Infrastructure and Procedure for Simulation of Cardiac Remote Monitoring: Experiences from the Telemedicine Agder Project

B.F. Smaradottir[1,2], **C.E. Moe**[3] **and R.W. Fensli**[1],
[1]Department of Information and Communication Technology, University of Agder, Grimstad, Norway
[2]Clinical Research Department, Sørlandet Hospital HF, Kristiansand, Norway
[3]Department of Information Systems, University of Agder, Kristiansand, Norway

Abstract - *Telemedicine are remote electronic clinical consultations using technology for delivery of health care services. Telemedicine can be offered as a service to citizens living at home with an aim of reducing the number of hospital visits or visits to the General Practitioner and improving long-term cost-effectiveness. In Norway, a recent health reform has caused municipalities to re-organize their design of health services, with an increased use of telemedicine. In this context, the "Telemedicine Agder" project focuses on the organization, implementation and operation of large scale telemedicine services. In the project, a simulation of a telemedicine service for monitoring of heart failure was made in a clinical laboratory together with a patient, nurses and physicians. In addition, there were technical professionals and a research team present. This paper presents the laboratory infrastructure for the simulation and experiences are shared from the research project.*

Keywords: Laboratory Infrastructure, Telemedicine, Simulation, Heart Failure

1 Introduction

Telemedicine can be defined as remote electronic clinical consultations using technology for the delivery of health care and the exchange of information across distance [1]. Telemedicine technology covers a diverse spectrum of applications, aiming to improve the equity of access to and the quality of health care services [2][3][4]. Telemedicine also aims to reduce the number of hospital visits and improve long-term cost-effectiveness of the health care budget [1]. In Norway, a health reform was adopted in 2012 targeting the care delivery and focusing on collaboration and the continuity of care [5]. The reform lead to municipalities starting to re-organize their service design of the health services, with an increased use of telemedicine to carry out care by distance. When modelling a new service design, there is a need to test and evaluate the technical solutions and service models. User-based simulation in a clinical laboratory provides a controlled environment for evaluation of technology and workflow interactions [6].

In this context, the research project *Telemedicine Agder* aims to evaluate service models and large-scale implementation of telemedicine technology [7]. The project is 3-year long (2016-2019) and includes three Norwegian municipalities, one hospital, two industry partners and one research institution. In an earlier project phase, simulation of diabetes remote monitoring was made [8]. In a following phase, the service design and the technical solution for telemedicine monitoring of heart failure patients was run as a simulation in a clinical laboratory together with the project participants. Based on the cardiac simulation experiences, this paper presents the technical and physical infrastructure of the clinical laboratory and lessons learned by the research team. The following two research questions (RQs) were addressed:

RQ1: What technical and physical infrastructure is suitable for simulation of cardiac telemedicine monitoring?

RQ2: What are the lessons learned from simulation of cardiac telemedicine monitoring that are transferable to other contexts?

After this introduction, the telemedicine technology is presented. In the next section, the simulation procedure and the technical and physical infrastructure for the clinical laboratory is described. The discussion reflects on lessons learned from carrying out the simulation. Finally, conclusions are drawn on the project contributions.

2 The technology

The telemedicine technology for remote monitoring was developed by the Danish vendor Open TeleHealth [9] and delivered by Siemens Healthineers [10] for implementation in Norway. The telemedicine technology consisted of a patient tablet with a remote monitoring application and an information and management system for remote follow-up by telemedicine nurses.

When a patient with heart failure is included to telemedicine monitoring at the municipal telemedicine center, (s)he receives a case containing the technical equipment and instructions. The patient has to log in to the tablet at home, see Figure 1.

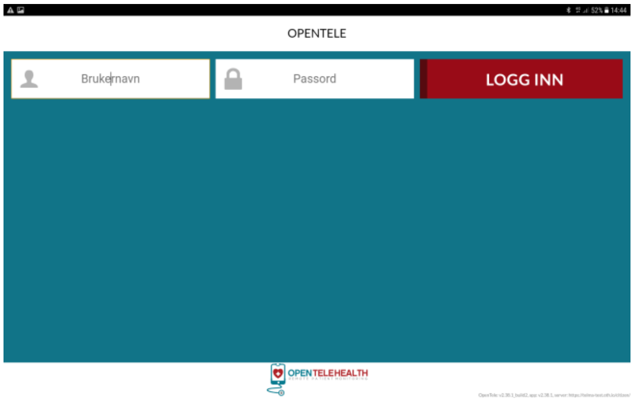

Figure 1. The log in screen for the tablet application.

