

# Tailoring Information for Operating Rooms

by Rasmus Agerup

The Oslo School of Architecture and Design

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Rasmus Agerup

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Internal supervisors (AHO):  
Main supervisor: Kjetil Nordby  
Secondary supervisor: Mosse Sjaastad

External supervisors:  
Karl Øyri, Ph. D., Section leader, Section for method development and industrial cooperation at The Intervention Centre, Rikshospitalet, Oslo University Hospital HF  
Ole Jakob Elle, Ph. D., Head of Technology research at The Intervention Centre, Rikshospitalet, Oslo University Hospital HF

Thank you to all my supervisors for great discussions and guidance. Thank you to the staff at The Intervention Centre for taking the time to talk to me and test my concepts and prototypes, and for sharing your knowledge. Thank you to the diploma class of spring 2017 for our discussions and your backing.





# Abstract

This project investigates how information should be delivered to staff in hospital operating rooms. I have designed a holistic platform for critical in-operation information.

I have worked in operating rooms observing heart procedures, which are high-risk procedures. The team performing these operations depend on accessible and precise information, to ensure that the procedure is done adequately.

This diploma aims to improve how information is delivered to the team and how they access it. As the team members have different needs for information, I have tailored the information delivery to meet their needs. Using technology like augmented reality and voice recognition, in addition to conventional interface design, I have tried to rethink how information is provided to the team.

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# Executive Summary

## Context

In this project I have been observing, learning and designing for a hybrid operating room in The Intervention Centre. The Intervention Centre is a clinical research- and development department at Oslo University Hospital Rikshospitalet, and acts as a toolbox for all departments at Oslo University Hospital, as well as other hospitals and clinics.

This project has been done in collaboration with The Intervention Centre. This has given me access to the context in which I have done my research and design. I have been working with medical staff and technologists, experts in their fields, giving me critical knowledge and information to create a relevant solution.

## Problem

When performing an operation, the responsible medical team rely on a lot of information about the patient, his or her condition, and other procedure specific information. Today this information is displayed on three different screens located in the operating room. The screens can only be controlled from the adjacent observation room.

Different procedures require different information. For example, when performing a liver surgery, the information the team need will be different from what they need during a heart surgery. However, the providers of this information are often software programs made to handle a lot of different procedures. The team has to navigate through several software programs with thousands of functions, in order to find the relevant functions to the specific procedure.

I have also considered the spatial issues with screens and the accessibility of information.

My working questions during this diploma have been:

- **What are the roles of the different people in the team?**
- **What kind of information do the different roles need?**
- **How can the information be provided in an efficient and optimal way, suitable to the context?**



## **Risk and Complexity**

To challenge myself and my education, I wanted to work in a complex environment with complex systems. Working in this context has been challenging as a designer without any pre-knowledge about the healthcare system in general, or in more specific, operating rooms, operating teams, and information systems used in this context. However, I believe that being able to adapt to new environments and seeing things from a new perspective is at the core of what it is to be a designer. In retrospect, I don't regret going into this topic, as I have discovered a new field in which I have gained knowledge and experience.

## **Solution**

I have decided to divide the solution into two parts, due to the fact that there are different user needs. One part consists of a augmented reality application, the other as a control panel in a large tablet format.

For the cardiologist I decided to design an augmented reality solution, based on their need for a clear view of the information. This will enable them to see their own hands and the patient while performing the procedure, as well as the information needed.

In the observations I found that the other team members are more dynamic in regards to the spatial position in the room. In addition, they are not dependent of having to look at the patient continuously. Therefore, I see it beneficial to keep some of the screens in the operating room, in order to convey information to the rest of the team. Nevertheless, it is necessary to be able to control the information on the screens from within the operating room, and not having to go to the observation room. For this reason, I have also made a control panel for the team to control which applications that are running on the large screens in the operating room.

# Introduction

This diploma is about the information provided to a medical operation team during a procedure. I have researched the different roles of the people in the team, what information they need to perform their jobs and how it could be provided for them to best fit their challenging and complex workdays.

In this diploma, I have had a holistic focus on information delivery to all team members in an operating team. Working in a professional environment, the applications that are being used are often complex in regards to function and usability. Several of the applications could be potential redesign diploma projects. However, redesigning the different applications has not been within my scope. I wanted to tie the applications together in an application management system so that they can be treated as pieces of a coherent information system, rather than being proprietary applications that is handled individually.

Through my research and design I have found that there are several areas within the context of operating rooms that have significant potential for improvement, in regards to user centered design. It has been difficult to find appropriate literature to support my research, but I have benefitted greatly from my collaboration with The Intervention Centre at Oslo University Hospital Rikshospitalet. Here, I have been able to talk to and observe experts performing their jobs.

This report is structured in four main parts. The background where I present my findings and research, the solution where I describe my solution to the problem, the process with methods and finally a conclusion and sum-up.



# 1. Background

# The Problem

When performing an operation, the responsible medical team rely on a lot of information about the patient, his or her condition, and other procedure specific information. Today this information is displayed on three different screens located in the operating room. The screens can only be controlled from the adjacent observation room.

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- **What are the roles of the different people in the team?**
- **What kind of information do the different roles need?**
- **How can the information be provided in an efficient and optimal way, suitable to the context?**

# The Context

## The Intervention Centre

In this project I have been observing, learning and designing for a hybrid operating room in The Intervention Centre. The Intervention Centre is a clinical research- and development department at Oslo University Hospital Rikshospitalet. They act as a toolbox for all departments at Oslo University Hospital, as well as other hospitals and clinics. They are conducting different types of procedures here, and develop and introduce new image guided techniques.

“There is no doubt these image guided techniques will change the whole field of cardiac surgery and intervention.” (Fosse, 2015)

The Intervention Centre is also one of the few departments that are conducting trials on live animals following Norwegian regulations of such activities (The Intervention Centre, 2015).

## The Collaboration

For this project, the collaboration with The Intervention Centre has been crucial, as it has given me access to the context in which I have done my research and design. I have been working with medical staff and technologists, experts in their fields, giving me critical knowledge and information to create a relevant solution.

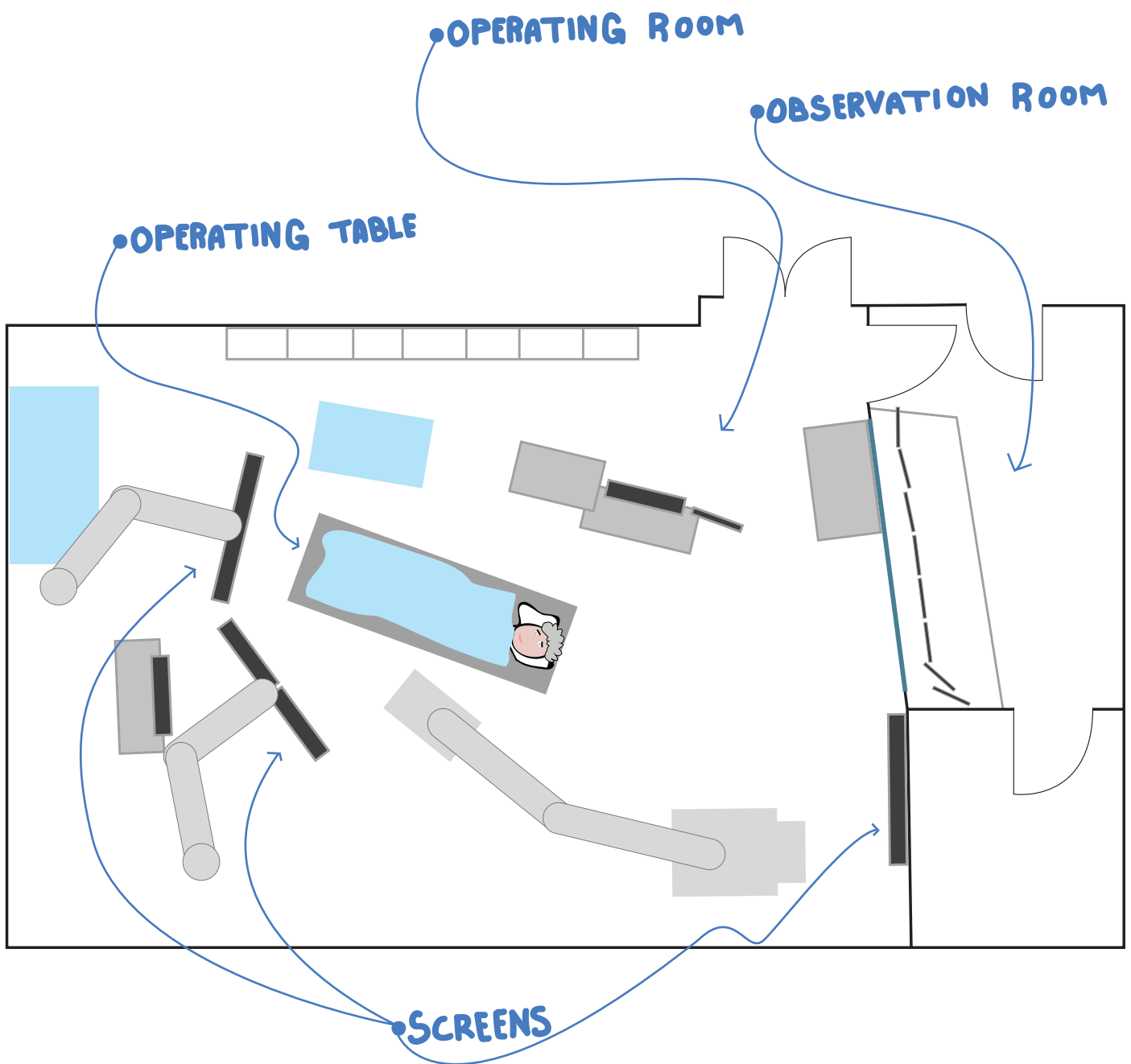


**Fig 1:** The operating rooms at The Intervention Centre are crowded with state of the art technical equipment.

### **Hybrid operating rooms**

One of the operating rooms in The Intervention Centre is a so-called hybrid operating room. It is in this room I have done most of my observations and interviews. Hybrid operating rooms are, as the name implies, designed for various types of procedures. This means that the spatial layout, as well as the digital information layout, should be easy to modify to suit a number of procedures.





**Fig 2:** Illustration of the hybrid operating room and the adjacent observation room at The Intervention Centre. During procedures here, a staff of 8-10 people is not uncommon. The screens in the room display critical information for the team during the procedures.

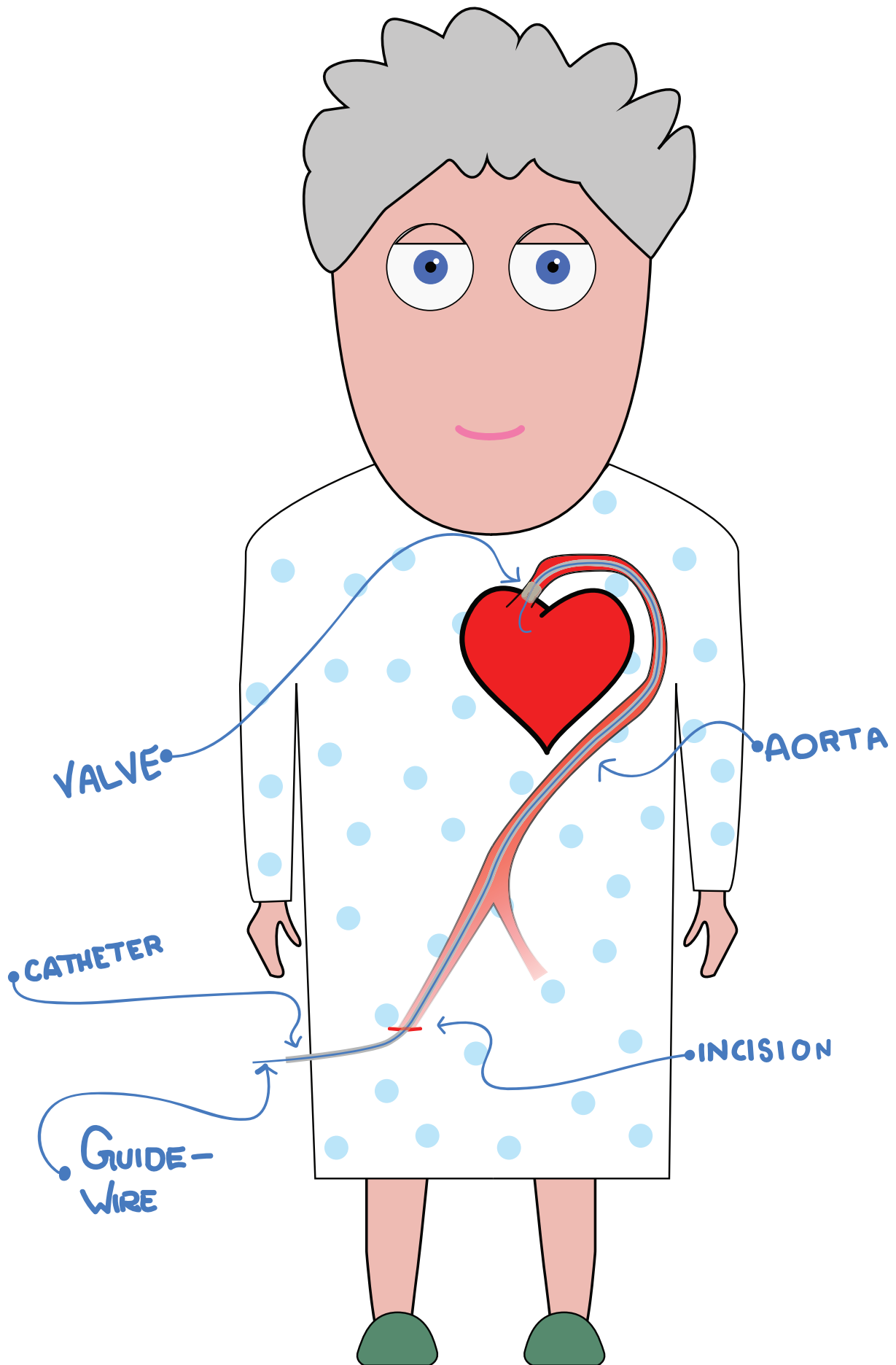
## **The Procedure in Focus**

I have chosen to look at one type of procedure in particular, the transcatheter aortic valve implantation (TAVI). During this procedure, an artificial heart valve is implanted in the left ventricle of the heart, through a catheter inserted in the patient's groin. The artificial valve enable the heart to easier pump blood out to the rest of the body.

