



Wireless Heart Health

Mobile-enabled Rapid Cardiovascular Screening
Improves Health Care for Rural Patients in China

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EXECUTIVE SUMMARY

Experts agree that the global health burden of cardiovascular disease (CVD) is on the rise and disproportionately affects rural residents. Researchers from the Shanghai Institute of Cardiovascular Disease recently concluded that “the morbidity and mortality of CVD in China are increasing persistently, although the government has taken an active part in the prevention and control of CVD.”¹ Fortunately, experts also agree that early detection and consistent monitoring, accompanied by necessary treatment, have the potential to decrease health risks associated with CVD.

To support the prevention and management of CVDs in China’s rural communities, Qualcomm® Wireless Reach™ launched the Wireless Heart Health program in collaboration with Life Care Networks and the Community Health Association of China in 2011. Wireless Heart Health targets providers in rural areas staffing both public and private clinics and features a one-lead electrocardiogram (ECG)-sensing smartphone, powered by Qualcomm’s Snapdragon S1 processor, with an electronic health record (EHR) application suite developed by Life Care Networks. Additionally, Life Care Networks provides mobile broadband-enabled services for remote consultation, diagnosis, and treatment through its call center, staffed around the clock by cardiac specialists in Beijing.

In the fall of 2015, Qualcomm Wireless Reach, Life Care Networks, and a team of experts from Vital Wave, Inc. designed and implemented a use and satisfaction survey for the Wireless Heart Health program. The goal of the survey was to understand experiences among health care providers using the ECG-sensing smartphones to care for their patients.

The survey showed that participating health care providers in rural China are very satisfied with the ECG-sensing smartphones and believe they are providing improved care and services to patients with CVD.

Key points from the research findings include:

- Two-thirds (66%) of providers were able to examine more patients than before by using the ECG-sensing smartphone, and 61% report making more CVD diagnoses using the device.
- Almost one-quarter (23%) of providers offered in-home ECG screenings to patients using the ECG-sensing smartphone.
- More than one-half of providers (62%) reported that the Life Care Networks Call Center increased the accuracy of their diagnoses and that call center feedback improved their confidence in providing diagnoses.
- Three-quarters (75%) of providers reported that the biggest benefit of the ECG-sensing smartphones is the long-run decrease in cost of CVD screening and diagnosis.
- ECG-sensing smartphones with the Life Care Networks platform are six times less expensive for patients than conventional 12-lead ECG machines: 4.47 RMB versus 26.48 RMB.

In conclusion, research findings demonstrate that the Wireless Heart Health program has been very successful in supporting rural residents, providers, and government agencies addressing the rising health burden of CVD. Simply put, with the ECG-sensing smartphones, costs are decreasing significantly, quality and reach of care is increasing, and satisfaction is high among patients and practitioners.

CASE DESCRIPTION

Cardiovascular disease: A rising health burden that increasingly affects rural residents

According to the World Health Organization, non-communicable diseases (NCDs) — including CVD — have placed a grave economic burden on countries.² In fact, China will lose \$27.8 trillion USD in national income between 2012 and 2030 —amounting to over \$1.5 trillion a year—due to the five main NCDs (CVD, cancer, chronic respiratory disease, diabetes, and mental health). CVD was one of two NCDs in the lead for most costly.³ CVDs such as coronary heart disease, heart failure, and arrhythmia are the leading cause of death in China, responsible for approximately 2.6 million deaths annually. By 2020, deaths caused by CVD are projected to increase to 4 million per year.⁴

Researchers from the Shanghai Institute of Cardiovascular Disease recently concluded that “[d]espite revolutionary advancement in medicine over the past century, CVD remains the leading cause of death and disability in the world. Likewise, the morbidity and mortality of CVD in China are increasing persistently, although the government has taken an active part in the prevention and control of CVD.”⁵ Luo Zhengxiang, head of the Guangdong Cardiovascular Disease Research Institute⁶ notes, “CVD has spread to many rural areas in most parts of China, where medical care is less adequate than what can be found in the cities.”⁷

A recent 800-person study published by the National Heart, Lung, and Blood Institute⁸ found that smartphones equipped with ECG sensors could accurately detect the most common heart arrhythmia, atrial fibrillation (AF). AF can increase the risk of stroke and, in some, chest pain and heart failure.⁹ Study participants noted that using a smartphone to monitor their heart significantly increased awareness of their heart rate and behavior. In a large study in China with over 450,000 individuals, researchers concluded that “[t]he lifetime risk of AF was approximately one in five among Chinese adults, and it increased with advancing age.” Further, “[t]he AF burden, as well as the risk of AF-related stroke, has increased significantly over the past 11 years in the southwest of China.”¹⁰ The potential burden and implications for health care systems are major given the common occurrence of this heart arrhythmia.

Experts from around the world agree that CVDs are on the rise and early detection and consistent monitoring through ECG screening, paired with necessary treatment, have the potential to decrease health risks associated with CVD.

