Journal of Geriatric Cardiology (2016) 13: 326–332


*Research Article* · Open Access ·

# Attitudes towards acceptance of an innovative home-based and remote sensing rehabilitation protocol among cardiovascular patients in Shantou, China

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**Abstract**

**Background** Cardiac rehabilitation (CR) protocols have diversified to include home-based cardiac tele-rehabilitation (HBCTR) as an alternative to hospital-based or center-based CR. To adopt the use of home-based cardiac tele-rehabilitation, it is necessary to assess cardiac patients' attitudes towards acceptance of such e-health technology, especially in China where knowledge of such technology is deficient. **Methods** Interviews were conducted in the First Affiliated Hospital of Shantou University Medical College, Shantou, China. After percutaneous coronary interventional (PCI) surgery, patients completed the survey. **Results** Among the 150 patients, only 13% had ever heard of HBCTR. After an introduction of our HBCTR program, 60% of patients were willing to participate in the program. From our multivariate analysis of questionnaire data, age (OR: 0.92, 95% CI: 0.86–0.98; $P = 0.007$), average family monthly income (OR: 0.13, 95% CI: 0.05–0.34; $P < 0.001$), education level (OR: 0.24, 95% CI: 0.10–0.59; $P = 0.002$) and physical exercise time (OR: 0.19, 95% CI: 0.06–0.56; $P = 0.003$) were independent predictors for acceptance of HBCTR. From the reasons for participation, patients selected: enhanced safety and independence (28.3%), ability to self-monitor physical conditions daily (25.4%), and having automatic and emergency alert (23.1%). Reasons for refusal were: too cumbersome operation (34.3%) and unnecessary protocol (19.4%). **Conclusions** Most patients lacked knowledge about HBCTR but volunteered to participate after they have learned about the program. Several personal and life-style factors influenced their acceptance of the program. These indicate that both improvement of technology and better understanding of the program will enhance active participation.

*J Geriatr Cardiol* 2016; 13: 326–332. doi:10.11909/j.issn.1671-5411.2016.04.006

**Keywords:** Cardiac rehabilitation; Mobile health; Remote-sensing; Tele-rehabilitation

## 1 Introduction

Cardiovascular disease (CVD) is a major cause for mortality worldwide.[1] Therefore, it is necessary to significantly improve treatment and recovery from CVD. Among different protocols, percutaneous coronary intervention (PCI) has been widely used to treat CVD. After PCI, cardiac rehabilitation (CR) has been recommended as a standard intervention procedure because it decreases the chance of secondary hospital admissions and reduces cardiovascular morbidity and mortality.[2,3] Specifically, cardiac rehabilitation improves functional capacity and quality of life through increased physical activity and secondary prevention education.[4] However, in China, CR is mainly limited to early mobilization and on-site physical exercises, and a very low proportion of patients are eligible for such CR programs. Many cardiac patients cannot attend CR programs for a variety of reasons, including financial difficulties, disease limitations, limited healthcare facilities and transportation.[5] In addition, there are limited insurance reimbursement for CR in China. On the other hand, China is poised to adopt the HBCTR technology as the country is expanding exponentially. For example, China has been leading the world in increasing mobile phone usage. In 2013, 89% of Chinese people own a mobile phone and 66% own a smart phone.[6] Therefore, the more convenient, flexible and reliable remote HBCTR program can be initiated in China.

Home-based cardiac tele-rehabilitation (HBCTR) is an alternative to hospital-based or center-based CR, and is

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**Received:** October 16, 2015 **Revised:** January 18, 2016
**Accepted:** March 15, 2016 **Published online:** April 18, 2016

useful to increase patient participation, especially among older people, disabled people or rural populations.[7] Several studies from Western countries have shown that there was no significant difference in outcomes between HBCTR and hospital-based CR for coronary heart disease patients on quality of life, mortality and morbidity over short durations.[8,9] With advanced telemedicine technology, HBCTR programs can incorporate a wide variety of upgrades, e.g. remote systems (i.e., mobile phones, physiological measurements and internet services) and advanced sensors, to achieve better health outcomes.[10]

Researchers have used modern communication technology to establish a variety of monitoring systems in HBCTR programs and to test their feasibility and adherence in post cardiac surgery patients. To adopt the use of HBCTR, it is necessary to assess patients' attitudes towards acceptance of such HBCTR technology, especially in China where knowledge of such technology is deficient. We have conducted such an investigation and the results are presented.