The regular patients for this kind of procedure are elderly people with a diagnosis called aortic valve stenosis. This diagnosis indicate a narrowing of the exit of the left ventricle of the heart, causing the heart work faster to pump blood out to the body. This can cause over exertion of the heart, and in utter consequence death. The procedure is carried out when the patient is awake, but anaesthetised. This does not hurt, but it can feel uncomfortable in some cases.

In addition to observing the TAVI-procedures, I have observed another type of procedure called Laparoscopy, a key hole liver surgery. I have also been allowed to be part of the department meetings where they review previous procedures and go through the schedule for upcoming procedures. However, TAVI procedures have been my main focus and I have observed 11 of these procedures.

Although my focus has been on the TAVI procedure, it has been important that my solution is applicable to other procedures as well. This is important because the solution will work in a hybrid operating room designed for different procedures. The importance of adapting to different procedures has also been communicated by my supervisors and other experts at The Intervention Centre.



**Fig 3:** After the incision is made, the catheter is inserted through the aorta (the main artery) to the left ventricle of the heart. Then a guidewire is inserted through the catheter before the artificial valve is lead through the catheter along the guide wire. When the new valve is put in place, the heart is paced by a pacemaker so that the heart is stabilised.

# Understanding the Users

## The complexity of the roles

All members of the team are specialised in their roles, making the teams knowledge and experience base vast. It has been important for me to get an understanding of the different roles the individual team members fill, to see what their needs are. It has been challenging to know how much information I need about each role to make informed decisions and good design solutions for the team as a whole.

## A stressful workday

The staff performing the TAVI procedures are working under a great deal of pressure, as illustrated by this quote from a cardiologist at The Intervention Centre:

“Strokes, cardiac arrests, patients dying on the table, unfortunately we have experienced it all. It’s terrible when something like this happens, but we have to remain calm and continue to do our job.”

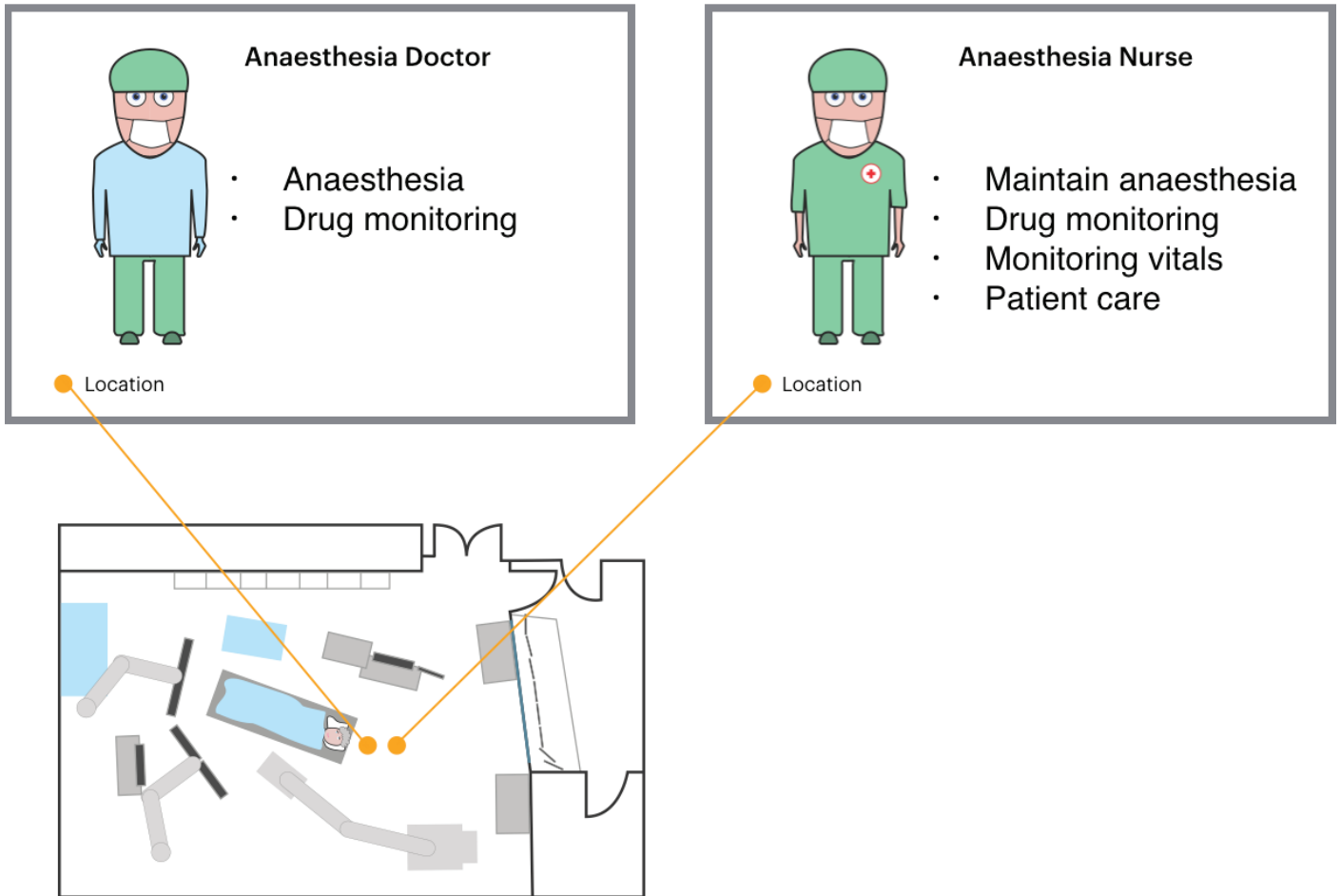
The TAVI procedure is only offered to those who need it. That means that the patients could die if they don’t get the treatment in time. If a mistake is made during a procedure, this could have fatal consequences for the patient. The cardiologists are often on call during night time, meaning they may have to rush to the hospital for acute operations during the night, before working a dayshift the following day. A regular workday for a cardiologist at The Intervention Centre often consists of three TAVI procedures.

While being in the operating room during a procedure, the staff needs to wear lead reinforced aprons and neck collars to be protected from the x-rays from the x-ray machine. These aprons are heavy and warm, and are for some worn for several hours straight. In addition most of the staff are standing or moving throughout the whole procedure.

When working in a stressful and complex situation like this, it is important to be able to rely on the information provided, and eliminate this as another source of frustration. For me as an interaction designer, it is a highly motivating thought that I can contribute to ensure this, and make their workdays a little bit better.

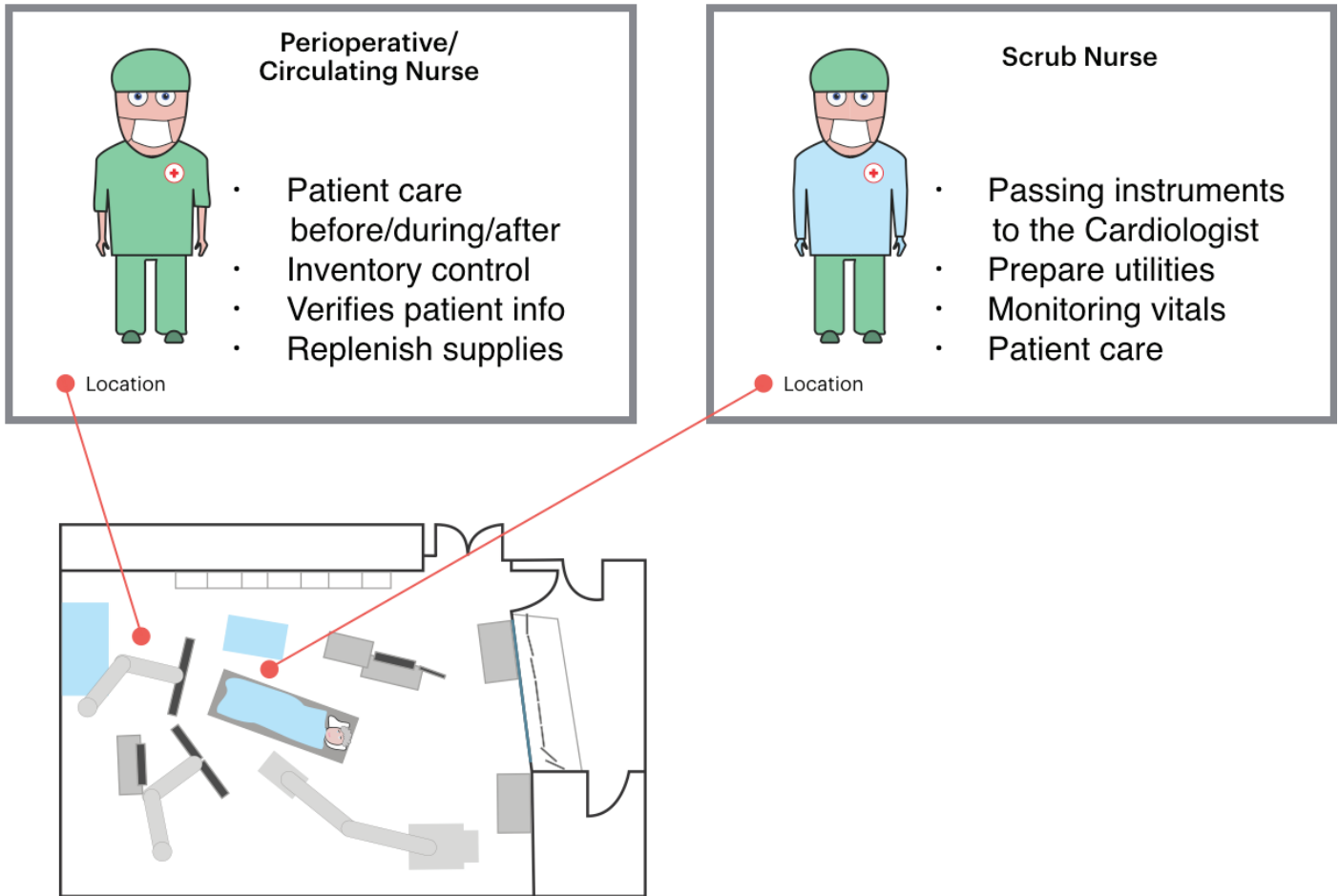


**Fig 4:** During observations, when being in the operating room during procedure, I got to experience the heavy x-ray protective apron and collar.