Wireless Heart Health: Using mobile broadband to assist underserved patients with CVD

In China, there are more than 1.3 billion mobile phone users – one for every person in the country.¹¹ As of late 2015, more than 620 million people in China were accessing the Internet via mobile phones, accounting for 90% of the country's Internet-using population.¹² Advanced wireless technology is not only creating business opportunities across a variety of industries, but is also offering incredible opportunities to solve social challenges and improve people's lives. To support the prevention and management of CVDs in rural communities in China, Qualcomm Wireless Reach launched the Wireless Heart Health program in collaboration with Life Care Networks and the Community Health Association of China. China Telecom helped them enter the public health arena and helped them engage local health bureaus and sell the device for public health data collection and other related work.

The Wireless Heart Health program features a mobile broadband-enabled system developed by Life Care Networks. This system includes a smartphone with three built-in ECG sensors comprising one-lead (or one angle of measuring the electrical activity of the heart), and an EHR platform that offers instant access to patient records, including ECG data. Providers hold the device to patients' chests for approximately 30 seconds while the ECG sensor collects their ECG data. The data is automatically stored in the patient's EHR and sent immediately over the 3G or 4G LTE wireless network for analysis by a cardiac specialist at the Life Care Networks Call Center, staffed around the clock in Beijing. The on-call cardiac specialists provide prompt feedback within minutes to clinic staff and patients via SMS or a phone call. Currently, the call center has 72 physicians and ten nurses triaging requests and providing rapid diagnosis around the clock.

Qualcomm Wireless Reach is the main funder of the Wireless Heart Health program and provides project management support. In addition to providing ECG-sensing smartphones and call center resources, Life Care Networks also trains many participating clinicians. From 2011 to 2013, Community Health Association of China aided in site selection, program implementation, and

impact analysis; from 2014 to present, China Telecom and Momentum have assumed this role. Patient data in the EHR and in the ECG-sensing smartphone is protected by SSL encryption. Life Care Networks partners closely with government health systems, so data adheres to the government's protection and privacy standards in order to integrate with government hospital-grade EHRs.

The Wireless Heart Health program targets rural providers at both public and private clinics. Patients that benefit from the program are largely rural, some of whom are managing known chronic CVD and some of whom are being screened for CVD for the first time. To date, there are approximately 600 community health centers and clinics actively using the ECG-sensing smartphones to screen patients and conduct remote consultation with the Life Care Networks Call Center. More than 160,000 patients across 21 provinces and direct-controlled municipalities have benefitted from the Wireless Heart Health program to date.¹³

Given that the need for CVD diagnosis and management will be ongoing, the Wireless Heart Health program was designed to be financially sustainable and is not reliant on future funding from Qualcomm Wireless Reach. The rural health care providers participating in the Wireless Heart Health program, of which there are over 600, received ECG-sensing smartphones at no cost. Moving forward, providers will continue to receive ECG-sensing smartphones for free, contingent upon a three-year commitment to pay a monthly service fee of 150 RMB (\$24 USD) to China Telecom. Market research by Life Care Networks has shown that each rural doctor will earn about 300 RMB (\$48 USD) per month from the delivery of ECG screenings, which means they will capture roughly 150 RMB (\$24 USD) in revenue. Patients will pay an average price of 10 RMB (\$1.60 USD) for a screening using the ECG-sensing smartphone. The Chinese government provides a 50 RMB (\$8 USD) subsidy toward health care costs, which patients can use to pay for ECG screenings.

Case in point: Wireless Heart Health program succeeds in Shandong

The northern coastal province of Shandong is the second most populous in China, with over 97 million inhabitants. Similar to other countries across the globe and other provinces in China, Shandong faces rising CVD risks. In response to this growing need for CVD screening and care, nearly 450 ECG-sensing smartphones have been deployed in Shandong as part of the Wireless Heart Health program. The following profiles of three clinics in Shandong illustrate the Life Care Networks system in action.

Lang Mao Shan Clinic, Shi Zhong District, Jinan City

Lang Mao Shan clinic is one of 1,300 private clinics outside Jinan city in Shandong province. Due to the imbalanced distribution of medical resources in China, the private clinic is an important supplement to public hospitals, particularly in remote and underdeveloped areas. Established in early 1990s, the clinic currently has two full-time providers and seven nurses. It serves about 80,000 community residents and delivers health services to an average of 350 patients per day.

Dr. Ren Nianbao and Dr. Xie Guangguo are the two full-time providers at Lang Mao Shan clinic and have both worked at the clinic for about 20 years. About 20% of the patients Dr. Ren and Dr. Xie see each day are suffering from CVDs.

In the past, the clinic relied on a conventional 12-lead ECG machine to screen for CVDs. The large, complex machine made it especially difficult to screen patients with a potential risk of acute CVD who may have needed immediate help.

To help Dr. Ren and Dr. Xie better serve their patients, Qualcomm Wireless Reach, Life Care Networks, and China Telecom worked together to deploy ECG-sensing smartphones to conduct quick and accurate heart screenings, as well as to connect community providers to heart experts at the Life Care Networks Call Center 500 kilometers away in Beijing for consultation. It takes two to eight minutes for the Life Care Networks Call Center

to send back diagnosis and treatment recommendations, depending on the seriousness of the case.

