Improving Shared Understanding with Hart

designing a telemonitoring smart care agent
to support transcatheter aortic valve implantation
patient care in perioperative journey

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"The greatest opportunity offtered by AI is not reducing errors or workload, or even curing cancer; it is the opportunity to restore the precious and time honored connection and trust - the human touch - between the patient and doctors."

- <Deep medicine>, 2019

Executive summary

This master thesis explores how Philips wearable biosensor can bring value in the cardiovascular disease care pathway. This project proposes a concept of product-service system to improve patient care in transcatheter aortic valve stenosis implantation (TAVI) perioperative journey.

The exploration of the context is based on literature review and contextual research with outpatient cardiologist, AUMC heart team, Cardio Vital stakeholders, and patient communication specialist.

Aortic valve stenosis (AS) is one of the most common and progressive valvular heart diseases in the aging society. According to European Society of Cardiology (2020), the burden of AS symptoms affects the patient's quality of life and survival. For intermediate or high risk patients experiencing severe symptoms, they are often suggested TAVI treatment, is a minimally invasive heart procedure to replace a narrowing aortic valve with a new valve. Compared to an open-heart surgery, TAVI is a less-invasive treatment option with the benefit of shorter hospital stay (Dimytri et al., 2012; Lung, 2003).

However, TAVI patients are also more frail and with comorbidities, which requires multidisciplinary teams to deliver perioperative patient care. The care processes include an effective selection of eligible patients before surgery and improving physical/psychological functioning through rehabilitation. These patient care highly relies on hospital-based protocols, and desires having a shared understanding of the health condition and care actions through patient-clinician communication.

The problem is defined as when patients step out of hospital, there is a lack of communication in (1) knowing when and what actions to take if complications occur; (2) Knowing how active can and should the patient during home recovering. Thus, the design goal is to " improve shared understanding by designing a telemonitoring product-service-system that supports patients and care teams to assess and build a shared knowledge of health conditions out of hospital."

This led to the creation of Hart, a telemonitoring PSS as a smart digital care assistant. The final design proposal is iterated from three preliminary concepts, initiating communications on helping patients reflect on their own health situation, building shared knowledge by using patient-shared contextual information with long-term monitoring during physical activities or experience of symptoms. The thesis brings great value in sparking discussions with health care professionals of using smart agentive technology in the perioperative care pathway.

READING GUIDE

This guide suggests how the readers can navigate themselves through the report. Each section introduction will be briefly introduced in this manner.

For readers who would like to succinctly get a grasp of the project, each chapter will begin with a summarised introduction and end with the main takeaways.

Among the content *" Power quotes from experts/users are presented in this manner. "*.

Insights within the paragraph are **highlighted** in this manner.

MAIN TAKEAWAYS

- Important learning from each chapters will be presented in this manner.

Figure X
Figures are depicted with this legend.

ABBREVIATIONS

A

AS - Aortic Valve Stenosis

C

CR - Cardiac Rehabilitation

E

ECG - Electrocardiogram
EHR - Electronic Health Record

H

HR - Heart Rate
HREC - Human Research Ethics Committee

M

MDO - Multidisciplinary Meeting
ML - Machine Learning

P

PA - Physical Activity
PSS - Product Service System

T

TAVI - Transcatheter aortic valve implantation

Q

QoL - Quality of life

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01

Introduction

This chapter introduces the initiation of the project, the stakeholder's interest investigated from the in-take meeting, and the initial design assignment of the graduation thesis.

1.1 Project background

This section unfolds how the project was initiated.

This graduation project is a collaboration between Amsterdam UMC medical center, Philips Research, and TU Delft CardioLab. Supervised by Prof. dr. Gerd Kortuem and Prof. dr. Maaike Kleinsmann, the overall aim of this initiative is to explore how smart technology can improve cardiac patient care. More specifically, how might we improve transcatheter aortic valve implantation (TAVI) perioperative care with the use of wearable biosensor (figure 1) data.

Figure 1
Philips biosensor patch (Philips, 2020)

1.2 Stakeholders

This section introduces the main stakeholders in collaboration.

The project kick started with an intake meeting, in which the initial interests of the main stakeholders were investigated.

1.2.1 AUMC Hartcentrum

AUMC Hartcentrum is a collaborative expertise center between the departments of cardiology and cardiothoracic surgery at the University of Amsterdam Academic Medical Centre (AUMC). The center specialises in research, education and patient care for cardiovascular diseases.

Patient care

AUMC hartcentrum consists of a group of medical specialists, known as the heart team. The team consists of cardiologists, cardiothoracic surgeons, specialist nurses, nurses, physician assistants and electrophysiologists. AUMC hartcentrum offers tertiary cardiac care for 15 referral hospitals in the region of north Holland, with a mission to support the well-being of cardiac patients.

Education / training / research

AUMC hartcentrum is also a part of the academic medical centre of University of Amsterdam. The heart center has been training doctors to become medical specialists and generating scientific knowledge through research in this field.

1.2.2 Philips Healthcare

Philips is a leading health technology company focused on improving people's health and enabling better outcomes across the health pathway (figure 2).

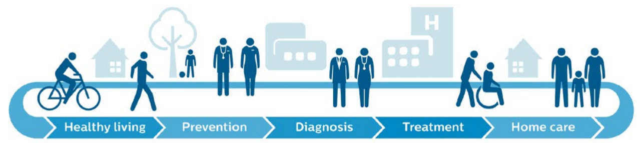


Figure 2
Transforming Healthcare through Innovation
(Koninklijke Philips N.V., 2018)

Philips products and services spread across healthy living, prevention, diagnosis, treatment and home care. In this project, we work with the Philips data and wearable technology team, and focus on the Philips wearable biosensor product.

1.2.3 TU Delft Cardio Lab

CardioLab is a collaboration between Philips Design and the TU Delft to explore how smart technology can improve cardiac care through data-enabled design methods.

1.3 Philips Wearable Biosensor

This section briefly introduces the Philips wearable biosensor, including how the device works and the data collected.

The Philips wearable biosensor is an unobtrusive, FDA-approved medical device that continuously monitors vital signs in an ambulatory manner (Philips Wearable Biosensor, 2020).

1.3.1 How it works

Self-adhered to the chest (figure 3), patients can wear the wearable patch up to 3-4 days. Data collected is transferred through bluetooth and a relay device with a coverage area of 10 meter. The patch is disposed of after one use.

The relay device (figure 4) can be set up in the patient's home environment, yet beyond the coverage area, the patient needs to carry a mobile phone as a relay device for data collection.

The wearable device was initially designed for a wide range of monitoring needs in the emergency department or general ward. With the wireless patch design, patients are able to move freely without feeling constrained. Once connected to the IntelliVue ward monitoring system or event manager applications, the device is able to timely alert caregivers with an early warning score (EWS) when the patient's condition deteriorates.

Figure 3
Patient adhere with biosensor (Philips, 2020)

Figure 4
Relay devices for transmitting data (Philips, 2020)

1.3.2 Biosensor Data

Informed by a previous study (Bream, 2019), the biosensor can gather the following data (appendic A):

ECG, Heart rate

Heart rate is the number of a person's heart beats per minute (bpm). As a person ages, the normal regularity of heart rate can change and may signify a heart condition that requires diagnosis. The heart rate is calculated from the electrocardiogram (ECG), whihc is a measurement of the electrical activities of the heart. The ECG data are captured via two single lead ECG-electrodes.

Respiratory rate

Respiratory rate is the breaths per minute, which can be used to indicate pulmonary symptoms such as shortness of breath.

Step count, level of activity, posture

The physical activity data are derived from the tri-axis accelerometer. With the algorithmn, the biosensor is capable of classifying different level of activity. For instance, figure 5 shows the differentiation betwen walking and running through signal magnitude area. (US patent US20180289289A1, 2018). However, for activities with similar activity level still need patients to report contextual information for clarification. The sensor is also able to detect posture change as shown in figure 6 (i.e. falling, sitting, or standing)

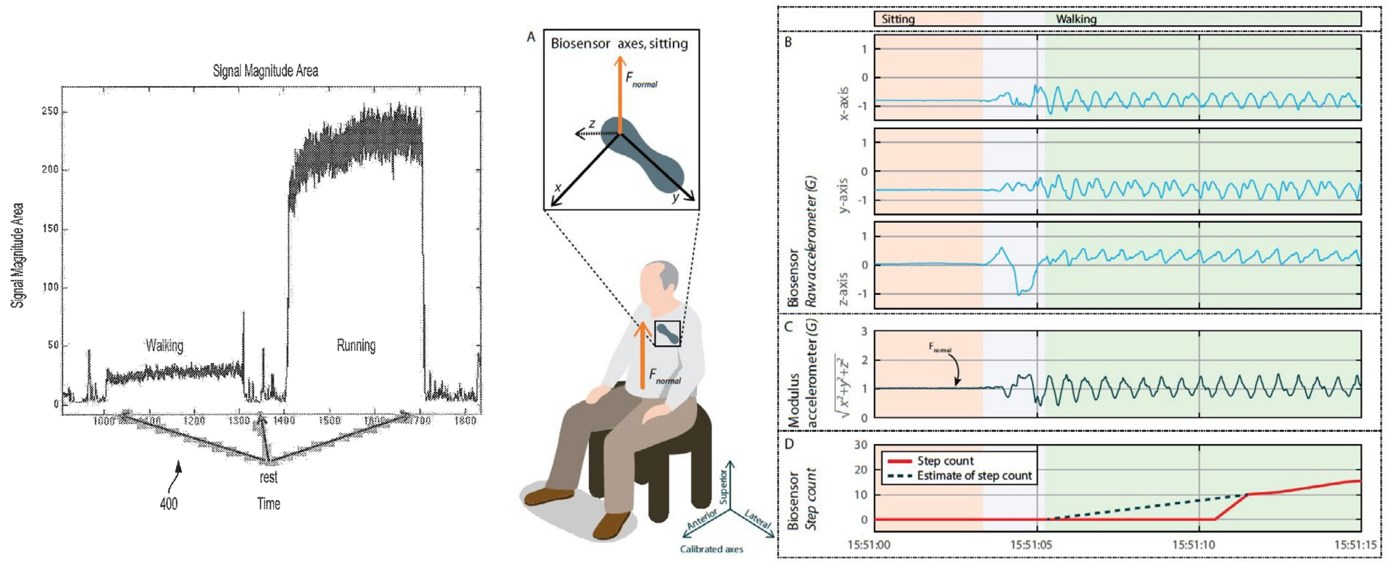


Figure 5 /6
(Left) Classification of activity level (patent US20180289289A1)
(Right) Physical activity insights from tri-axis accelerometer (Bream, 2019)

1.4 Initial assignment

This section defined the initial assignment:
Explore how Philips wearable biosensors data can improve TAVI patient-clinician communication through a product-service system.

Philips has developed a wearable biosensor device that collects vital signs in an ambulatory way. The wearable device is not yet implemented into AUMC workflow, but already attracting interests. During the intake meeting, each stakeholder's interest were investigated as following:

The Amsterdam UMC stakeholders sees the device promising to be adopted in the transcatheter aortic valve implantation (TAVI) care pathway. TAVI is a minimal-invasive surgery often suggested for aortic stenosis patients with moderate or high risk. The interest revolved around how the biosensor may be used to improve perioperative patient care before or after the TAVI surgery.

In pre-procedure care management, one possible situation discussed is if the biosensor has the capability of classifying frailty, it may support TAVI nurses better prioritise patients before surgery, or even improve the current way of clinical visits. The stakeholders briefly described the challenges from their experience interacting with patients as following:

" ... from the patient's point of view, the most important question is, 'Will I get better?' In our decision making, we assess the patient's comorbidities. If the patients can only survive shorter than one year, we shouldn't go for the procedure. The assessment is done in the regular outpatient clinic visits, which maybe this patch can replace it. Perhaps we can communicate to the patients to know 'Oh, I'm doing fine, I don't have to go see a physician'. "

- Intervention Surgeon, 2020

In post-procedure care management, clinicians find it challenging to encourage patients to become more active after surgery. The possible use of data may provide personalized guidance and help patients mitigate the emotional distress of physical activities during recovery.

For Philips stakeholders, they showed interest in exploring how the data collected from the wearable device would be valuable for cardiac care. This project is seen as a continuation of the previous research (Bream, 2019) from Amsterdam UMC and Twente University, of which the reliability and physical usability of the Philips wearable biosensor was examined for TAVI perioperative assessment.

Lastly, from TU Delft CardioLab point of view, the lab is interested in developing new knowledge in data-enabled design methodologies for cardiac healthcare care. As an MSc Design for Interaction student graduating from the lab, my contribution is to explore how the use of biosensor data can inspire and inform my design process.

Conclusion

To conclude, all stakeholders showed interest in how the role of biosensor can be explored in the TAVI patient care pathway. The researcher discovered several assumptions of how the use of biosensor data may improve TAVI patient care:

1. use of biosensor data may enable a more efficient assessment process to prioritise patients and support treatment decision making with patients

2. use of biosensor data may support patient to overcome fear of doing physical activities in recovery process

Both supporting treatment decision making and helping patients recover relies on the communication between patient and clinicians. Therefore, the researcher posits that patient care can be improved by strengthening clinician-patient communication. The initial assignment was to **explore how Philips wearable biosensors data can improve TAVI perioperative clinician-patient communication through a product-service-system.** To have a concrete plan of action, the design approaches are planned in the next section.

1.5 Design approach

This chapter describes the design approach for this project.

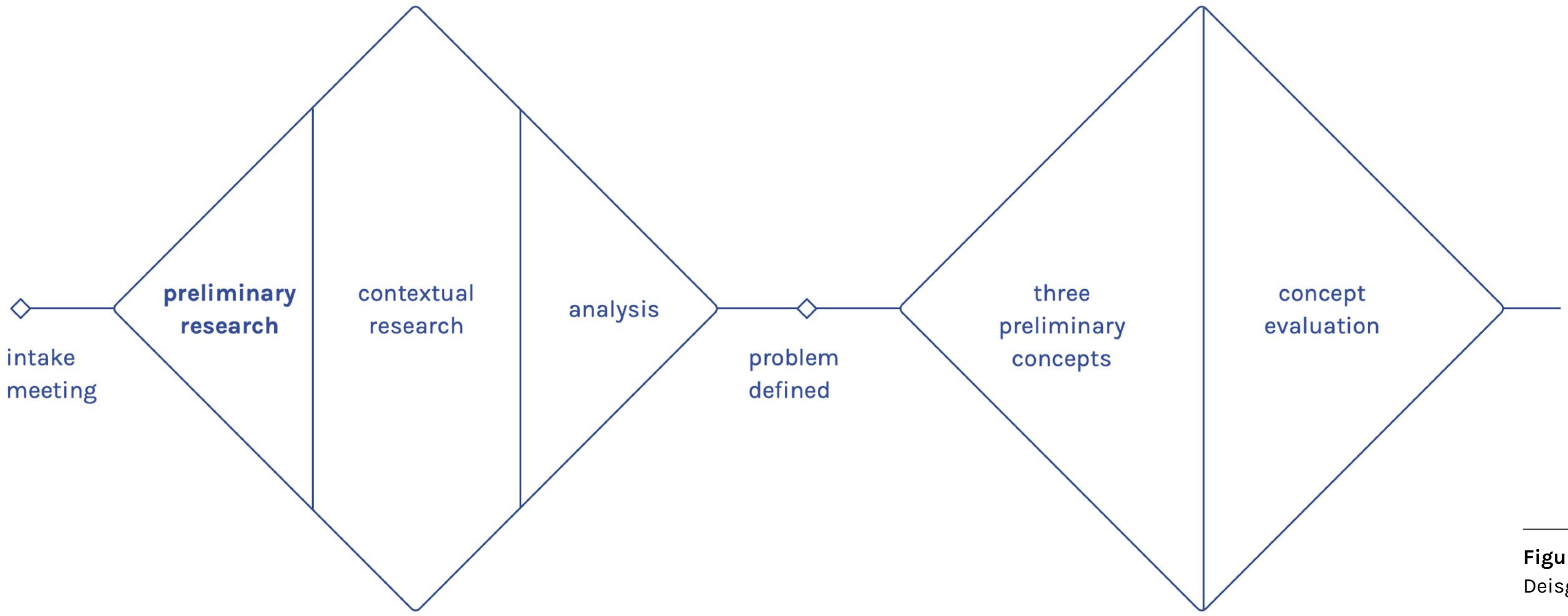


Figure 7
Deisgn approach.

Based on the preliminary literature review, the researcher assumed that doctor-patient communication may improve TAVI patient care. In figure 7, The double diamond (British Design Council, 2019) is chosen as the design approach. The project follows a converging and diverging flow:

Kickstart
The project investigated main stakeholders' interests in the intake meeting.

Discovery
During the discovery phase, the aim is to understand how patient-clinician communication is practised. The researcher begins the investigation through a preliminary desk research (chapter 2). Next, a contextual research is conducted, using different methods (sensitising probes, expert interview, and observation) to investigate the status quo of clinician-patient communication in context (chapter 3).

Define
For the define phase, the aim is to reach a problem definition for the product-service system (PSS) development. This is done by analysing the contextual findings, and understanding the value proposition of the PSS through stakeholder interviews (chapter 4, 5).

Development
For the development phase, the aim is to determine what PSS features should be designed to strengthen clinician-patient communication. This is done by designing three preliminary concepts that addressed the problem areas, and co-reflect with relevant stakeholders. (chapter 6)

Deliver
For the delivery phase, the aim is to evaluate the final PSS design and envisioned interactions with relevant stakeholders. The design is compared with the existing workflow.

Limitations
In the middle of the project, the outbreak of COVID-19 pandemic results in strict social-distancing measures. To protect the health of the vulnerable patient groups, all research activities are then adjusted or replanned as online interaction.

CHAPTER 1 MAIN TAKEAWAYS

- The initial assignment was to explore how Philips wearable biosensors data can improve TAVI perioperative clinician-patient communication through a product-service-system.

- A double diamond approach is used to guide the project.

Preliminary Research

This chapter investigated the TAVI context through preliminary desk research. The findings are help to set up the research questions for contextual research.

2.1 About TAVI

This section describes the TAVI procedure, an less-invasive treatment option for aortic stenosis patients with high risks.

Aortic stenosis (AS)

Aortic valve stenosis (AS) or valve narrowing is one of the most common and progressive valvular heart diseases. As shown in figure 8, when an aortic valve does not open fully, flow of blood is restricted and it affects the pressure in the left atrium (American Heart Association, 2019). According to European Society of Cardiology (2020), AS symptoms include feeling short of breath, chest pain, pressure or tightness in chest, fainting/syncope, palpitation, feeling heavy and noticeable heartbeats. In some asymptomatic cases, the patient may not suffer from above discomforts, but notice a decline in their physical activity level or reduced ability to do normal activities.

Depending on the severity of the aortic valve condition and medical professional's clinical decisions, the patient may be advised the following treatments: monitoring and medication (figure 9), valve repair surgery or valve replacement surgery. The scope of this graduation project is related to the second intervention and focuses on investigating the transcatheter aortic valve implantation perioperative care path.

Transcatheter aortic calve implantation (TAVI)

Transcatheter aortic valve implantation (TAVI), is a minimally invasive heart procedure to replace a narrowing aortic valve with a new valve. Compared to an open-heart surgery (also known as surgical aortic valve replacement, SAVR), TAVI is a less-invasive treatment option for patients with intermediate or high risk (Dimytri et al., 2012; Lung, 2003).

Benefits of TAVI include shorter recovery time and improvement in serious symptoms. Ideal surgical outcomes have shifted in recent times from survival as-a-single-indicator to overall improved quality of life (QoL) (Rumsfeld, 2003). Yet, due to the patients are mainly advanced age groups with different comorbidities, the level of frailty varies in individuals. Patients with lower frailty may experience the potential risks, such as: severe bleeding (1%), damaged blood vessel (less than 1%), heart rhythm issues, stroke (1.7%), heart attack, malfunctioning of the newly replaced valve (less than 5%), need of re-admission (less than 0.5%), and risk of death (around TAVI 0.7%, within 30 days after approximately 2.6%).