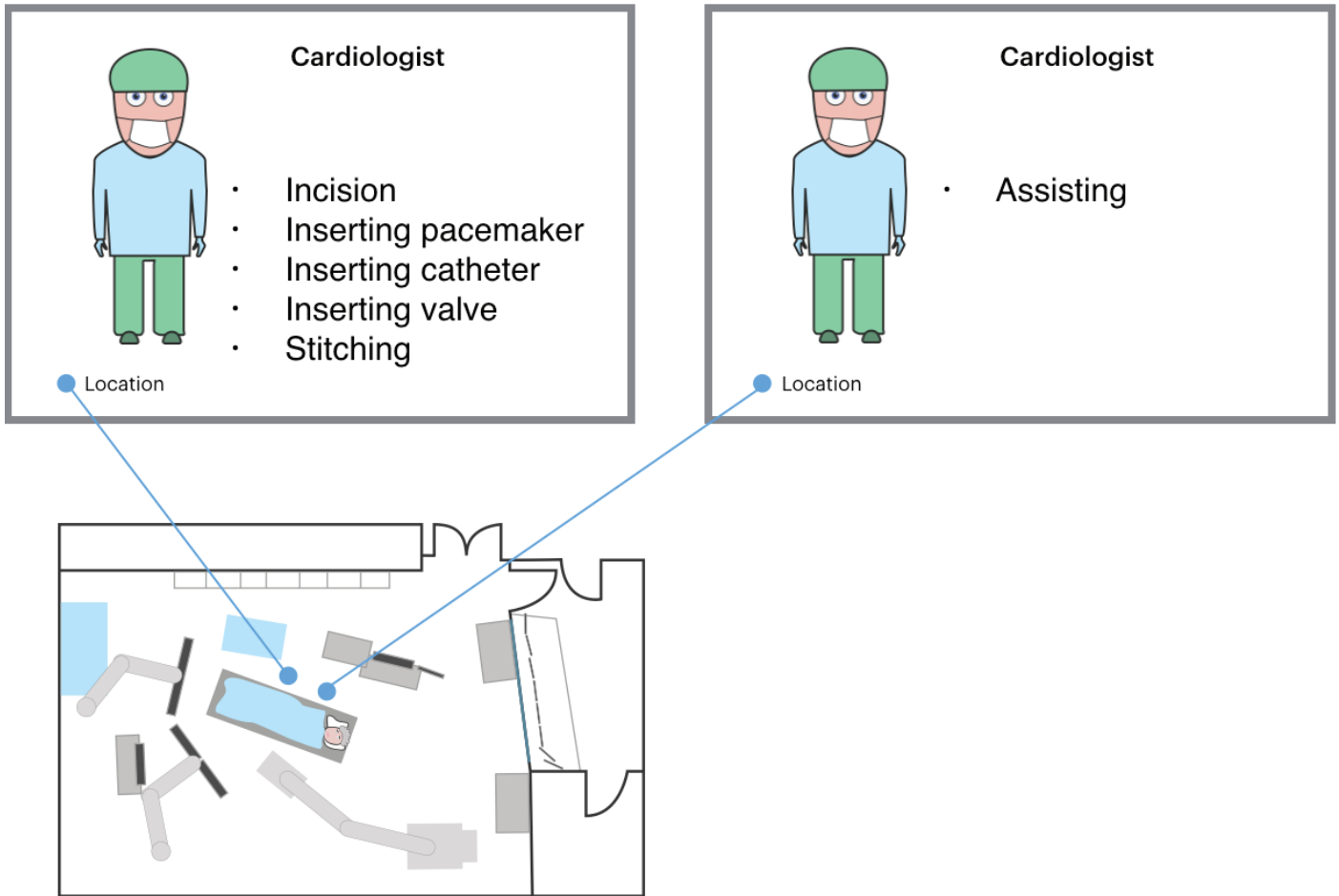
**Fig 5.**

The anaesthesia doctor is responsible for the anaesthesia and drug monitoring before the procedure starts. He or she instructs the anaesthesia nurse on how to maintain the anaesthesia. The anaesthesia nurse then maintain and make sure that the patient is comfortable.



**Fig 6.**

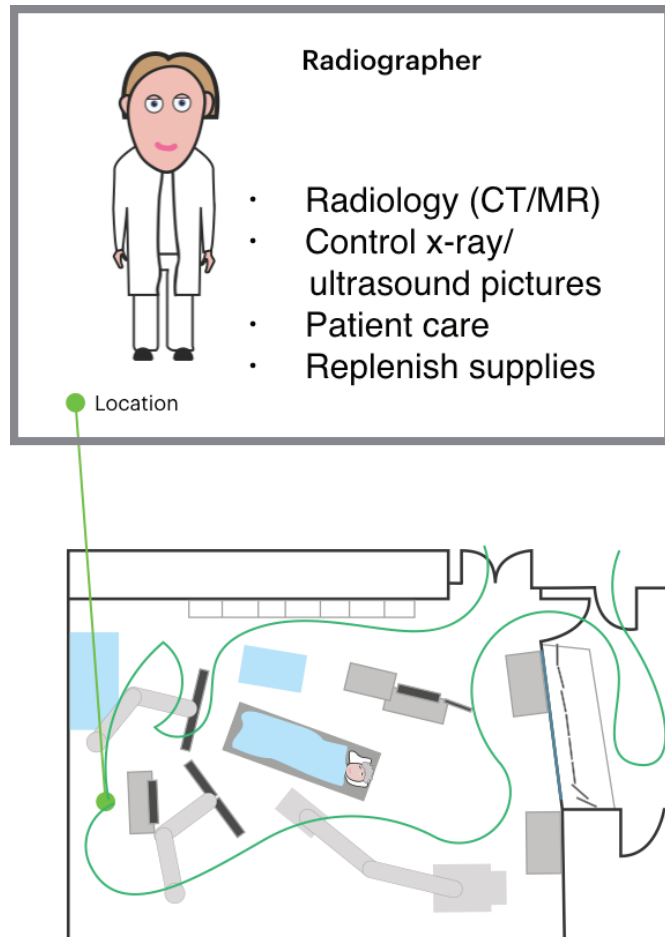
The Perioperative Nurse has the main responsibility for patient care before, during and after the procedure, as well as having control over inventory, verifying patient information and replenishing supplies if needed. The Scrub nurse is the one passing the instruments to the cardiologists.



**Fig 7.**

One cardiologist is in charge of the procedure while the other assists.





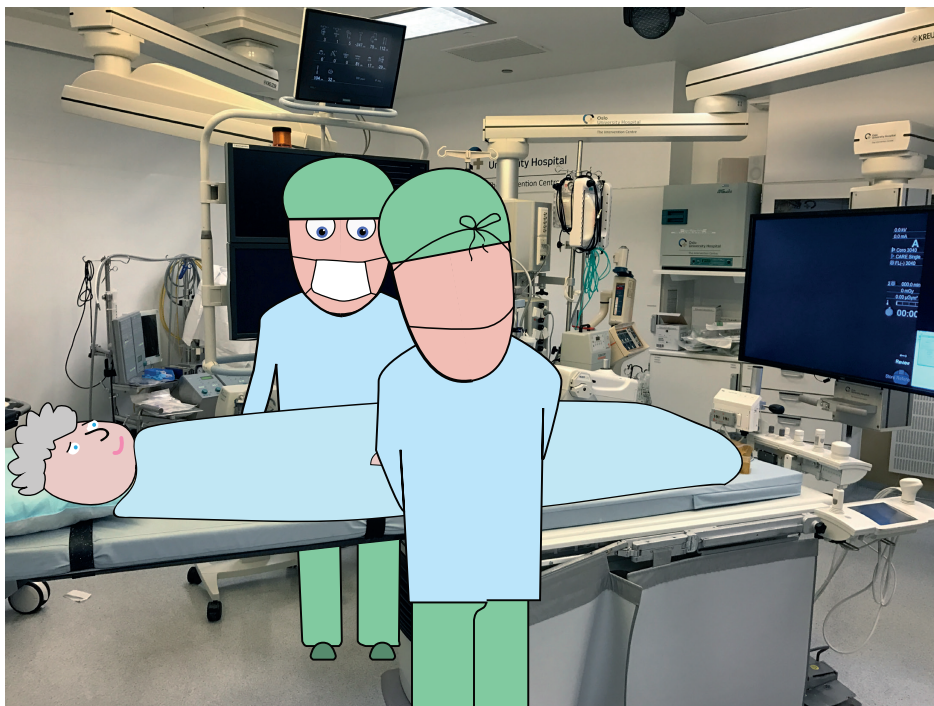
**Fig 8.**

During observation, I noticed that when the cardiologist wanted to see a different picture on one of the screens in the operating room, the radiographer had to leave her post, go to the observation room, and change the picture. The communication between the cardiologist and radiographer was difficult because of background noise, and because of the masks they have to wear. It took a long time to change the picture, and when the cardiologist and radiographer shouted to each other in order to hear, the patient asked if everything was ok.

# The information

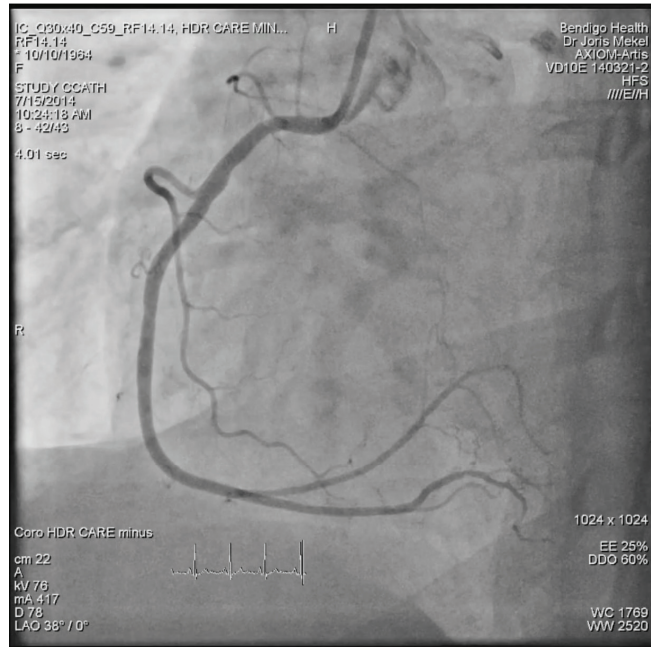
## Today's Situation

Today, the information comes from individual applications that is brought up on screens in the operating room by mirroring the screens from the observation room. Hence, the applications need to be controlled from the observation room. The screens are positioned to best suit the needs of the different team members.



**Fig 9.**

When the cardiologists are working with the patient, they have to look up on screens situated behind the operating table, and sometimes at the screen positioned at the foot-end of the operating table, to view the live images from the x-ray robot (videofluoroscopy). A problem with this is that they don't see the patient or their own hands while operating, only the inside of the patient through a technique called videofluoroscopy. In the following, I will go in more detail about the information that the team relies on during the procedure.

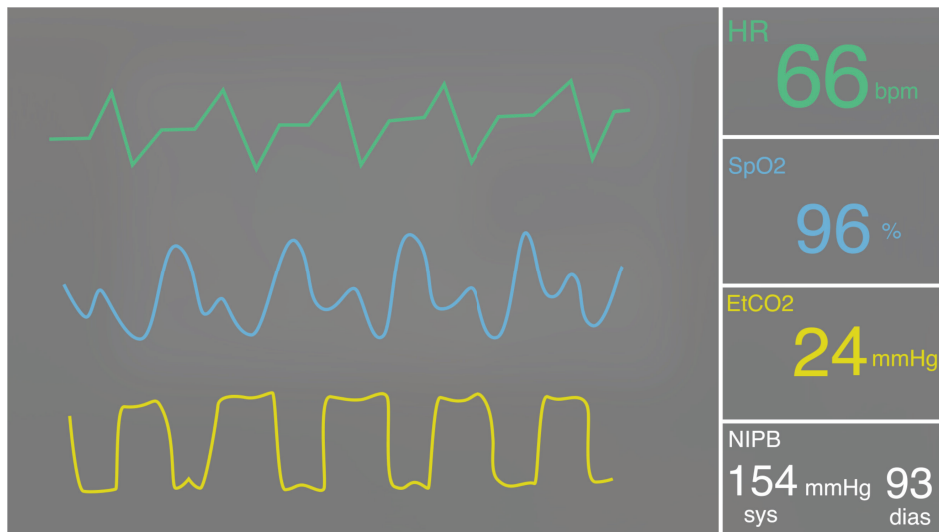


**Fig 10: Videofluoroscopy**

## Videofluoroscopy

For cardiologists to see what they are doing and to look inside the patient, they rely upon a x-ray system called videofluoroscopy. This technique uses a robot arm mounted x-ray machine that takes pictures at a minimum of 25 frames/second, creating video of what is going on inside the patient as they operate. The robot system is delivered by Siemens, and is called Siemens Zeego.

The videofluoroscopy system consists of two parts. One is the control and reference system of the robot, the other is the picture output. The x-ray robot is controlled by a joystick on the side of the operating table.



**Fig 11:** Patient monitor

## Patient monitor

The patient monitor is crucial for monitoring the patients vital signs, and should always be accessible during procedure. For example it measures the patient's heart rhythm (HR) and the oxygen level in the blood (SpO2).