In 2015, there were five cases where patients' screening results showed serious myocardial infarction (heart attack) symptoms. Thanks to the innovative heart health technology offered by the ECG-sensing smartphone, patients received timely referral recommendations for treatment by specialists at hospitals.

When asked how using the smartphone has changed his practice, Dr. Ren stated gravely, "[w]e can't live without the device and go back to the way things were before." He cites increasing demand for ECG services due to younger and younger patients being at-risk for CVDs – patients in their forties are now showing signs of CVD risk.

With the improved ease and access to ECG screening, patients are beginning to understand the risks better and are more willing to comply with treatment recommendations. Dr. Xie noted, "[m]any patients proactively request to be screened with the smartphone now...they trust it more than the old machine!" All providers offered high praise for the Life Care Networks Call Center services and considers the ECG-sensing smartphone to be more convenient, equally accurate, and more reliable compared with ECG machines.

Community Clinic, Shanghe County, Xin Zhuang Village

Xin Zhuang village community clinic is one of about 500 public community clinics in Shanghe county. Established in 2005, it is one of 20 community clinics in the county that have benefitted from Qualcomm Wireless Reach's support as part of the Wireless Heart Health program.

The community clinic currently has two full-time providers and four nurses. For 15 years, Dr. Li Zhongcheng and Dr. Kang Chunli, a married couple, have led the clinic in serving about 1,110 residents of two nearby villages. The average patient load is 70-80 per day. The ECG-sensing

smartphone is used to screen 10-15 CVD patients on a daily basis, about 20% of the total patients seen. The providers love the functionality of the device and the built-in EHR records and will frequently refer to previous ECG readings and diagnosis stored in the system when re-screening patients at their regularly scheduled check-up.

In addition to the screening and record-keeping benefits of the ECG-sensing smartphones, Dr. Li and Dr. Kang are able to transport the device to patients' homes immediately, if they call with symptoms of cardiac distress. Dr. Li has made emergency visits to patients' homes when they are experiencing heart pain or other issues to provide them immediate diagnosis and peace of mind. He likes to be able to provide this kind of service. In the winter it is especially convenient because patients don't have to remove their shirt completely for the screening.

What Dr. Li and Dr. Kang cite as most helpful is the expert recommendations from the call center. Because they are not specialists, the cardiac experts provide diagnoses that are much more accurate than their own, and they learn from working closely with the call center doctors. For example, they cited the case of a teenager who had a fast heartbeat and a slightly irregular ECG screening. They thought it might be myocarditis, or inflammation of the middle layer of the heart wall, but the LCN call center recommended they look into potential emotional issues causing the irregularities. After talking to the teenager further, Dr. Li and Dr. Kang uncovered that he missed his parents because they had migrated to another city to work and left him behind with other family members. Instead of treating him for a very serious heart condition, they referred him to a psychologist.

Dr. Li and Dr. Kang also appreciate that the Life Care Network Call Center not only offers diagnosis and treatment recommendations, but provides disease prevention suggestions such as alimentary control, nutritional supplement and physical exercise. For this clinic in Xin Zhuang Village, providing patients with unprecedented access to expert opinions right in their own backyard has transformed their ability to treat patients with CVD. Not only can local providers improve

or validate their own diagnoses, but patients also trust the diagnoses and follow through with their treatments more because of the cardiac experts' recommendations.

Shang Bo Tou Community Clinic, Xiawa County, Binzhou City

The Shang Bo Tou community clinic has been serving patients for over 30 years. This public clinic currently has three full-time health care providers: one attending doctor, one paramedic, and one public health specialist.

Dr. Zhang Yanzhao, the attending doctor, serves about 1,200 residents of one nearby village. The average patient load is 50 to 60 per day. He uses the ECG-sensing smartphone to screen about 10 to 15 CVD patients on a daily basis, about 20 to 25% of the total patients seen. He has one elderly patient who was diagnosed with coronary heart disease and at one point had a heart attack. After the heart attack and treatment, the patient continued to receive screenings every two weeks to monitor his condition. The patient complied with his treatment regimen, and Dr. Zhang could see that the patient's treatment compliance correlated with improved ECG screenings by tracking his ECG regularly on the smartphone. The results demonstrated that the treatment was working. Before using the ECG-sensing smartphone, Dr. Zhang felt there was much more risk of incorrectly diagnosing or treating patients. Now, with the assistance of the Life Care Networks' call center cardiac specialists and the smartphone solution, he has confidence in his ability to serve patients.

With expert medical advice and electronic ECG records at his fingertips, Dr. Zhang is pleased that he can take a more scientific approach to his patients' health care. These Shandong case studies have demonstrated that Life Care Networks' ECG-sensing smartphone is creating sea change in CVD care across China, one mobile connection at a time.



Methodology and execution: Capitalizing on collaborative resources

In the fall of 2015, Life Care Networks, Qualcomm Wireless Reach, and a team of experts from Vital Wave, Inc. designed and implemented a self-administered use and satisfaction survey for health care providers participating in the Wireless Heart Health program. The goal of the survey was to better understand the use and satisfaction of Life Care Networks' ECG-sensing smartphones and call center services.