The tablet is used for answering a symptom-specific questionnaire for heart failure and for sending physiological measurements to a server. The home screen also has a few administrative functions and overview of earlier measurements, see Figure 2.

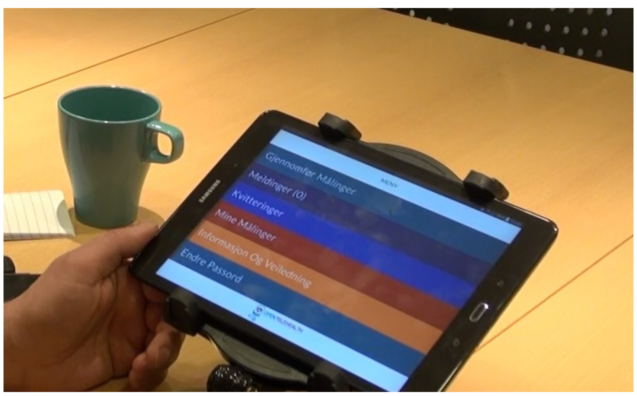

Figure 2. The tablet on a stand, showing the home screen.

The nurses at the telemedicine center accessed the measurements and questionnaire details through a specific information and management system for telemedicine, see Figure 3. The system had a video-consultation function.

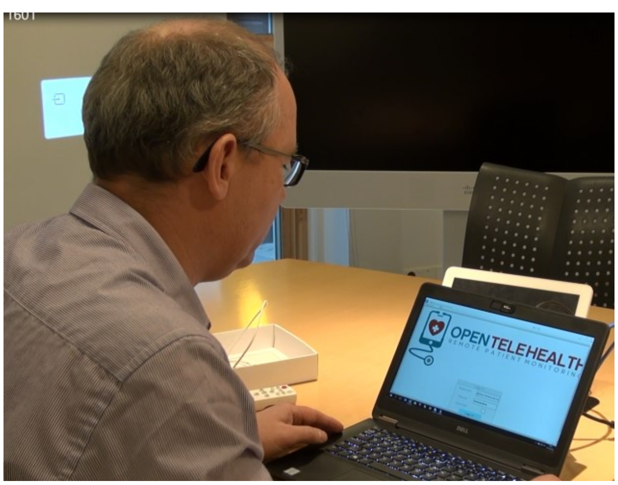

Figure 3. A nurse logging into the information and management system.

The system has an automated health assessment function with color-coded icons to show the severity of the patient's measurements and questionnaire answers. With a red alert, an immediate follow-up has to be made. There is a feedback function where the nurse can send an individual message to the patient's tablet.

3 The simulation infrastructure

A simulation with a task-based scenario for telemedicine monitoring of heart failure was made in the Clinical Laboratory at the University of Agder in Norway during April 2018. The simulation was organized and led by a research team consisting of three people with a health informatics background. Ten people from the *Telemedicine Agder* project's partners participated in the simulation.

3.1 Simulation scenarios

The test scenario targeted telemedicine monitoring situations for a heart failure patient. Before start, a 15 minutes long introduction was made of tasks and roles. Two different scenarios were carried out as a role-play in the clinical laboratory facilities. In the first scenario, a patient was included to telemedicine monitoring after a recent heart attack. He received the technical equipment and was instructed on the log in procedure by a technical instructor. The telemedicine center made a "first time" video-consultation for registrations of the cardiac status, for setting personal goals and for individual user training on the tablet. As a next step the patient made measurements of blood pressure, weight and pulse oximetry with Bluetooth transmission to the tablet and filled in a self-evaluation questionnaire on heart symptoms that was sent to the telemedicine center. The nurse at the telemedicine center evaluated the measurements and questionnaire answers and made an ordinary daily follow-up video-consultation. In the second scenario, the patient was elderly with hypertension, diabetes, obesity and heart failure. The remote measurements and questionnaire answers showed a worsening condition. The telemedicine nurse made a follow-up video-consultation based on a clinical worsening condition, also conferring with the patient's General Practitioner (GP) by phone for medical advices in the scenario.