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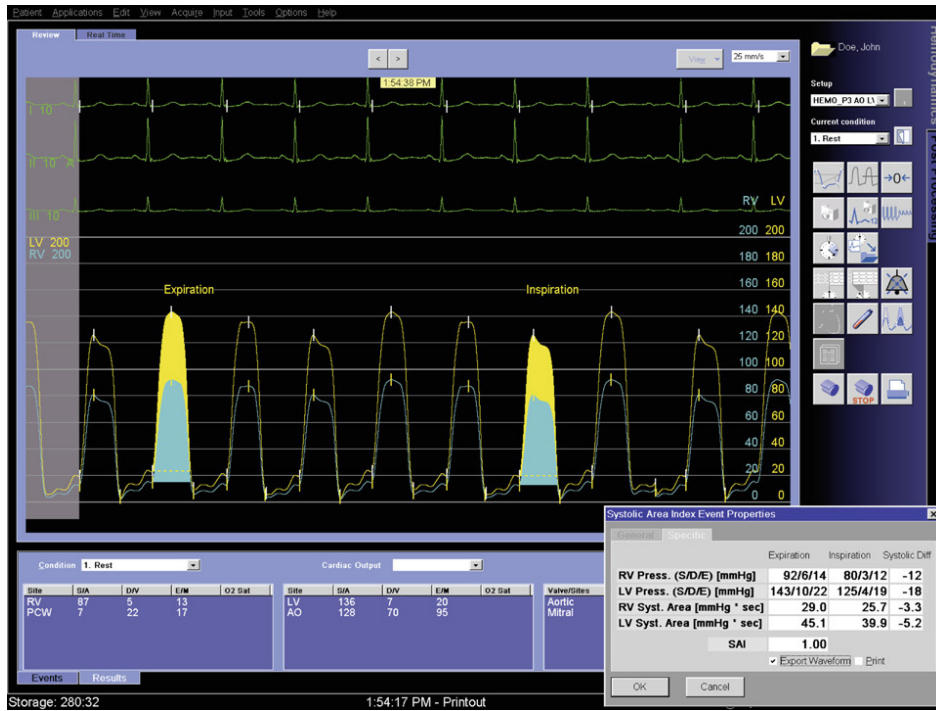
1. Vis dokumenter 2. Utvalg

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26829667	14.05.09	HMED	Pasientbrev - Endring av tim	KOT102	Kolstrøm, Tove	Godkjent	14.05.2009 13:18:2			
26768791	12.05.09	EKIR	Sykmelding SO	THM100	Moksness, Mai Torild	Godkjent	12.05.2009 13:12:1			Konsultasjon GKIR avd den 11.12.2008
26755721	12.05.09	KKIR	SPL Innkomstnotat SO	KRISE	Kristiansen, Elin	Ikke ferdig				Konsultasjon GKIR avd den 11.12.2008
26792119	10.05.09	LRAD	Foreløpig - RG thorax	LRAD	Radiologisk Avd, Lilleh	Godkjent				
26653513	06.05.09	KKIR	Observasjonsskjema SO SK	SKANK	Skanninggodkj, Kongsv	Godkjent				
26572074	04.05.09	KORT	Ekstern epikrise SO SK	SKANK	Skanninggodkj, Kongsv	Godkjent				
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25456597	09.03.09	KGYN	Infeksjonsregistrering SO SK	SKANK	Skanninggodkj, Kongsv	Godkjent				

Fig 12: Electronic Patient Journal

## Electronic Patient Journal (EPJ)

The team reads up on the patient in advance of the operation. They read about the patient in the Electronic Patient Journal, where the patient's former medical enquiries are listed. This gives the team some guidelines to how they can treat the patient. This step is important in order to uncover abnormalities or discrepancies in regards to anaesthetics or other variables. The system used in The Intervention Centre today is called DIPS.



**Fig 13: Cath Lab**

## Cath lab

The cath lab system monitors the hemodynamics of the patient. Hemodynamics is the dynamics of blood flow. This system gives an important overview of hemodynamics, especially in TAVI procedures.

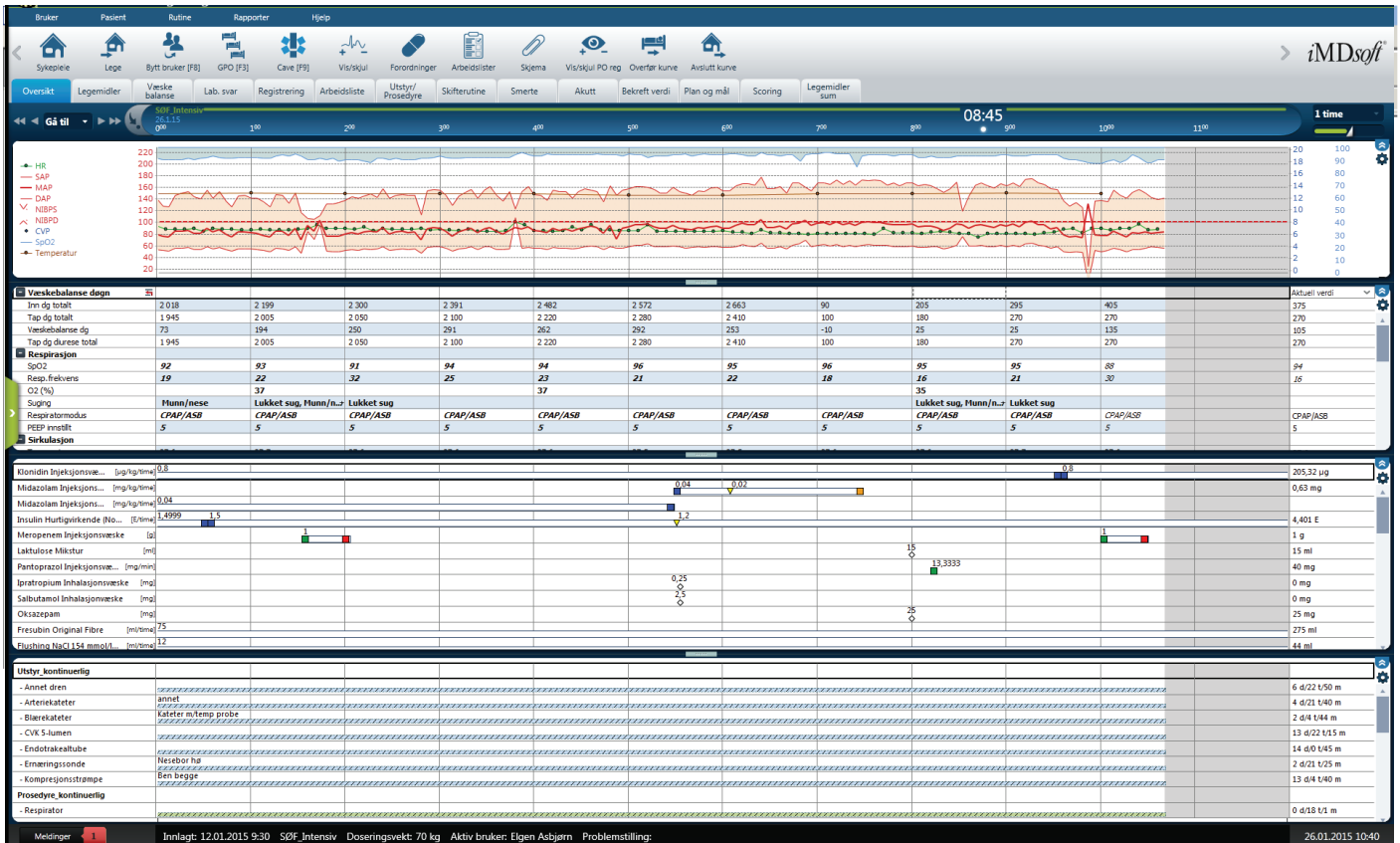


Fig 14: Electronic Patient Curve

## Electronic Patient Curve (EPC)

The Electronic Patient Curve is monitoring and recording the patients drug intake as well as the treatment given. During procedures the EPC is used in relation to the anaesthetics and is usually operated by the anaesthesia doctor or anaesthesia nurse.



**Fig 15:** Picture Archiving and Communication System/Radiology Information System (PACS/RIS)

### **Picture Archiving and Communication System/Radiology Information System (PACS/RIS)**

Radiology taken before the procedure are stored in PACS. These pictures can be CT, MR, Ultrasound, etc. and is often used before surgery to plan the procedure, but also during surgery to compare the live pictures from the videofluoroscopy with the pictures taken before the procedure. The images taken during the procedure by the videofluoroscopy is transferred to PACS after the procedure.





*Fig 16: Ultrasound*

## Ultrasound

Serving many of the same needs as the video fluoroscopy system, ultrasound imaging can also show leakage from the valve implant. This is mostly used in surgical TAVI post-procedure to ensure that the valve implant is inserted correctly and doing what it is supposed to. However, it can also be used pre-procedure to ensure that the procedure is going according to plan.

# Situation Awareness

During the research phase, I looked into other information heavy and attention demanding contexts, such as airplane cockpits and ship bridges. When looking into these environments, I was pointed in the direction of situation awareness by main supervisor Kjetil Nordby.

Definition of situation awareness: Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1988). Endsley (1995) describes three layers of situation awareness:

**Layer 1:** perception of the elements in the environment. What elements/information are worth paying attention to? Where are the team members, and what are they doing?

**Layer 2:** comprehension of the current situation. How is the patient's condition? How is what I'm doing effecting the patient and the other team members?

**Layer 3:** projection of future status. Is the procedure going as wished, and if not, what can be done to correct and ensure a positive outcome?

Situation awareness theory is, amongst other contexts, used in training of the U.S. military (Pew and Mavor, Eds., 1998). In everyday parlance, the term situation awareness, means the up-to-the minute cognizance or awareness required to move about, operate equipment, or maintain a system. The term has received considerable attention in the military community for the last decade because of its recognized linkage to effective combat decision making in the tactical environment.

This seem adequate for the operating room context as well, but what separates the mentioned contexts from the operating room, is that it is a human being in the centre of attention.



## **2. Solution**

# Introduction

I have decided to divide the solution into two parts, due to the fact that there are different user needs. One part consists of a augmented reality application, the other as a control panel in a large tablet format.

For the cardiologist I decided to go with an augmented reality solution, based on their need for a clear view of the information. This will enable them to see their own hands and the patient while performing the procedure.

In the observations I found that the other team members are more dynamic in regards to the spatial position in the room. In addition, they are not dependent of having to look at the patient continuously. Therefore, I see it beneficial to keep some of the screens in the operating room, in order to convey information to the rest of the team. Nevertheless, it is necessary to be able to control the information on the screens from within the operating room, and not having to go to the observation room. For this reason, I have also made a control panel for the team to control which applications that are running on the large screens in the operating room.

# Control Panel System

I have not designed/re-designed any of the applications in the control panel because of the time frame and scope of this project, but I have designed the control panel itself. The advantage of making a platform for the different applications rather than making an integrated solution with all the necessary information, is that it can be easily modified in order to be relevant to other procedures as well - adding new applications. It can be customised by the end user. This is especially useful in a hybrid operating room (like the one I have been working in), where different procedures are being conducted.

## Why Tablet?

If the control panel were to be on a stationary computer or a laptop, it would require a table. This is a problem considering the already crowded space in the operation room. A tablet can be mounted on the wall and is therefore more space efficient. It can also be brought to other places in the room where it is most needed at a certain time.

## Solution

When the team arrives at the operating room, they can select a preset that fits the information need of the scheduled procedure. They also have the option to make a new preset if a matching preset isn't already made. When a preset is selected the adequate information is presented on the screens in the operating room. The user is then presented with an overview of the screens and applications on the control panel. From here he or she can edit the screens by changing the information presented or view the screens and applications in detail. To edit the screens, the user can also go to the screens page. Here, new screens can be added to the system. In the application page, the user can see all applications in the system as well as viewing them in full screen.

Following in the next eight pages is a description of my solution for the control panel system. Screenshots from the solution will be presented on the left side of the page, supported with explanatory text on the right side.

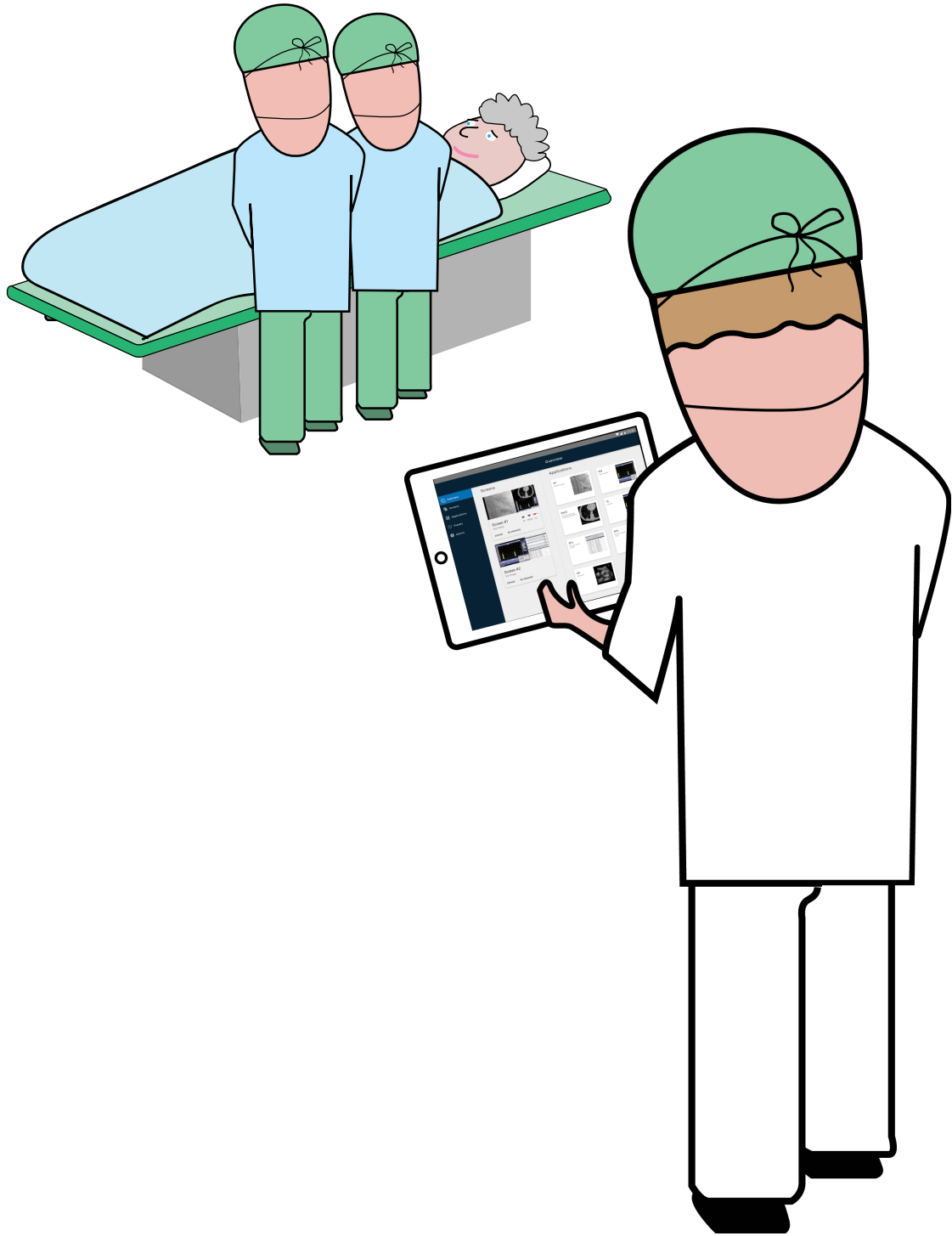


Fig 17.