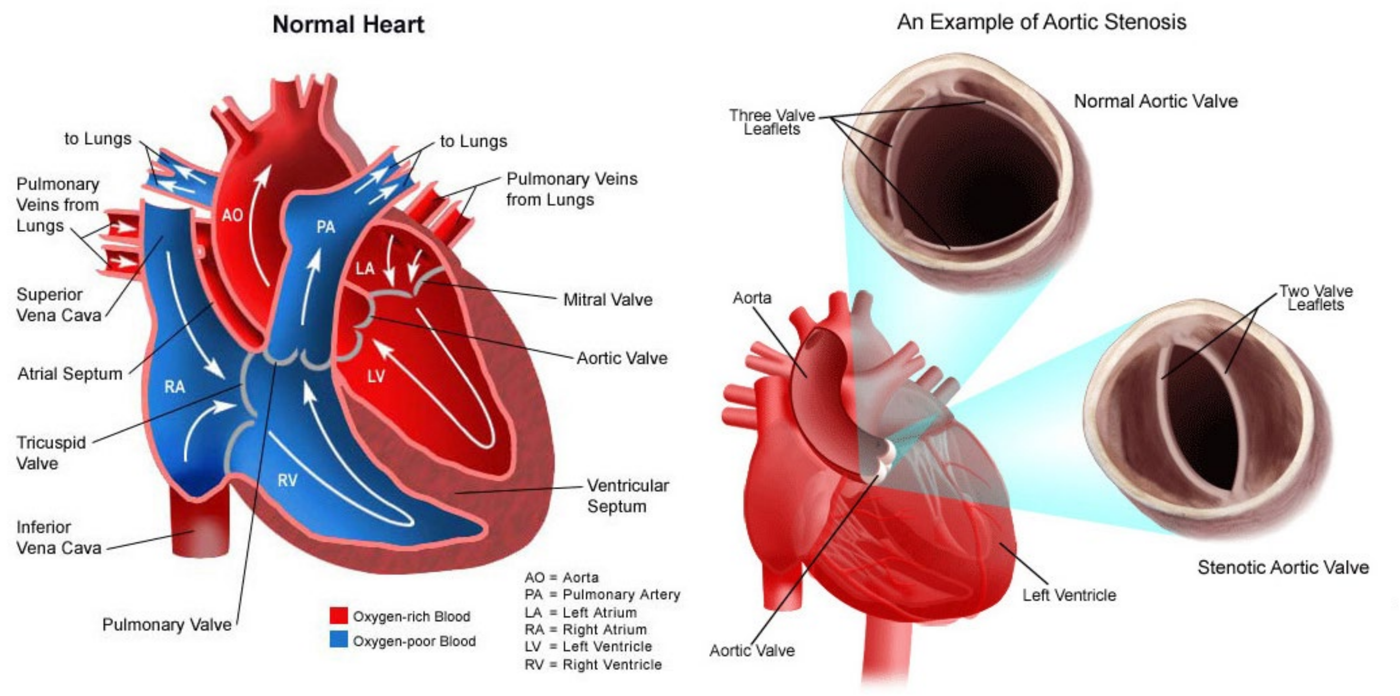


Figure 8
An illustration of aortic stenosis valve disease (CHOC Children's Heart Institute, 2020)

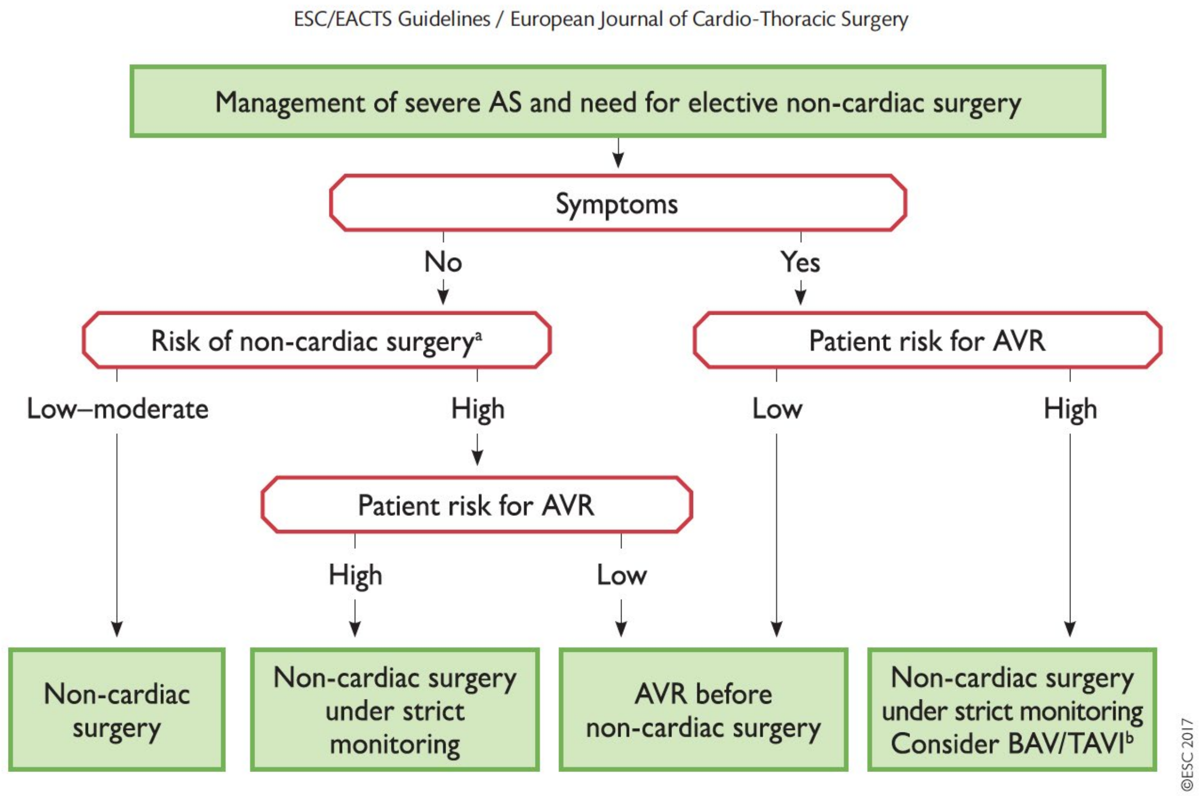


Figure 9
Guideline for managing severe aortic stenosis valve (European Journal of Cardiothoracic Surgery, 2017)

AS: aortic stenosis; AVR: aortic valve replacement; BAV: balloon aortic valvuloplasty; TAVI: transcatheter aortic valve implantation.
a. Classification into three groups according to the risk of cardiac complications (30-day death and myocardial infarction) for non-cardiac surgery (high-risk >5%; intermediate risk 1–5%; low risk <1%).
b. Non-cardiac surgery performed only if strictly needed. The choice between percutaneous aortic valvuloplasty and TAVI should take into account patient life expectancy.

TAVI Procedure Overview

In the Amsterdam UMC, a TAVI surgery typically takes place in the heart catheterization room. The implantation is performed by either an interventional cardiologist partnered with a cardiothoracic surgeon, or two interventional cardiologists. The surgery follows the protocol below and takes 2 to 3 hours to complete:

1. In preparation for the surgery, the patient will be put under anesthesia and connected to a patient monitoring system. His / her vital functions, such as respiration and circulation, will be intensively monitored.

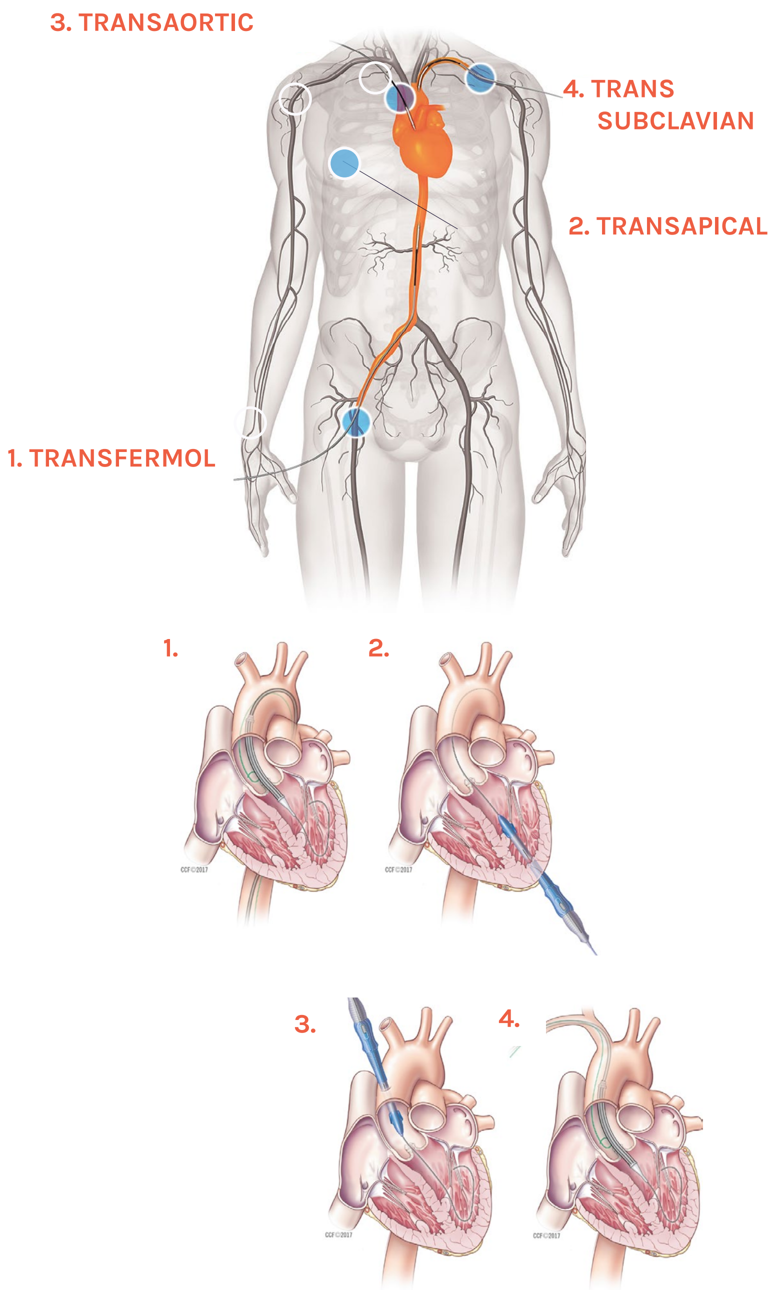
2. A sheath will be placed for various devices to pass through and access the heart. There are four delivery routes for TAVI. As illustrated in figure 10, they are respectively transfemoral (via femoral artery), transaortal (via the aorta just above the heart), transapical (via over tip of heart through the ribs) and trans subclavia (via the artery at the clavicle).

3. An artificial valve will be compressed on a balloon delivery system. Edwards Sapien 3 s a FDA approved artificial valve used in AUMC TAVI procedures. The metal stent is attached with a biological aortic valve to replace the diseased valve. The delivery system and the new valve will be inserted through the sheath.

4. Once the delivery system reaches the diseased valve, the balloon will be inflated with fluid and expand the artificial valve into place. The new valve will push the leaflets of the diseased valve aside and use the diseased valve leaflets to secure itself in place.

5. The balloon will then be deflated and removed. Before closing up the incision, the surgeon will inspect if the new valve is inspected is working successfully.

6. After the procedure, the patient will be admitted to the Cardiac Monitoring or Intensive Care Unit (ICU). Until the patient reaches a stable situation, he/she will then be transferred back to the regular nursing ward. In an uncomplicated situation, the patient can be transferred back to his/her own hospital within 1 to 3 days by ambulance.



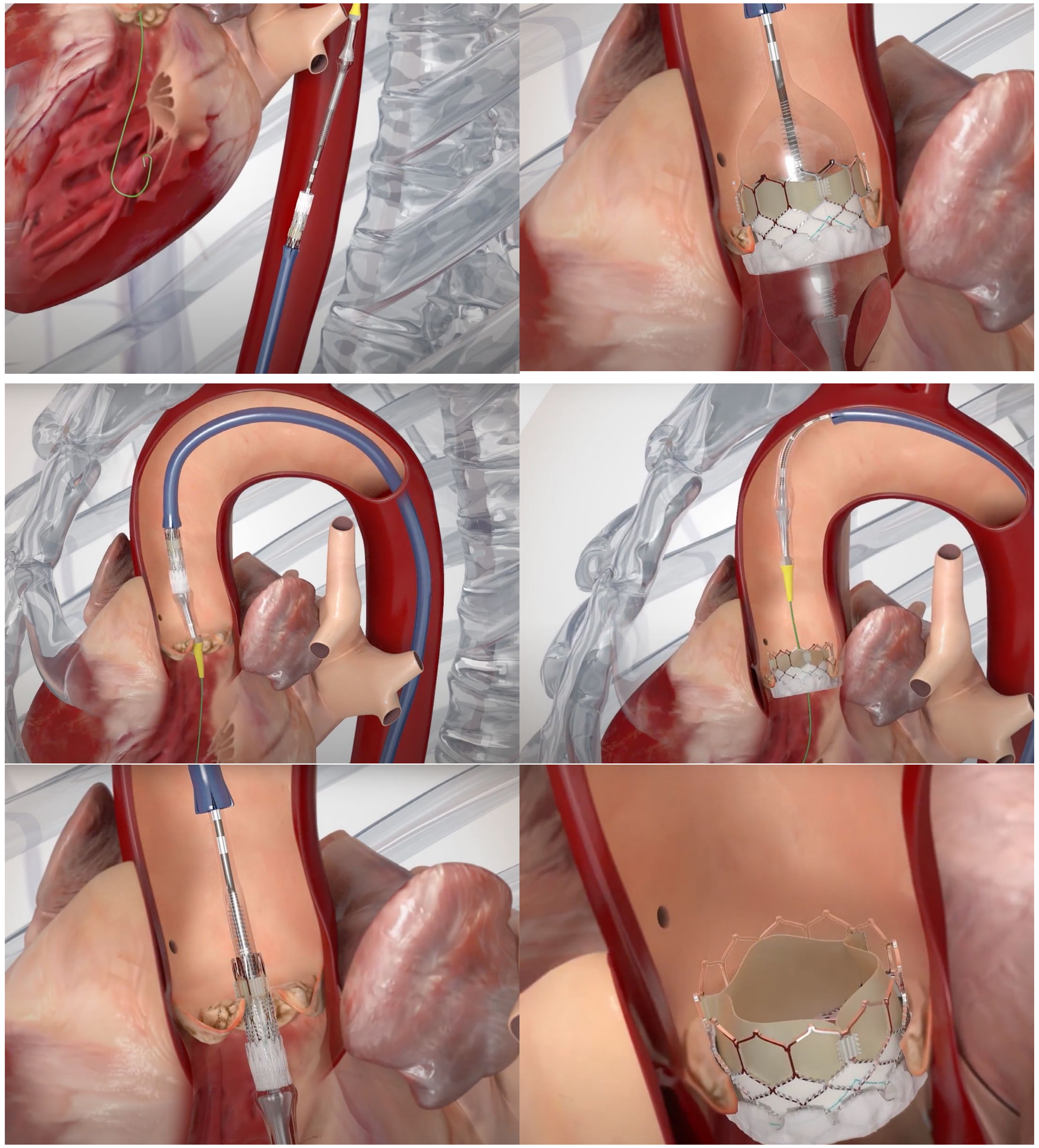


Figure 10/11

(left) Four incision locations and delivery routes for TAVI (Medtronic, 2020; Cleveland Clinic Foundation, 2020)

(This page) The Edward Sapien 3 artificial valve and procedure (Barnes-Jewish Hospital, 2017; Edwards Lifesciences, 2020)

2.2 Preliminary desk research on TAVI

This section explores how TAVI patient care is delivered through preliminary desk research, which "patient-clinician collaboration is defined as the key aspect.

In order to design a product-service-system, we first need to understand what is the context we are designing for. In this section, the context is being explored through reviewing literature and work documentations. The findings will be used to shape the research questions for the contextual research.

Research question

RQ 1. How is patient care delivered in TAVI?
RQ 2. What are the interactions that affect the delivery of TAVI care?

Literatures are searched in google scholar, using the following keywords: 'transcatheter aortic stenosis implantation', 'TAVI', 'TAVI patient care', 'TAVI experience'.

Findings

RQ1. How is care delivered in TAVI?

The delivery of TAVI care not onlyconsists of the surgery procedures, but also the the perioperative care activities. **Perioperative care can be seperated in three phases: preprocedure, intraoperative, and postprocedure care management.** Perioperative care begins when the patient is informed the need for surgery, and ends once the patient is relased from clinician's care and returns to normal living. Ideally, TAVI is able to increase survival and improve health related quality of life. Informed by several studies (Levi & Kornowski, 2017; De Ronde-Tillmans et al., 2020), a patient-centered TAVI care pathway requires:

a. Preprocedure: effective selection of eligible patients

According to European Society of Cardiology (ESC) and European Association for Cardio-Thoracic Surgery (EACTS) 2017 guidelines for AS management, patients recommended to TAVI are mainly deemed with severe symptomatic AS and high risks for cardiac surgery. In order to minimize futility in ineffective TAVI outcomes and increase patient safety, pre-procedure patient care focuses on examining potential operation risks. This is to enable a more informed decision-making process and select patients who will benefit from TAVI. (Puri et al., 2016) Operation risks considered in the patient selection and decision-making process include: severity of aortic stenosis condition and symptoms, comorbidities, and level of frailty.

Comorbidity refers as having multiple co-existing medical conditions (i.e. Chronic obstructive pulmonary disease (COPD), diabetes, cancer, hypertension, etc). The prevalence of comorbidities complicates the diagnosis process, since a symptom may be caused by multiple conditions. Therefore, the screening process relies on a collaborative effort of multidisciplinary health professionals: cardiology, cardiac surgery, anesthesiology, geriatrics, or other disciplines if necessary.

Frailty describes a state of vulnerability including reduced physical strength, declined fitness, cognitive and social functioning. Frail AS patients have a significantly increased risk of falls, morbidity, dependency, and mortality. (reference, 2020). Among different ways to access frailty, AUMC uses the Edmonton Frail Scale (EFS). The scale consists of 10 questions and 1 physical assessment. Ranges from 0 (not frail) to 18 (very frail), patients scoring above 8 are defined as frail and referred to geriatricians.(Perna et al., 2017).

In pre-procedure, multidisciplinary teams deliver patient care by collaboratively risk assessment and making optimal decisions for the TAVI surgery.

b. Postprocedure: physical/psychological support through rehabilitation treatment

According to KNGF Dutch guideline (2011), cardiac rehabilitation is a multidisciplinary program that aims to improve everyday physical and psychological functioning.

Physical therapy refers to the interventions helping individuals increase exercise capability and overcome physical limitations. As for psychological and lifestyle coaching, both supports patients overcome emotive participation restrictions (i.e. fear to move) and induce an active lifestyle.

In postprocedure, multidisciplinary teams deliver patient care by assessing and planning a treatment plan that may improve exercise and psychological functioning. making a treatment plan.

RQ2. What are the interactions that affect the delivery of TAVI care?

a. Teamwork between multidisciplinary health professionals

As learnt from RQ1. how care is delivered, there is a need of teamwork between multidisciplinary health professionals in both pre- and post-procedure patient care. As stated by Ignatavicius (2018), prioritising patient safety throughout the perioperative period demands teamwork and interprofessional collaboration.

b. Communication between patient and clinicians

Another aspect of patient care delivery is the communication between patient and clinicians. Both pre- and post-procedure require assessment of the patient's condition and eliciting patient's health preference. The end result is to gain patient's informed consent for decision making or make a suitable treatment plan.

Patients and clinicians come from different perspectives. The Patients care how the care is effectively and timely received, while the clinicians focus more on how the care is better executed.

Despite the heterogeneous perspective, patient care requires an interdependent knowledge exchange between patient and doctor (Lussier & Richard, 2008; Ha et. al, 2010). Patients need clinician's medical knowledge to diagnose and treat their health condition, while a doctor needs patient's participation and knowledge of own experience to execute care.

Conclusion

To conclude, the purpose of perioperative patient care is to prepare the patient both physically and psychologically for the surgical procedure and support him/her to recovery. Patient care are delivered through:
- pre-surgery patient selection and planning
intra-procedure operation,
- post-procedure physical/psychological rehabilitation and follow-ups

Due to the complexity of comorbidities and progression of stenosis severity, perioperative patient care delivery replies on:
- the teamwork between interprofessional teamwork,
- as well as patient-clinician communication and knowledge exchange.

By addressing the challenges faced in the above interaction, may improve patient care.

Since the findings from the literature are general, detailed clarification on who is involved, what is the care pathway, and what are the challenges faced is needed to better understand the context we are designing for.

As the next step, the researcher aims to gain a deeper understanding of the status quo through contextual research.

Yet before diving into the contextual research, looking into how effective teamwork and clinician-patient communication are described in existing literature will help the researcher better form the research questions.

2.3 Teamwork and patient-clinician communicaiton

This section discusses what are the key aspects to effective teamwork and patient-clinician communication. This gives the researcher an idea of what is an ideal state to pursue in the system interaction design.

Research question

From the desk research on TAVI, we understood **teamwork and communication are important aspects to deliver perioperative patient care.** Before diving into contextual research, the researcher looked into:

RQ 1. What is teamwork / patient-doctor communication in modern healthcare?
RQ 2. What leads to effective teamwork / patient-doctor communication?