The survey was designed to collect self-reported answers to the following key research questions:

- Does the device improve the health care provider experience by making ECGs easier to conduct, saving time, improving data management, and providing expert diagnosis?
- Does the device improve the patient experience, as perceived by the health care provider, by reducing wait time for results, screening costs, and time and cost for expert opinions?
- Are quality of care and doctor-patient trust improved by connecting rural providers and patients to experts via a remote device and a mobile broadband connection?

The survey instrument was designed collaboratively by Qualcomm Wireless Reach, Life Care Networks, and Vital Wave, Inc. Once the instrument was finalized, Life Care Networks built a data collection tool on the ECG-sensing smartphone platform and pushed the survey out to the population of about 600 participating health care providers already using the devices.

Survey participation was voluntary. In order to increase response rates, China Telecom and Shan Hai Dan (Momentum), two distribution partners of Life Care Networks, aided in the recruitment of responses from health care providers. A total of 220 health care providers completed the survey.

It is important to acknowledge the limitations of the survey design and the potential bias these limitations may have introduced. First, the survey sample was not representative of the entire population of Life Care Networks' ECG-sensing smartphone users, because only the population participating in the Wireless Heart Health program were asked to complete the survey. Also, due to the support of China Telecom's recruitment effort, many of the responses are concentrated in Heze, Shandong. Similarly, recruitment by Momentum resulted in responses from 21 provinces.

In addition, the fact that Life Care Networks was collecting data about its own products and services may have made respondents hesitant to offer any negative or critical feedback. This is known as social desirability bias and is a common phenomenon in survey research. Importantly, participants' names were not collected, they were encouraged to give honest feedback, and all were informed that their responses would only be analyzed at the aggregate, not individual level, protecting their anonymity.

Despite the limitations caused by these sources of potential bias, the research team was able to understand and correct for the bias created by selection into the survey by using inverse attrition propensity weighting. This is done by calculating the sample average responses that would have been observed if 100% of device users had responded to the survey.¹⁴

RESEARCH FINDINGS

Overall, the survey showed that rural providers in China are very satisfied with the ECG-sensing smartphones and have experienced a great improvement in the care they are able to provide to CVD patients. The device reduces the cost of conducting ECGs and simultaneously improves the accuracy of results and treatment recommendations via the Life Care Networks Call Center. Patient access to ECGs is increased through the ability to conduct in-home screenings using smartphones. For clinic-based screenings, providers cite a reduction in patient waiting time and increased efficiency of data management.

Findings suggest that from the providers' perspective, increased patient education about the device could improve acceptance and satisfaction among patients, and further system enhancements would increase their own satisfaction with the devices.

Detailed findings are outlined in the following pages.



Respondents are rural providers at private and public clinics

Survey respondents work at a mixture of public (60%) and private (40%) clinics. Most clinics serve small catchment areas of under 1,000 people, and serve fewer than 100 patients per day. Almost half of the respondents are providers, one-third are community health workers that conduct home visits, and the remainder are nurses; most (61%) have worked at the clinic fewer than five years.

The majority of respondents report that 1 in 5 patients at their clinic have issues related to CVD. Around one-third (35%) of providers surveyed report that conventional 12-lead ECGs are still used at their clinic.

Clinic role of survey respondents



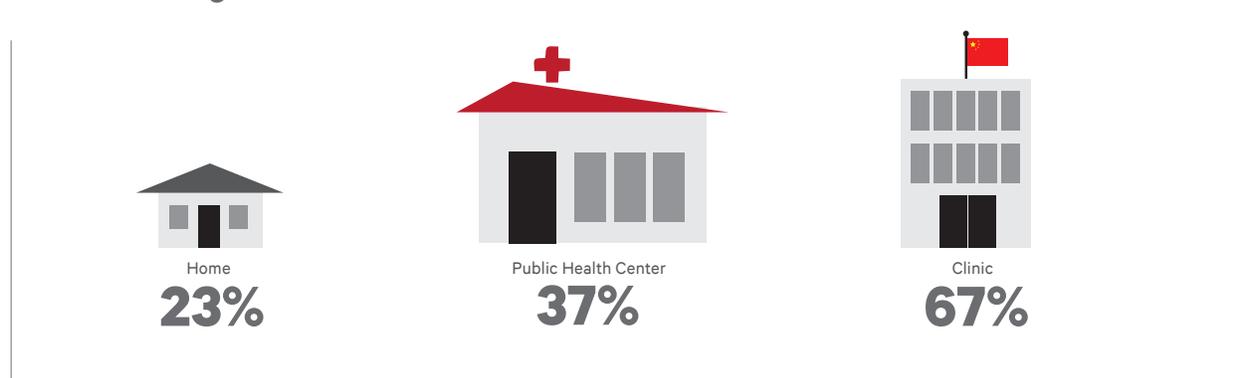
Smartphone-based ECG testing is improving access to CVD care

The ECG-sensing smartphone from Life Care Networks is increasing the volume of ECGs being conducted in rural China. Since 2012, over 525,000 ECG images have been sent over the wireless network using ECG-sensing smartphones, about 160,000 of which were devices covered by the Wireless Heart Health program.¹⁵ Just half of the providers surveyed had used traditional 12-lead machines to administer ECGs prior to obtaining the ECG-sensing smartphone. Therefore, we can conclude that the ECG-sensing smartphones are increasing patient access to CVD testing. In addition, two-thirds (66%) of providers responded that they are able to examine more patients

than before through use of the ECG-sensing smartphone, and 61% report more CVD diagnoses using the device.