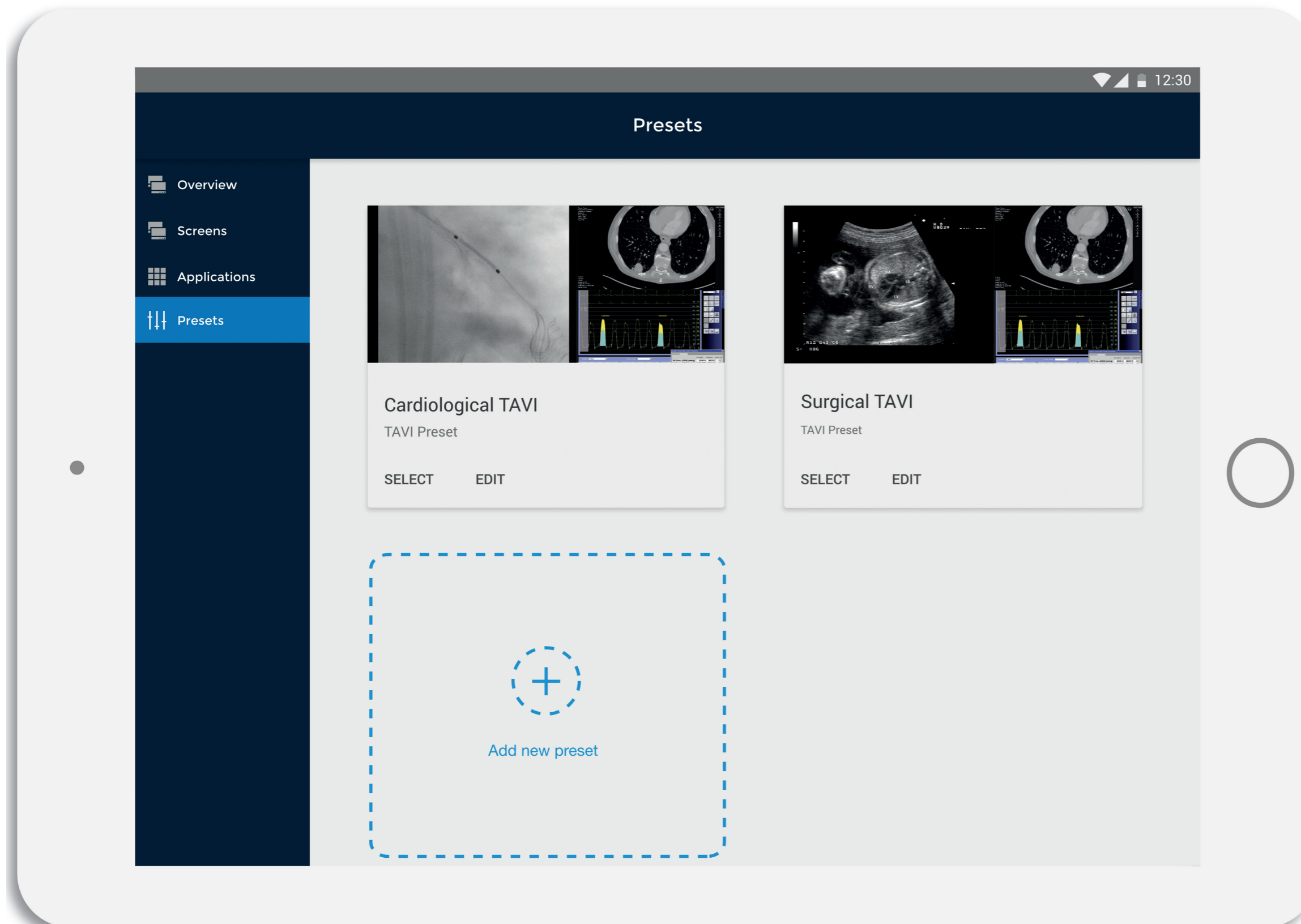


Fig 18.

## Presets

In a hybrid operating room, there are different types of procedures performed. As mentioned, the information the team needs differs from procedure to procedure. To avoid spending much time on setting up the different information on the screens before each procedure, my solution includes the functionality of presets. Presets can be made to suit the different procedures information need, and simply be chosen before the procedure starts.

### Use Case

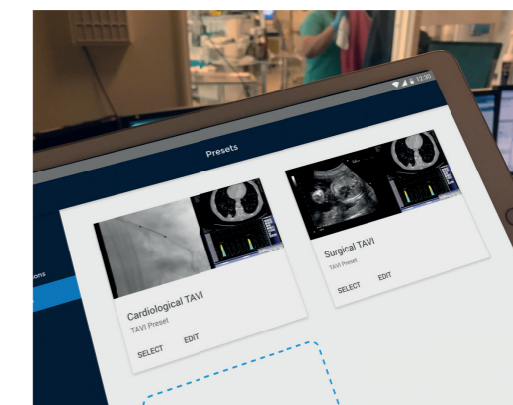


Fig 19.

When the team arrives at the operation ward, as they prepare the operating room for operation, the radiographer chooses a preset for the procedure. Today there is a cardiological TAVI procedure scheduled, hence the radiographer selects the cardiological TAVI procedure preset. The screens in the operating room are then equipped with the adequate information. To make a new preset, the user presses "Add new preset".



# New Preset

Before a new type of procedure is conducted, a new preset can be made. This is done by selecting a layout and dragging the wanted applications from the "Application" tab to the new screen area.

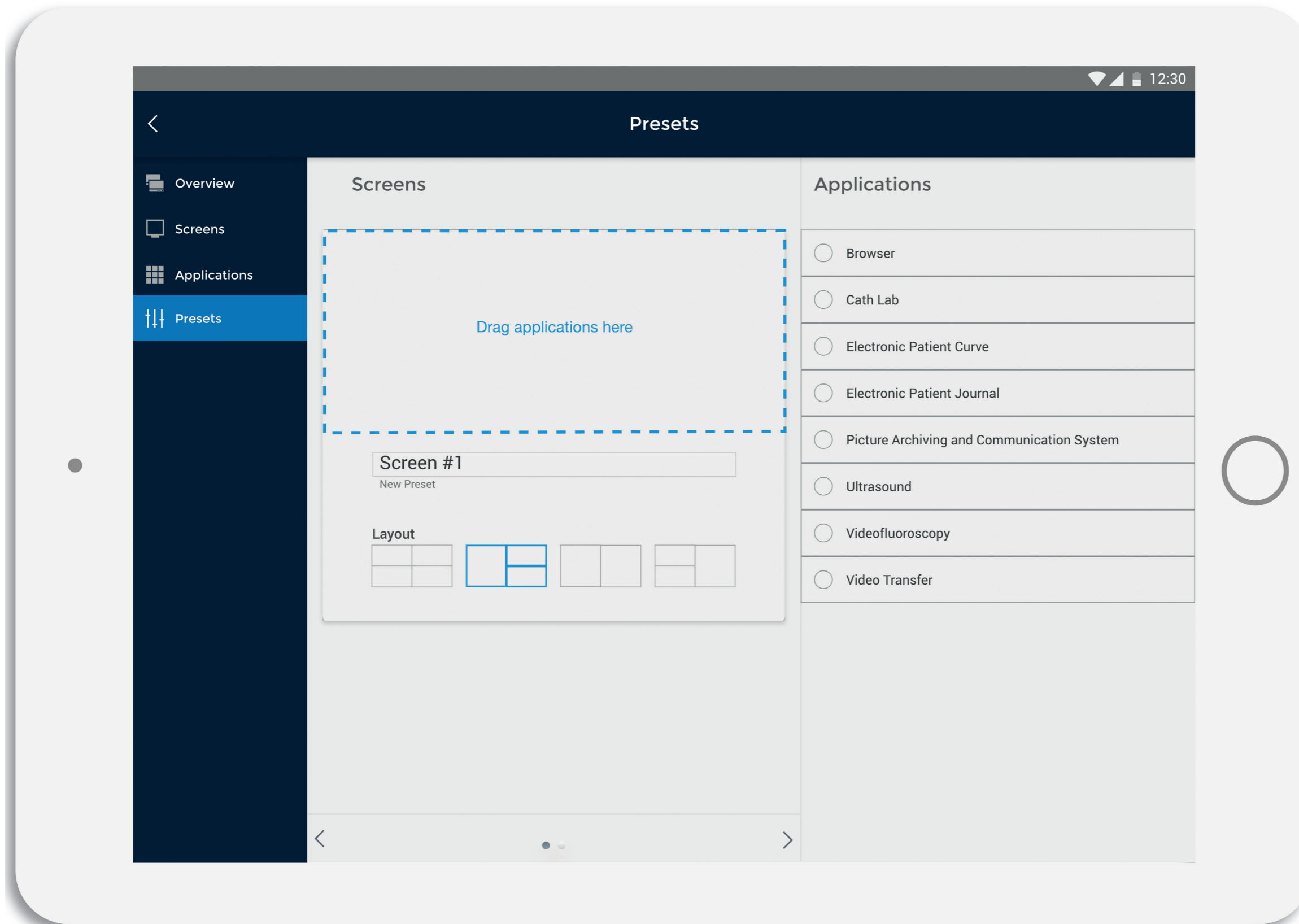


Fig 20.

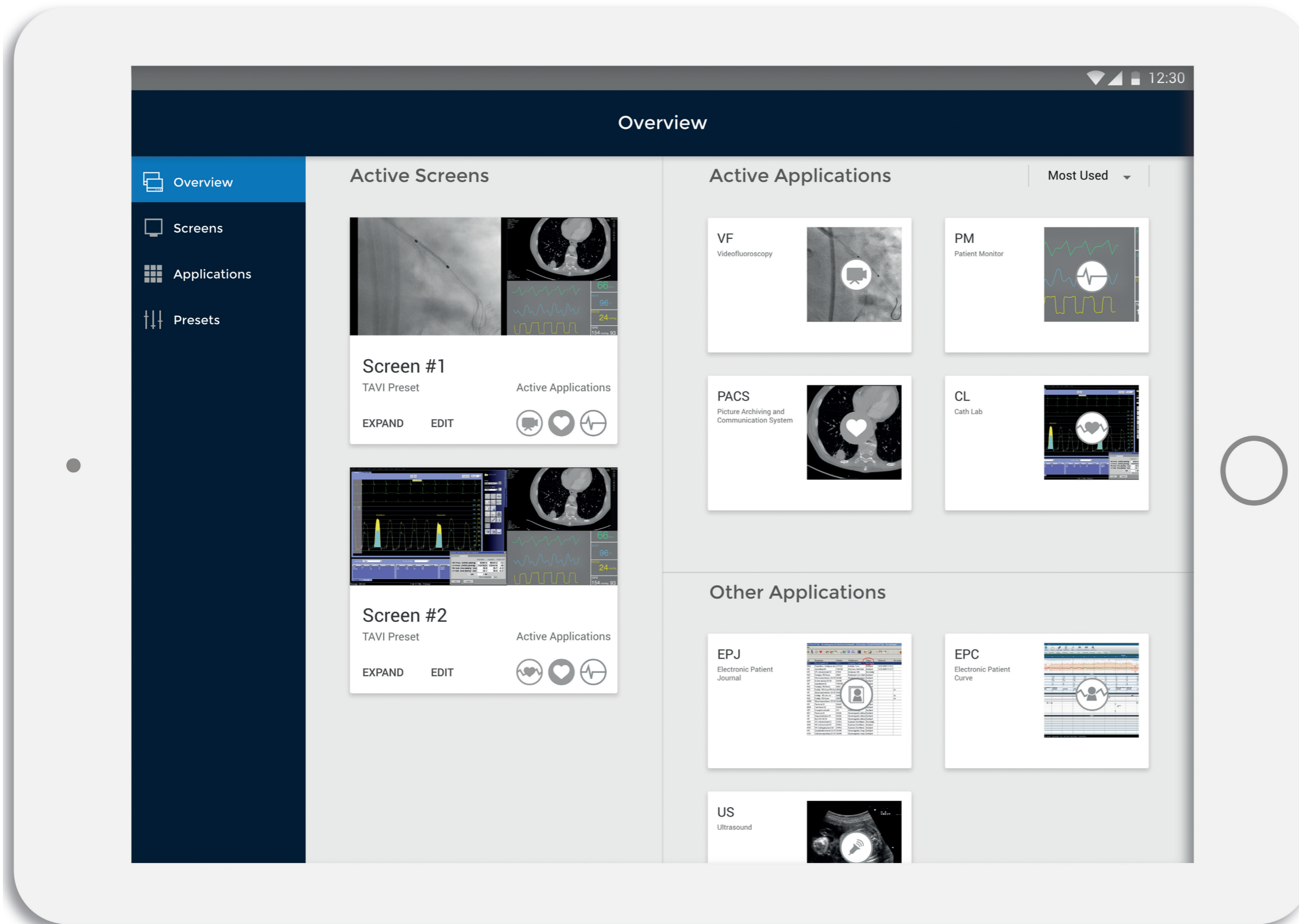


Fig 21.