Similarly to TAVI desk research, literature is searched in google scholar, using the following keywords: 'patient-clinician communication", 'effective teamwork', 'collaboration'. During the searching, additional keywords such as 'shared understanding', 'shared knowledge', 'shared cognitive' are added.

Findings

RQ 1. What is teamwork / patient-doctor communication in modern healthcare?

The concept of a team is defined as a set of two or more people who interact dynamically, interdependently and adaptively towards a common goal (Babiker et. al, 2014). A single care activity, such as a clinical appointment, requires the involvement of a multidisciplinary group of healthcare professionals, administrative staff, patients, and their informal caregivers. For multiple care activities across the perioperative care pathway, it requires different care teams to coordinate across organisations. If seeing patient as a part of the team, Doctor-patient communication a certain action in teamwork.

RQ 2. What leads to effective teamwork / patient-doctor communicaiton?

A major challenge of teamwork and communication in modern healthcare comes from the involvement of heterogeneous actors. According to WHO, there is an increasing importance of effective teams in health care delivery due to: (i) the increasing complexity and specialisation of care; (ii) increasing comorbidities; (iii) increasing chronic disease; (iv) shortages in the global medical workforce. (WHO, 2020).

As an effective teamwork can positively influence patient safety and result in better quality of care delivery (Rosen et. al, 2018; Babiker et. al, 2014), it is important to understand how to improve such effectiveness.

A number of literatures claimed **effective teamwork comes from the establishment of a mutual understanding between actors and within a certain context.** (Marks et. al, 2001). Shared meaning is the degree to which group members interpret a concept in the same, of a number of possible ways. Shared mental models refer to the degree to which mental models of cause and effect are similar among group members. Shared information means the degree to which people in a group agree on the value of the characteristics of things they are interested (Bittner & Leimeister, 2014). This establishment of mutual understanding is referred as 'shared understanding', 'shared mental model', or 'collective intelligence'.

Shared understanding

One aspect of shared understanding is the **sharedness in knowledge** (Kleinsmann et al., 2007) defines shared understanding as a similarity in the individual perceptions of actors. In her case study of innovative collaboration relies on developing a knowledge base, or transactive memory system in the process. A transactive memory system is a set of individual memory systems in combination with the communication that takes place between individuals (Wegner, Giuliano, & Hertel, 1985). In other words, effective transactive memory enables heterogenous actors to collborate.

A different interpretation of shared understanding can be seen as an ability and dynamite state (Bittner & Leimeister 2013). Smart et al. (2009), defining shared understanding as the ability of multiple agents to exploit common bodies of causal knowledge for the purpose of accomplishing common goals.

Learning from the above litertures, the researcher **define shared understanding in as an shared mental for multiple actors using shared knowledge to coordinate towards a common goal**.

The biggest challenges when trying to integrate knowledge into a shared understanding are relies in the differences in perspective of group members, and also difficulties in understanding and interpreting each other's knowledge (Kleinsmann, Buijs & Valkenburg, 2010). Based on Van den Bossche et al.'s shared mental model (2010). there are three phases to build a shared understanding.

Constructive
The starting of building a shared understanding of a problem is first having actors to develop an individual understanding of the situation.

Co-constructive
The next step is to recognise the different understanding in different actors and co-construct a mutual meaning of the situation. There are different means to co-construct a mutual meaning, including communication between actors.

Constructive conflict
The last step is to reach an agreement and of the co-constructed meaning. Shared understanding is reached when the co-constructed meaning is accepted. The agreed mutual meaning can be seen as a common goal to reach.

The following gives the researcher an idea that how shared understanding are built conceptually.

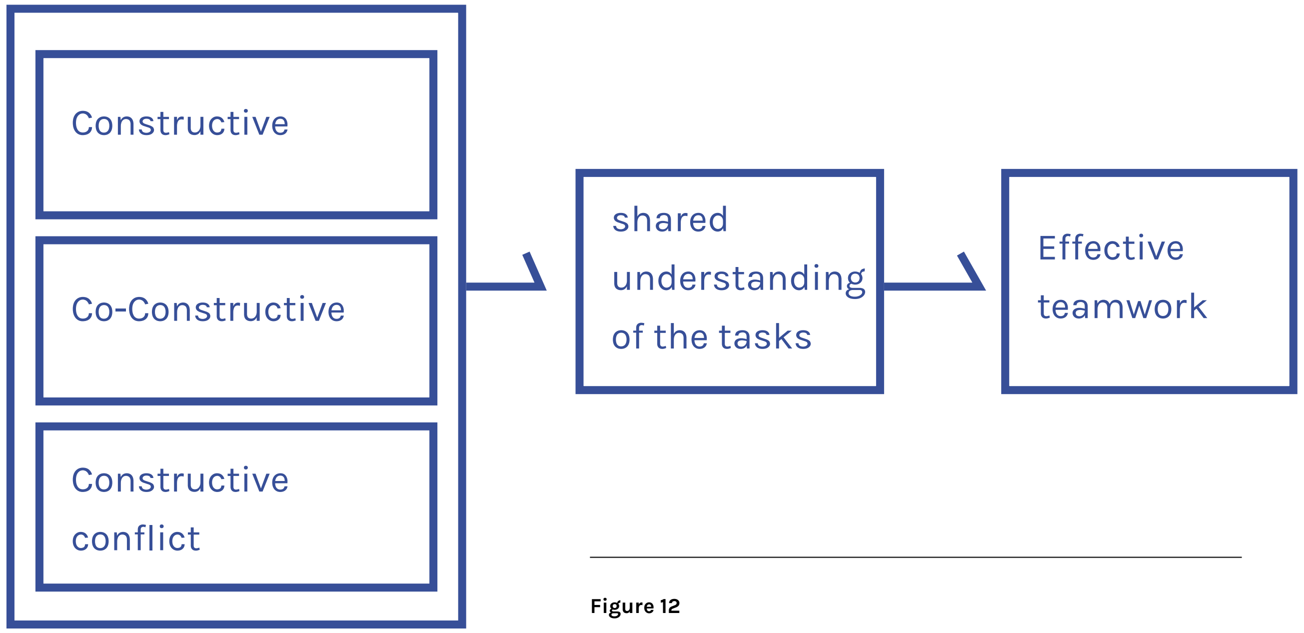


Figure 12

Van den Bossche et al.'s shared mental model (2010).

CHAPTER 2 MAIN TAKEAWAYS

Patient care are delivered through:
- pre-surgery patient selection and planning
intra-procedure operation,
- post-procedure physical/psychological rehabilitation and follow-ups

Due to the complexity of comorbidities and progression of stenosis severity, perioperative patient care delivery replies on:
- effective teamwork between interprofessional teamwork,
- as well as effective patient-clinician communication.

- Shared understanding is a shared mental state for different individuals to know how to coordinate towards a common goal. Shared understanding is dynamite, and needs to be built when changing context.

- Shared understanding is built through developing an individual perspective of the situation (constructing), communicating towards a mutual meaning of the situation (co-constructing), and agreeing on the meaning

How is communication being done in the current care pathway? How do multidisciplinary teams coordinate? Are there any challenges faced? These context-related questions motivates the researcher to perform a contextual research of the perioperative care pathway. A list of context-specific questions are listed:

(1) How is teamwork and communication being done in practise? Who are the actors involved in the team? How do they coordinate with each other? Where does it take place?

(2) Are there any efforts that contribute / challenges that inhibit the development of shared understanding between actors?

(3) What is the status quo of the use of data in the care process?

Contextual Research

This chapter explains how the contextual research is conducted. This includes the research questions, user research methods used, and the analysis process.

3.1 Research objective

This section explains what are the contextual research aims and the rationale in choosing the methods.

From the preliminary desk research, we have understood perioperative patient care relies on teamwork and communication. A key aspect to effective teamwork and communication is developing shared understanding. However, there are several context-specific questions not being answered by the literature.

The aim of the contextual research was to gain a holistic understanding of the care process and answer the following questions.

3.2.1 Research questions

To plan and set-up the research, a set of research questions are defined:

RQ 1. How is patient care like in practise? Who is involved? How do different actors communicate?
1.1 What are the main activities in perioperative care? What are the activity goals?
1.2 How do actors interact or collaborate in the activities? How do they communi cate?

RQ 2. What are the challenges faced in pa patient-clinician communication/multidis disciplinary teamwork?
2.2 How are the things you need to communicate to patient? What are the bggest challenge you face? How do you overcome it?

RQ 3. What is the status quo of the use of data ? What is its role?
3.1 What are data generated, used and transit between different activities? How Do these data play a role in care activities?
3.2 What are the perceived value of weara ble biosensor data? RQ 1. How is patient care like in practise? Who is involved? How do different actors communicate?
1.1 What are the main activities in perioper ative care? What are the activity goals?
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RQ 3. What is the status quo of the use of data ? What is its role?
3.1 What are data generated, used and transit between different activities? How Do these data play a role in care activities?
3.2 What are the perceived value of weara ble bisensor data?

3.2.2 Selection of methods

With the research objectives in mind, a variety of research methods are used to collect contextual data (figure 13). Several factors are considered when selecting the research methods, including reaching the target stakeholders, identifying the desired data types, and obligating the COVID-19 pandemic measure.

Figure 13
overview of different research methods intend to investigate the research aims

3.2 Research set-up

This section describes in summary how each research methods are conducted.

To better explain the research process, summary of the research set-ups are presented:

Online desk research

The online desk research included two main resources, retrospectively:

1. A number of TAVI-related documentations were examined.This include a remote walkthrough of software in use (EPIC electronic health record system, vital 10), Dutch cardiology rehabilitation guidelines and TAVI brochures. These resources help the researcher gain more knowledge of the care process.

2. In parallel, a scanning of aortic stenosis and TAVI-related websites are routinely visited to familiarise with patient stories. Due to the need of protecting of patient's health during COVID-19 pandemic and difficulty to conduct phone interviews with language barriers, souring patient perspective stories was seen as a more realistic alternative to gain an overall understanding of what the patients are experiencing throughout the TAVI journey. The scanned website is listed in appendix B.

Observation

Observation is chosen as a mean to collect contextual data attentively observing and listening, in a systematic and meaningful way. The purpose is to gain a first-hand impression of how the patients and clinicians interact in the context.

Two situations were chosen to observe: **a group information giving session before the surgery** and **a online group training after the surgery**. These situations are chosen with convenience sampling, which were also suggested from the care professionals as the most interaction between patient and clinicians. As observation details are thoroughly denoted in appendix C, hereby a summary of observations process and main findings were presented:

1. Pre-surgery group information giving

The observation at AUMC heart center was led by the TAVI specialist nurse, who walked us through how the AUMC care team would guide patients during the pre-surgery visit, and we were invited to observe the session. The goal of this session is to provide more TAVI-related information to the patients before the treatment decision making.

The presentation last for an hour, mainly done through power point presentations and Q&A sessions. Eight groups of patients participated, aged between 70 - 90, and mostly accompanied by their younger family members or spouses.

Insights on information and interaction were collected. Since photos with the presence of patients were not allowed to personal privacy, detailed observatory notes were taken during the session, and unmoderated interviews were done with the presented clinicians.

2. Post-surgery online group training

In normal circumstances, the physical activity training is done at rehabilitation hospitals in groups. However, during the COVID-19 pandemic, the training was done remotely in a group video call. The goal of this session is to encourage the patients to become more active and help them increase their exercise capability according to their rehabilitation plan.

The training session lasted for an hour and was observed through group calls. The video conferencing tool used is Zoom, yet at the same time the physicians can access the patient's medical record via Vital 10 platform. Insights on information and interaction were collected. To respect the privacy of the patients, screen recording was not allowed. Yet, due to the interaction being done in Dutch, detailed observatory notes were taken and audio recordings were made and translated. These notes and transcripts were then coded, and the audio recording was immediately deleted after transcribing.

Sensitising probes

Sensitising booklets were sent out to AUMC TAVI specialist nurse, cariad surgoen, secretary, referral cardiologist and the cardiac coordinator of CardioVitaal rehabilitation center. The probes are sent in digital form, as shown in appendix D. The usage of sensitising booklets is based on the context mapping generative approach, with the purpose to elicit deeper needs of the participants' own experience (Visser et al., 2005). The sensitising booklet consists of three sections:

The first section aims to empathise on participants' role in the care process and main responsibilities. Question are raised such as:
- Could you share what are the main tasks you're responsible for?
- Could you briefly describe your typical workday in AUMC?
The second section aims to map out the relationship between individuals and focus on how individuals communicate with each other. Question are raised such as:
- Could you sketch out the medical team members who are involved in TAVI care?
- Could you share what situation you need to communicate during the TAVI care process? (Please highlight the important elements such as purpose, ways you use, challenges you face)

The last section aims to find out what are the data needed to accomplish in each care process, and what are the perceived value of the biosensor data. Question are raised such as:
- Could you write down how data is being used in the TAVI care?
- These are the current data the biosensor may collect. In what way would this information affect the TAVI treatment? Please also share what will be the benefits/concerns if wearable sensor data is introduced in TAVI care?

The recollection of the probes are done in rge expret interviews.

Expert interviews

Expert interview is done to source the knowledge from the medical practitioners and patients experts in the field. A total of 11 experts participated in 1-on-1, semi-structured interviews. The interview takes around 45 to 60 minutes. The questions are shown in appendix E.

The selections of participants aims to cover the main clinical professionals and patient experts involved in the journey. Recruitment started with the AUMC stakeholders, including the specialist nurse and the cardiac surgeon. Throughout the first rounds of interviews, the researcher understood the AUMC stakeholders are responsible for a fragment of the care process, and it is necessary to involve other stakeholders such as outpatient cardiologists and rehabilitation care teams. Researchers in relevant fields (i.e. physician, geriatrician) were also contacted since they possess relevant expertise in the context. In Additionally, to source patient point of views, a patient communication specialist and frail patient researcher were also interviewed.

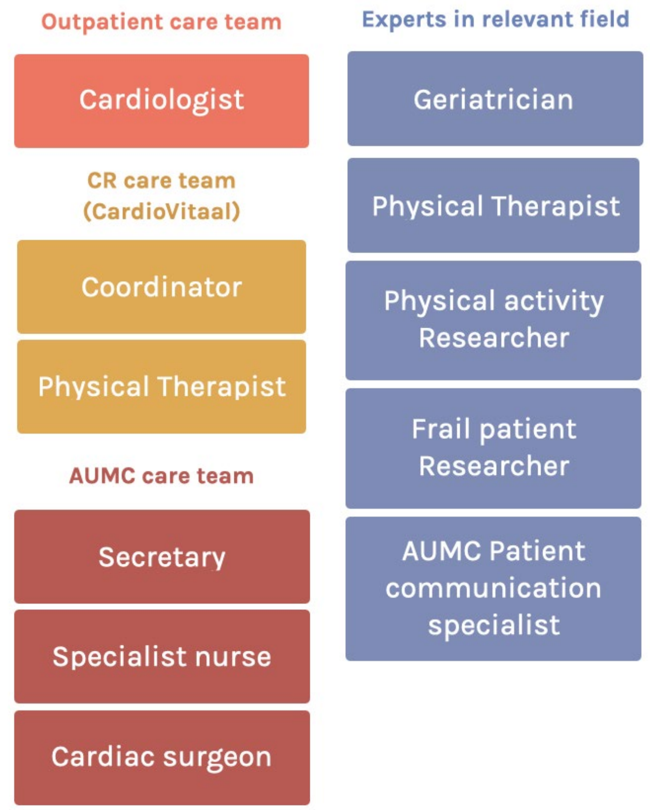


Figure 14
Participants in expert Interview

3.3 Data Analysis

This chapter explains the data analysis process and rationale.

Analysis method

The data gathered from previous chapters are analysed through affinity diagramming. into 3 frameworks. Affinity diagramming was chosen due to its advantage to externalize, make sense of, and organize large amounts of unstructured, far-ranging qualitative data. An overall impression of the analysis process is shown in appendix F. .

Analysis process

The analysis was divided into three stages:

1. Labeling

Data collected from the research methods mentioned in chapter 2, the following results were coded and kept visible on the work-space:

a. Coded quotes from the online patient stories.

b. Coded notes from the observation.

c. Translated sensitising booklets, including timelines.

d. Coded transcripts/notes from the observations, and from the expert interviews are made into statement cards.

2. Cluster

All the prepared results materials were first examined and reviewed thoroughly. Using affinity diagramming, **relevant information were clustered** into a perioperative map, the roles of different stakeholders, and challenges.

3. Synthesis

The final stage was to look beyond the surface and put together the puzzles of information. This synthesis process allows the researcher to interpret the meanings of the collected data. **Perioperative journey map** is chosen as the main framework to understand the care process. **Actors map** are then used to gain a deeper understanding of the actors' involvement; while **challenge clusters** are used to identify the challenges with the care activities. In the next chapter, the analysed results are presented.

CHAPTER 3 MAIN TAKEAWAYS

A contextual research is conducted to understand how patient care and communication is done in practise.

The research questions are:
RQ 1. How is patient care like in practise? Who is involved? How do different actors
RQ 2. What are the challenges faced in pa patient-clinician communication/ multidis disciplinary teamwork?
RQ 3. What is the status quo of the use of data ? What is its role?

The contextual research uses observation, sensitising kit, expert interview and online desk research to explore the TAVI journey.

Data is analysed through affinity diagramming, which is observed notes and interview recordings are transcribed. The analysis process includes labelling the raw texts, clustering relevant data, and synthesising into a perioperative journey map and an actor map. Described challenges during the journey are also clustered as problem spaces.

04 Contextual Findings

This chapter presents the findings of the contextual research, including a TAVI journey map, care teams surrounding the patient, recognition of different patient types, and status quo of use of data. The discussion is done to answer the contextual research questions.

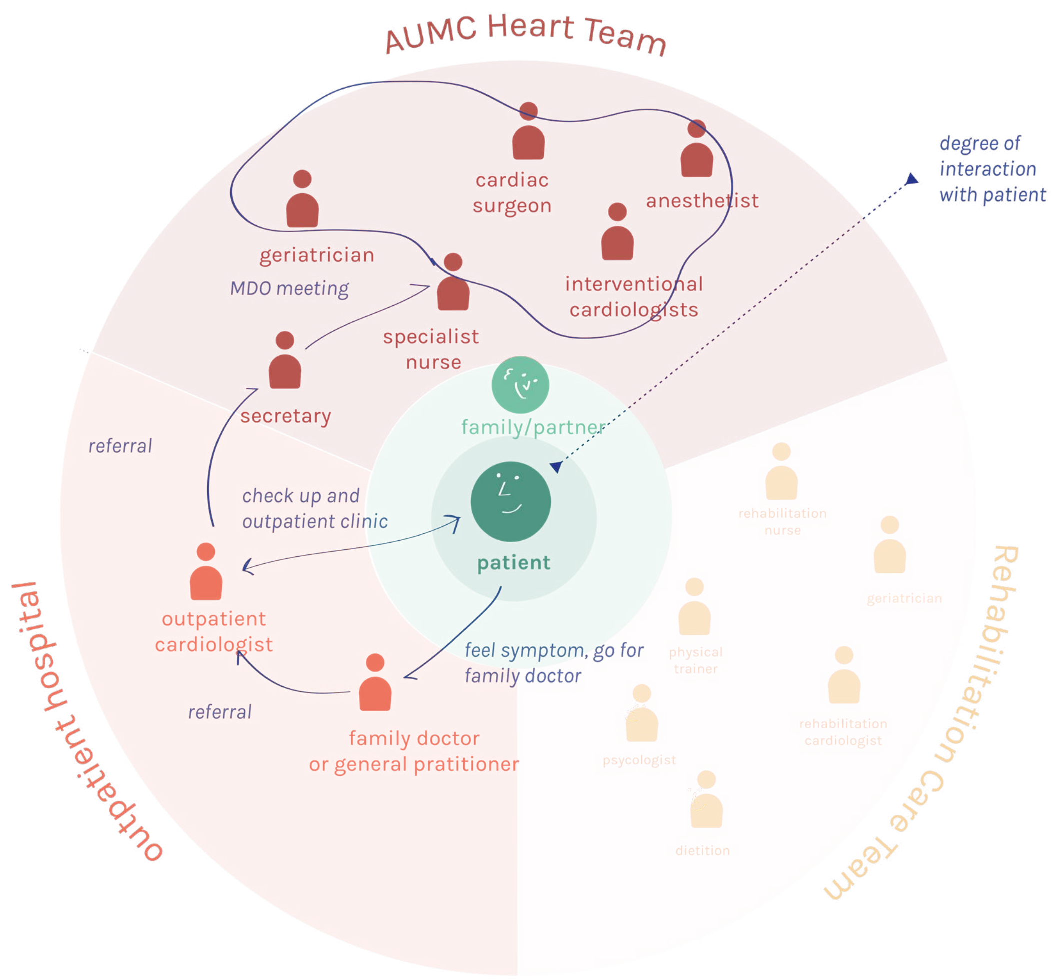
4.1 Care team around the patient

An actor map is created to understand how actors relate within a specific context. Throughout the TAVI care path, there are three separate care teams involved, which are "AUMC care team" , "outpatient care team" and "cardiac rehabilitation (CR) care team". Each care team consists of multidisciplinary medical professionals to act on the patient care in different parts of the journey.