3.2 The physical infrastructure

The simulations were performed in a clinical laboratory environment that had two separate test rooms and one control- and observation room. The physical infrastructure for the simulations is illustrated in Figure 4. Test room 1 represented the patient's home and Test room 2 the telemedicine center. In each test room, there was a separate recording camera source. In the observation room, the simulation was followed simultaneously on 4 monitors, one for each camera source and one monitor for merging and showing all sources simultaneously.

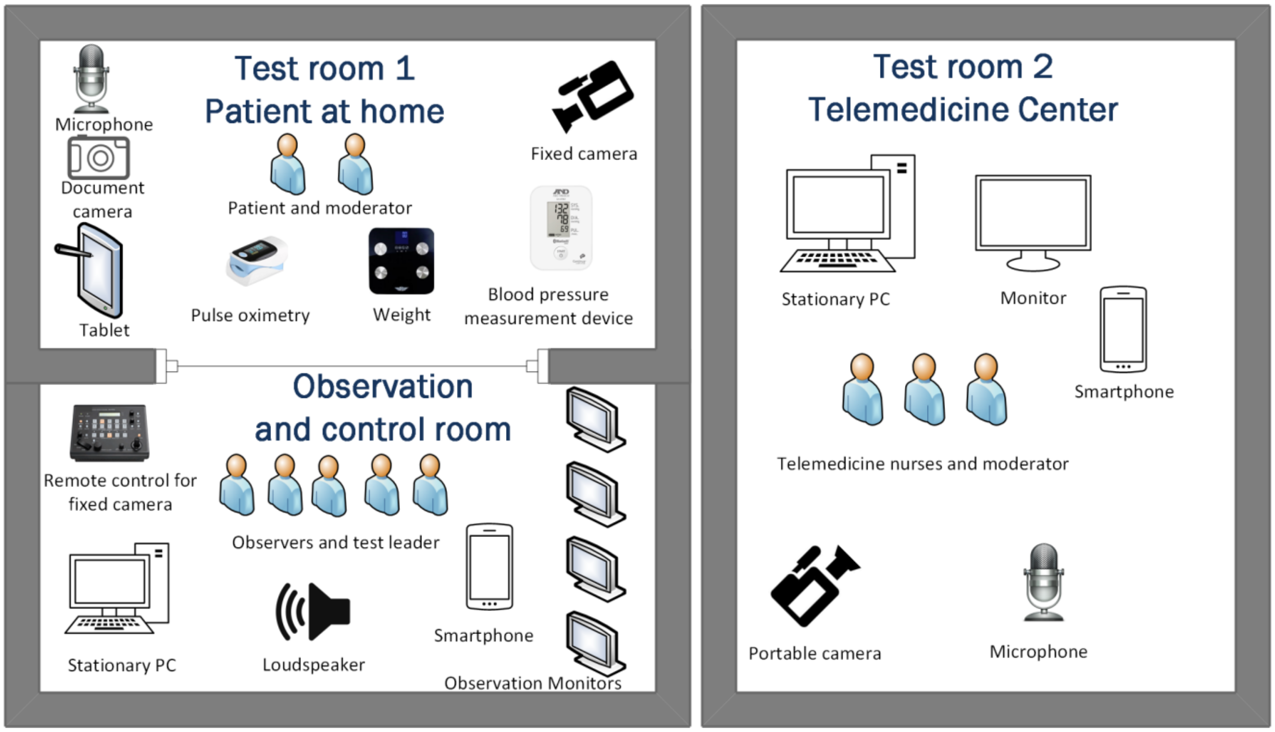

Figure 4. The technical and physical infrastructure for the simulation of cardiac telemedicine monitoring.

Between the Test room 1 and the control- and observation room there was a one-way mirror that allowed the observers to closely follow the simulation. In the Test room 1, the patient (played by a heart patient) used a device for blood pressure, a weight and a pulse oximetry device that sent the measurements to a tablet with Bluetooth transmission. The tablet had an application for remote monitoring and videoconference between the patient and the telemedicine nurse. In the Test room 2, a test application for the information and management system for remote monitoring was accessed and used in a desktop PC. There was also a smartphone available for communication with the patient and GP. The observation room had a desktop PC connected to four large monitors, allowing the observers to remotely follow the simulation and the interactions between the test rooms. Another monitor showed the camera sources simultaneously in one screen, using the software application Tricaster [11]. The operation of the fixed and portable cameras for recording purposes was made in the control- and observation room.