## Overview

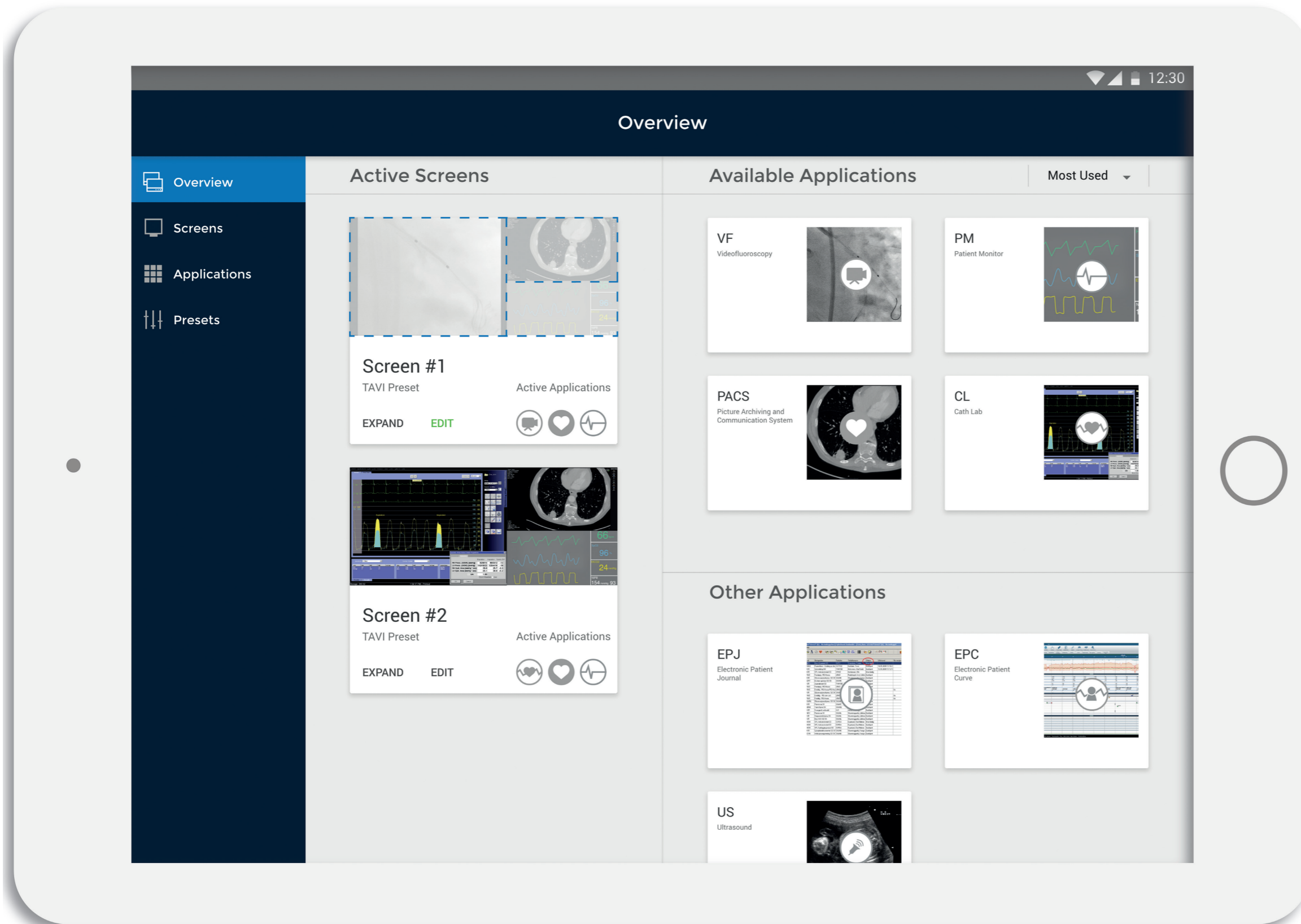
The overview is the front page of the control panel. It gives the user a quick understanding of which applications that are running on the screens in the operating room. In addition, all the available applications are listed in the "Available Applications" tab, including the applications that are not active on the screens in the operating room. This gives the user the ability to look at other applications on the tablet in the operating room without having to interrupt the information flow on the large information screens.

### Use Case



Fig 22.

During the procedure, the team might have to change what kind of information that is shown on the different screens in the operating room. My solution offers to do so without having to leave the room. When the radiographer wants to view a different application, he or she can press "EDIT" on one of the screens in the "Overview" and drag a new application to the screen. If he or she want a bigger view of the screen on the tablet, the "EXPAND" button is pressed.



## Edit Screen

When the "EDIT" button is pressed, the user is allowed to drag the application of choice to the active screen. When done, the user presses the "EDIT" button again, and the screen is updated with the new application(s).

Fig 23.

# Screens

When entering the "Screens" tab, the user gets an overview of the active screens in the operating room. From here, a screen can be selected and expanded. This is also where new screens are added to the active preset, if an extra screen is available and connected to the system. To set up the new screen, the user presses "Add new screen". The process of setting up the new screen is similar to how the "new presets" are made. If a user want to view a screen in greater detail, the "Expand" button is pressed.

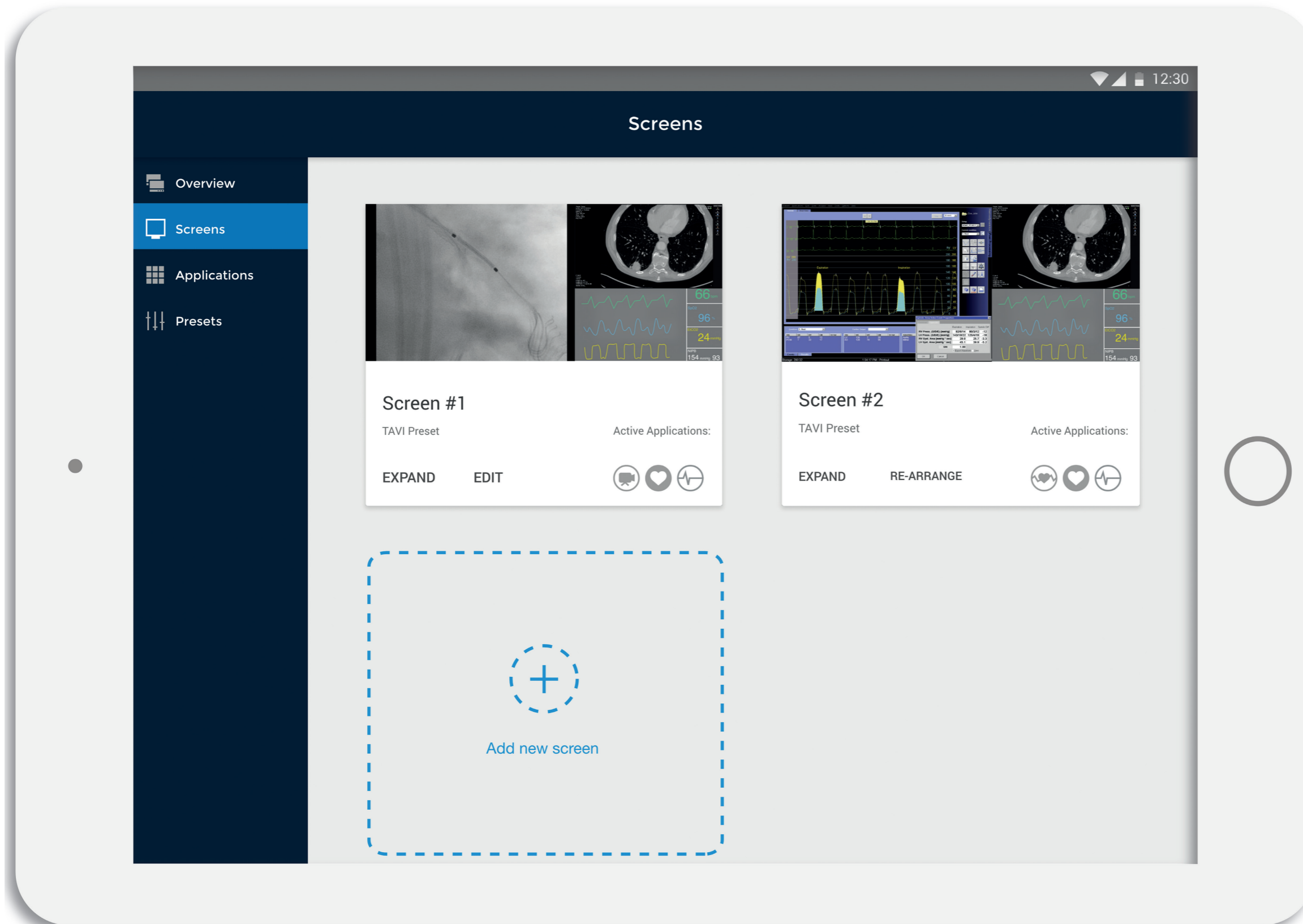


Fig 24.

## Expanded Screen

This functionality gives the user greater detail of what is happening on the screen. The user can swipe between the active screens as indicated by the dots at the bottom of the screen. The different applications can be pressed to view the applications in expanded view.

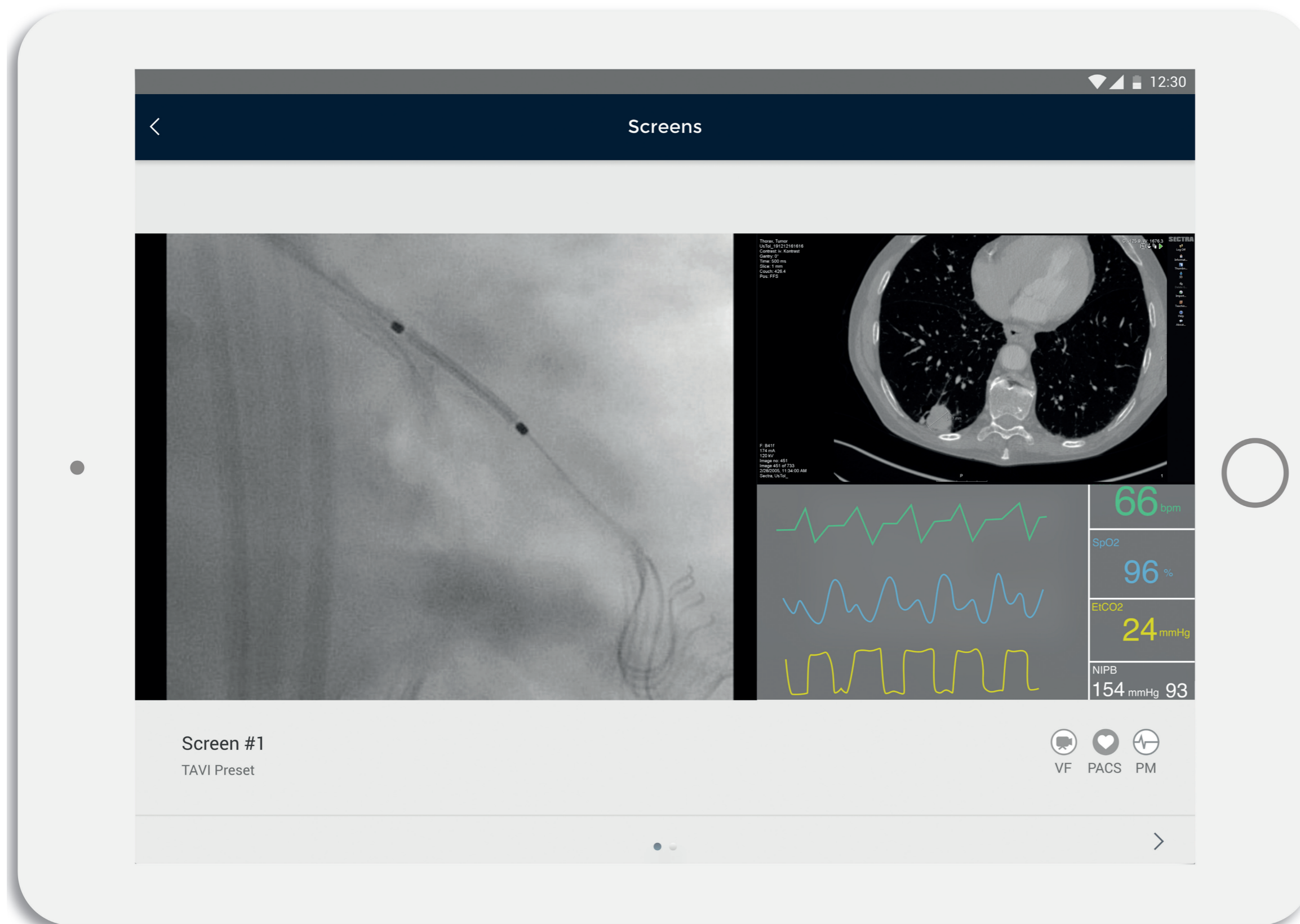


Fig 25.