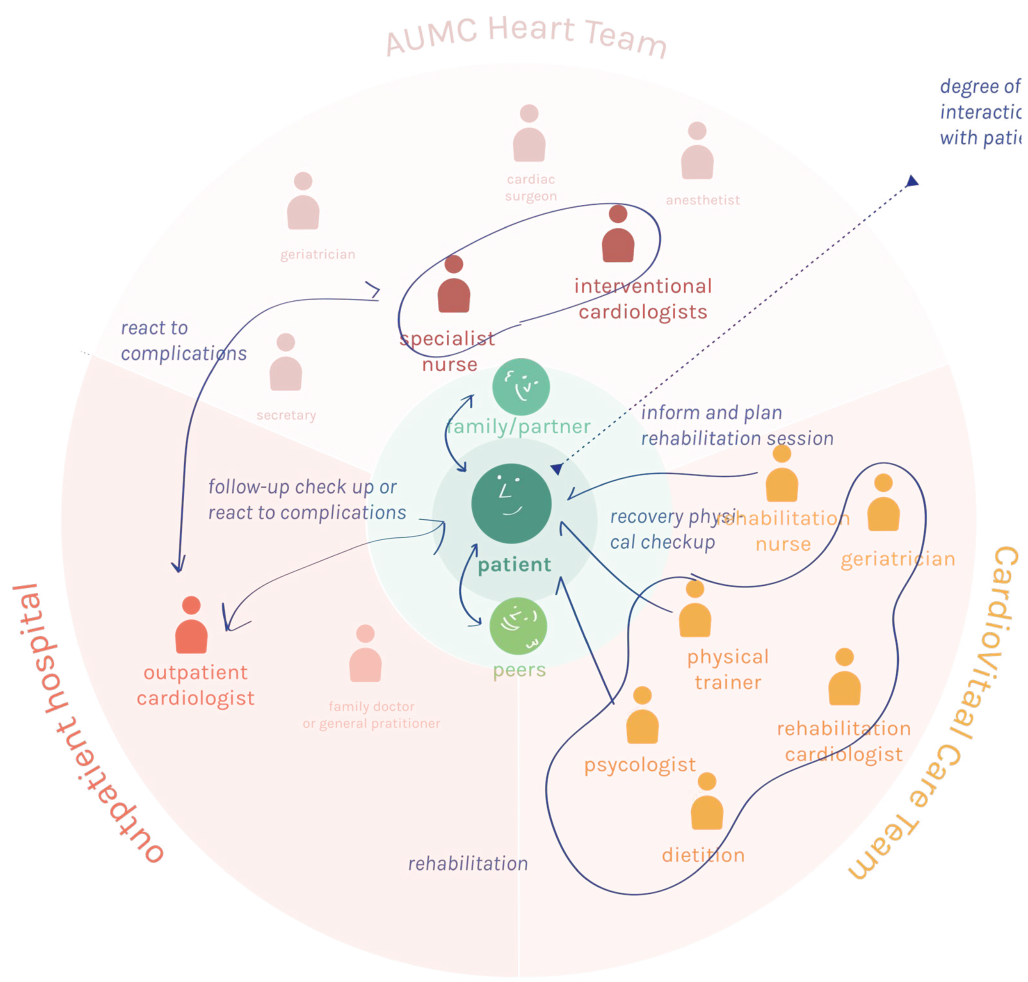
Normally a general practitioner (GP) serves as the first care touchpoint with a patient, yet since the scope of TAVI perioperative care focuses on specialised care, the role of GP is investigated in detail.

As illustrated in figure 15, we can see the care teams' responsibility change perioperatively. The outpatient care team is responsible for diagnosis of the condition making the decision of referral to AUMC / CR care team, and follow-up post-surgical assessment. The AUMC care team involves two rounds of screening and selecting patients for interventions, making optimal surgical decisions, performing the intervention, perioperative care, and long term research to improve care. The CR care team is responsible for assessing risk for rehabilitation, setting goals, coaching in physical fitness or lifestyle changes, and providing psychological support.

Pre-operative involvement



Post-operative involvement



4.2 TAVI perioperative journey

A perioperative journey map was created to understanding theTAVI perioperative care process in practise.

A journey map is made to gain a holistic view of the care process. The care process was analysed on different layers. A complete journey map is presented in the appendix G.

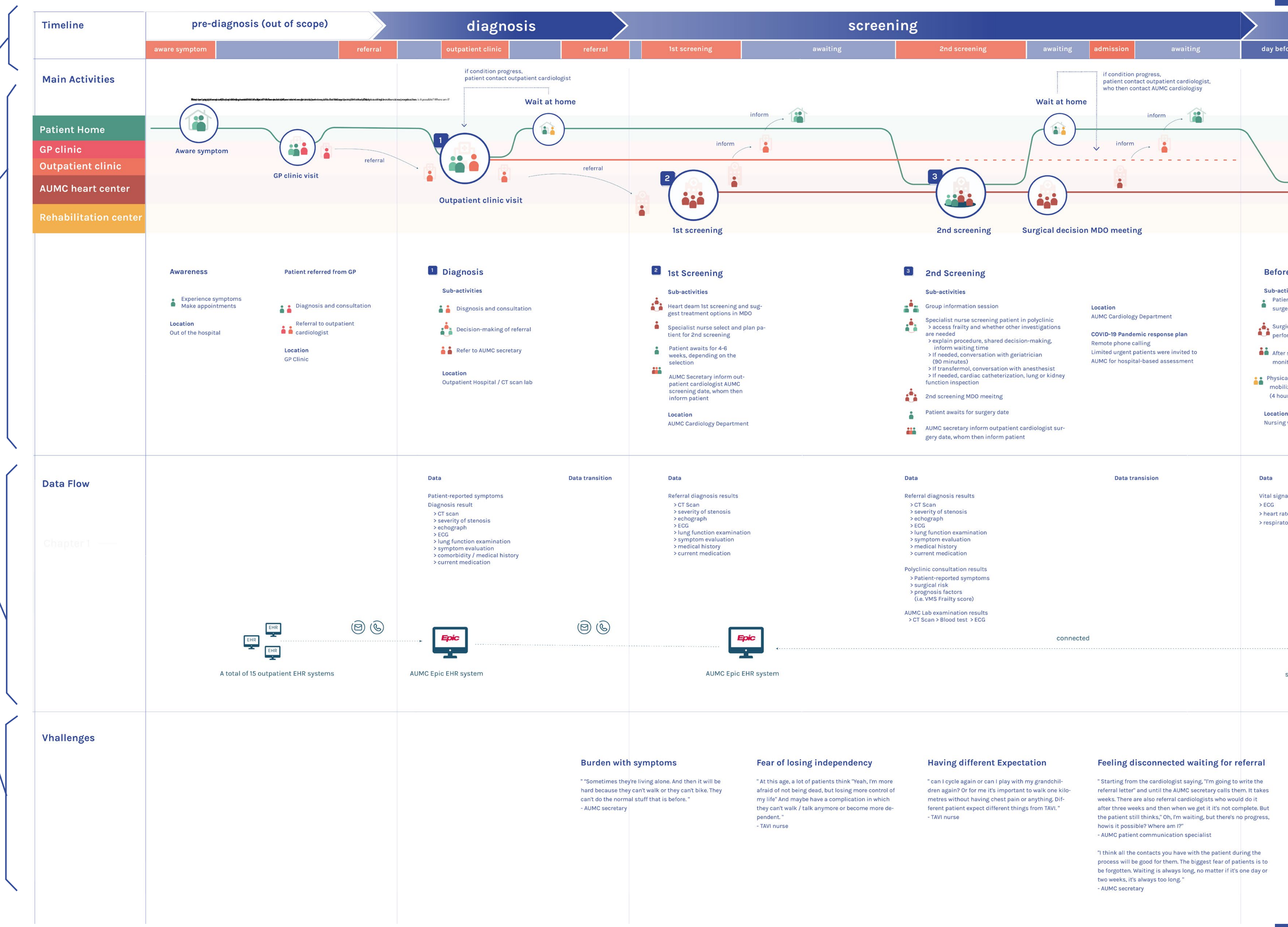
On the top layer, six stages were mapped as the 'timeline' of perioperative journey.

On the second layer, 'main activities' were highlighted. The researcher focuses on understanding who is involved, where, what are the actions performed and the goal of the activity.

On the third level, a 'relevant data flow' explains the existing data points and what type of data is needed.

On the last layer, challenges are identified and clustered.

This chapter discusses the findings.



Summary of main care activities

1. Diagnosis

Once referred from GP, the patient are first examined through CT scan and blood tests, which the clinician examine on the severity of stenosis. Patient's experience of symptom and comorbidities are being consulted to decide what treatments are suitable for the stenosis condition. If the patient experiences severe symptoms and has high risks, the outpatient cardiologists will suggest the referral to AUMC for screening.

Goal

The goal of diagnosis is to reach a shared decision of treatment. In the case of TAVI, this is to gain the patient's informed consent to refer to AUMC.

2. 1st screening

"We can't meet the patients during the first MDO meeting, it's all numbers. - AUMC TAVI specialist nurse

After making the referral decision, the outpatient cardiologist will refer the diagnosis information to AUMC. The is mostly done through phone call or email through AUMC secretary. Once the information is referred, AUMC secretary will manually input the patient into the EHR system and plan for screening. The first screening is done during a multidisciplinary (MDO) meeting based on referred information. The TAIV nurse and heart team specialists will examine the severity of TAVI and comorbidities to decide if the patient is eligible for TAVI.

During waiting, when a patient faces any issues or experiences progression of symptoms, they are advised to call their cardiologists. These progressions mostly occur during physical exertion.The cardiologists often make an appointment to examine the progression and will communicate the urgent patients with the AUMC secretary. AUMC secretary and TAVI nurse also manage to not only prioritise patients with severe conditions, but also patients with mild conditions that are on the waiting list for more that 5-6 weeks.

Goal

The goal of 1st screening is to prioritise and select eligible patients for second screening.

2. 2nd screening

Once a patient is admitted to TAVI, they are invited to visit AUMC for a second screening. The visit included a lab examination, a group information-giving session, and an 1-on-1 polyclinic consultation with a TAVI nurse. During the polyclinic consultation, the level of frailty is being examined. The patient's living condition is also investigated to ensure there is enough functional and social support after discharging home from surgery. If needed, additional consultations with geriatrician and anthenesists are scheduled. The above information acquired is then updated in the EHR system and discussed again in a 2nd MDO meeting.

Goal

The goal of 2nd screening is to evaluate surgical risks and plan the need of the surgery based on the patient's need (i.e. optimal surgical route, the date, and social support).

4. Hospital stay & rest at home

If the newly implanted valve is stable, patients are sent back to their own outpatient hospitals after 2-3 days. During the hospital stay, the patient is contacted by a local rehabilitation nurse for rehabilitation. Since TAVI has the benefits of shorter hospital stay, most patients can return home after 2-3 days. Patients are given the suggestion to take rests but try to move as much as possible.

Goal

The goal is to monitor any complications with the newly implanted valve and encourage patients to mobilise early.

5. Rehabilitation

"The fitness programme is not only about the fitness levels, it's also about "Do you dare to move? Do you know how to listen to your body? Do you know how to climb to a better fitness level?"

- CR coordinator

Cardiac rehabilitation is a multidisciplinary treatment to help patients achieve a healthy lifestyle. The care process describes the protocols of CardioVitaal, a main cardiac rehabilitation in collaboration with AUMC. During on-boarding , the patients are asked the preference about their lifestyle change. Patients are asked by rehabilitation nurses three activities they enjoy most, and rate out of 10 how difficult it is to achieve the activity (0 hard to achieve - 10 easily achieved).

The patients start the rehabilitation with a group information giving and individual consultation session. After the initial consultation, a MDO meeting is organised to assess ten vital factors and decide what the patient wants and needs. The care plan is based in 3 months, with 12 times fitness sessions and 4 times psychological and information workshop. During the middle and end of the rehabilitation program, another two consultations sessions are done to adjust the plan if needed.

For patients who are too frail to travel, a home-based rehabilitation is recommended. It is either done by home visits, or the remote consultation sessions being developed currently.

Goal

The goal of cardiac rehabilitation is to examine a patient's physical, psychological, social functioning needs and promote a healthy lifestyle.

4.3 Different patients

During the contextual research, different patient characteristics are depicted by the health professional and patient experts.

" Can I cycle again or can I play with my grandchildren again? Or for me it's important to walk one kilometres without having chest pain or anything. Different patients expect different things from TAVI. " - TAVI nurse

These patient types are differentiated by how active in lifestyles and how positively do they interpret thier exercise capability. The two extreme patient types are illustrated.

Different patient types can be recognised by assessing the lifestyle and understanding their expectations after recovery. It is important for care professionals to recognise the different patients so they can adjust their communication towards their expectations.

inactive ———————————————— **active**

The inactives

"I just want to go back to my everyday living ."

The inactives refers to patients who live an inactive lifestyle and interpret they can not do much because of their physical health. TAVI is seen as a treatment to live their normal living without being burdened by symptoms. After surgery, they are challenged in cardiac rehabilitation to transform towards a more active lifestyle. In the description of inactive patients, they are more advanced in age or more loss in physical functioning.

The achievers

"I want to be able to live my life again."

The achievers refers to patients who live an active lifestyle and interpret their exercise capability positively. TAVI is seen as a treatment to help them maintain their active lifestyle. After surgery, they are also more likely to overachieve during recovery, and are challenged to adjust their expectations towards exercise limits. In the description of achiever patients, they are younger in age or less frail.

4.4 Discussion

The researcher visits back to the research questions and reflects on the status quo of TAVI perioperative patient care.

Visiting back to the research objectives, these are the main learnings:

RQ 1.
How is patient care process done in practise? Who is involved? How do actors communicate/collaborate?

Before surgery, communication between doctor and patient are done through appointment visits and information giving sessions. After surgery, communciation are done during goal-setting meetings, group physical training sessions, and information workshops. In cases of patient experiencing complications, phones calls are made, mainly to setup additional appointments.

Cycle of communication

1. Assessing patient's health condition

Each care process starts with assessing and patient health condition. These are mainly done in hospital-based, one-time tests. For instance, CT scan, lab tests, frailty tests, exercise tests. The clarity and sufficiency of these assessed data affect the clinician's ability to interpret a patient's health status.

2. Information exchange

Clinicians and patients interpret their health status differently. The clinician interpret based on the previously assessed data; while patients interpret their health status based on how their subjective experience. During interpretation, there is a demand for information exchange. Clinicians need patient's sharing of experience and preference, while patients need clinician's help on interpreting their health condition.

3. Exploring a decision / goal / care plan

The preprocedure communication goal is to make a treatment decision. When the health condition progresses, additional cycles of communication are required. An effective communication occurs when there is an informed and shared consent for the decided treatment.

The postprocedure communication focuses on improving the patient's physical and social functioning. Since a patient's health condition can be improved or worsen throughout the rehabilitation, the cycle of communication is more iterative. An effective communication occurs when there is a shared goal that aligns with a patient's capability and preference.

Interprofessional teamwork

1. MDO meetings

MDO meeting is an event where multidisciplinary health care professionals together discuss the health evidence and make a decision or plan.

2. Referral across organisations

For care teams to collaborate across organisations, they rely on referral processes. The current referral processes are done mainly with phone or email, which also require a transfer of information. In the care journey of AUMC, patients are referred from a total of 15 referral hospitals, which each have their own cardiac rehabilitation center.

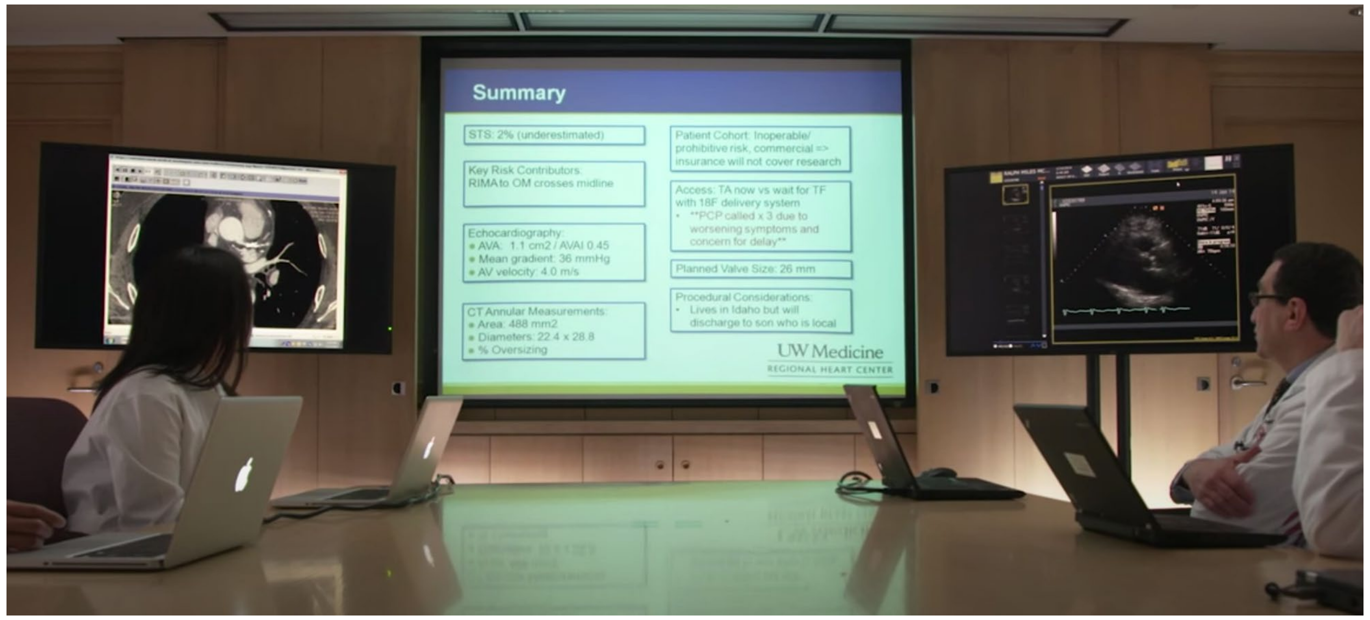


Figure 16
Impression of a MDO meeting (UW medicine)

RQ 2.
What and when are the challenges faced in patient-clinician communicaiton/muldiscinplinary teamwork?

The researcher discovered the following challenges:

1. Assess and exchange information in limited time

" I think you get most of the stress when you are really thinking, "Oh, I only have 10 minutes for my patients and I really have to do it in 10 minutes. When you have to explain TAVI to patient, that takes time. "
- Outpatient cardiologist

Most communications are being done during consultations. The challenge is to access the patient's health condition and fully inform patients treatment-related information in a limited consultation time. This makes the communication process stressful and overwhelming.

2. Rely on patient to recall contextual information

"It's very difficult because sometimes patient's cognition is bad or they have delirium. So first you have to be patient. But then you have your own clinical vision of the patient and you ask the family, family doctor and geriatrician. "
- Outpatient cardiologist

Contextual information is important for assessing the patient's condition. For instance, in consultation patients are asked to share the symptoms experienced past week. In training, the patients are asked what he did for the past week and how was the exercise. However, the longer the contextual experience is asked, the less detailed the patient can provide due to the memory.

3. Patient feel uncertain when to reach for help

" After the procedure, patients often go home thinking ' If I'm feeling this way, is this something I need to talk about with my doctor? ' It's all blurry in their head. "

"if a patient is very scared, most of them don't feel the freedom to ask questions because they think they are bothering the doctors or maybe the doctors do not have much time. "- AUMC patient communication specialist

Out of hospital, clinician relies on the patient to self-report progression of condition before surgery or complications after surgery. When patients did not react to their progress, which led to delay of care. Challenges are faced that there are no means to assess a patient's progression of complications when stepping out-of-hospital.

4. Fear to move

" Sometimes the patients stop and say 'Well I'm afraid I'm doing too much', then we reply 'It's okay, I don't think you can do too much at this moment. Just give it a try . " - CR coordinator

" It's not about patients training more in our rehabilitation center, it's about patients having to feel confident and move more in their own home surroundings."
- CR coordinator

Being active are important to prevent complications after surgery. However, patients have different active levels and interpretation of their own exercise capability, which affects what they can achieve. Especially during the rest period after surgery until rehabilitation sue to patient adjusting to the newly implanted valve.

