

iCONCEPTS

CONCEPTS ON THE VERGE OF TRANSLATION

Robot-Assisted Remote Echocardiographic Examination and Teleconsultation

A Randomized Comparison of Time to Diagnosis With Standard of Care Referral Approach

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ABSTRACT

The strategy using cardiological consultation in addition to the robot-assisted remote echocardiography at a distance was tested in a prospective, randomized open-label trial to evaluate its feasibility and to define its clinical value in a rural area. The present study involved 1 primary healthcare center in the north of Sweden, 135 miles from the hospital where the echocardiograms and the cardiology teleconsultation were performed long distance in real time. Nineteen patients were randomized to remote consultation and imaging, and 19 to the standard of care consultation. The total process time was significantly reduced in the former arm (median 114 days vs. 26.5 days; $p < 0.001$). The time from randomization until attaining a specialist consultation was also significantly reduced ($p < 0.001$). The patients' satisfaction was reassuring; they considered that the remote consultation strategy offered an increased rapidity of diagnosis and the likelihood of receiving faster management compared with the standard of care at the primary healthcare center. (J Am Coll Cardiol Img 2014;7:799-803) © 2014 by the American College of Cardiology Foundation.

The demographic profile in most Western countries is changing, with an increasing number of elderly people and increased requirement for advanced diagnostic and management facilities. Primary healthcare centers (PHCs) and smaller hospitals usually lack such facilities and do not always provide the specialized services. In addition, the expensive transport costs from sparsely populated areas at long distances remain prohibitive for transfer of the sick to the advanced care centers. The wide availability of the information technology and wireless transmission has allowed development

of electronic health (eHealth) solutions to overcome these shortcomings not only in developed nations but also in low- and middle-income countries. The

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use of numerous diagnostic modalities at a distance (e.g., ultrasound, long-distance video-assisted consultations, management support systems [remotely guided intensive care units]) is being evaluated for superior healthcare delivery.

To determine the feasibility of providing cardiology consultation with robot-assisted remote

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Manuscript received February 5, 2014; revised manuscript received May 5, 2014, accepted May 5, 2014.

ABBREVIATIONS AND ACRONYMS

CRF = case report form

GP = general practitioner

HF = heart failure

PHC = primary healthcare
center

echocardiography at a distance (CARDIA concept) in a rural county of northern Sweden, a pilot project was developed during 2010 to 2013 (Fig. 1). The goal was to establish a safe and efficient eHealth solution for communication and examination to improve the quality of life in heart failure (HF) enrollees. This initiative enabled: 1) long-distance, real-time, robot-assisted echocardiography; and 2) cardiology teleconsultation for a rural PHC as reported earlier (1). In this study, the sonographer estimated that in most cases, the image quality was satisfactory to be used for clinical purposes. As a logical translational next step, a prospective randomized study was undertaken to define the clinical value of remote consultation and echocardiographic examination, and to establish the feasibility of providing an early definitive diagnosis and treatment.

The primary aim of the present study was to test whether the time to diagnosis could be shortened by at least 1 month with the inclusion of the remote echocardiography and cardiology teleconsultation at the PHC compared with the standard of care consultation approach wherein the patient needed to visit the secondary/tertiary care hospital. A secondary aim was to compare the patient experience and satisfaction for receiving remote consultation with remote echocardiographic examination versus the standard of care referral for cardiology consultation. This prospective, randomized study was undertaken in patients suspected of HF at the Storuman PHC in the rural north area of Sweden. Storuman is 135 miles from the Skellefteå county hospital. The remote echocardiographic examination was conducted from Skellefteå, and cardiology teleconsultation was offered on the same day (Fig. 1, Online Video 1).

The remote consultation arm included the following steps. First, the patient was examined by 1 of 3 general practitioners (GPs) at the Storuman PHC, and the case report form (CRF), including medical history, clinical findings, list of medications, and an electrocardiogram (ECG), was electronically transmitted to the consultant cardiologist in Skellefteå. Second, a spot for the remote-controlled robotic arm echocardiogram at the Skellefteå county hospital was reserved once every 2 weeks when a trained sonographer performed the echocardiogram on the patient situated at the Storuman PHC. Third, after the remote echocardiographic examination, teleconsultation by the cardiologist (and sonographer) in the Skellefteå county hospital was performed with the patient in the presence of the GP at the Storuman PHC. During this bidirectional communication, the

cardiologist could elicit additional information from the GP and the sonographer, and the patient could ask questions. The primary diagnosis and differential diagnosis were discussed, and further investigations as well as the management strategy were outlined.