# Applications

In the "Applications" tab, the applications are listed. They are divided into "Active Applications" and "Other Applications". The applications are by default sorted by most used, but can also be viewed in alphabetical order. Sorting may not be necessary with the amount of applications used in my example, but due to scalability, this is an important feature.

If an application is pressed, it will appear in expanded view.

In this case the user presses the Cath Lab Application.

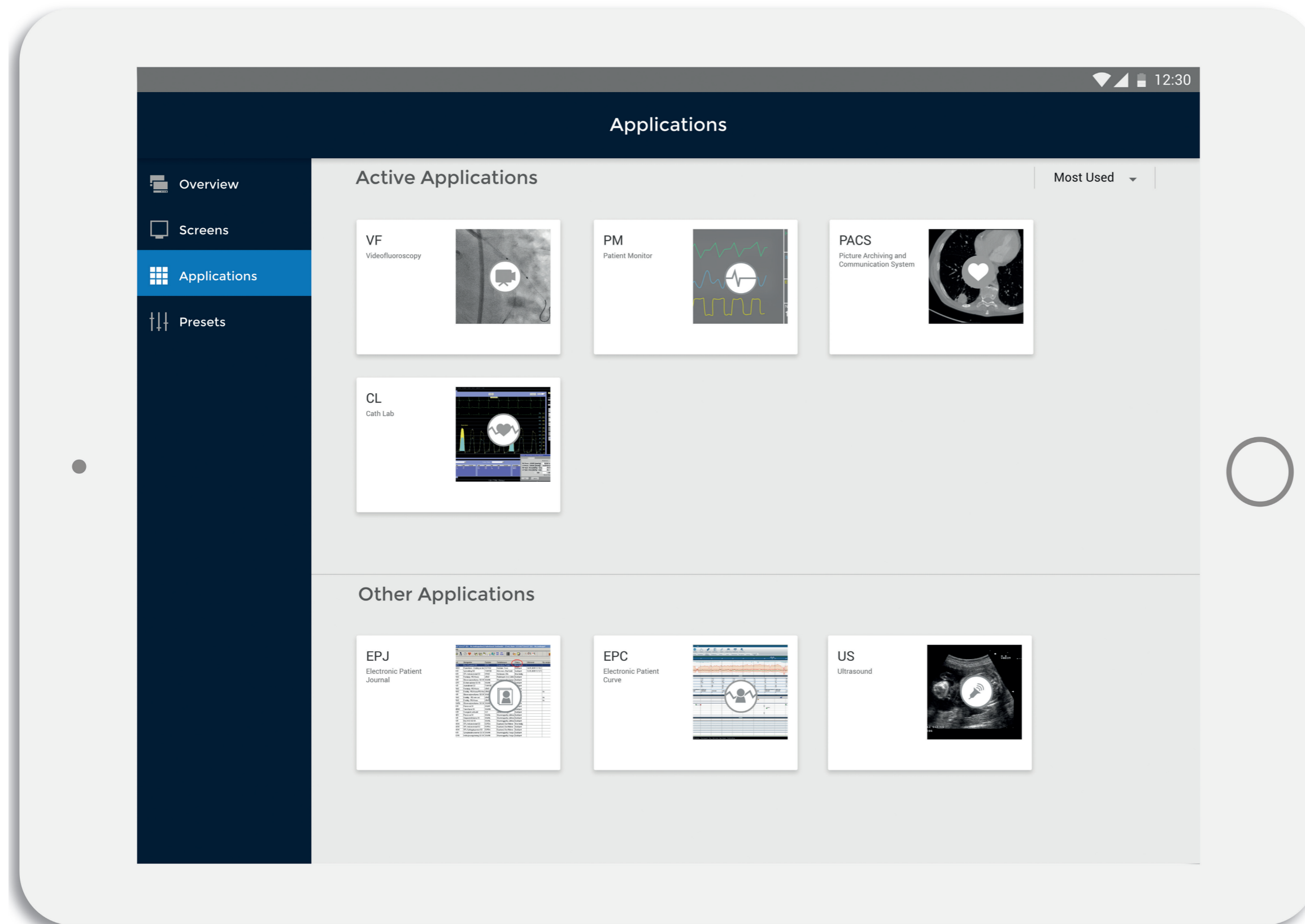


Fig 26.

# Expanded Application

When viewing an application in expanded view, the user can look at the application on the tablet without having to leave the room or interfering with the information flow on the information screens in the operating room.

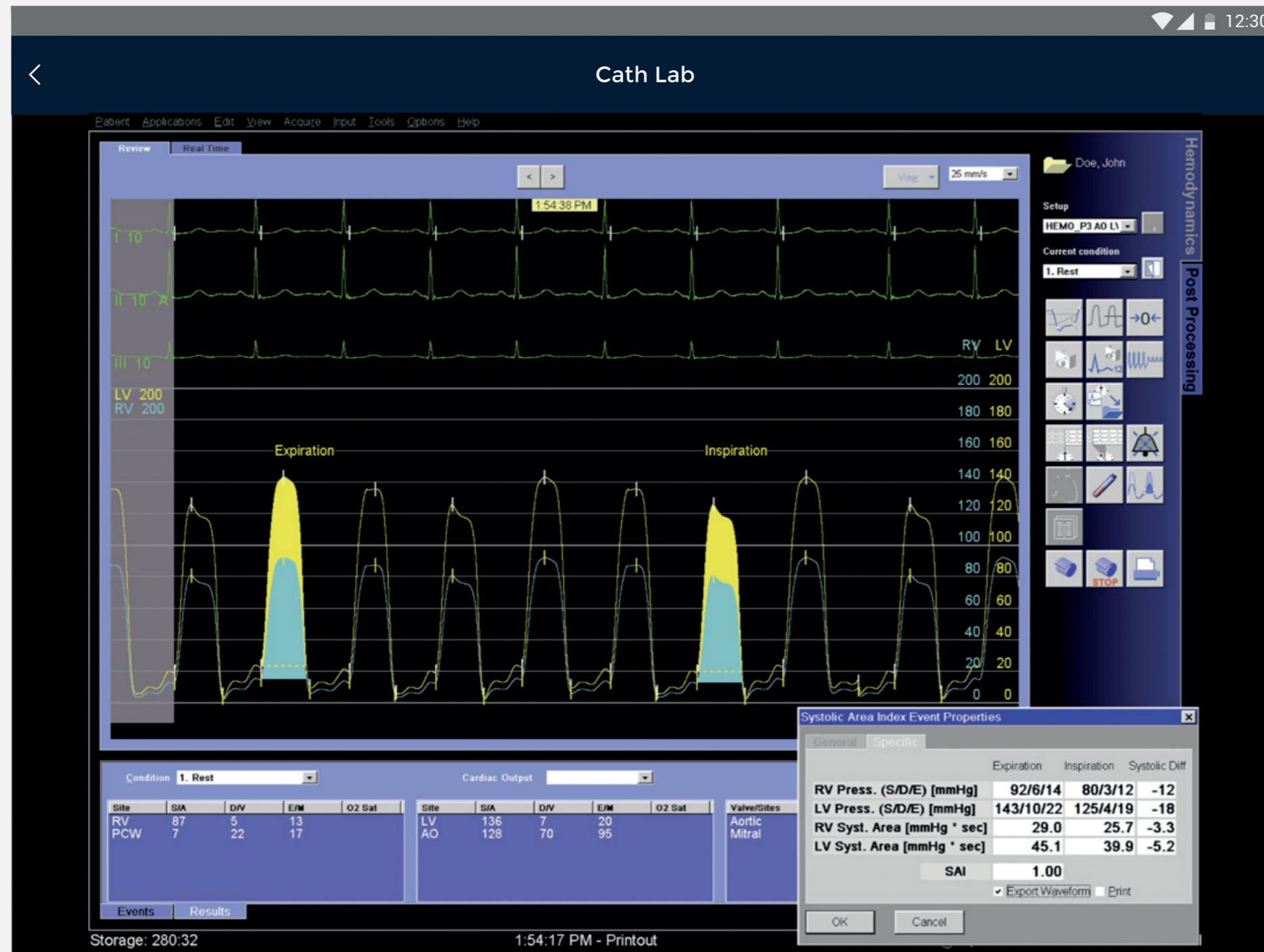


Fig 27.

# Design Elements

## Contrast

I have used the same colour and contrast principles for the control panel and the augmented reality system. The contrast is checked using a contrast checking tool from [webaim.org](http://webaim.org), ensuring that the fonts are readable against the background colours.

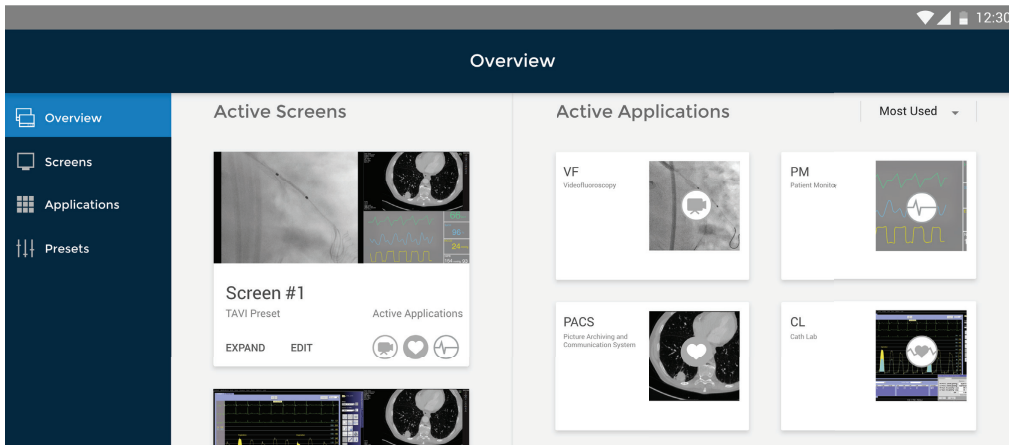
## Colours

Researching the operation room as a context, and other similar information heavy contexts I found that colours have a high value in delivery of information. For example, yellow and red are typically used to indicate abnormal/critical values or alarms, while green indicates that values are OK/normal. Therefore, I have chosen to stay away from these colours when designing the framework for the applications.

The framework around is dark blue (Hex: `##002136`) with white text. The icons in the framework are light grey (Hex: `#ADADAD`) when not selected, but turn white when selected. The selected tab gets a brighter blue to highlight the selection (Hex: `#0571B5`).

The background within the framework is light grey (`#EEEEEE`), and the cards that contain the main content is white to stand out from the background. A drop shadow is also added to enhance this effect, and make the cards appear clickable (see figure X).