5. Overwhelmed by information

" Patients are going home with a lot of information with a lot of folders or telephone numbers or an appointment for the follow up next week and also lots of information about medication. "
- AUMC patient communication specialist

In the group information giving . The researcher observed an attention drop at the end of the session. After the observation, the health care professions shared patient can only process short-term information and needed to be reminded again with the some information related to later care processes (i.e. what to do after surgery ...)

6. Feeling disconnected while awaiting

When selecting patients, urgent cases are being proceeded while others are put on the waiting list. Before surgery, a common question being asked from the patient is "when will be my turn.

" Starting from the cardiologist saying, "I'm going to write the referral letter" and until the AUMC secretary calls them. It takes weeks. There are referral cardiologists who would do it after weeks or when we get the information it's not complete. But the patient still thinks," Oh, I'm waiting, but there's no progress, how is it possible? Where am I?" - AUMC secretary

"I think all the contacts you have with the patient during the process will be good for them. The biggest fear of patients is to be forgotten. Waiting is always long, no matter if it's one day or two weeks, it's always too long. " - AUMC patient communication speciality

"We are worried about not being able to reach patients with urgent conditions . "- AUMC secretary.

During the first MDO meeting, patients have not yet visited AUMC. Therefore, the screening decision relies on the referral information. However, AUMC takes in referrals from a total of 15 outpatient hospitals, which each cardiologist has their own workflow. When the referred information are insufficient or unclear, back-and-forth confirmations are required. Also outpatient cardiologists have their own habits of referrals, some may immediately refer at the end of the day, while some prefer to refer bateched of patients weekly. Especially for patients with severe or progressive conditions, any late referrals may delay the treatment.

RQ 3. What is the status quo of the use of data ? What is its role?

Patient health status is a dynamite state that can be worsened due to the progressive heart condition or improved by the treatment applied. The use of data is to help clinicians assess a patient's health status.

Role of data

Support making surgical decisions

Before the surgery, the data is used to predicting surgical risks and make the optimal surgical decision. These include CT scan, Echo image, blood pressure, and assessment of frailty. For instance, when blood pressure readings are exceeding 180/120 mmg and symptoms (such as shortness of breath, chest pain) are experienced, it may be a sign of hypertension which needs immediate attention. Also, CT scan and echogram (Echo) is used to check the patient's heart structure (size, thickness of the heart walls) and how well the heart functions. Looking for signs of stenosis, regurgitation, or other conditions.

Particularly for TAVI, assessment of frailty has a correlation of patient's survival after surgery. Level of frailty is assessed through 6 minutes walk test, grip strength, and Edmonton frailty score (shown as figure 17). Patients who are rated higher in the frailty score are referred to a geriatrician consultation.

d.o.b. : ____________________ **DATE :** ____________________

Frailty domain	Item	0 point	1 point	2 points
Cognition	Please imagine that this pre-drawn circle is a clock. I would like you to place the numbers in the correct positions then place the hands to indicate a time of 'ten after eleven'	No errors	Minor spacing errors	Other errors
General health status	In the past year, how many times have you been admitted to a hospital?	0	1–2	≥2
	In general, how would you describe your health?	'Excellent', 'Very good', 'Good'	'Fair'	'Poor'
Functional independence	With how many of the following activities do you require help? (meal preparation, shopping, transportation, telephone, housekeeping, laundry, managing money, taking medications)	0–1	2–4	5–8
Social support	When you need help, can you count on someone who is willing and able to meet your needs?	Always	Sometimes	Never
Medication use	Do you use five or more different prescription medications on a regular basis?	No	Yes	
	At times, do you forget to take your prescription medications?	No	Yes	
Nutrition	Have you recently lost weight such that your clothing has become looser?	No	Yes	
Mood	Do you often feel sad or depressed?	No	Yes	
Continence	Do you have a problem with losing control of urine when you don't want to?	No	Yes	
Functional performance	I would like you to sit in this chair with your back and arms resting. Then, when I say 'GO', please stand up and walk at a safe and comfortable pace to the mark on the floor (approximately 3 m away), return to the chair and sit down'	0–10 s	11–20 s	One of : >20 s , or patient unwilling , or requires assistance
Totals	Final score is the sum of column totals			

Scoring :
0 - 5 = Not Frail
6 - 7 = Vulnerable
8 - 9 = Mild Frailty
10-11 = Moderate Frailty
12-17 = Severe Frailty

TOTAL /17

Administered by : ____________________

Figure 17
Edmonton frailty score (2017)

Seeking signs of complication

After the surgery, complications after surgeries can be found in ECG, for example atrial fibrillation. This is a sign that the patient is not doing well and needs medical attention. Patients experiencing symptoms is also an indicator to reach for help.

Support rehabilitation planning

The Metabolic equivalent of task (METs) is used to help trainers set a goal of physical activity training. METs measure the rate a person expends energy on a certain activity. For instance, if the patient wants to do activities of daily life, it requires a MET of 4-5. During exercise text, the patient's exercise capability is being examined. When the patient can only achieve a MET of 2 at the moment, they need to work toward the required METs.

Metabolic equivalents of some activities.

capacity (watt)	Metabolic equivalents (METs)	daily life activities	occupational activities	leisure activities	leisure and
0	1	sitting quietly, eating		sleeping	
1,5	1,5	washing, shaving		tv kijken kaarten	rechtop staan gedurende 15 minuten naai- en knipwerk
20	2	driving a car, cooking, brushing, mopping, dusting	light desk work (e.g. typing), light handicrafts (while sitting down)	playing music (piano, guitar), light woodworking, drawing, fishing, playing billiards / snooker	light cycling exercises with little or no resistance
40	3	making beds, vacuuming, ironing, polishing furniture,	standing upright for 15 minutes	bowling, golfen (vervoer), schilderen, vliegtuig nemen, autowassen, boogschieten	fietsen 8 km/u, wandelen 3-4 km/u lichte gymnastiek
60	4	showering, cleaning windows, scrubbing the floor, descending stairs, mowing the lawn (motor-driven mower), weeding, raking mown grass together, trimming hedges and lawn edges	assembly line work < 20 kg, driving in screws, electrician, bricklaying, painting, driving a truck, car mechanic	dancing (slow tempo)	fietsen 10 km/u, wandelen 5 km/u, volleybal, tafeltennis (2), golfen, zwemmen (schoolslag), badminton seksuele activiteiten
80-90	5	shopping with heavy shopping bags, sexual activities (with other than own partner), digging in the garden, mowing the lawn (hand-pushed mower)	heavy desk work, wall papering, pushing wheelbarrow, constructing footpath, mixed construction work: digging, brick laying / farming: feeding animals	dancing, river fishing, hunting, playing golf (carrying own bag)	cycling at 12 km/h, walking at 5.5 km/h, horse riding (trot), tennis doubles, badminton singles, rowing (exercise machine)

Figure 18
METs of some activities
(KNGF Dutch cardiac rehabilitation guideline, 2017)

Yet activity insights need to be compared with other information, such as experience of symptoms, heart rate and subjective feelings of fatigue. BORG or RPE (Rating percieved exertion) scale is used to evaluate a patient's subjective perceived fatigue level of exertion. For patients with limited physical functioning r advanced age, the KATZ independence in activities of everyday life are also used.

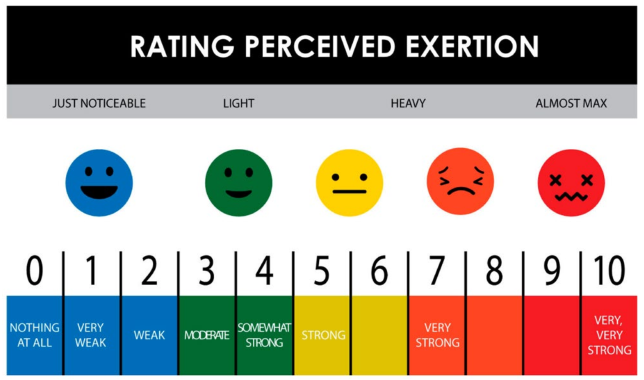


Figure 19
Rate of perceived exertion (RPE) table
(Alsamir Tibana et al., 2019)

Patient Name: ____________________ **Date:** ____________
Patient ID # ____________________

Katz Index of Independence in Activities of Daily Living		
Activities Points (1 or 0)	**Independence** (1 Point) **NO** supervision, direction or personal assistance.	**Dependence** (0 Points) **WITH** supervision, direction, personal assistance or total care.
BATHING Points: ________	**(1 POINT)** Bathes self completely or needs help in bathing only a single part of the body such as the back, genital area or disabled extremity.	**(0 POINTS)** Need help with bathing more than one part of the body, getting in or out of the tub or shower. Requires total bathing
DRESSING Points: ________	**(1 POINT)** Get clothes from closets and drawers and puts on clothes and outer garments complete with fasteners. May have help tying shoes.	**(0 POINTS)** Needs help with dressing self or needs to be completely dressed.
TOILETING Points: ________	**(1 POINT)** Goes to toilet, gets on and off, arranges clothes, cleans genital area without help.	**(0 POINTS)** Needs help transferring to the toilet, cleaning self or uses bedpan or commode.
TRANSFERRING Points: ________	**(1 POINT)** Moves in and out of bed or chair unassisted. Mechanical transfer aids are acceptable	**(0 POINTS)** Needs help in moving from bed to chair or requires a complete transfer.
CONTINENCE Points: ________	**(1 POINT)** Exercises complete self control over urination and defecation.	**(0 POINTS)** Is partially or totally incontinent of bowel or bladder
FEEDING Points: ________	**(1 POINT)** Gets food from plate into mouth without help. Preparation of food may be done by another person.	**(0 POINTS)** Needs partial or total help with feeding or requires parenteral feeding.
TOTAL POINTS: ______	**SCORING:** 6 = High (*patient independent*) 0 = Low (*patient very dependent*	

Figure 20
KATZ independence of daily activities
(ADL Checklist - Determine If It's Time for Assisted Living | Pathways SCA, 2020)

Status quo of the use data

Transition of data across organisations

Referral to admission:
Referral emails or calls from outpatient cardiologists reports the complaints, preliminary examination results, ECG images to the AUMC secretary. **IntelliSpace Cardiovascular (ISCV) & EVOCS** are used for medical image transfer (i.e. ECG, CT scan).

Once referred, AUMC secretary then records the patient information into EPIC. **EPIC** is the EHR system adopted in AUMC. Features include recording patient health information, scheduling, and follow-up. EPIC is authorised to the specialist nurse and the heart team, with features like recording patient health information, scheduling meetings, and follow-ups. AUMC is currently testing cross-system communication tools (such as **MediMap**) to help integrate information and better inform patients and informal caregivers in the journey.

Before/after surgery data flow:
Once the patient is situated in the ward, the **Philips IntelliVue Guardian Solution** is in use for patient perioperative monitoring. The solution enables ward nurses and doctors in real-time to track vital functions (such as heart rhythm, heart rate variable, respiratory rate) and support them to react to emergencies with the early warning scoring (EWS).

Recovery data flow :
Each cardiac rehabilitation center has their own EHR system to help CR care teams tailor care plans for patients. Taking the example of cardioVitaal, **MyVital10** is a e-personal portal currently in use. The care team can keep track of the patient's health condition through ten essential risk factors (including blood pressure, weight, steps, sugar values, stress levels, diet intake, drinking, and sleep quality). The data allows different professionals to give healthy lifestyle coaching and help patients keep track of their training progress

Making sense data through a collective comprehension

Data itself does not make sense without having a reference. When care professionals are accessing the data, clincians understand the data by a comprehensive view od:

- Evaluating according to a criteria
For instance, in CT scan results, care professionals look if the highest pressure on the AVA (p max), is above 90; or if the alpha, the surface or the valve (alpha) is smaller than 0.6 square centimetres. These indicated high risk patients.

- Comparing with past data
Comparisons are made to see if there are improvements.

- Jointly evaluated with other data.
There is a relation to combine heart rate data with physical activity data.

- Combining with other medical professions knowledge or patient's own contextual knoeledge of the health condition

Mainly rely on hospital-based examiniation

The collection of patient condition data mainly based on hospital-bases measure protocols and instruments. When there are changes in patients health condition, appointments are arranged to assess these changes. However, the changes either will be reported by patient when experiencing symptoms, or being examined through standarised check-ups. .

CHAPTER 4 MAIN TAKEAWAYS

A contextual research is done using observation, sensitising kit, expert interview and online desk research to explore the TAVI journey.

During care process, a cycle is being repeatedly take place
1. Assessing patient's health condition
2. Information exchange
3. Exploring a decision / goal / care plan
When the patient's condition changes, a new cycle needs to be initiated.

Before surgery, communication between doctor and patient are done through appointment visits and information giving sessions. After surgery, communication is done during goal-setting meetings, group physical training sessions, and information workshops. In cases of patient experiencing complications, phones calls are made, mainly to setup additional appointments.

Communication between teams is done through MDO meetings and referral processes.

Several challenges are faced:
1. Reacting to progression or complications out-of-hospital
2. Need to assess and exchange information in limited time
3. Rely on patient to recall contextual information
4. Rely on hospital-based assessments
5. Barriers in home activities

The gathering of data in the existing journey is mainly from hospital-based assessments. Data is made sense by comparing with previous data or reviewed jointly.
The role of data is to :
1. Support making a surgical decision
2. Seek signs of complications
3. Support rehabilitation physical training

Clinicians need a comprehensive view of the data, contextual information, and other expertise; patients need to have a personal awareness and clinician's medical support in understanding their own health condition.

05

Problem Definition

This chapter congregates the research insights from chapters 2,3,4 and reaches a problem definition. Interest of different stakeholders sought in the biosensor PSS are revisited and a design goal is stated.

5.1 Value of PSS for stakeholders

Before defining a problem definition, the researcher reflects on the known information and define main values of using the biosensor for different stakeholders.

Coming from the first intake meeting, more stakeholders are involved in this project. Each stakeholder has a different perceiving value of using the biosensor. Before defining a problem definition, the researcher reflects on what are the main values mentioned in the expert interview and stakeholder interviews.

Value for AUMC

Better plan for the TAVI procedure by staying connected with the patient

Learnt from AUMC stakeholder's experience, it can be a long period of time since getting the referral information at the heart team to getting accepted in TAVI. For example, during CT scan, other comorbidities such as lung conditions may be found. Patients therefore need to fix these conditions before admitted, which may take months. If the patients were equipped with the biosensor, the AUMC heart team can stay connected and plan for surgery if symptoms occur.

Value for CardioVitaal

Support coaching in home environment

Learnt from CardioVitaal coordinator, the perceived value for using the biosensor is being able to help patients improve their everyday physical and psychological functionings in their own home environment. The goal of the rehabilitation is to help patients understand their own exercise limits and become more active in a safe zone.

Value for Outpatient hospital

Early detector for complications

Learnt from outpatient cardiologist, cComplications after surgeries often happen in physical exertion. Complications can be indicated by experience of symptoms and detected from ECG, for example atrial fibrillation. This is a sign of which patient is not doing well and needs medical attention. Since patients are referred to AUMC, outpatient cardiologists do not always know where the patient is in the care pathway. However, when complications happen, they want to be able to react.

Value for Philips

Additional stakeholder interviews are done with 3 Philips team members (a data designer, a connected product lead, and a researcher). The set-up of the interview and questions asked in the session are explained in the session are explained in appendix H.

'We have Philips products collecting data points in the hospital, beside ward bedsides... but out of the hospital, patient data becomes a black box. We want to help our healthcare clients unlock this black box.'

- Philips stakeholder, 2020

During the conversation we've understood the Philips biosensor is part of the patient monitoring portfolio. Other wearable biosensors including BX100, the newly debuted model BX100 used in intensive monitoring during COVID-19 pandemic (Philips, 2020); as well as the health dot, are also in development. These wearable biosensors are mainly used in the context of the emergency department and general ward to collect up-to-date patient status and alert caregivers with early deterioration.

Philips is expanding the use cases of the wearable biosensor beyond ward bedside, and looking into the potential for telemonitoring.

Overlapping interest

Between Philips and medical teams, the researchers see an overlapping interest of staying connected with patient conditions out-of-the hospital.

5.2 Problem Definition

" When stepping out of the hospital, patient and clinicians struggle to reach a shared understanding in communicating health progress and decide an ideal course of care actions."

Investigated in the contextual research (chapter 3,4), a communication cycle is repeated in care process, that to reach a shared understanding, patients and clinicians need to

1. Be able to assess patient's health condition
2. Be able to interpret health status through information exchange
3. Be able to explore a decision / goal / care plan.

However, not always patients and doctors are communicating when needed.

6.1.2 Problem definition

Reviewing the challenges in perioperative journey, the main challenge occurs out-of-hospital. Clinician lack of means to gain a comprehensive idea of the patient's health condition out of hospital, and can only rely on the previous examined results, which may not be reflecting on the patient's changing condition. This makes it difficult for the health care team to react or provide personlised feedback for a patient's changing condition.

Patients on the other hand, can only rely on their subjective interpretation on health conditions until the next communication appointment. This can lead to misunderstanding in expectation and not being able to take suitable actions (i.e. exercising safe or enough).

The problem is then narrowed as

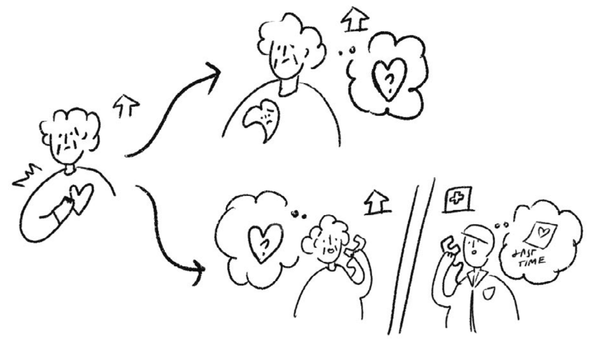
" Out of hospital, patients do not know when to react to complications and how active they can be. Clinicians struggle to provide medical advice without knowing the patient's health condition and needs."

Two kinds of communication towards shared understnding needed to be built out of hospital context, which are illustarted in figure 21:

1. knowing when and what actions to take if complications occurs

2. Knowing how active can and should the patient during home recovering

Current interaction → Envisioned interaction



Patients not knowing when to react to symptoms or complications. This may result in not reaching out for medical care in time. Clinician struggle to suggest medical actions without knowing the condition.

Patients knowing when and what actions to take if complication happens. Clinicians know what medical care can be provided.

Patient not knowing how active can they be when returning home from surgery. This may result in inactive lifestyle or overachieving. Clinician struggle to give personalised advises.

Patients knowing an ideal range of physical activity. Clinicians know what phsyical/psychological guidance can be provided.

Figure 21
Current and envisioned interaction

5.3 Design statement

" Design a telemonitoring product-service-system (PSS) that supports patients and care teams form a partnership to collaboratively access health progress and feel supported to explore a goal/care plan."

Design statement

" Improve shared understanding by designing a telemonitoring product-service-system that supports patients and care teams to assess and build a shared knowledge of health conditions out of hospital."

The PSS aim to:
- make patients feel informed, safe, and supported during the perioperative journey.
- make clinician feel empowered to personalise a care plan and support patients when needed

The researcher come up with a set of design strategies to build share knowledge:

1. By building a shared information base of the patient's dynamite health status

2. By helping patient to better interpret their own health condition

3. By helping clinician to empathise on patient's contextual experience

Limitations

There are several limitations not being able to solve by the scope of this project. Therefore, several assumptions are made.

Use of biosensor

The requirement of the PSS is to use the data collected from the Philips wearable biosensor, which limits what are the incorporated data types.

Willingness to adopt the biosensor

There are a total of 15 outpatient hospitals and each having thier cardiac rehabilitation center to refer to. It takes an effort of having all the organisations onboard. The project assumed that all outpatient, AUMC and rehabilitation center are onboard with using the biosensor in the care process. In real implementation, It takes an effort to inform all the organisations and gain agreement to participate, which is out of the scope of this project.

Data interoperability

There is a challenge of data interoperability between different organisations. Different electronic health record systems require referral of data, which may create a gap in transmitting data. These obstacles are important to address in implementation, yet not solved by this project.

Consider of cost

The project also assumes there is no strict restriction in selecting the technology or devices used in the design. In real implementation, the consideration of cost may be a big decision factor to seek the most cost-effective solution. However, this project focuses on exploring a concept to spark an interesting discussion.

06

Conceptualisation

This chapter generates three preliminary design concepts to co-reflect with relevant stakeholders the aspects of the PSS.

6.1 Preliminary design concepts

This chapter discuss on the three preliminary concepts generated.

The design goal is to " Improve shared understanding by designing a telemonitoring product-service-system that supports patients and care teams to assess and building a shared knowledge of health conditions out of hospital." A requirement for the PSS is to use data collected from the wearable Philips biosensor.

Due to the context of design existing a geographical barrier between patient and care professionals, the researcher is looking into digital solutions that can remotely transfer and use the monitored data.