The remote consultation arm was compared with the traditional standard of care referral approach at the secondary/tertiary care hospital for the cardiology consultation. After the first visit to the PHC, patients were referred to the nearest specialty hospital in the city of Lycksele (65 miles away).

We established the measurable time points for each approach (Table 1) that included initial patient visit at the PHC, referral after randomization, securing the appointment, ultrasound examination, cardiology consultation, and when the consultation and plan of care were accomplished. In addition, all patients completed a questionnaire comprising 15 pre-specified qualitative questions with a variable number of alternatives and added narrative as appropriate. The study design and the use of comparative strategies were approved by the ethics committee and the institutional review board of the Umeå University (Dnr 09-036M), and verbal and written consent were obtained from each patient before enrollment.

Those patients with symptoms or signs suggestive of HF were enrolled who, in the opinion of the GP, needed a cardiology consultation with an echocardiographic evaluation. Refusal to participate in the study was the only exclusion criterion. After informed consent was provided, a CRF was completed for each patient. The total time to diagnosis was measured in all cases from the initial patient encounter at the PHC to the final consultation when the CRF was signed off by the GP after teleconsultation or after the in-person consultation and echocardiographic examination.

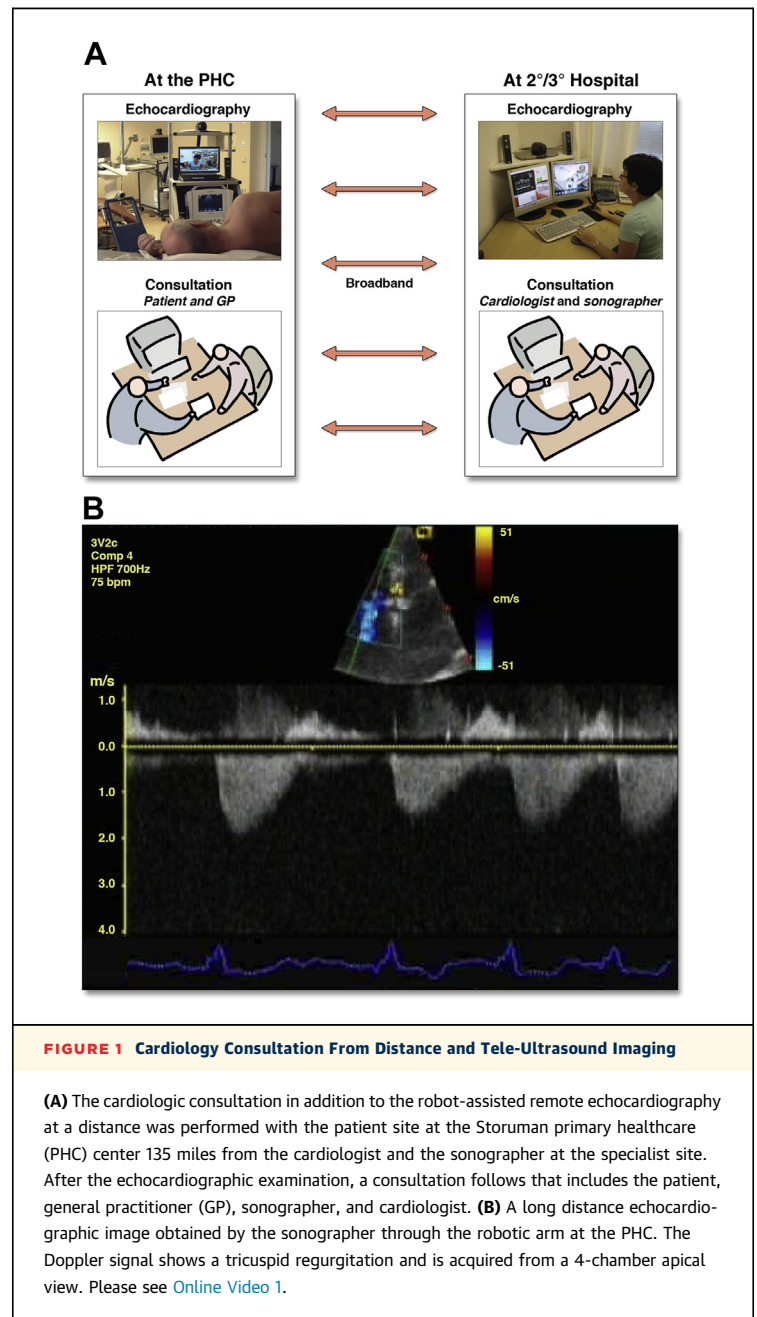
Continuous data are expressed as mean \pm SD and categorical variables as proportions. Non-normally distributed data are calculated as medians, with quartiles and minimum and maximum times given. Normally distributed values were analyzed with the Student *t* test, and the chi-square test with the Fisher exact test was used for categorical data. Differences in the process times between the 2 groups at various landmark events were tested using a nonparametric method (Mann-Whitney *U* test); *p* values <0.05 were considered statistically significant. A power calculation was performed as described below. The usual wait time for a routine cardiology consultation at Lycksele hospital from the Storuman PHC was estimated to be 3 months, and we hypothesized that the long-distance remote echocardiographic and teleconsultation strategy had the potential to reduce