## 2 Methods

In selection of equipment for our HBCTR program, we have compared the UCARE RG10 system which is available in China, with those from outside (Table 1). As shown in the Table, the system in China has excellent features too. The advantages are that it provides real-time data which are visible to patients in the mobile phone and it provides automatic alarms for abnormal activities. The disadvantage feature is that it uses a chest strap which is a little cumbersome compared to a wrist device. Therefore, the system is useful in China.

**Table 1. Comparison of different sensors for home-based cardiac tele-rehabilitation.**

| Sensors | Company | Functions | Equipment | Advantages and disadvantages |
|---|---|---|---|---|
| UCARE RG | MicroSensor®, China | 1. Real-time ECG signal<br>2. Heart rate<br>3. Energy consumption<br>4. Activity types (walking, running, standing, lying, fallen) | A chest strap and a smart phone | 1.Real time ECG and heart rate monitoring<br>2. Automatically alert when detected abnormal data<br>3. Compatible with most Android phones |
| BioHarness 3 | Zephyr®, USA | 1. Heart Rate<br>2. R-R Interval<br>3. Breathing rate<br>4. Posture<br>5. Activity level<br>6. Peak acceleration<br>7. Speed & Distance | Exercise clothes with sensors | 1. Comprehensive exercise monitoring<br>2. No automatically alert |
| Mio, Heart Rate watch, alpha | Mio®, USA | 1. Average and max HR<br>2. Calories burned<br>3. Total exercise time | Heart Rate watch | 1. Real-time continuous heart rate monitoring without use of chest strap<br>2. Bluetooth® Smart (4.0) technology<br>3. Only compatible with iphone4s/5, Samsung S3/ Note2 |
| Alive Heart and Activity Monitor | Alive Technologies, Australia | 1.ECG<br>2.Heart rate<br>3.Activities<br>4. Body position | Detector with sensors | 1. Real-time continuous data monitoring (ECG, heart rate, activity, body position) |

### 2.1 Recruitment of patients

Patient sample size was determined by power analysis using preliminary data obtained in our study with the following calculation formula: [$n = \frac{Z^2_{\alpha/2}(1-P)}{\varepsilon^2 P}$, $\alpha$ = 0.05 (two-tailed), $P$ = 0.6, $\varepsilon$ = 0.15]. Therefore, a minimum of 114 patients were needed.

This cross-sectional study was designed to assess patients' acceptance of HBCTR. A total of 150 patients aged 40–80 years were recruited from the Department of Cardiology, First Affiliated Hospital of Shantou University Medical College from July 2014 to August 2015. The hospital is the largest comprehensive hospital in our region of 25 million people. Patients with diabetes, malignancy, a history of cerebral-vascular accident, severe liver or kidney damage or cognitive, impairment, aphasia, and mental disorder or inability to inspection and treatment were excluded. And patients with low risk post PCI, live with at least one other person, and able to accept transmission's feedback were included. Based on the above criteria, we recruited patients with PCI from the hospital for our first investigation. In the future, more serious cardiac surgery patients can be included. The study protocol was approved by the First

Affiliated Hospital of Shantou University Medical College (SUMC-36-2014).