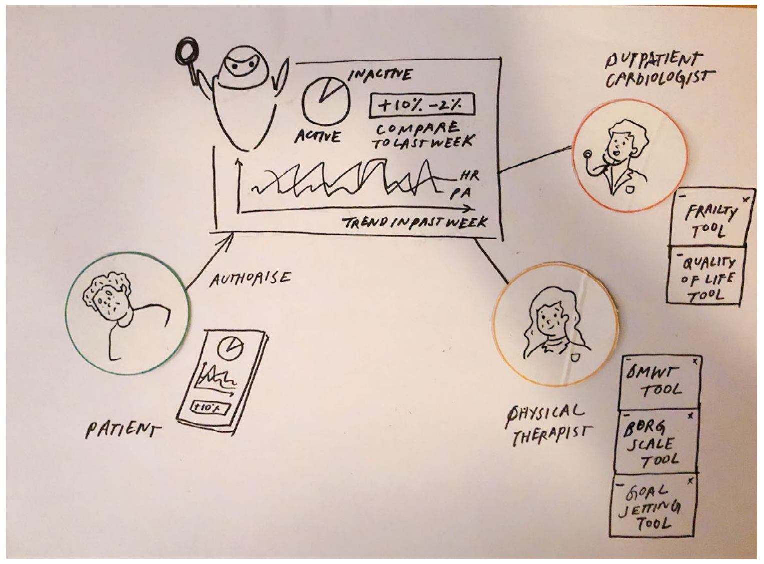
Brainstorming sessions are done to ideate **how can Hart, a digital care assistant play a role in helping patient and doctors build a shared knowledge out-of-hospital?** The generated ideas were clustered into three preliminary concepts (shown as figure 22).

Three preliminary concepts

Concept #1 Hart as a ‘supportive examinator’

Hart aims to provide patient and clinician a common interface to collaboratively discuss on the health condition.

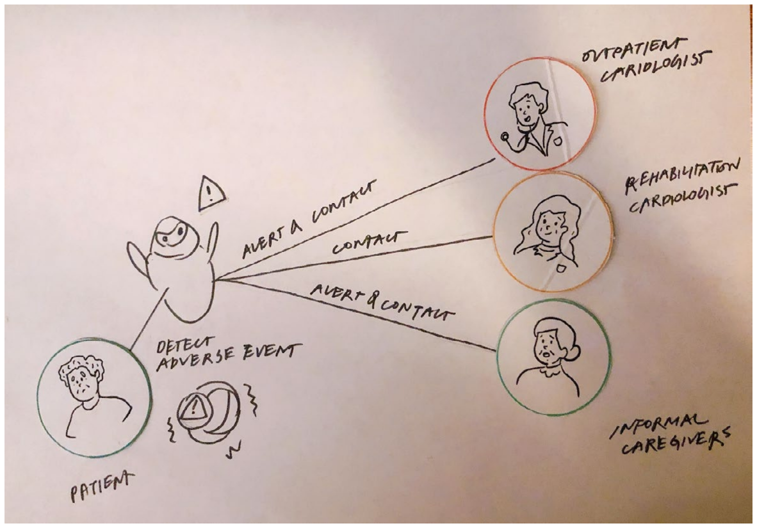
Use of design strategy:
- By helping patient to better interpret thier own health progress
- By helping clinician to empathise on patient’s contextual experience



Concept #2 Hart as a ‘home training companion’

Hart aims to help patient become more active by reflecting on everyday physical and psychological wellbeing.

Use of design strategy:
- By helping patient to better interpret thier own health progress
- By helping clinician to empathise on patient’s contextual experience



Concept #2 Hart as a ‘safe guard’

Hart aims to provide patient a sense of safety providing a mean to share symptom and by detecting complication.

Use of design strategy:
- By helping patient to better interpret thier own health progress
- By helping clinician to empathise on patient’s contextual experience

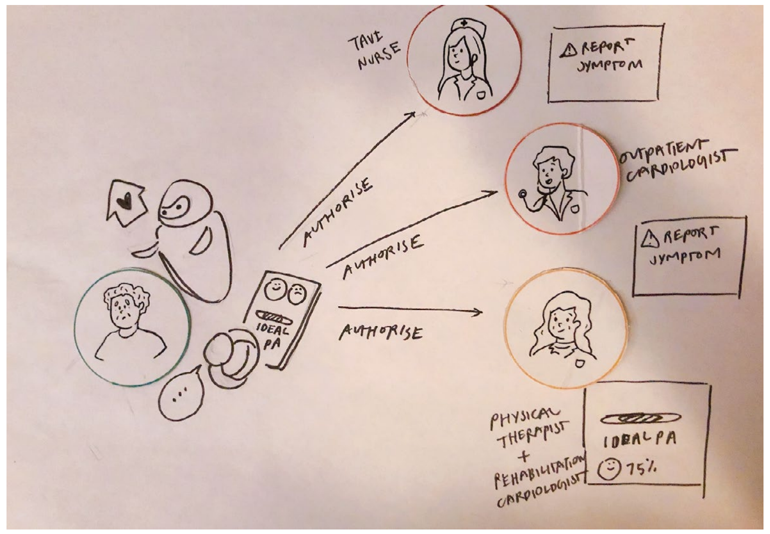


Figure 22
Three preliminaty concepts

Concept #1 Hart as a 'supportive examinator'

Concept one presents a dashboard containing contextual and objectively measured information for clinicians to collaboratively discuss the health condition with patients.

The highlight of the dashboard is to allow clinicians to combine different objectively measured and contextual data in trends.

Concept one proposes the monitoring data to be authorised once to the care teams and continuously collected throughout the monitoring period.

Propose features:
A dashboard of long-term trends to select and compare desired information

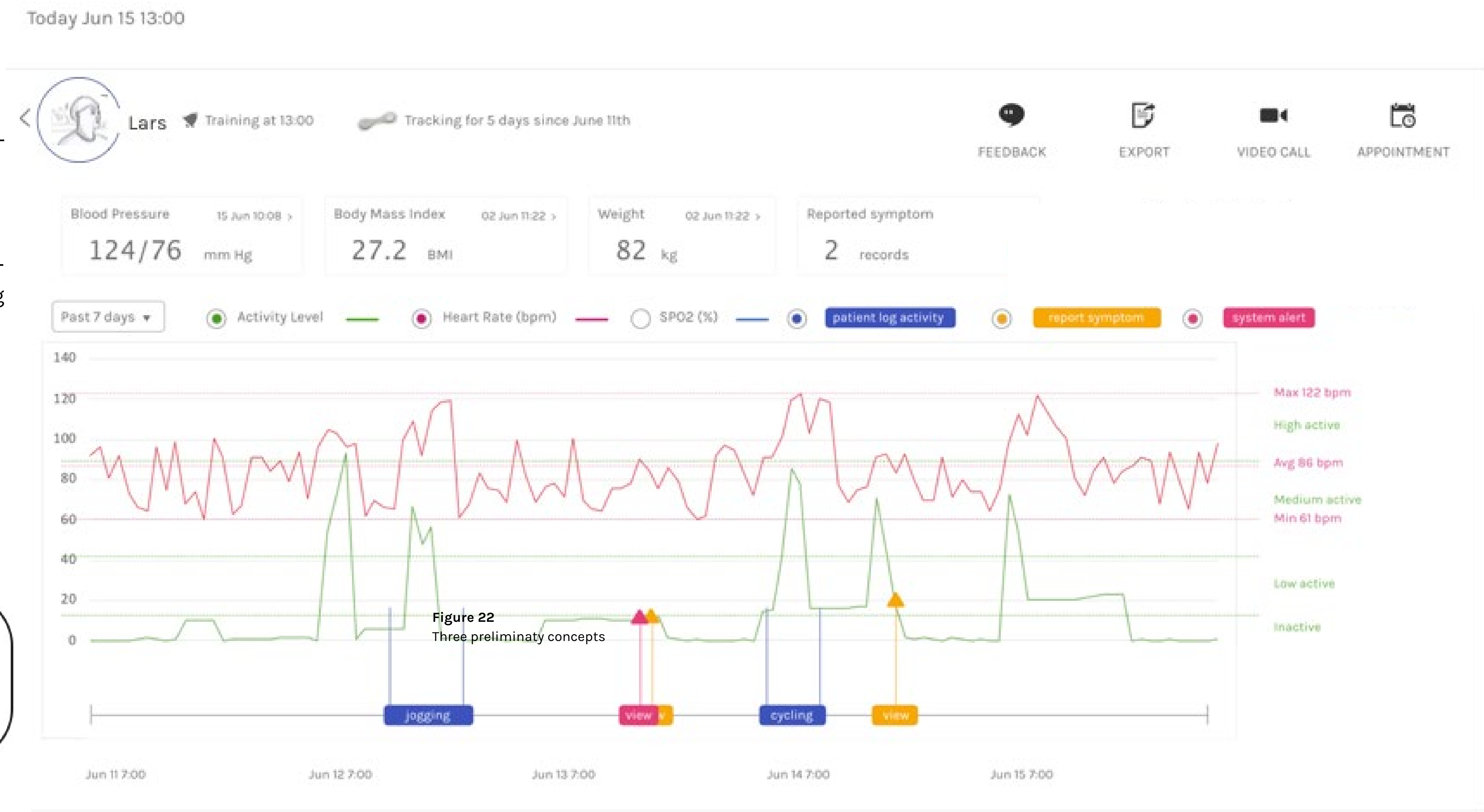


Figure 22
Three preliminaty concepts

Figure 23
Concept 1 dashboard

Concept #2 Hart as a ‘home training companion’

Concept two presents a conversational voice assisstant hosted on a smart watch. Patients interact with the conversationaal agent to reflect on everyday physical and psychological wellbeing.

The highlight is to have a natural interaction to inquire is it safe to engage in exercise and share exercise experience.

Through the hosbital based exercise test, the biosensor can classify on the intensity of the activity, and suggest an ideal activity level according to the patient’s ideal maximun heart rate. The clinician can adjust this ideal activity level range, which serve as a exercise safe zone. After leaving the hospital, the Patient can decide on when to track the exercise and whether to share the contextual data to the care team.

Propose features:

Create an ideal activity level reference
Patient share contextual information
(how exhausted, what kind of exercise)
Daily check-in on emotional status
System check exercise safe zone
(using heart rate and exercise intensity)

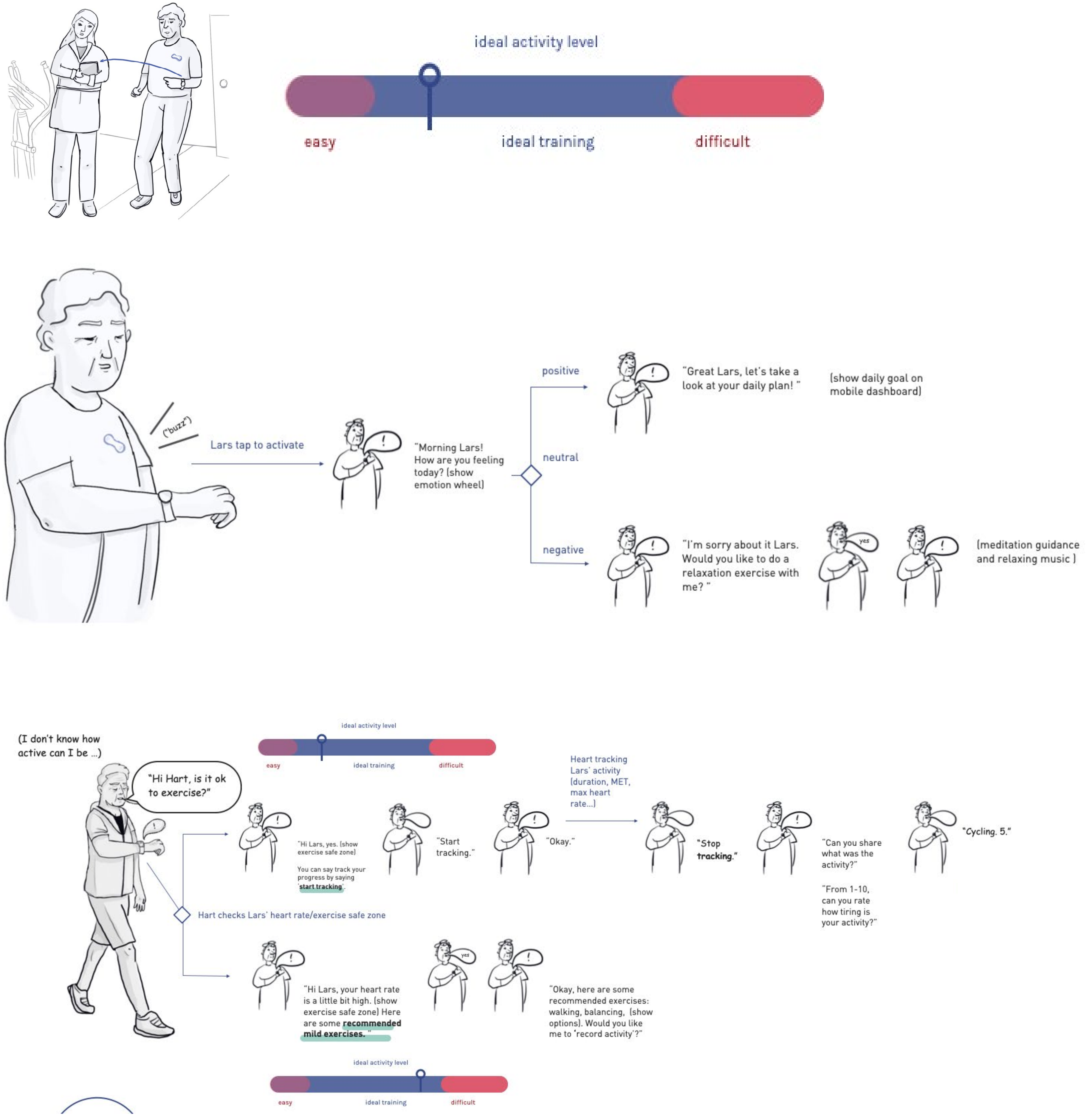


Figure 24
Concept 2 conversational flow

Concept #3 Hart as a 'safeguard'

Concept three also presents a conversational voice assistant hosted on a smart watch. A sense of safety by allowing patients to share experienced symptoms. Another interaction is signs of complications occurring (i.e. abnormalities in ECG) worsen, the system sends an alert to the patient, which can be shared to the care team. In the case of serious emergency (detection of heart stroke or fall), the system will automatically contact 112 if the alert is not deactivated for a period of time.

The highlight of concept 3 is to provide preventive actions for abnormalities and reactive actions for emergent situations.

Propose features:
Patient share symptoms
System detect and Alert abnormalities
System detect emergency event

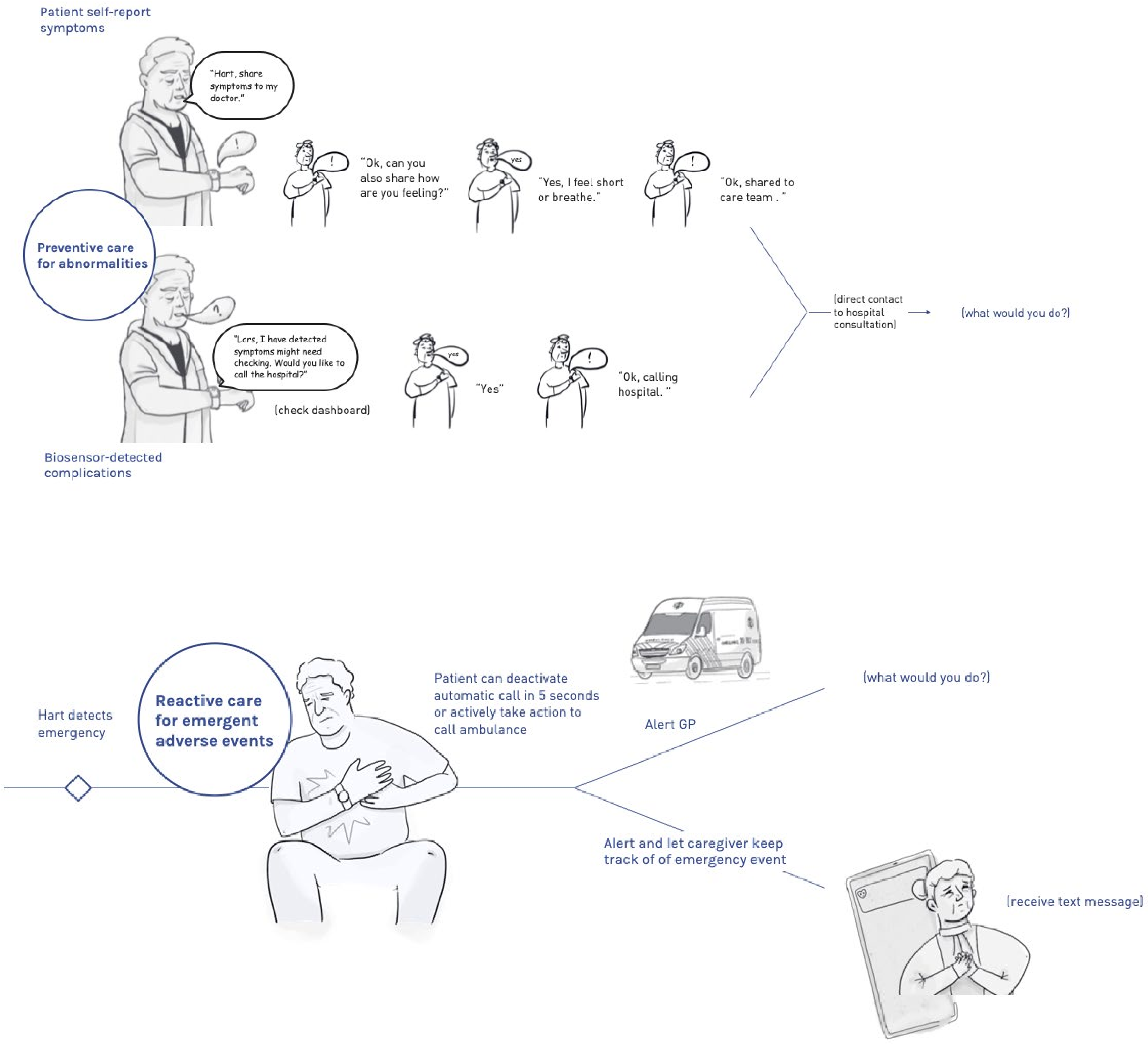


Figure 25
Concept 3 conversational flow

6.2 Concept evaluation

This section explains the co-reflections with the relevant stakeholders and iterations on the design concept.

The three preliminary concepts were presented through narrative storytelling and co-reflected with stakeholders. The evaluation focus on the feedback of the stakeholders, including:
1. What is perceived valuable in this solution?
2. What can be improved in this solution?
3. How do you see this solution compared with your current workflow?
4. How concerned are you in this solution?

The feedback was used to iterate on three aspects of the P-S-S:
- product aspect (ideal set of feature)
- service aspect (users, cycle of use)
- technology aspect (data flow)
These aspects were elaborated and use to develop the final P-S-S design.

The three concepts are co-reflected with relevant stakeholders (1 patient specialist, 1 TAVI nurse, 1 cardiac surgeon, 1 physical therapist). Narrative storyboards are used to describe the concept and interaction scenarios (***refer to appendix ?***).

Reflecting on concept 1

The first concept of a dashboard is seen helpful using in the existing consultations. The advantage is to allow clinicians focusing on the why and explore solutions towards the health condition. The dashboard is especially perceived useful for remote coaching in home-based rehabilitation.

Enabling individual feedback in remote coaching

"Then advice can be given as: Why do you move so less? I see you are active, but why mostly at a low heart rate level or too short? It's good that you move a lot, but the exercise seems to exhaust you. The conversation can focus on the "Why" of how they can overcome the barrier. - CR coordinator

Together with CR stakeholders , we reflected that the current remote training is done in groups, which in the first 15 minutes is to ask the patients to share what happened last week. If the patient has a blood pressure measuring device or fitness watch, they are asked to share what was the health rate and blood pressure. When patients don't have a training device or cannot clearly recall the past activities, the given advice is also general.

Being able to the compare different monitored data in trends

The care professinals stress that data only make sense when there is a reference or being viewed jointly.

"The trainer will focus on the total workout time, the intensity, distance, heart rate, observation of how tired the patient is. The given advice is a comprehension of all this information." - CR coordinator

"Heart rate means nothing if there is no reference, it is the balance to reach the minimal activity level and intensity in home-training that matters ..."

What can be improved/concerns:

Comparison before/after

For AUMC stakeholders, they have more of a research interest to see if the patient actually moves more after TAVI is given. The CR stakeholder also addressed it would be nice to see how the exercise capacity changes after TAVI, as the improvement on exercise capability itself could be a reward for the patient.