the total process time by at least 1 month. With this presumption, 20 patients in each arm were calculated to be sufficient for concluding the study with a power of 90% and a p value <0.05 , allowing for the risk of withdrawals and discontinuation. Statistical calculations were performed with PASW Statistics version 18 (IBM SPSS Statistics, IBM Corporation, Armonk, New York).

Of the 40 patients eligible for enrollment, 38 were randomized to the present study; 1 patient refused to participate and 1 patient denied randomization to the standard of care referral group which is why he could not be randomized in the study. Baseline characteristics of the 38 patients are presented in [Table 2](#). There were 23 female subjects and 15 male subjects; their mean age was 69.6 years. There were significantly more female subjects in the remote consultation arm, and patients were more symptomatic compared with the standard of care group. The total process time was significantly reduced in the remote consultation arm (median 27 days vs. 114 days; $p < 0.001$) ([Table 3](#)). The time from randomization until attaining a specialist consultation was also significantly reduced in the remote consultation arm (median 12 days vs. 86 days; $p < 0.001$). There were no significant differences between the 2 groups for the time from initial clinical examination to randomization. Of the 19 patients in the remote consultation arm, 17 (89%) responded favorably to the new way of examination and found the experience of robotic echocardiography comparable to standard ultrasound examination. However, 2 patients found the remote ultrasound examination uncomfortable but did not find it frightening. All patients in the remote consultation arm were satisfied with the information provided, and 95% claimed that they believed that they had received faster care compared with the traditional care. They believed that the remote consultation was a superior strategy for expediting their medical care. The perceived superiority was based on: 1) obviating the need to travel; 2) rapidity of diagnosis; and 3) the likelihood of receiving faster treatment. Eight (42%) of 19 patients in the remote consultation arm had earlier been examined in the traditional manner; 6 (75%) of 8 patients preferred remote consultation, 1 found it similar, and 1 preferred the traditional referral approach.

DISCUSSION

The present study demonstrated a substantial reduction in the time to delivery of care in the remote consultation arm, including the possibility of a rapid specialized consultation for HF patients in a remote rural region where advanced medical facilities are



not available. In the traditional care arm, the median diagnostic process time was 114 days, which was similar to the usual wait time reported for PHC specialty consultations in the entire country. In the power calculation, we estimated that the remote consultation had the potential to reduce the process time by at least 1 month. The time to diagnosis varied widely in both arms and was highest for the standard of care arm (212 days) compared with the remote consultation arm (169 days). There were a

TABLE 1 Record and Time of Landmark Events in CRF

	Standard of Care Strategy	At-Distance Consultation and Echocardiographic Strategy
Initial patient visit at PHC	Patient examination by the GP; the GP decides to refer for specialist consultation	Patient examination by the GP; the GP decides to refer for specialist consultation
Referral after randomization	Lycksele hospital approached for cardiologist consultation and echocardiography	Skellefteå Hospital appointment secured for remote echocardiography and cardiology consultation*
Appointment secured	Patients scheduled for visit to the Lycksele hospital cardiologist consultation	
Ultrasound examination and cardiology consultation	Echocardiogram and cardiology consultation at the Lycksele hospital	Same-day remote echocardiography examination followed by cardiology consultation in the presence of the GP, patient, and sonographer. CRF signed off by the GP at the PHC with complete decision and plan of management*
Consultation and echocardiography report available to GP	Consultation and echocardiographic results sent back to the GP	
Plan of care completed	CRF signed off by the GP at the PHC with complete decision and plan of management	

*Events of substantial time-saving.
CRF = case report form; GP = general practitioner; PHC = primary healthcare center.

number of factors that influenced the length of the diagnostic process in the remote consultation arm, and suggest that patient care can be further accelerated. For example, the PHC was offered a consultation and remote echocardiography time slot only once every 2 weeks, and the remote encounter varied from 0 to 106 days after randomization. It is conceivable that a more liberal availability of such a facility may further reduce the diagnostic process time drastically. Most importantly, the remote consultation brought the GP, cardiologist, and sonographer together as they all shared the information at the same time with the patient in videoconferencing. Questions could be asked by the patient and clarifications sought, similar to the standard of care approach. Importantly, the remote consultation markedly abbreviated the healthcare

delivery process and also offered an important clinical education opportunity for the GP.