### 2.2 Data collection

Our research assistant provided each volunteer patient with an education session about our specific remote sensing HBCTR program and demonstrated how to use the monitoring system. Our HBCTR program included real-time functional monitoring with remote sensor, customized exercise prescription and CVD secondary prevention education materials. The remote monitoring system consisted of a belt strap with a sensor (Ucare RG10, http://www.microsenstech.com), a smartphone with an application, servers and a web portal. The external dimensions of the sensors were 56 × 32 × 16 mm and the weight was 25 g.

Participants wore the sensor and turned on the application on their smart-phone when they started to do exercise training. The sensor would automatically measure and record participants' real-time electrocardiography, maximum and average heart rate, type of activity, energy consumption, activity duration (including the start and end times), walking/jogging speed and the Global Positioning System location. Collected data from each patient were displayed in real-time on the individual's mobile phone and transmitted via the phone into a central server so that the care team professionals were able to review these data remotely and in real time from web portal and could send customized feedback to patients through Short Message Service. The feedback included the week's rehabilitation summary, behavioral change comments, and an updated exercise plan for the subsequent week. The work components in the system are shown in Figure 1.

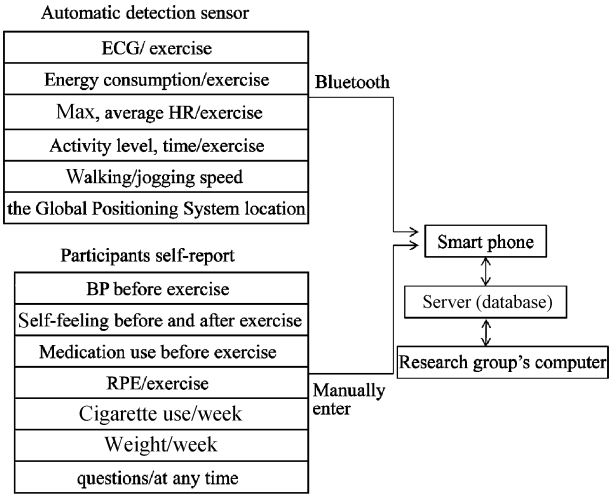


**Figure 1. The work components of our HBCTR system.** BP: blood pressure; HBCTR: home-based cardiac tele-rehabilitation; HR: heart rate; RPE: rating of perceived exertion.

In case a patient experienced physical discomfort during HBCTR program, the patient could make emergency calls by pressing one button on the mobile phone. In addition, the sensor would activate a warning and an emergency call automatically if it detected (1) clinically significant ECG changes; (2) interrupted data connection and collection; (3), heart rate (HR) exceeded normal range; or (4) a patient falls down.

After the education session, patients completed the HBCTR acceptance questionnaire under guidance from the coordinator. The questionnaire including three parts based on the current survey results,[5,11,12] and real situation in Chinese population. Part one is about demographic information including the patient's age, gender, occupation, educational level and living conditions. Part two refers to knowledge of CR. Importance of five basic components of cardiac rehabilitation (risk factors management, diet/nutrition counseling, physical activity counseling, psychological counseling and exercise training guidance) is with five-point scale. The theoretical maximum total score (the highest detected acceptance level) was 25. Therefore, higher score would indicate higher level of acceptance. The third part is about main reasons for participants to accept or refuse HBCTR. Respondents who were willing to participate were labeled "HBCTR-yes"; not willing were labeled "HBCTR-no".

### 2.3 Data analysis

Descriptive statistics were used to test respondents' characteristics and reasons for accepting or rejecting HBCTR. Chi-square tests (two sided) were conducted to test differences between "HBCTR-yes" and "HBCTR-no". Stepwise logistic regression analyses were used to identify variables that predicted willingness to participate in HBCTR. Data were analyzed using SPSS for Windows version 13.0 (SPSS Inc., Chicago, IL, USA). The reliability of the administered questionnaire was estimated by Cronbach's alpha. $P < 0.05$ was considered statistically significant.