The ability to provide ECG screenings to patients confined to their homes offers a great advantage over traditional ECG machines and is opening up access to CVD care for patients who were previously left out. In addition to availability at public health centers (37%) and clinics (67%), almost one-quarter (23%) of surveyed providers reported offering in-home ECG screenings to patients using the ECG-sensing smartphone.

Percentage of surveyed providers who offer smartphone-based ECG screenings at each location



Smartphone-based CVD screening is affordable and sustainable

The survey data shows that the ECG-sensing smartphone significantly reduces ECG screening cost to patients. A majority (75%) of respondents stated that the biggest benefit of the ECG-sensing smartphone is the long-run decrease in cost of CVD diagnosis and monitoring. Based on the survey only, the average cost to patients who receive an ECG using the ECG-sensing smartphone and the Life Care Networks platform is twelve times less expensive than a conventional 12-lead ECG machine (2.84 RMB or \$0.42 USD versus 34 RMB or \$5.20 USD). Yet, 66% of respondents report that ECGs delivered via smartphone are actually provided free due to government and other subsidies. Providers report that hospitals charge an average of 287 RMB or \$44 USD per visit for specialized CVD care, so wireless technologies are further lowering the cost of care by providing the equivalent of specialized care, access to experts in the Life Care Networks Call Center, at the local clinic level for a fraction of the cost.

Survey respondents charge less for smartphone, more for traditional screening



Given the importance of the cost reductions to make the overall case for smartphone-based screening, it is useful to apply attrition propensity weights to the reported costs of ECG screenings and specialized care to estimate what would have been observed if all users from the China Telecom and Heze Peony catchment areas (the only two with Wireless Heart Health users) had responded to the survey.

Attrition Propensity Weights for China Telecom and Heze Peony Catchment Areas

	Unweighted	Weighted
Patients receive traditional 12-lead	35.0%	46.0%
Administered w/12-lead before LK86	50.5%	66.4%
Charge for traditional 12-lead	¥ 34.04	¥ 26.48
Charge for LK86	¥ 2.84	¥ 4.47

The weighted data provides an estimate of the 100%-response answer. The differences illustrate that the survey respondents are less likely to use traditional 12-lead tests. The costs for a traditional test are lower in the weighted data; conversely the smartphone costs more in the weighted data. This indicates that had 100% of the users of these catchment areas responded, the cost advantage of the smartphone would be lower.

Nonetheless, this represents a shift from a 12:1 cost advantage to a 6:1 advantage, which is still a sizeable cost savings. As usage rates in the sample of non-respondents approach those in the survey response sample, it is likely that costs of the wireless tests would decrease. This indicates that the affordability of the smartphone-based ECG screening system relative to traditional methods is robust to survey non-response.

ECG-sensing smartphone is more or equally reliable as 12-lead ECG machine

Providers surveyed believe that the ECG-sensing smartphone is more or equally reliable as the conventional 12-lead machine. Of those who previously used traditional 12-lead ECG machines, 37% said the ECG-sensing smartphone was “much more reliable,” 25% said it was “somewhat more reliable,” 35% said that reliability was “the same,” and 3% said it was “somewhat less” or “much less” reliable. In some complex cases, providers noted that they still used the conventional 12-lead machine to confirm results of ECG-sensing smartphone tests or to offer more comprehensive testing. However, more than one-quarter (26%) of providers also responded that they may use the traditional ECG machines if a patient does not trust the ECG-sensing smartphone. This is a common occurrence when new technology is introduced and presents an opportunity for Life Care Networks to support health care providers in educating patients about the accuracy of the ECG-sensing smartphone.

Life Care Networks’ Call Center improves rural providers’ care for CVD patients

More than half (62%) of providers reported that the Life Care Networks Call Center increased the accuracy of their diagnosis and that call center feedback improved their confidence in providing diagnoses. Overall, providers reported being pleased with the call center services provided as part of the ECG-sensing smartphone package.