Almost all patients were satisfied with the remote consultation, including information offered and their expectations fulfilled regarding an appropriate diagnosis and treatment. In fact, most of the patients who had received the standard of care earlier and happened to be randomized to the remote consultation arm during the present study preferred the teleconsultation. The main reasons for such a preference included the expedited care and being able to avoid travel to the secondary or tertiary care facility. For such patients, a consultation in the traditional manner was at least a 100-mile trip, which may not be easy for patients with HF.

Interest has been growing in the use of telemedicine (2). Numerous different modalities for telemedicine, such as store-and-forward and real-time videoconferencing, have been reported. A digital echocardiogram (often several single cardiac cycle loops) can be stored at 1 site and forwarded across a telemedicine network to a receiving station for subsequent review. Promising clinical results have been published for pediatric cardiology in rural areas with real-time videoconferencing using a face-to-face interaction between the medical specialist and the patient. In PHCs and smaller hospitals in rural areas, there is a paucity of trained personnel for echocardiographic examination. The present study indicates that not only can remote consultation be useful in developed nations, but it may be equally feasible in underprivileged countries. These study patients were comparatively more satisfied and acknowledged that they preferred consultation at their own healthcare center. We must emphasize that the goal of remote consultation is not to replace echocardiographic examinations for more complicated clinical

TABLE 2 Baseline Characteristics

	All Patients (N = 38)	Remote Consultation (n = 19)	Standard of Care Referral (n = 19)	p Value
Female	23 (61)	15 (79)	8 (42)	0.02
Male	15 (39)	4 (21)	11 (58)	0.02
Age, yrs	69.6 ± 11.6	70.7 ± 10.6	68.4 ± 11.6	0.48
BSA, m ²	1.85 ± 0.19	1.83 ± 0.21	1.89 ± 0.16	0.40
Hypertension	14 (37)	5 (26)	9 (47)	0.31
CAD	16 (42)	9 (47)	7 (37)	0.74
Valvular heart disease	3 (8)	2 (11)	1 (5)	1.00
Dyspnea	20 (53)	13 (68)	7 (37)	0.05
Fatigue	14 (37)	13 (68)	1 (5)	<0.001
Edema	14 (37)	11 (58)	3 (16)	0.007
Systolic BP, mm Hg	148 ± 20	150 ± 18	147 ± 23	0.62
Diastolic BP, mm Hg	81 ± 10	83 ± 8	79 ± 12	0.32

Values are n (%) or mean ± SD.
BP = blood pressure; BSA = body surface area; CAD = coronary artery disease.

TABLE 3 Time to Landmark Events

	Remote Consultation			Standard of Care Referral			p Value
	Median (Q1-Q3)	Minimum	Maximum	Median (Q1-Q3)	Minimum	Maximum	
Total process time, days*	27 (12-60)	1	169	114 (75-140)	7	212	<0.001
Randomization to echocardiography, days	12 (7-29)	0	106	86 (66-117)	30	208	<0.001
Baseline examination to randomization, days	0 (0-13)	0	37	0 (0-0)	0	89	0.45
Clinical examination to the report of consultation, days	0 (0-0)	0	0	0 (0-1)	0	4	NA
Clinical examination to GP signs off the result, days	5 (0-19)	0	79	6 (4-25)	0	103	0.35

*Time from the initial patient examination until the final consultation was signed off in the case report form by the general practitioner (GP).

NA = not applicable; Q1-Q3 = quartile 1 to quartile 3.

situations; it is meant to facilitate healthcare delivery at the PHC. Although we learned that we can substantially reduce consultation time, the logical next step is to evaluate whether the diagnostic process abbreviation would translate into improved clinical outcomes.

CONCLUSIONS

Although this is a small study conducted at 1 rural healthcare center in northern Sweden, PHCs in most nations usually share common problems, including lack of modern facilities and increasing age of population with a rising number of comorbidities

and a suboptimal transport support system for the sick. With real-time echocardiography followed by cardiologic consultation at a distance, the total diagnostic process time could be substantially reduced. Patient satisfaction with such an option has been reassuring, enabling patients to have easier access to echocardiography and specialist consultations within the precincts of a PHC.

REPRINT REQUESTS AND CORRESPONDENCE:

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KEY WORDS real-time, remote consultation, remote-echocardiography, robot-assisted, telemedicine

APPENDIX For a supplemental video and legend, please see the online version of this article.