## 3 Results

### 3.1 Patient characteristics

Table 2 shows a summary of demographic characteristics of the 150 PCI patients. The mean age of the group was 63.3 ± 9.63 years old, the range was 40 to 80 years, and 77.3% of the patients were men. In total, 89 participants (60%) were identified as HBCTR-yes and 61 (40%) were "HBCTR-no".

According to univariate analyses, elder age, male, higher education level, higher average family income, shorter distance to hospital, higher average exercise time per day,

**Table 2. Patient population baseline characteristics.**

| Variable | Total ($n$ = 150) | HBCTR-yes ($n$ = 89) | HBCTR-no ($n$ = 61) | $P$-value |
|---|---|---|---|---|
| Age, yrs | | | | 0.03 |
| Range, *n* | 40–80 | 44–80 | 40–75 | |
| Mean, *n* | 63.28 | 63.76 | 62.67 | |
| Gender | | | | 0.04 |
| Male | 116 (77.3%) | 74 (83.1%) | 42 (68.9%) | |
| Female | 34 (22.7%) | 15 (16.9%) | 19 (31.1%) | |
| Education level | | | | < 0.001 |
| < Elementary school | 64 (42.7%) | 20 (22.5%) | 44 (72.1%) | |
| Middle school | 48 (32.0%) | 39 (43.8%) | 9 (14.8%) | |
| > High school | 38 (25.3%) | 30( 33.7%) | 8 (13.1%) | |
| Annual family income in Yuan | | | | < 0.001 |
| < 2000 | 45 (29.3%) | 12 (10.1%) | 33 (57.4%) | |
| 2000–3999 | 52 (44.7%) | 40 (56.2%) | 12 (27.9%) | |
| > 4000 | 53 (26.0%) | 37 (33.7%) | 16 (14.7%) | |
| Living place | | | | < 0.001 |
| City | 77 (48.7%) | 70 (78.7%) | 7 (11.5%) | |
| Countryside | 73 (51.3%) | 19 (21.3%) | 54 (88.5%) | |
| Distance to hospital | | | | < 0.001 |
| < 5 km | 47 (31.3%) | 41 (46.1%) | 6 (9.8%) | |
| 5–20 km | 55 (36.7%) | 36 (40.4%) | 19 (31.1%) | |
| > 20 km | 48 (32.0%) | 12 (13.5%) | 36 (59.0%) | |
| Physical exercise time/day | | | | < 0.001 |
| < 30 min | 61 (40.7%) | 20 (22.5%) | 41 (67.2%) | |
| 30–60 min | 54 (36.0%) | 42 (47.2%) | 12 (19.7%) | |
| > 60 min | 35 (23.3%) | 27 (30.3%) | 8 (13.11%) | |
| Self-care ability | | | | 0.36 |
| Completely self-care | 107 (71.3%) | 66 (74.2%) | 41 (67.2%) | |
| Partly self-care | 43 (28.7%) | 23 (25.8%) | 20 (32.8%) | |
| Phone using | | | | < 0.001 |
| Not use the phone | 39 (26.0%) | 13 (14.6%) | 26 (42.6%) | |
| Non-smart phone | 92 (61.3%) | 61 (68.5%) | 31 (50.8%) | 0.001 |
| Smart phone | 19 (12.7%) | 15 (16.9%) | 4 (6.6%) | 0.001 |
| Living condition | | | | 0.18 |
| Living alone | 16 (10.7%) | 12 (13.5%) | 4 (6.6%) | |
| Living with family | 134 (89.3%) | 77 (86.5%) | 57 (93.4%) | |
| PCI surgery times | | | | 0.25 |
| One time | 135 (90.0%) | 78 (87.6%) | 57 (93.4%) | |
| More than one time | 15 (10.0%) | 11 (12.4%) | 4 (6.6%) | |

Data are presented as *n* (%) unless other indicated. HBCTR: home-based cardiac tele-rehabilitation; HBCTR–no: did not accept HBCTR; HBCTR-yes: accept HBCTR; OR: odds ratio; PCI: Percutaneous coronary intervention.

urban living location and having mobile phone usage were associated with participation in HBCTR (all $P < 0.05$).