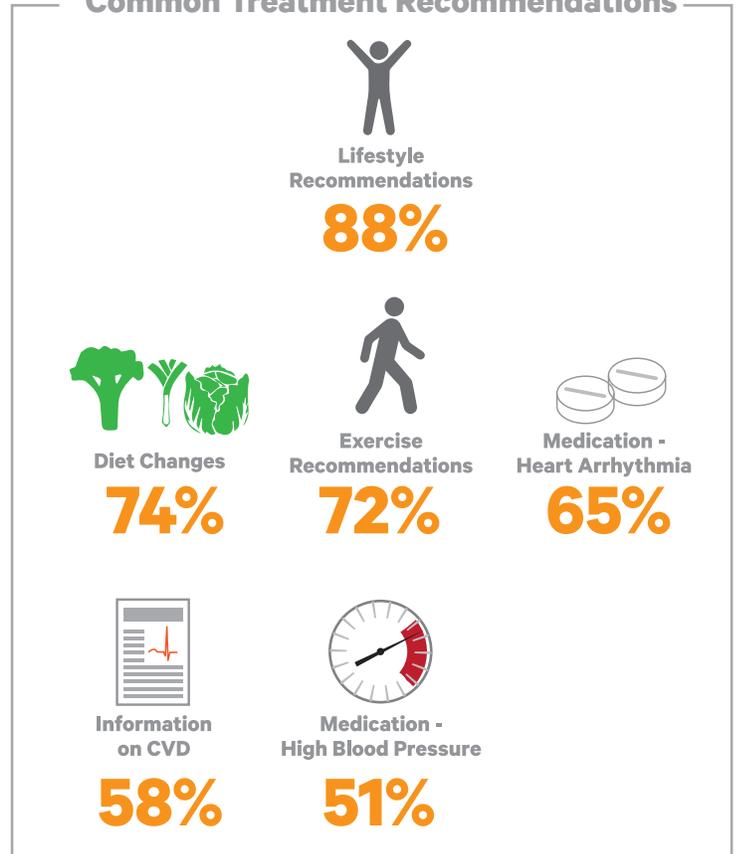
Nearly all (98%) of respondents reported being either “very satisfied” or “somewhat satisfied” with the call center response time. Similarly, 96% were either “very satisfied” or “somewhat satisfied” with the feedback they received from the call center.

Providers have access to treatment recommendations via the Life Care Networks Call Center when they conduct ECGs with the ECG-sensing smartphone, or if they simply would like to consult an expert. The most common information providers reported receiving from the call center were technical readings of the ECG, possible serious diseases, and prevention recommendations.

The most common prevention recommendations for patients with CVD were lifestyle changes, such as stress reduction and smoking cessation (88%), followed by

diet changes (74%), and exercise recommendations (72%). Other common recommendations were related to various CVD-related medications. Only occasionally (17%) had respondents received a recommendation from the call center for an emergency referral.

Common Treatment Recommendations

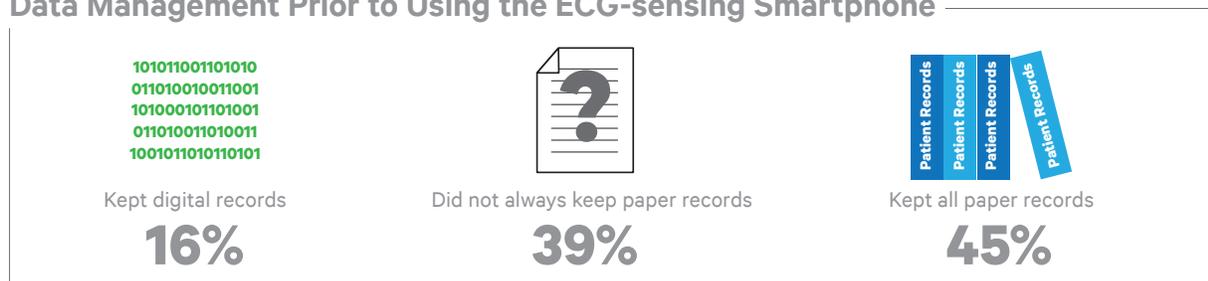


ECG-sensing smartphone improves data management and serves multiple functions

The ECG-sensing smartphone has improved recordkeeping for providers. Prior to obtaining the ECG-sensing smartphone, 45% of respondents reported keeping all paper records, only 15% reported keeping digital records, and 39% said sometimes they did not keep records at all. The majority of respondents (78%) feel that data management has improved since obtaining the ECG-sensing smartphone. Respondents reported this improvement is primarily due to convenience of data collection and storage, ease of use, and ability to track ECG readings over time on the smartphone directly.

Predictably, 88% of respondents confirm using the device for ECG screenings to screen new and monitor existing CVD patients. In addition, more than half of all respondents use the ECG-sensing smartphone to save and review ECG readings, to communicate directly with the Life Care Networks Call Center, and to print out ECG readings. Other uses were to enter patient history and patient insurance information, track CVD symptoms, send data to an electronic health record (EHR), and use other standard smartphone functions such as phone calls, text, and internet.

Data Management Prior to Using the ECG-sensing Smartphone



Satisfaction with the data management functions is high overall – 55% of respondents reported being “somewhat satisfied” and 40% “very satisfied.” Top reasons for being satisfied included ease of operation and the convenience the data management platform provides.

Opportunities for increasing patient education and advancing technology further

Providers report that most patients are happy with the new method of conducting ECG screenings, though many lack full knowledge about the device, and remain more ambivalent toward the new technology than providers. When asked whether patients generally prefer the ECG-sensing smartphone to the traditional ECG machine, 60% said patients like it equally, 24% said patients like it better, and 16% prefer the conventional 12-lead machine. The most commonly cited reasons for patient ambivalence toward the ECG-sensing smartphone is lack of familiarity and lack of trust in the accuracy of results. This is not unusual when new technology is introduced and often user education is the first step to a successful and sustainable technology deployment.