Reflecting on concept 2

Being at the moment

The voice conversation with Hart is seen as a non-obstructive way to interact during workout. Stakeholders find the idea of using voice-based interaction has the advantage to allow patients self-monitor at the moment of exercise. This raises an assumption of whether the patient will be more willing to share the contextual information.

What can be improved/concerns:

Focus on regaining confidence

TThe care professionals and patients experts stressed the goal of rehabilitation is to help patients regain confidence and feel encouraged to become more active in their everyday life. In existing care, a traffic light model is used to help patients self-reflect on how they feel before exercise. The goal is not to judge patients on how close the goal is achieved, but give encouragement and help to overcome the barriers of achieving. g.

"From my own rehabilitation experience, always go for baby steps. This way we slowly build up the trust towards the care system and regain our self-confidence in life." - AUMC patient specialist

"The first goal is to teach patients to reflect on how they feel and decide on whether they feel confident to engage in a workout, then we can talk about how to progress." - CR physical therapist

Providing secondary interaction for VUI

A concern is addressed that purely voice interaction may be a challenge for elderly patients due to the hearing impairments. Yet, they addressed that secondary interaction element is desired.

Reflecting on concept 3

Capturing complaints during exercise

The care professionals share the complaints of aortic valve stenosis often occur during exercise. The wearable smart band allow the patient to be mobilised while having a touch-point.

Providing possible actions

In current care process, the patients are mostly given a number to dial. Over the phone conversation, the rehabilitation doctor will make a decision of whether the shared situatoin is safe or unsafe, and suggest actions to take (i.e. change in medication or make an appointment). The advantage of this concept is to provide the action of contact and share the health condition (ECG and experienced symptoms) when complications are experienced or detected.

"Patients are mostly given the number of hospitals to dial, some can also take the extreme as dialing 112 for emergencies. Despite the patient's actions vary, giving the option of action is essential." - CR

What can be improved/concerns:

Manging expectations

In case of system false detection, the care professionals concern whose responsibility is to take. The care professionals and patient experts also shared when patients share a symptom, they expect feedback and guidance. However, it is not possible to 24 hour giving real-time feedback to the patient. The system should give an expected buffer time to manage the patient's expectation.

When patients report, it's important to manage their expectations. Real-time feedback is not feasible, then they ought to know what will be the action. - AUMC & CR

General reflection

Understanding patient's personal goal

The care professionals are curious about the patient's personal health preference before the monitoring.

It's ideal to already communicate the patient's personal goal first, so the care can be catered towards his/her need. - AUMC

Avoid negative terms

A general remark is to be aware of not using negative terms, which may trigger a patient's emotive distress.

" Inactive/risk/danger are the negative wordings we want to avoid, may trigger anxiety for patients, instead we say rest/easy/training/difficult. "
- CR physical therapist

Possibility to integrate in EHR

Although this is out-of-scope for this project, the care professionals shared in their workflow, the EHR is the hubspot of all patient information. The monitored data is seen as an additional data point that ideally to be integrated on the existing system.

A decision is made that Hart will take up different roles during different parts of the journey, which leads to a second iteration of discussion: cycle of use.

Reflecting on cycle of use

To clarify on how Hart can play different roles in different parts of the journey, the cycle of use is explored. The **changing of roles is regarded as triggering different features of the product-service-system.**

The **entry point of interacting** with Hart is originally proposed before the hospital discharge by the physical therapist to health baseline before training starts. After discussing with stakeholders, this is suggested to take place **after the 2nd screening in AUMC during polyclinic,** where Hart plays the role as an supportive examinator to keep track of patient's progression of heart condition and establishing the health baseline before the surgery.

" It would be valuable to know what was the active level before the training started that would be the actual health baseline. "
- quote from CR physical therapist, 2020

" It is ideal to have the baseline already established in screening, so not only patient can see what they can benefit after the surgery, but we can start communicating with the patient's what are their personal goal and cater the care towards his/her need. "
- quote from AUMC TAVI nurse, 2020

The first phase of service takes place during the awaiting time before the surgery, mainly as a safeguard to report the progression of heart condition and support the patients to self-report symptoms.
The third, also the **main use of Hart, is during home training**. Hart takes up a mixed role as a safeguard and a home recovery companion.

The **second phase of service** is after patients get discharge from the hospital and before onboarding the rehabilitation. The goal of this 1-2 weeks gap is to **support the patients to onboard rehabilitation**. Features such as providing rehabilitation-related information and monitoring complications can be helpful. Hart may play the role as the home companion to manage emotive distress through daily check-in.

During the discussion, the question of whom to be responsible and involved in the PSS integration is raised, which leads to the 3rd iteration of the collaborative scheme.

Reflecting on who to be involved

Related to home-based rehabilitation, we discovered that **the current care activities in rehabilitation are mainly done in groups (i.e. group PEP introduction, group training), which a more general advice is given.** Three individual sessions are planned, which are beginning, halfway, and end of the rehabilitation.
If the PSS is introduced and individual feedback is required, possibly a tele-coach needs to be added to the team portfolio.

As for reacting to symptoms, originally the concept proposed the PSS to suggest course of actions depending on symptom classifications. However, feedback shows the preference of having human-in-the-loop. Currently the patient is given a contact number to contact either the outpatient cardiologist or rehabilitation cardiologist. According to the phone conversation, they make the decision of whether the best course of action is changing medication, schedule appointments for diagnosis or an urgent action is required. Patients can also take the extreme to dialing 112 for emergencies.

"Although patient's may prefer to take different actions when experiencing symptoms, it is essential to provide them the options whenever needed."
- quote from AUMC TAVI nurse, 2020

A concern is raised that when giving the option to let patients report symptoms, it is crucial to manage their expectations. Real-time feedback is not a feasible way since it will significantly increase the workload of clinicians, yet expecting reply within 24 hours is realistic.

Reflecting on technology

The product-service-system needs to switch between different features, the researcher looked into agentive technology. Agentive technology, according to Christopher Nossel (2017) is one form of narrow artificial intelligence that does things on users' behalf. Compared to assistive technologies of completing things, these agents interact on the promise of user-centered design.

To sum up, the co-reflection of three preliminary design concepts is valuable for iterating on the final PSS proposal.

CHAPTER 6 MAIN TAKEAWAYS

Three preliminary concepts of the PSS system generated to explore what role can a digital care assisstant take The concepts are 'Hart as a supportive examinor', 'Hart as a home training companion', and 'Hart as a safeguard'.

Concept 1 'Hart as a supportive examinor' presents a dashboard to collaboratively interpret the health condition with patients. Perceived values include enabling individual feedback in remote coaching and Being able to the compare different monitored data in trends. A comparison before/after the sugery is desired.

Concept 2 Hart as a home training companion' presents a conversational voice assisstant to help patient reflect on everyday physical and psychological wellbeing. The main perceived values is allowing patient to be at the moment, yet, a suggestion is given to focus on regaining patient's confidence.

Concept three also presents a conversational voice assistant, but focus on providing a sense of safety by allowing patients to share experienced symptoms or alerting signs of complications. The perceived values are Capturing com,plaints during exercise and Providing possible actions. However, there is a concern of manging expectations of whose responsibility to react and the buffer time to respond.

Overall, the design gives possibility of patient's experience in everyday life, yet does not explicitly to help understand patient's personal preferences. There is also a suggestion to integrate with existing EHR to not create more tasks in the workflow.

The feedbacks also helped discussed on cycle of use, who to be involved and possible use of technology.

To sum up, the co-reflection of three preliminary design concepts is valuable for iterating on the final PSS proposal.

07 Product-Service-System

This chapter proposes the final design of the PSS, comprising of the a set of feartures, service flow, and the main envisioned interaction design.

7.1 PSS Overview

This section persents an overview of the PSS, a care package for home telemonitoring during TAVI perioperative joureny.

The presented PSS is a care package named 'Hart kit'. The kit is given to the patient for home telemonitoring during TAVI perioperative care. The Hart kit consists of a smart band, a tablet and a set of biosensors sufficient during the monitored period.

Hart consists of three patient interfaces: the biosensor, smart band, and a tablet. The selection of smart bands is to allow elderly patients to interact with Heart while being at the moment in everyday activities. The provision of tablets is considered for the use of tele-coaching, in which not all patients are equipped with a digital interface.

Patients interacted with a voice assistant on the smart band. The collected data can be accessed either by inquiring through the smart band or the dashboard on the tablet.

The biosensor gathers data through exercise test (frailty 6MWT, endurance test), patient shared contextual information (experienced symptom, level of frailty, type of activity), and the tracking of biosensor (heart rate, ECG, and physical activity data). The monitored data is transmitted to the smart band and tablet via bluetooth BLE.

The data collected is owned by the patient, and being authorised to different care teams at the starting of the telemonitoring period. Before consultations, the data is being authorised. With patient's authorisation, the data collected are shared to the clinicians interface: a dashboard via their working desktop.

This chapter will walk through the main features sets of the PSS and their aim. Design details and conversational flow of the PSS can be access via this virtual space: https://miro.com/app/board/o9J_knEK6aM=/.

Figure 26
PSS final design vision

7.2 PSS feature set

This section describes the feature sets chosen for the final PSS.

The final structure of the PSS consists of three feature sets: my guiding journey, self-training, reflecting on symptoms. The overall structure is presented as following:

- Guiding journey
  - reflect personal goal
  - exploration
- Self-training
  - track activity
  - activity report
  - system alert overachieving
- Reflect on symptom
  - daily greeting
  - share symptom
  - symptom diary
  - system alert abnormalties

States of Hart

Normal state

The idling state of Hart is a friendly character, which is an embodiment of a caring care assistant.

Catching attention state

When Hart wants to catch the patient's attention, the smart band vibrates and flashes blue lights.

Rewarding state

When an action is done, Hart gives a happy expression to give the patient a sense of rewarding feeling.

Listening state

When Hart is triggered by 'Hey Hart', Hart changes into the attentive listening state to capture audio input.

Alerting state

When Hart needs the patient's immediate attention, the smart band vibrates and turns red in colour. Hart also changes its expression to concerning.

Interactions

Voice trigger

Hart is triggered by semantic keywords (such as 'start tracking', 'share symptom', or 'is it safe to move'), which allows patients to quickly access feature sets.

Rating

Patients can communicate the subjective level of experience through a rating wheel. Once decided, the patient can tap on the confirm button.

Selecting

Patients can tap right and left to select options. Once decided, the patient can tap on the confirm button.

Record audio messages

Patients can also share the symptoms or activities types not covered in the presets by leaving audio messages.

Self-training

The Self-training module enables patients to learning to explore own exercise limit through guidance. The system is continously cross-checking an ideal activity range set during the exercise test. When overachieving this safety range, the system will remind the patient to take it easy; on the opposite, when patients achieved the ideal intensity, the system will give encouraging remarks to reinforce the active behaviour.

Start activity

The patient can start tracking everyday activities through voice commands (keyword: start activity). The system will continously cross-checking an ideal activity range set during the exercise test.

System alert/encouragement

System analyse the activity intensity and heart rate comparing to an ideal range set using MET and max heart rate during the exercise test. During exercise, the system analyses the activity level and heart rate comparing to an ideal range set during the exercise test.

Reflect after activity

Patients can effortlessly share contextual data during exercise. This function help patients better reflect on their activity subjectively and provide the clinicians to gain contextual information in the next remote coaching session.

Activity report (access on tablet)

The activity report is created showing the recent activities done and comparing the activities in trends. The patient and clinician can together discuss on this activity report during remote coaching.

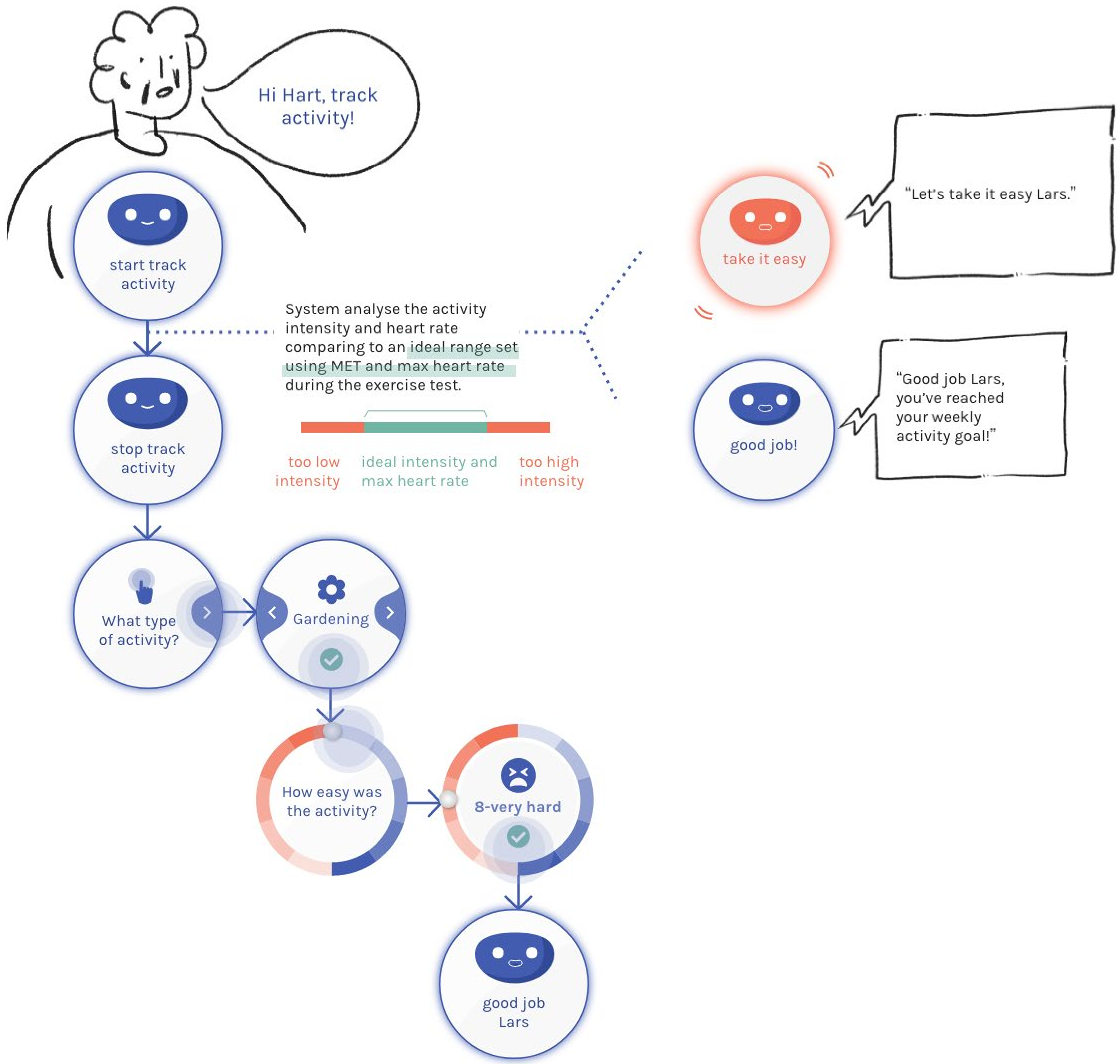


Figure 27
how a patient use voice trigger to track activity and guided to reflect on the activity. / activity report

Reflecting on Symptom

The wellbeing reflection enable patients to subjectively evaluate on their wellbeing and be alerted with early detection abnormalties. Hart can be triggered through following situations:

1. Patient report symptoms
2. System detection ECG abnormalties
3. Daily greeting

Daily greeting

Hart greets the patient everyday by reflecting on the well being of the patient

Share symptoms

This allows the patient to share thier unwell experience at the moment. The system will manage the patient's expectation by letting patient know within what time range and how the patient will respond.

System alert

This system detects abonormalties in ECG signals and alert the patient. The paitents can choose to contact clinician or report system false detection.

View feedbacks

The patient will recieve messgaes when care professionals send feedbacks or suggestions (i.e. make an appointment, suggest change in medication).

Syptom diary (On tablet)

The symptom diary record the occurance of the symtoms and level of severity in a longer period. This is to allow the patient and clinician to collaboratively interpret the health condition.

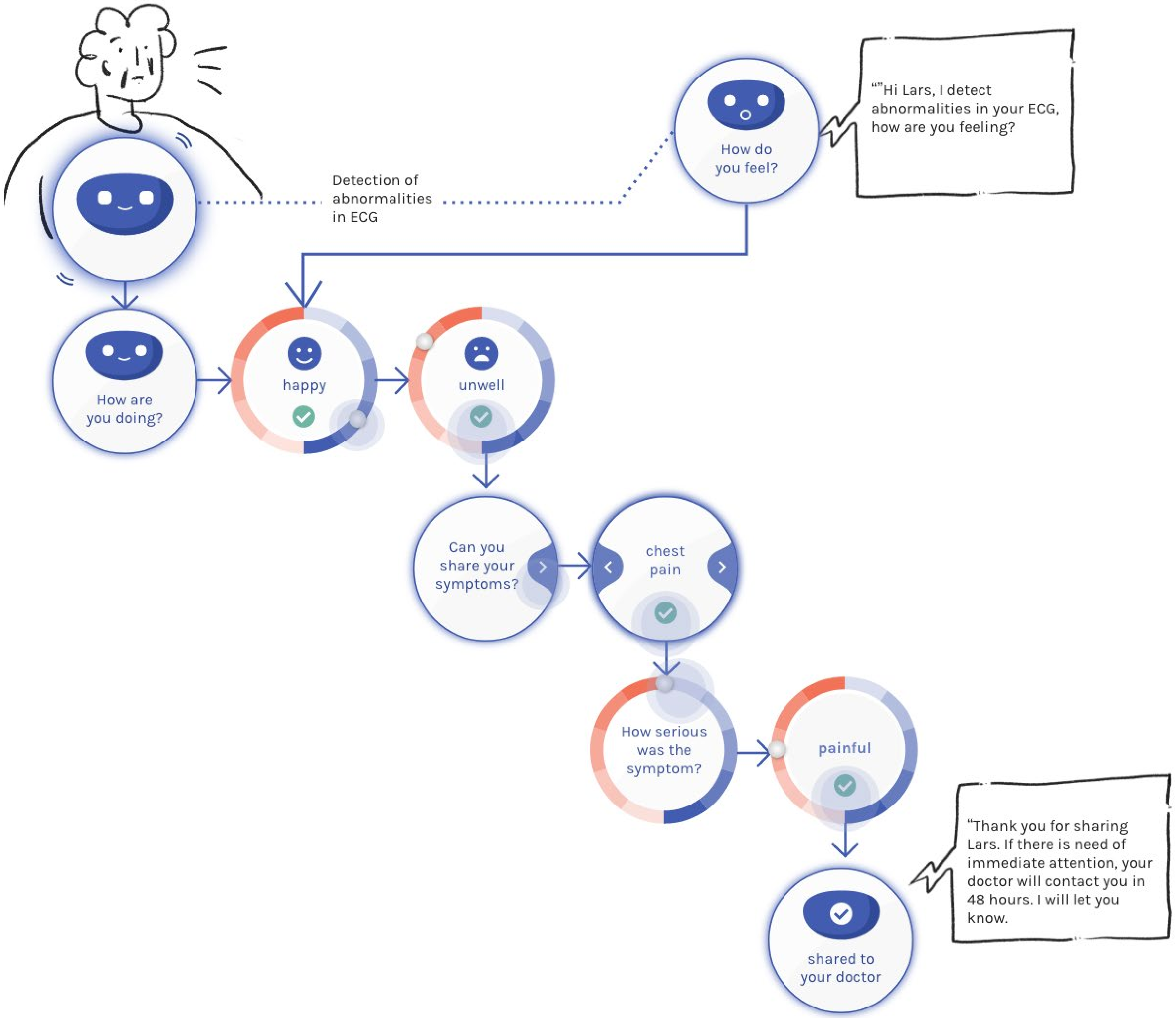


Figure 28
how a patient is greeted by the PSS and share his experienced symptom

My Guiding journey

The guiding journey module help patients to reflect on personal goal and seek treatment related information when needed. The advantage is to allow patients share what they expect from the care and access information accordingly to where they are situated in the TAVI journey.

Reflect on personal goal

This feature aims to help patient reflect and share personal health preference. Moreover, clinicians are able to better empathise on patient's expectation. The feature provides two kinds of self-assessment tools that is used before and after TAVI. Before the polyclinic, patient can reflect on quality of life through the 'My health goal' self-assessment. The measures are adapted from WHO Quality of Life Scale (WHOQOL). Before onboarding rehabilition, patient can share thier preference on activity goal through 'My activity goal' self-assessment. Paitent can always reflect and change these personal goals throughout the journey.