### 3.2 Determinants of willingness to participate in HBCTR

From multivariate analysis, age (OR: 0.92, 95% CI: 0.86–0.98; $P$ = 0.007), average family monthly income (OR:0.13, 95% CI: 0.05–0.34; $P < 0.001$), education level (OR: 0.24, 95% CI: 0.10–0.59; $P$ = 0.002) and physical exercise time per day (OR: 0.19, 95% CI: 0.06–0.56; $P$ = 0.003) were independent determinants for HBCTR. The results show that average family income per month was the largest contributor to participating in HBCTR, followed by physical exercise time/day, education level and age (Table 3).

**Table 3. Logistic regression analysis predicting Willingness to participate in HBCTR.**

| Predictor | B | SE | Walds $\chi^2$ | $P$ | OR (95% CI) |
|---|---|---|---|---|---|
| Age | –0.09 | 0.03 | 7.34 | 0.007 | 0.92 (0.86–0.98) |
| Average family income per month | –2.08 | 0.51 | 16.41 | < 0.0001 | 0.13 (0.05–0.34) |
| Education level | –1.41 | 0.45 | 9.71 | 0.002 | 0.24 (0.10–0.59) |
| Physical exercise time/day | –1.66 | 0.55 | 8.97 | 0.003 | 0.19 (0.06–0.56) |

HBCTR: home-based cardiac tele-rehabilitation; SE: standard error.

### 3.3 Desire for five basic components of cardiac rehabilitation

Among the patients, only 13% had ever heard of CR. CR programs are a series of secondary prevention interventions including five basic components: physical activity counseling, psychological counseling, diet/nutrition counseling, exercise training and risk factors management. The five components' averages and standard deviation of the five-point scale mean scores were calculated and shown in Figure 2. The mean total score was 14.77 ± 2.59 (theoretical scale from 5 to 25). The risk factors management and diet/nutrition counseling factors received the highest scores of 4.01 ± 1.11, 3.69 ± 1.00 respectively. This was followed by the physical consultation (2.92 ± 1.06) and exercise training

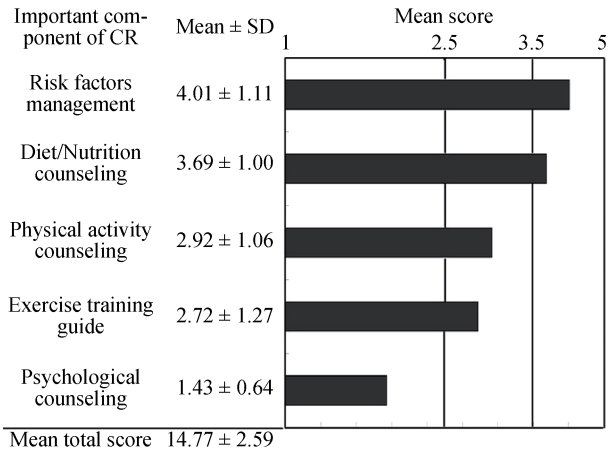


**Figure 2. Desire for five basic components of CR.** CR: cardiac rehabilitation.

guidance (2.72 ± 1.27) factors. The patient counseling factor received the lowest score of 1.43 ± 0.64 points.

### 3.4 Reason for accepting HBCTR or rejecting HBCTR

Of 89 (59.3%) patients who had accepted to participate in HBCTR, 49 (28.3%) declared that making life more safe and independent was the main reason for them to join HBCTR, and 44 (25.4%) stated that they could use the technology to monitor self physical condition. Forty (16.8%) believed that HBCTR could make life (exercise) more secure, 29 (16.8%) believed that automatic emergency alert was an effective method of supervision, and 11 (6.4%) believed that HBCTR could provide assurance to family members (Table 4).