Providers suggested some potential technology advances for the next iteration of the devices, including: adding more sensors for more leads (77%), and improving wireless connectivity (67%). While most providers reported overall satisfaction with the device, the few who reported being dissatisfied noted connectivity issues as a reason. Wireless connectivity in rural areas has greatly improved in the past decade and is expected to continue to improve steadily in the coming years. With better connectivity, even more patients in rural areas with limited access to advanced medical care can have access to CVD screening, diagnosis, and treatment.

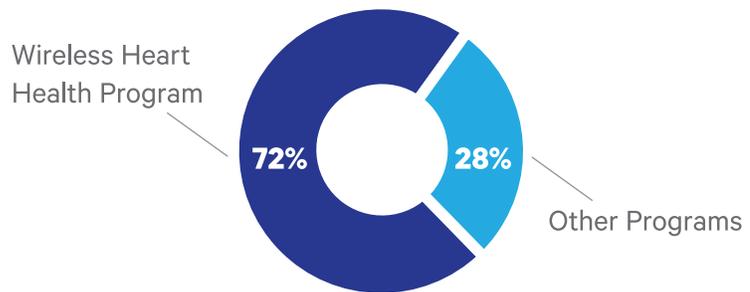


ROBUSTNESS CHECKS

Respondents are more frequent and better users of the devices than other providers

To understand and correct for potential bias in the survey data, researchers compared the population of Wireless Heart Health program devices and users to the total population of Life Care Network's wireless ECG devices and users. The 600 devices covered in the Wireless Heart Health program only make up about 13% of all devices deployed by Life Care Networks' distribution partners – a total of about 4,500 devices. As of fall 2015, these 4,500 devices had been used to conduct over half a million screenings, detecting 121,000 abnormal readings (23%) in patients across the four main catchment areas currently deploying the device.

Images Sent Using Life Care Networks' ECG-sensing Smartphones, by Program



The striking difference between the two catchment areas using devices covered by the Wireless Heart Health program, China Telecom and Heze Peony Public Health Department, and the other catchment areas, is that the Wireless Heart Health program catchments have by far the heaviest users of the devices, collectively accounting for 72% of the total images sent.¹⁶

Furthermore, those who responded to the survey are more active and more effective users of the wireless ECG device than even others in the same catchment areas. This can be seen by comparing device usage data of survey respondents to the overall averages from the two catchment areas to which they belong. The number of images per device is more than three times as high for survey respondents relative to users in the same catchment that did not respond to the survey. This is driven primarily by a large number of devices outside of the survey sample that have not yet sent any images. Additionally, the rate of invalid readings (primarily due to user error) is lower. This can be seen by comparing mean averages for the survey sample to the two catchment areas as a whole.

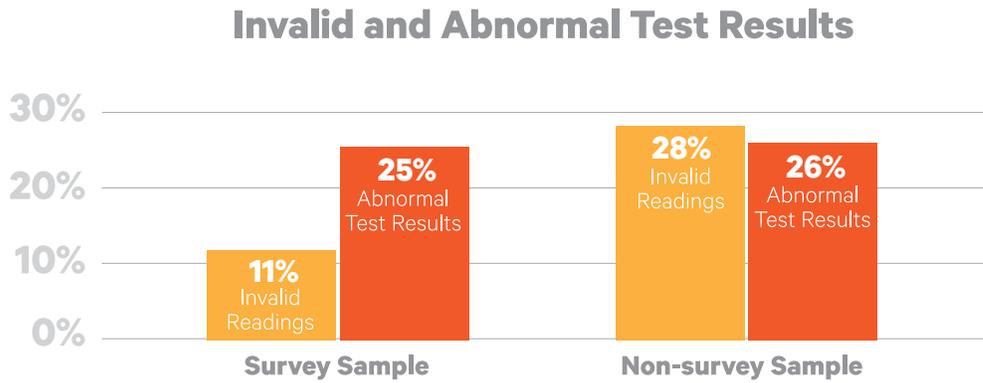
Average Number of Images Sent per ECG-sensing Smartphone in the Wireless Heart Health Catchment Areas

226
Survey Sample

72
Non-survey Sample

Respondents' patients are not systemically different than those of other providers

While the error rate in image readings is much lower for the survey sample than the non-survey sample, there is no evidence that the patient population has a systematically different prevalence rate of abnormal ECG readings, as demonstrated in the charts below.



By conducting these robustness checks it is clear that there is nothing systemically different about the patient population's CVD prevalence that is causing providers in the program to use the device in a different manner than other providers. The difference in use could potentially be a result of the providers' involvement in the program itself. For example, providers in the Wireless Heart Health program may be better trained than those not in the program, or simply motivated to use the devices more frequently in patient care. More research would be needed to further understand if there are any causal mechanisms for this difference.

CONCLUSIONS

Overall, health care provider satisfaction with the ECG-sensing smartphone for conducting ECG screenings is high. Perhaps the clearest benefit of the ECG-sensing smartphone, from the perspective of providers surveyed, is the ability of the technology to dramatically decrease the cost of CVD screening. The cost to patients is one-sixth of what was being charged on average for ECG screening using a conventional 12-lead machine. This is a significant cost savings, particularly in rural areas where the ECG-sensing smartphone is deployed.