3.3 The technical infrastructure

The test rooms and the control and observation room were connected through a dedicated segment of the secured LAN infrastructure of the Centre for eHealth at University of Agder using VLAN technology. The same connection was also used for the IP-based streaming of video and audio signals from the test rooms. The recordings from the audio-visual sources were merged into one file including multiple video perspectives. For replication purposes the equipment used is listed.

Test room 1:

- Android Samsung A tablet device with Open TeleHealth application installed.
- A&D device model UA-651BLE for blood pressure and pulse measurement.
- A&D weight model UC-352BLE.
- Nonin device model 9560BT for pulse oximetry.
- Tobii eye-tracking equipment, camera and stand.
- Fixed Camera: SONY BRCZ330 HD 1/3 1CMOS P/T/Z 18x Optical Zoom (72x with Digital Zoom) Colour Video Camera.
- Sennheiser e912 Condenser Boundary Microphone.

Test room 2:

- Desktop for the Open TeleHealth information and management system (test version).
- 2x 27" monitors.
- Portable Camera: SONY HXR-NX30 Series.
- Logitech 886-000012 Boundary Microphone.
- Smartphone.

Control-and Observation room:

- Stationary PC: Mac Pro.
- Monitor: 4x 55".
- 27" Mac Monitor.
- Streaming: 2x Teradek RX Cube-455 TCP/IP 1080p H.264.
- Software Tricaster.
- Smartphone

3.4 The simulation procedure

The scenarios were performed as a telemedicine monitoring procedure where the interactions between the test rooms were made with use of technology. Both scenarios had a detailed description of the context, role and tasks for both the patient and the telemedicine nurse. In the patient role, there was a heart failure patient performing the defined tasks and measurements. In the telemedicine nurse role, there were two nurses from a telemedicine center carrying out the scenario together. The GP's role was acted in the observation room by a GP involved in the project team. In both the test rooms, there was a moderator from the project group to assist during the scenarios. In the observation room there were 7 people from the project participants observing the simulation and making annotations, (see Figure 5), and there was also one research team member controlling the recordings and simulation procedure. After both scenarios there was a group debrief with all participants to go through the task solving and actions made.

Figure 5. Observers in the control and observation room following the simulation in the test rooms and making annotations.

3.5 Ethical considerations

This research study was approved by the Norwegian Centre for Research Data with project number 53693 [12]. The participants received oral and written information about the project and they all signed an individual consent form.

4 Discussion

This paper has presented a technical and physical infrastructure for simulation of telemedicine monitoring, based on the research project *Telemedicine Agder*. The experiences shared by the research team performing the simulation could be useful for other projects within telemedicine and health informatics.

The two research questions (RQs) are answered based on the study. RQ1 asked about a suitable technical and physical infrastructure for simulation of cardiac telemedicine monitoring. When simulating a clinical scenario, it is of importance to create a realistic environment for performance of tasks and roles. The infrastructure needs to have the flexibility to adapt to changes in the scenarios, roles and technical equipment, both during a simulation but also between different contexts. We recommend using different test rooms simultaneously to add a dynamic dimension and to study interactions and work processes in addition to the technical solution, in line with [6]. The use of different test rooms requires technical equipment to record multiple sources simultaneously. We recommend recording both in separate files for detailed analysis, and in one synchronized file to ease the analysis retrospectively.

RQ2 asked about lessons learned from the cardiac telemedicine simulation that can be transferable to other contexts. Test and evaluation of technology under development is important to identify errors that need refinements, but simulating clinical models and workflow is also of importance. Simulations are complex when involving different user groups that interact with each other between the test rooms. It is of importance to involve multiple user groups as observers in the control and observation room to follow and annotate the scenarios, users who are experts of the user context and work processes. A group debrief that combines the practical experiences of the test participants and the observations of the observers is highly recommended, to discuss errors and need for refinements in the technology and clinical logistics. The group debrief allows the participants to speak more freely, compared to the simulation scenarios where there are defined tasks solve, so we recommend recording the debrief for retrospective analysis. For safety reasons, a participant should never be left alone in a test room, but always be accompanied by a moderator as being observed in laboratory can be a stressful experience and for avoiding claustrophobia. The test leader should have a detailed knowledge of the scenarios and the tested technology, to be able to make the correct decisions and lead the participants through a simulation.

