco

Millions of heart failure patients are readmitted to hospitals every few months to adjust medications. It sends medical costs sky-high and patients suffer unnecessarily. A new bathroom scale could give clinicians the data they need to cut hospitalizations and treat patients remotely before they suffer too much.

"Good morning. Bill. Please. Step onto the scale. Touch the metal pads." The device records an electrocardiogram from Bill's fingers and—more importantly—circulation pulsing that makes his body subtly bob up and down. Machine learning tools compute that Bill's [heart failure symptoms](#) have worsened.

This is how researchers at the Georgia Institute of Technology envision their experimental device reaching patients someday, and in a new study, they reported proof-of-concept success in recording and processing data from 43 patients with [heart](#) failure. A future marketable version of the medical monitoring scale would ideally notify a doctor, who would call Bill to adjust his medication

at home, hopefully sparing him a long hospital stay and needless suffering.

The pulsing and bobbing signal is called a ballistocardiogram (BCG), a measurement researchers took more commonly about 100 years ago but gave up on as imaging technology far surpassed it. The researchers are making it useful again with modern computation.

"Our work is the first time that BCGs have been used to classify the status of [heart failure patients](#)," said Omer Inan, the study's principal investigator and an associate professor in Georgia Tech's School of Electrical and Computer Engineering.

Healthcare crisis

Heart failure affects 6.5 million Americans and is a slow-progressing disease, in which the heart works less and less effectively. Many people know it as [congestive heart failure](#) because a major symptom is fluid buildup, which can overwhelm the lungs, impeding breathing and possibly causing death.

Patients endure repeat hospitalizations to adjust medications when their condition dips, or "decompensates," making heart failure a major driver of hospital admissions and healthcare costs. Home monitoring reduces hospitalizations but currently requires an invasive procedure.

Georgia Tech research was behind the launch of such an implantable heart failure home monitoring device in 2011. But this new solution would potentially dispense with the procedure, cost much less, and be much simpler to use—lowering patients' resistance to home monitoring.

Given its early stage, the study's BCG-EKG scale performed well in hospital tests but also in in-home tests, which was promising, since the solution principally targets eventual home use.

The research team, which included collaborators from the University of California, San Francisco, and Northwestern University, published their results in the journal *IEEE Transactions on Biomedical Engineering*. The research was funded by the National Heart, Lung and Blood Institute at the National Institutes of Health.

clinicians have understood for 100 years, and now, computers read it a lot of the time," Inan said. "Elements of the BCG signal aren't really known well yet, and they haven't been measured in patients with heart failure very much at all."

The EKG is electrical; the body conducts its signals well, and the recordings are clear.

The BCG is a mechanical signal; body fat dampens it, and it faces a lot of interference in the body like tissue variations and muscle movement. BCGs are also noisier in people with cardiovascular disease.

Patients with heart failure tend to be feebler, and initially, the researchers worried they would wobble on scales during home tests, adding even more noise to the BCGs. But the recordings were very productive.

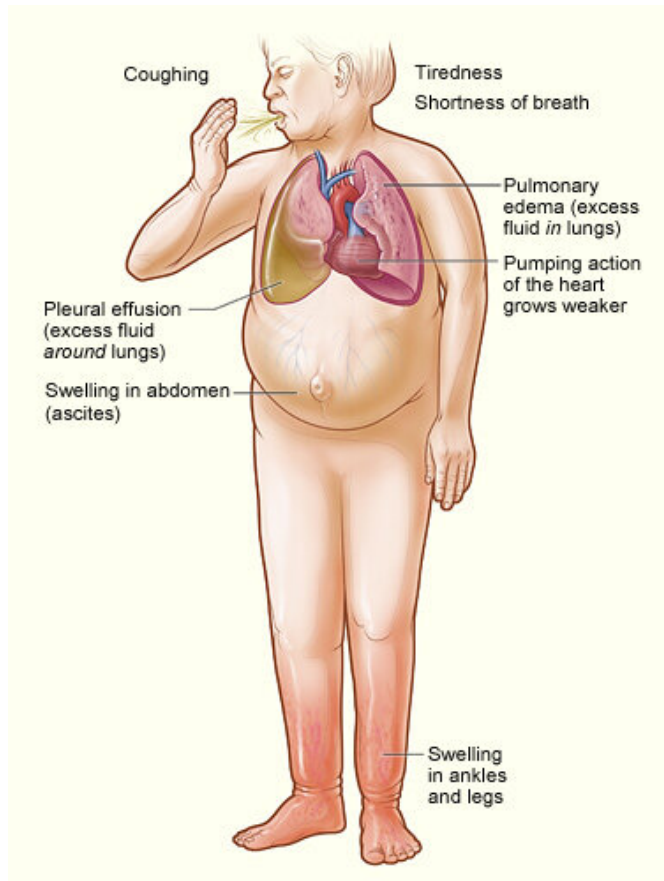
Though a BCG read-out is scribble compared to an EKG's near-uniform etchings, BCGs have some patterns that parallel an EKG's. For example, the big upward spike in an EKG is followed by the BCG's big "J-wave."

Inconsistent throbbing

The researchers processed BCGs with three machine learning algorithms, revealing patterns that differ when a patient's heart failure is compensated, that is, healthier, from when it is decompensated.

"In someone with decompensated [heart failure](#), the cardiovascular system can no longer compensate for the reduced heart function, and then the flow of blood through the arteries is more disorderly, and we see it in the mechanical signal of the BCG," Inan said. "That difference does not show up in the ECG because it's an [electrical signal](#)."

"The most important characteristic was the degree to which the BCG is variable, which would mean inconsistent blood flow. If you chop up the recording into 20-second intervals and the individual segments differ from each other a lot, that's a good marker of decompensation," Inan said.



Symptoms of heart failure. Credit: NIH/National Heart, Lung, and Blood Institute

Ballisto scribble

The EKG part of the experimental scale is not new nor its great diagnostic information, but it alone does not say enough about heart failure. The BCG part is mostly new, and it appears valuable to heart failure monitoring but also challenging to record and interpret.

"The ECG (EKG) has characteristic waves that

More information: Varol Burak Aydemir et al,
Classification of Decompensated Heart Failure from
Clinical and Home Ballistocardiography, *IEEE
Transactions on Biomedical Engineering* (2019).
[DOI: 10.1109/TBME.2019.2935619](https://doi.org/10.1109/TBME.2019.2935619)

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