**Table 4. Reason for accepting or rejecting HBCTR.**

| Reason | Frequency |
|---|---|
| Reason for accepting HBCTR | |
| Making life safer and independent | 49 (28.3%) |
| Being able to self-monitor Physical conditions daily | 44 (25.4%) |
| Making emergency alert automatically | 40 (23.1%) |
| Having regular professional rehabilitation | 29 (16.8%) |
| Assurance to family members | 11 (6.4%) |
| Reason for rejecting HBCTR | |
| Cumbersome operation | 37 (34.3%) |
| Unnecessary cardiac rehabilitation procedure | 21 (19.4%) |
| Unreliable technology | 18 (16.7%) |
| Inaccurate monitoring information | 14 (13.0%) |
| Needing specialized coaching | 10 (9.3%) |
| Concerns for safety | 5 (4.6%) |
| Breach of privacy | 3 (2.8%) |

Data are presented as *n* (%). HBCTR: home-based cardiac tele-rehabilitation.

Of 61 (40.7%) patients who had refused to participate in HBCTR, 37 (34.3%) declared that cumbersome operation was the main concerns for not joining and 21 (19.4%) stated that they did not need cardiac rehabilitation. Eighteen (16.7%) reported that they thought this technology was unreliable and 14 (13.0%) stated that monitoring information was inaccurate. Due to personalize coaching, ten (9.3%) stated that HBCTR did not matter to them. Five (4.6%) expressed uncertainties about the safety of HBCTR and three (2.8%) worried about lost of privacy (Table 4).

### 3.5 Questionnaire reliability

Cronbach's alpha analysis was performed using data from the questionnaires. The value was found to be 0.83 which indicate good internal consistency and reliability.

## 4 Discussion

CR is an essential component of secondary prevention of CVD and post PCI health care. Therefore, HBCTR programs which have not been readily adopted in China should be of enormous value to Chinese cardiovascular patients. Although there are surveys on patients' attitudes towards tele-health programs, to our knowledge, our investigation is the first HBCTR attitude survey in China to assess post-PCI patients' willingness to participate in remote sensing HBCTR program and identify factors that could affect their attitude towards the program. Furthermore, the proposed system allows a multidisciplinary team to extend rehabilitation service to patients at home by using mobile technology. Specific benefits are (1) the hospital-based or center-based rehabilitation team can remotely monitor multiple patients' key health indicators at the same time; (2) clinicians can provide timely customized feedback to patients; and (3) patients might be highly motivated and confident to conduct self-improvement activities.

Knowledge about CR programs among our patients was grossly deficient because only 13% of them were aware of such programs. For the five basic components of cardiac rehabilitation, patients indicated that risk factors management and diet/nutrition counseling were the most desirable features. Although physical exercise is the core component which can generate great benefits in CR, the low scores for physical consultation and exercise training guidance indicated that these two features were not considered as important by our patients. The patient psychological counseling factor received the lowest score of 1.43 ± 0.64 points, which is less than 2.5, indicating that patients view psychological counseling as the least significant factors. Furthermore, the mean total score was 14.77 ± 2.59 (theoretical scale from 5 to 25) which indicates that our patients did not think cardiac rehabilitation was significant. Although they did not know much about HBCTR, they were enthusiastic about the technologically advanced program after they had a learning session of the program. They were positive towards the HBCTR program. This is encouraging and is indicative that patients were willing and could be trained to utilize the high HBCTR technology. Consequently, their acceptance of physical exercise and psychological counseling will improve.

Our data show that elder age, higher educational level, higher average family income and higher average exercise time were independent determinants for acceptance of HBCTR. Similar to findings in other studies which used hospital-based CR,[13–16] patients with higher income and education were more likely to participate.

It was a surprise to learn that patients who lived further away were less likely to accept our program. Our patients who live far away and in rural areas have lower educational level and income. Therefore, as indicated by our data, these characteristics lowered their willingness to accept the program. Another possibility is that they were worry that our device would reveal complications which would cause them to return to the hospital. Therefore, we need to provide better explanations. Nevertheless, in our follow-up study with patients who actually used the system, we had several far away patients. One of them lived on an island which could only be accessed via a 1-hour boat ride and then bus rides.