We experienced some technical issues regarding the infrastructure and recording equipment and needed immediate technical assistance. We recommend having technical support available on short notice to avoid interference and distortion of the results. In addition, two external technicians with expertise on the telemedicine technology participated during the simulation to assist in case of technical failure. We needed the expertise during the simulation to be able to use the technology as intended.

The patient in the simulation had chronic heart failure for real. For ethical reasons, it is important to instruct the patient very clearly that (s)he is playing a role in the simulation and the main contribution is sharing experiences on using technology and procedures, and not sharing sensitive medical information. To illustrate this, our patient played both the role of a male and a female during the simulation, and one of them in a severe condition. It is important to consider that simulation can be exhausting for a patient, and we recommend multiple breaks and facilitation of a comfortable transport to and from the simulation facilities. Playing a role that you do not understand or have not experienced is challenging, and for that reason we recommend having real nurses and physicians playing the associated roles to have a reliable and valid outcome.

This study had some limitations, such as including data from one single research project. However, several end-user groups were represented in the simulation, which provided useful experiences on how the two-test room infrastructure worked. The empirical data from the simulation is not in the scope of this paper, as it targets the technical and physical laboratory infrastructure for telemedicine simulation.

5 Conclusion

This paper was made within the project *Telemedicine Agder* to share experiences from laboratory simulation of telemedicine. The main contribution lies on how the technical and physical infrastructure was used in the simulations of cardiac telemedicine monitoring, and the lessons learned may be transferable and applicable in other contexts of health informatics. As telemedicine technology is used by multiple user groups, there is a need to test both technical functionalities and how the technology would be used in a clinical workflow before final implementation. The physical and technical laboratory infrastructure enabled studying the user interactions with the technology and provided an environment for carrying out clinical work processes. Future research agenda should target simulation of other telemedicine scenarios, with an extension of the clinical user group.

6 Acknowledgement

The research team would like to thank all participants and informants for their disinterested contribution in the study. Thanks to Åsmund Rodvig Somdal for technical assistance in the clinical laboratory. The Research Council of Norway provided financial support with Grant number 247929.

7 References

[1] World Health Organization (WHO), "Telemedicine. Opportunities and developments in member states," [retrieved: May, 2018]. Available from: http://www.who.int/goe/publications/goe_telemedicine_2010.pdf

[2] D. A. Perednia and A. Allen, "Telemedicine technology and clinical applications," JAMA, 273(6), pp.483-488, 1995, doi:10.1001/jama.1995.03520300057037.

[3] R. L. Bashshur, "On the definition and evaluation of telemedicine," Telemed J, 1(1), p. 19-30, 1995, doi:10.1089/tmj.1.1995.1.19.

[4] J. Craig and V. Patterson, "Introduction to the practice of telemedicine," J Telemed Telecare, 11(1), pp. 3-9, 2005.

[5] Norwegian Ministry of Health and Care Services. "The Coordination Reform, Proper treatment – at the right place and right time"; Report No. 47 (2008-2009) to the Storting. [retrieved: May, 2018]. Available from: https://www.regjeringen.no/contentassets/d4f0e16ad32e4bbd8d8ab5c21445a5dc/no/pdfs/stm200820090047000dddpdfs.pdf

[6] B. Smaradottir, R. Fensli, E.B. Sundby and S. Martinez. "Infrastructure for health care simulation- recommendations from the Model for Telecare Alarm Services project"; In proceedings of the 3rd International Conference on Health Informatics and Medical Systems (HIMS'17), p. 64-69, July 17-20, 2017 in Las Vegas, USA, CSREA press.

[7] Telemedicine Agder. [retrieved: May, 2018]. Available from: http://www.telma.no/

[8] B. Smaradottir, R. Fensli and C.E. Moe. "Recommendations of a laboratory infrastructure for simulation of telemedicine services" (diabetes); In press, IEEE, 2018.

[9] Open TeleHealth. [retrieved: May, 2018]. Available from: http://opentelehealth.com/

[10] Siemens healtineers. [retrieved: May, 2018]. Available from: https://www.healthcare.siemens.no/

[11] Tricaster. [retrieved: May, 2018]. Available from: https://www.newtek.com/tricaster/

[12] The Norwegian Centre for Research Data. [retrieved: May, 2018]. Available from: http://www.nsd.uib.no/nsd/english/index.html