Exploration

The 'exploration' feature divided existing TAVI information brochure and informtaion pamphlets into different section, which patient can access whenever needed. This componet improves the current way of information giving without overwhelming the patient .

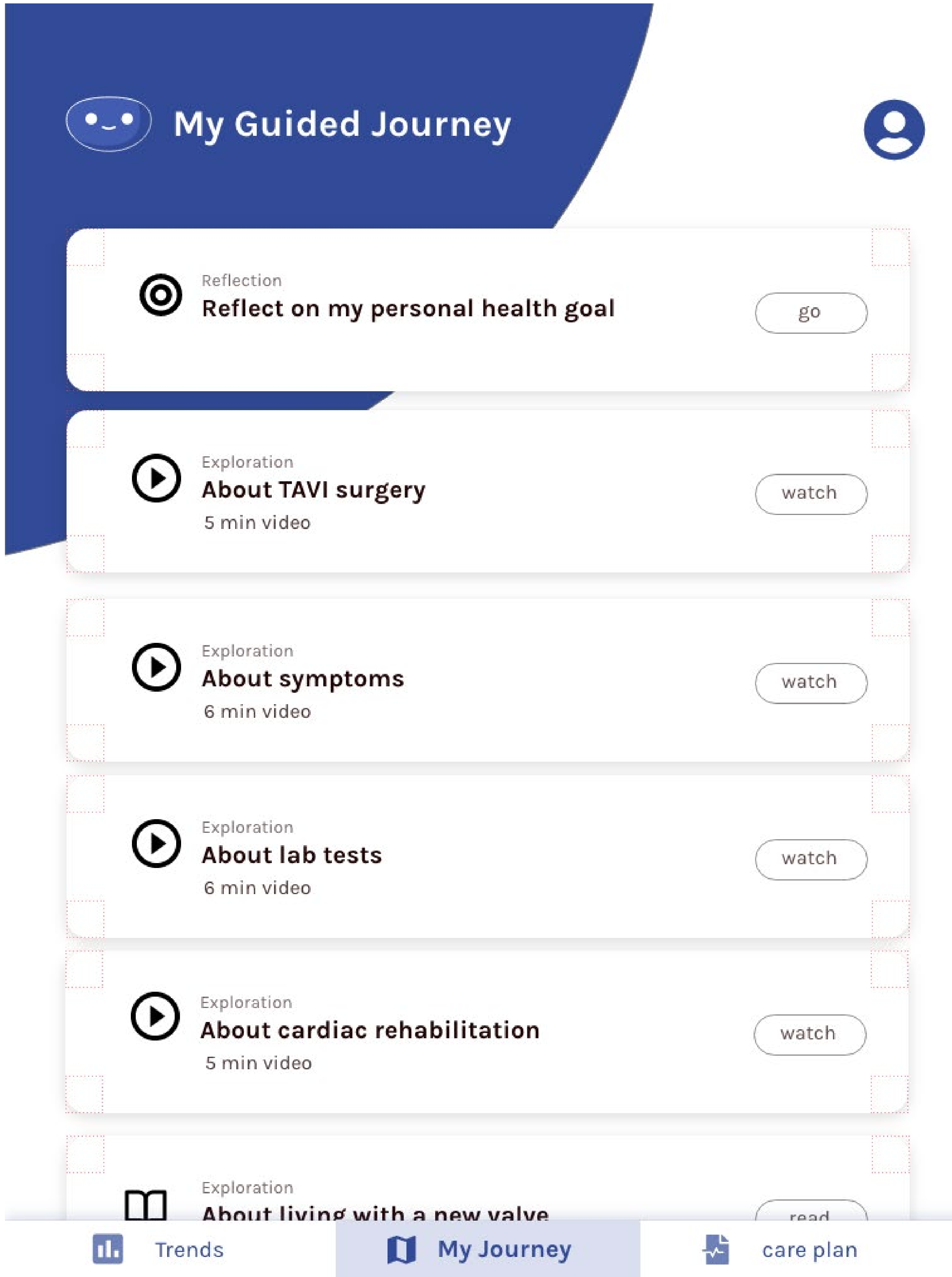


Figure 31
An explaination of my guiding journey

Clincian dashboard

Different care teams have responsibility in TAVI perioperative patient care, which provides different needs in using the PSS (chapter 5.1).
- AUMC need to prioritise patients and make decisions in MDO meeting
- cariac rehabilitation team need to make a care plan and help patient improve physical/psychological functioning
- outpatient cardiologists or rehabilitation cardiologist need to react to complications

The dashboard provide the following information for these needs.

Activity/Symptoms status

This system makes a preceding decision patient to classify activity / symptom tracking information into 'active-inactive-over-achieving' and 'normal-mild-severe'. The parameters for classification is set-up during exercise test.

Progress

The overview of progress shows the recent and trends of activity/symptoms. The source are from patient shared information and system objective measured information. A filter allow clincicians to crosscheck different information, either recent activities or compare in history.

Send feedback

Clinician can take additional care actions to compose a feedback message. Particularly when the patients shared unwell meassgaes, the system will send a notification to the incharging doctor.

Setting

Patient's reflected personal goals as well as the ideal range of physical activity is accessible in the setting tab. which clinicians can adjust the parameters during consulttaions.

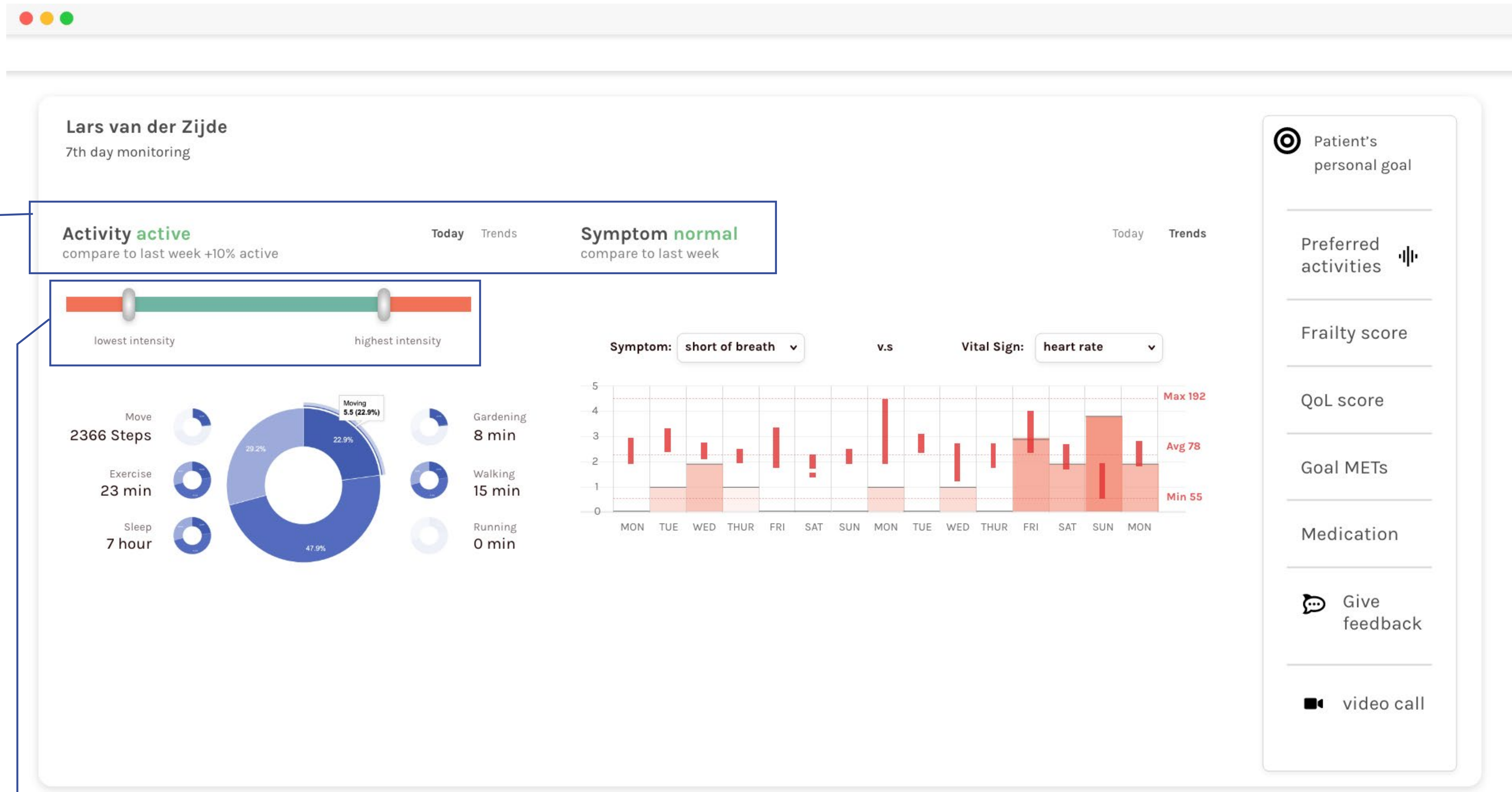


Figure 31
A glimpse of clinicial dashboard

7.3 PSS Service Flow

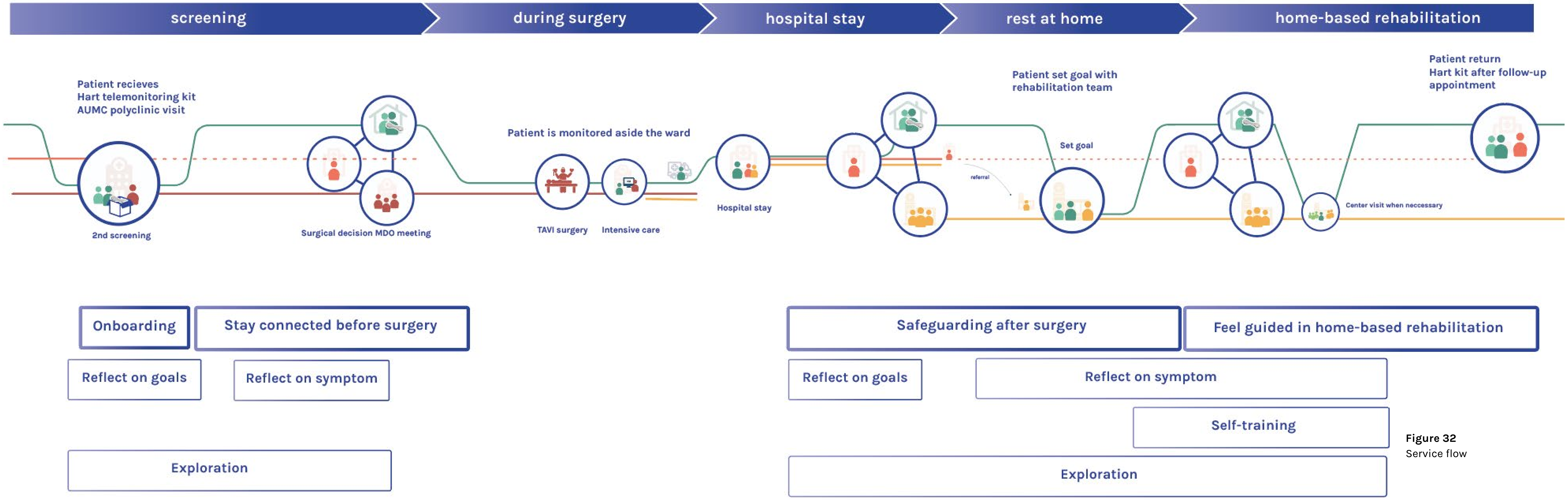


Figure 32
Service flow

1. Onboarding

The service starts when a patient is accepted to the second screening. The patient receives the Hart telemonitoring kit on the arrival at the AUMC. While awaiting for the polyclinic, the patient started by using the 'reflect my goal' and 'exploration' feature. The patient is walked through an introduction of Hart. To start, the system requires the patient to authorise the sharing of data to AUMC. During the polyclinic, the patient is guided to attach the biosensor and go for a frailty test. This included a 6 minutes walk test (6MWT), which the biosensor builds a health baseline of the patient.

2. Stay connected waiting for surgery

After returning home, Hart helps patients reflect on daily wellbeing, express doubts of physical activity and react to changes in heart condition). The dashboard is mainly accessed by AUMC TAVI nurse and AUMC secretary. The AUMC secretary and TAVI nurse uses these information to prepare for the MDO meeting and plan for the surgery.

3. Safeguarding after surgery

Before transitioning to the outpatient hospital, the patient can access the setting of the system to authorise sharing data with their outpatient cardiologists and cardiac rehabilitation center. AUMC researchers can also request patient's consent to share data for researchers. Before rehabilitation, the patient can use the 'self-explore' feature to reflect on personal goals and recovery-related information. The system safeguards the patient by detecting signs of complications.

4. Home-based rehabilitation

While resting at home, the system again helps patients reflect on daily wellbeing, express doubts of physical activity and react to changes in heart condition. Patients can compare their wellbeing before and after the surgery. Both the self-training and reflecting on symptom fearure sets aim to encourage patient's confidence in physical exertion.

The endpoint of service is when during follow-ups, the patient is free of patient care and ideally having an improved quality of life.

7.4 Envisioned interactions

This section describes the envisioned interaction with Hart PSS.

The following storyline describing a fictive experience of Lars demonstrates how Hart can interact with the patient and clinician throughout the TAVI journey. The storyline (accessible via this virtual space: https://miro.com/app/board/o9J_knEK6aM=/.) covers the main feature sets to help patients and care professionals initiate communication outside of the hospital.

Onboarding TAVI journey with 'Hart'

Lars, a 80 year-old patient visits AUMC the first time for his TAVI screening. Nurse delivers Hart kit when he arrives at the hospital (shown as figure 33)

Before Lars' visit, the clinician familiarised with the Hart kit through playbook. While waiting for his polyclinic appointment, Lars self reflect with Hart his quality of life and what he enjoys in daily life .

During the polyclinic, Hart supports the clinician to access Lars' frailty level through a 6 minute walk test (6MWT). Together they discuss anout surgery. When leaving, Lars brings Hart back home.

Stay connected before surgery

Lars returns home, awaiting the screening result and TAVI date. Lars self-explores with the TAVI related information, while Hart monitors the ECG and activity level. DUring MDO meetings, AUMC TAVI team discusses the optimal surgical route using Hart collected information as additional evidence.

When the third week waits for symptom, Lars discovered his symptoms worsen through the symptom diary. Hart warned the TAVI nurse and secretary of the condition. He shared the experiencing of symtom, which Hart tells him his doctor will reach out if immediate medical attention is required and sends a notification to the doctor in charge.

Lars got a call about having his TAVI date rescheduled earlier. One day before TAVI, Lars arrives at the hospital, and his biosensor is connected to the IntelliVue Guardian ward monitoring system

A sense of safety after surgery

After 3 days of hospital stay, Lars is discharged home. Lars is greeted by Hart everyday during the 3-weeks resting period, encouraging him to share the physical/psychological challenges.

Before rehabilitation starts, Lars reflects again on his activity goal. On the first rehabilitation meeting, the rehabilitation care team suggests a care plan based on the previously tracked data and an exercise test. An ideal activity intensity range is set during the exercise test.

Regaining confidence during home rehabilitation

Lars decides to join a home-based rehabilitation. Lars uses the 'self-training' function by voice commands. When exercising, Hart encourage the patient when reaching ideal active level. Lars feel safeguarded knowing the system will alert him when overachieveing.

After exercising, Lars shares contextual information (i.e. the type of activity, reflecting on how tired was the activity)

During remote coaching sessions, the physical and Lars together explore how can they do better and set new goals.

Figure 33
Example storyline of how a patient's visit to AUMC experience will be transformed with the use of Hart kit PSS

08

General Discussion

This chapter concludes with a general discussion of the project. The final design, reflection back on initial assignment, project limitations are discussed.

General Discussion

Reflecting back to the problem statement the design addresses to the two shared understnding need to be made out-of-hospital:

1. knowing when and what actions to take if complications occurs

In the exisitng care journey, the burden of reacting to complications is laid on patient, including subjectively feeling when bad to reach out and recalling the contact to reach out. The suggested feature set 'reflecting on symtom' successfully address this need by giving a space to share patient's unwell feeling and being alerted when abnormalties are detected. A commnuication is initiated by letting patient know when to reach out and providing the possible actions, which is lacking in the current patient care.

For the clincian, the provided monitored and experience symptoms gives them more information in interpreting the situation. However, it is still unknown whether these information are sufficient to make care decisions remotely. During current consultation, the clinician can guide the conversation to seek the needed information, while the remote provision of these information does not replace this layer of interaction.

2. Knowing how active can the patient be during home recovering

Another need comes from gaining a shared understanding of how active can the patietn be. The feature sets of 'self-training' address this need by reassuring the patient through check-up of how safe the

After the concept evaluation with 'self-training features', the design is more focused on supporting the patient to better understand thier physical activity limit and regaining the confidence to become active.

Other added values

Other added values of the final design include adding touchpoints to communicate personal and changing the existing way of information giving. These are being done by the 'guiding journey' feature set. By sharing patient's preference on quality of life and activity goals before consultation, it allows clinicians to recognise the different perspective patient is seeking in the care and start managing expectations. As for the changing way of information giving, it aims to help patient be informed without feeling overwhelming throughout the journey. However, it also relies on whether the patient has the behaviour of browsing through information on his or her own.

In general, the final concept adressses the design goal " Improve shared understanding by design a telemonitoring PSS that supports patients and care teams to assess and building a shared knowledge of health condition out of hospital." by helping patient to better interpret thier own health condition, where care teams plays a role to step in when needed and manage expectation.

Further questions

The design concept also generate several unanswered questions:

Does the design encourage patients to take actions when feeling unwell?

One of the intended aim is to to helping patients to reflect and informing when unwell. When complications occur, the patient may not take actions for several reasons. During the reflection of concept with medical stakeholders, they shared even knowing what to do, patients may have different preference whether to react to the symptom or not. Therefore even knowing what to do does not mean patients would be actually taking the action for help. It is interesting to see how many patients actually take action to share symptoms?

Does the design encourage the patient to become more active?

Another intended aim to let patient feel reassured enaging in physical activities. However, it is interesting to know does the design help overcome the barrier to move, or extra motivations are needed.

Enabling effective communication or adding more workload

The deisgn suggested beside using the monitored information in existing workflow (i.e. consultations, MDO meetings), the clinicians can take actions by composing a message. However, this is assuming a care professional will be taking on this role. Despite the benefit to initiate a communication cycle remotely, it can also be a pitfall of adding more workload. There is a need to rethink about the collaborartive scheme of care teams when introducing the PSS solution.

System or care professional to make decisions

The deisgn suggested the system to detect the ECG abnormalties and when overachieving in physical intensities. This is also to suggest the smart system to take actions in the care process, which both the Philips stakeholder and the care professional concern the decision may have corresponding responsibility. In this scope project, we are not able to touch apon this topic, yet it is interesting for future researchers to explore the dilemna between system suggesting care decisions and when a care professional should loop in.

Data ownership across organisations

There is a challenge of data interoperability between different care teams. Different organisations have different electronic health record systems and data points.

Limitations

Significant challenges are encountered when investigating the context and evaluating on the design. Due to the COVID-19 pandemic, the interaction are strictly limited online. Also, since the target patient group are in advanced age and reached out via phone in Dutch, there is a difficult to interview or evaluate with patients. However, the project did manage to source patient perspectives through experts, especially a patient communication specialist which has a pool of knowledge of how patients may think.

Another complexity is added with multiple care organisatons involved in the TAVI journey. Each organisation have thier workflow, system and interest in the PSS, which is a major challenge out of the project scope.

The project also spent a considerable amount of accessing permit to access the previously gathered data set, understanding what the Philips wearable biosensor can do, and investigating on the context. Althrough in the end some of these information are not used or made the research phase longer than expected, it also helped the researcher to comprehend the complex context. A personal learnt lesson is to be more decisive and narrow the scope when defining a problem statement with the discovered information.

Lastly, due to the limitation of time, unexpected personal health challenges and obstacles in recruitment, an evaluation of the final is not fully managed. However, conversations are either done or scheduled with patient communicaiton specialist, medical stakeholders and Philips data team as both a valuable personal learning experience and to use this project to inspire thier work. As organisations and health technology providers, this projects provides valuable discussions on how may the biosensor be used for perioperative care.

Summing up

To sum up, this project successfully achieved the initial assignment "to explore how Philips wearable biosensors data can improve TAVI perioperative clinician-patient communication through a product-service-system. " Several value and concepts are generated by looping in relevant stakeholders and start a conversation.

As shared from the AUMC patient communication specialist

"Removing a problem or curing is not always possible for cardiology patients. So you have to take care of those patients. And it's not always just about surgery or a device. It's more about how we can help our patients for as long as you're here in the AUMC? How can we take care of you in our best ways? "

The researcher can confidently share this project managed to address these human values in the field of healthcare.

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