In our investigation, we found significant difference between men and women in acceptance of HBCTR which is in accordance with previous study.[17,18] Despite its proven benefits and need in the elderly,[19] previous research had established that older patients were significantly less likely to participate in hospital-based CR programs for the following barriers: lack of an accurate understanding about CR, perception of exercise as tiring or painful, lack of physician encouragement, perceptions that other patients do not attend CR, had a low level of exercise capacity and a high level of co-morbidity, and perception that CR will not improve their health and their ability to self-manage disease.[20,21] We show that our remote sensing home-based CR program can be used as an alternative program for elderly patients and can improve CR attendance rate.[22] The application of in-home technology may have enormous potential in prolonging older adults' ability to remain safe and independent in their homes. In accordance with a previous study,[23] older patients wanted more information on disease management and prevention than younger and employed patients. In addition, patients who exercised more than 30 minutes each day had higher perception than those who exercised less than 30 minutes.

In our study, the most motivating factors which attracted patients to HBCTR were: improvement of safety in life (exercise) and independence, self-monitoring of physical conditions daily and having emergency alert automatically. These features indicate that patients were enthusiastic about the technologically advanced HBCTR and were proactive about their recovery. The main unfavorable reasons were: operation was too cumbersome, and cardiac rehabilitation was not necessary, unreliable technology, inaccurate monitoring data and fear for breach of personal privacy. Our discovery of unfavorable reasons provides excellent opportunity to enhance acceptance of HBCTR. Such enhancement may include improving its user-friendliness, providing more knowledge about its safety and usefulness, and improving confidentiality in data transmission and handling.

For most cardiovascular patients in China, they receive limited medical follow-up and almost no rehabilitation services. Therefore, the introduction of remote sensing HBCTR represents a great opportunity for both government and patients to leverage emerging technologies for cost effectiveness and for significantly improved recovery. The results may provide guidance on how remote sensing HBCTR program should be designed and deployed in China. Since China is facing challenge in implementing CR programs including low program participation, low doctor-patient ratio and high financial burden, remote sensing HBCTR program which utilizes home-based and self-administered protocols can be of wide-spread use and for a variety of medical services in China. Successful deployment of this technology among Chinese patients will allow more international collaborations in this growing and meaningful application.

Our study has several limitations. First, our study only considered a sample from one comprehensive hospital in one geographical location. Thus, we may not be able to generalize our results to those living in other regions of China. Second, we had a relatively small study population and had more males than females. However, we have expanded our study to include patients who actually used the HBCTR system. The results which will be submitted for future publications have been encouraging. Third, we did not assess knowledge and attitudes of physicians towards HBCTR in physicians therefore they may not be highly supportive of the program. However, in our follow-up study with patients actually using the system, we found most physicians to be supportive. Fourth, it would be too expensive and challenging for patients in China to accept the system. In our follow-up study, we provided reusable and shared equipment to patients therefore we did not charge patients. Consequently, we have been highly successful in the recruitment of patients who actually used the HBCTR system. Despite their limited technical expertise and residence in remote locations, we have encountered little problem. In the future, the cost for the system will come down due to reduced cost for manufacturing of equipment. More importantly, we need to provide evidence of success to convince insurance companies to cover the cost.

## Acknowledgements

The authors thank the past and present members of the continuing cardiac care team for support and assistance throughout the duration of this study. This work was supported by the Shantou University Medical College; the MITCS Globalink Research Award [IT03822] and David

Johnston International Experience Awards. The investigation is an academic program for the co-authors and none of them have any conflict of interest. In addition, the equipment was purchased from manufacturers which provided guarantee to the products. The manufacturers, however, did not have any contract with the investigators regarding the design of the study and the interpretation of the results.

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