In addition, the ECG-sensing smartphone appears to be improving the quality of care and patient accessibility to ECGs. While it is highly unlikely that traditional 12-lead ECGs were conducted at the homes of patients, given the difficulty of transporting such a machine, nearly one-quarter of those surveyed reported conducting in-home ECG screenings using the ECG-sensing smartphone. This allows patients to be screened who are not able to travel to a clinic. The variety of services offered through the call center, including diagnosis and treatment recommendations based on test results, is also an example of the ECG-sensing smartphone improving the quality of patient care.

Providers may not be aware or taking full advantage of the broad range of ECG-sensing smartphone functions, specifically its ability to track and manage a variety of patient data over time. Additionally, patients familiar with the 12-lead ECG machine appear to be skeptical of a new alternative. Health care providers report that some patients still believe the ECG-sensing smartphone may be less accurate than the conventional 12-lead machine. While 65% of providers said that they received training on how to use the ECG-sensing smartphone, increased and improved training to providers on both practical use issues and patient education could improve both the providers' use of the device and patients' acceptance of the new wireless technology.

The survey findings illustrate that the Wireless Heart Health program has been very successful in supporting rural residents, providers, and government agencies addressing the rising health burden of CVD. Simply put, with the ECG-sensing smartphones, costs are decreasing significantly, quality and reach of care is increasing, and satisfaction is high among patients and practitioners.

ACKNOWLEDGEMENTS AND PROGRAM STAKEHOLDERS

Execution, Collaboration and Shared Innovation

In recognition of the overall success of the Wireless Heart Health program, the China Association of Enterprises with Foreign Investment along with the China WTO Tribune named the original pilot project to their 2014 list of Corporate Social Responsibility Outstanding Case Studies by Foreign Enterprises in China. In addition, the original pilot project was recognized as a 2012 Computerworld Honors Laureate in the health category. The program was selected by a panel of twenty-two distinguished judges who evaluated the submissions based on both the humanitarian benefits and the measurable results of applying technology to meet a specific social need.

The success of the Wireless Heart Health Initiative can be attributed to the strength of its partners. Qualcomm Wireless Reach, Life Care Networks, China Telecom, Momentum, and the Community Health Association of China have demonstrated exemplary execution, collaboration, and shared innovation.

Qualcomm believes access to advanced wireless technologies can improve people's lives. Qualcomm® Wireless Reach™ is a strategic initiative that brings wireless technology to underserved communities globally. Wireless Reach invests in programs that foster entrepreneurship, aid in public safety, enhance the delivery of health care, enrich teaching and learning and improve environmental sustainability. Qualcomm believes that "Execution, Collaboration and Shared Innovation" is the foundation of Wireless Reach's success, and is the foundation of Qualcomm's long-term commitment to China.

For more than 20 years, Qualcomm has collaborated with a range of Chinese companies to create new ways to connect people and communities. Qualcomm is proud of the work it has accomplished in tandem with its Chinese partners and looks forward to contributing to China's sustainable development. The company is inspired by the ubiquitous spirit in China that views technological innovation as the key for sustainable progress now and in the future. This spirit resonates with Qualcomm's core company values.

Life Care Networks is a technology pioneer and reformer in remote medical treatment. Established in 2005, the company focuses on researching and developing remote health monitoring and management services built upon the unprecedented advantages of internet and mobile technologies.

For 11 years, Life Care Networks has collaborated with central and local health authorities in China to bring advanced technologies and products to remote Chinese counties and villages, enhance the nation-wide remote ECG monitoring network, and promote the development of public health in China.

China Telecom is a Chinese state-owned telecommunications company and one of the largest mobile communication providers in China. China Telecom provides wireline and mobile telecommunications services, Internet access services, information services and other value-added telecommunications services to Chinese users. For the Wireless Heart Health program, China Telecom has collaborated with Life Care Networks on product marketing and health care provider trainings.

Momentum is a wholly-owned subsidiary of Shaanxi Pharmaceuticals. Established in 1995, Momentum focuses on developing traditional Chinese medicine on pediatrics, cardiovascular and cerebrovascular diseases, orthopedics, gynecology, urology, hepatology, dermatology, and nephrology. For the Wireless Heart Health program, Momentum has collaborated with Life Care Networks on product marketing and health care provider trainings.

Community Health Association of China is a national non-profit organization under the management of the Ministry of Health and Ministry of Civil Affairs. The Association aims to promote the development of community health services and establish a communication platform for community health workers in China. For the Wireless Heart Health program, the Association assisted Life Care Networks in promoting the program among community health centers across multiple provinces and cities.

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- ¹⁴ By combining survey data with Life Care Network's server information on the total population of wireless ECG device users (providers), and using information present for all devices, it is possible to predict the probability that a survey response is received from a given device. The inverse of this probability can then be used as a statistical weight in the analysis of the survey data to correct for survey non-response. The inverse attrition propensity weighting calculation is subject to the assumption that the attrition can be explained by the observable variables at hand.
- ¹⁵ From Life Care Networks' "Remote Cardio Management System" internal operations output.
- ¹⁶ Of the 220 Wireless Heart Health survey respondents, 140 are in the China Telecom catchment area and 75 are in the Heze Peony Public Health Department catchment area.