**Fig 28.**

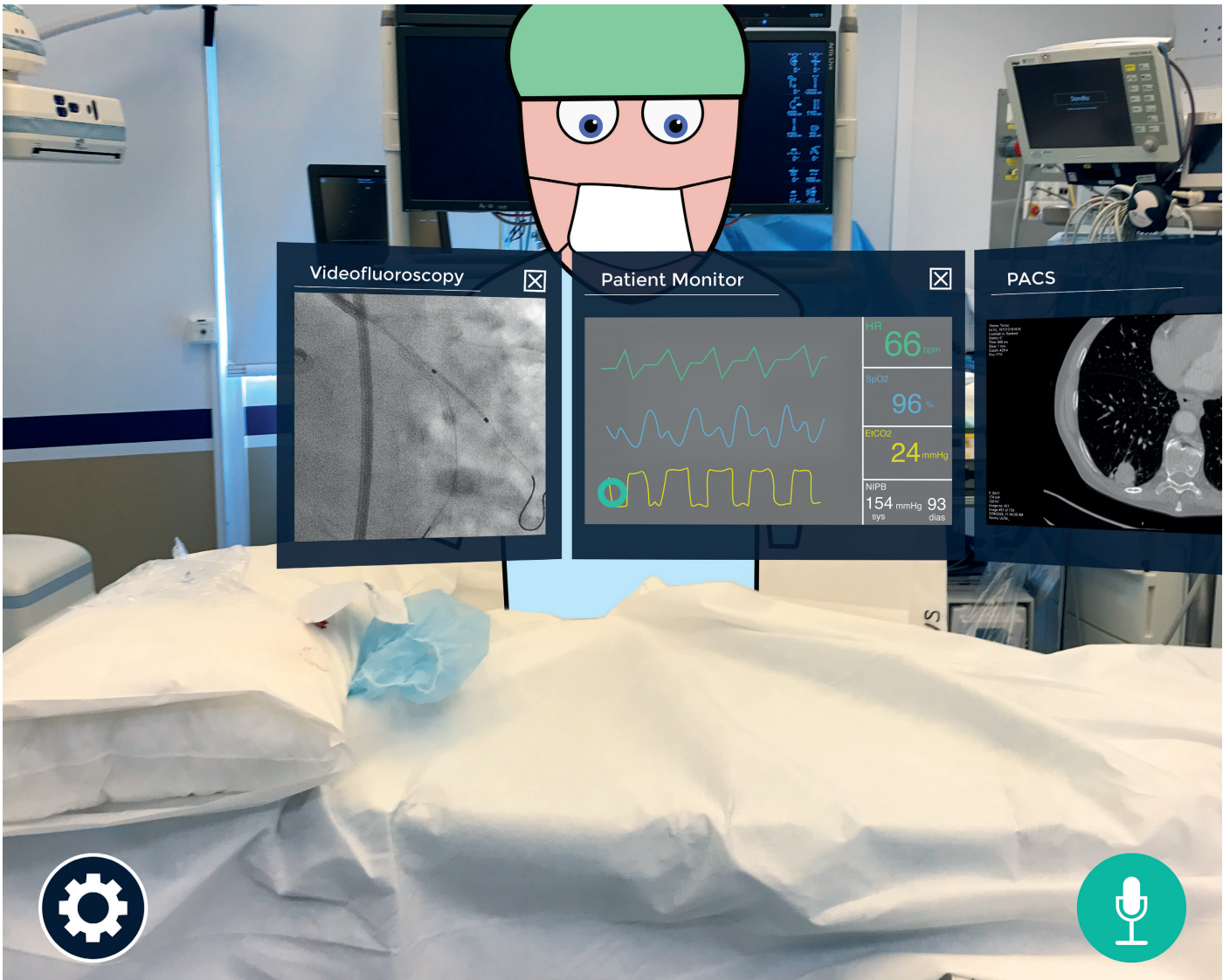
## Fonts

Regarding fonts, I have focused on finding clear and readable fonts for screens, and chosen Montserrat for headlines and Roboto for content.

# Augmented Reality System

## Why Augmented Reality

The main argument for using augmented reality as a part of the solution is the spatial independence this provides. The user's vision of the information will not be blocked by other people or equipment when adding a virtual layer of information on top of the "real world". The information can be placed where the user wants, leaving him or her in control of where he/she wants to stand. This enhances the work position for the cardiologists.



**Fig 29:** The illustration shows applications from a cardiologists point of view. The cardiologist is wearing a augmented reality headset. The applications can be seen without blockage from the colleague on the other side of the operating table.

## Settings

In the “Settings”, represented by a cogwheel icon, the user can choose from presets and applications. Similar to the control panel, the augmented reality system lets the user choose a pre-composed preset containing the most used applications for a specific procedure. The presets can be found under the “Presets” icon (see figure) and is selected with radio buttons. When the preset is selected the applications appear in augmented reality, fixed to positions in the physical room.

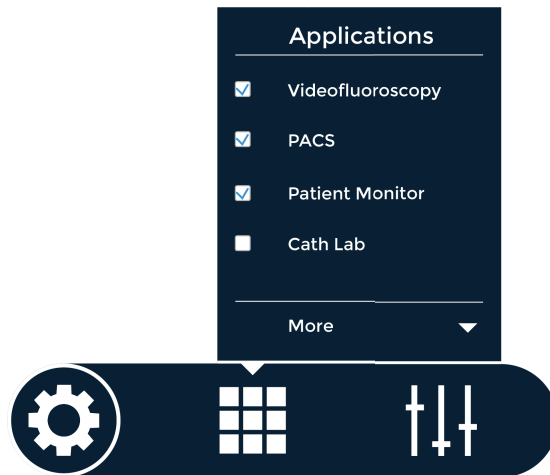
During the procedure, if the user wants to see an application not present in the preset, he/she can find it under the application icon. When the user has navigated to the wanted application, a checkbox is ticked to confirm that the application is selected and active.



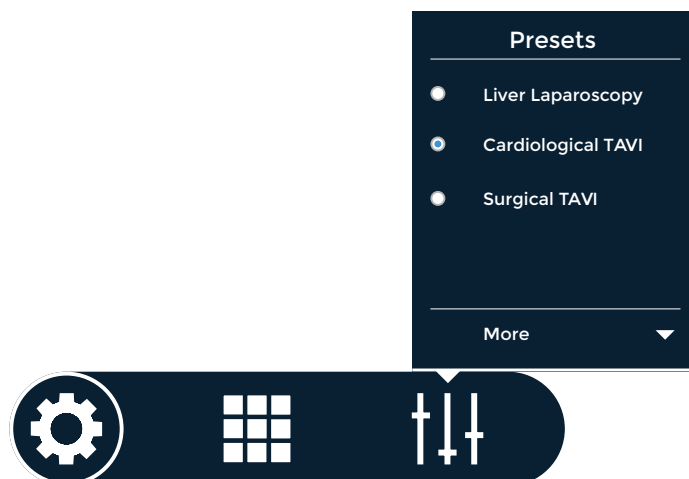
*Fig 30: The “Settings” button collapsed.*



*Fig 31: The “Settings” menu expanded, revealing the “Applications” and “Presets” buttons.*



**Fig 32:** The applications are available under the applications icon. They are selected by ticking the checkbox on the left side of the application name.



**Fig 33:** The presets are available under the presets icon. A preset is selected by checking the radio button on the left side of the preset name.

## **The View**

During the procedure the cardiologists can see the applications and keep an eye on both their hands and the patient. This enhances their control and patient contact. Several of the cardiologist I talked to, likes to talk to the patient during the procedure. This can give clues to the patient's condition. This will be easier when the cardiologist can face the operating table and the patient instead of the foot end of the table.

## **Fixed and Tag-Along elements**

Fixed elements are virtual elements that are fixed to a position in the physical room with a so called "world anchor". Tag-along elements are virtual elements that follow along with the users head movement. By default, the applications are fixed elements, but can be made tag-along elements with a voice command. The "Settings" menu and the voice command icon are tag-along elements,



**Fig 34:** The augmented reality system from the cardiologist's point of view. The "Settings" panel and the voice control icon are tag-along elements, the applications in the background are fixed elements, fixed to a position in the room.

## **The Headset**

I have had the chance to try the Hololens, which they also have some experience with at the intervention centre.

One of the advantages of the Hololens is that it is wireless. This enables the user to move freely without the concern of being tangled up in wires. It also eliminates a supporting computer in the operating room, which is crowded as it is. This, of course, means that the it relies on battery power, which means good routines for charging would have to be in place for the Hololens to be operative. Another disadvantage with using the Hololens is that it only has 30 degrees field of view. In comparison, competitor Meta 2 has 90 degrees field of view.

New headsets are emerging in a fast rate, developing the technology rapidly. My guess is that regardless of my efforts, this technology will be more and more used, also in professional settings such as operating rooms.

## **Practicalities**

I have talked to one of the surgeons at The Intervention Centre who have actually went through a procedure with a Hololens on, to test if it is comfortable to wear and how it feels having it on for the extended period of time that it takes to do a complicated procedure. He said that it was comfortable enough, and that it shouldn't be a problem to wear it for an extended period of time.





*Fig 35: I got to test out the Hololens with developers from Sopra Steria.*

# AR Interactions

## Gestures

The augmented reality application can be customised by the user to fit his or her needs. The placement of the different applications can be done by “pinching” and holding the virtual element with the thumb and index finger and drag it into position. Buttons are tapped by a rapid pinch movement with the same fingers.

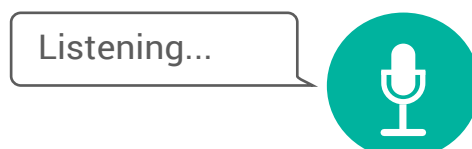
## Voice Recognition

Using voice command during the procedure, the cardiologist can show or hide information in an instant without taking their hands off the patient.

The voice command technology is becoming more and more used, and is a priority for many tech giants like Apple with “Siri”, Google with “Google Assistant” and Amazon with “Alexa”. I had concerns whether the facemasks worn during the procedure would affect the reliability of the voice recognition. I made a test with both “Google Voice Search” and “Siri” and neither of the systems had problems understanding my speech. I also tried the voice recognition while breathing heavily after a run and wearing a facemask. Both systems successfully recognized the words spoken.

## Voice Commands

To activate the voice control, the says “Voice control”  
“Hide Settings” - collapses the settings bar  
“Settings” - expands the settings bar  
“Hide [Application]” - hides application  
“Show [Application]” - shows application  
“Hide all” - hides all virtual elements  
“[Application] tag-along” - makes the application tag along with head movement



**Fig 36:** When the voice assistant is activated, a feedback is given to the user, indicating that he/she can give the voice command.

## Gaze Control

Another handsfree solution for interaction is gaze control. The gaze pointer is effectively a circular point on the headset display moving along with the users head movement. We can imagine that there is shot a ray from this point and straight out in the room, intersecting with other virtual elements. When the user looks at a certain virtual element, for example the patient monitor, the imaginary ray intersect with it and can be engaged.

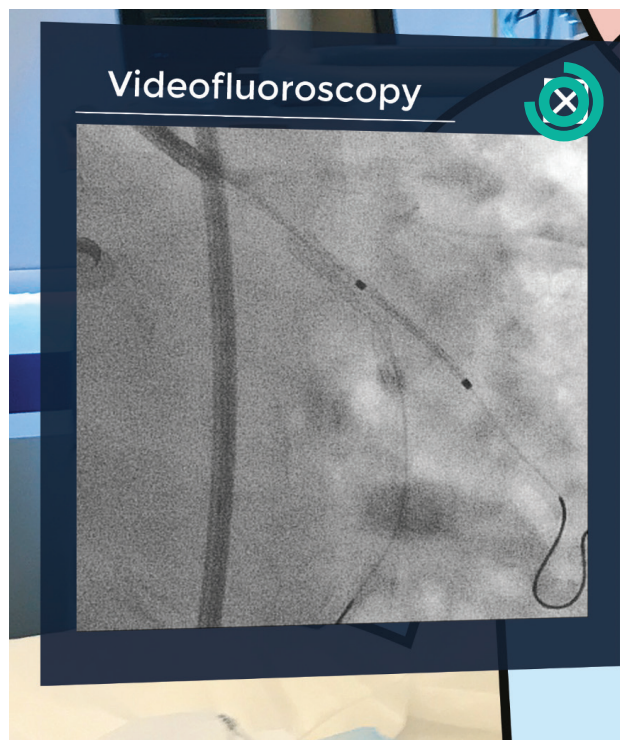
When an interactable object is intersected by the gaze pointer, a ring will start to shape around the point. When gazing at the interactive element for two seconds, the ring around the pointer is complete and an event is triggered by the interaction.



**Fig 37:** Gaze pointer



**Fig 38:** Gaze pointer intersects with interactable element.



**Fig 39:** The user has directed the gaze pointer onto the "x" for about 1.5 seconds, meaning the videofluoroscapy window will close in 0.5 second.

# 3. Process

# Introduction

This being a relatively complex and, for me, alien field of study, I have used a lot of effort trying to acquire knowledge about the context and situation I have been working in. This has been important in regards to making relevant design proposals. I have also benefitted from discussions with my supervisors at AHO and at The Intervention Centre along the way.

I have had an iterative process, especially with the control panel as this has been easier to prototype than it has been with the augmented reality system. Prototyping augmented reality has been an issue that has forced me to be creative with the prototyping methods.

I have had user involvement in both discussions and testing the prototypes throughout the project period. This has contributed to validate or discard functionality and driven me to new iterations.

# Research

## Observations

I have been allowed to observe more than ten TAVI procedures, giving me valuable insights in what the team do and need during procedures.

The first few observation sessions was new and different experiences, being in an operating room during procedure. I noticed immediately that it was very important not to get in the way of the team as it could, occasionally, be critical situations, demanding the team's full attention.

## Informal Conversational Interviews

This form of interview gave me room to ask questions related to the situation or context, that would be difficult to foresee. If I was to rely on an interview guide, I would have to lead the interview accordingly, leaving little room for question and answers related to the ongoing situation.

An objection to the informal conversational interview approach, is that the lack of structure and the inconsistency in questions asked, makes the interviews hard to code (Cresswell, 2007). I recognize that a more structured form of interviews would have given me an easier job of coding the interview, but I still believe that I have gotten a lot of useful information with the informal conversational interview method, that would have otherwise been difficult.

## Interview Subjects

Starting this project, I knew I was dependent on getting in contact with users working in operating rooms. My main supervisor, Kjetil Nordby, put me in contact with The Intervention Centre, allowing me to get a foot in the door in a professional and experimental environment perfect for my case. I got to observe procedures here, and it gave me access to talk to real users.

I came in contact with Karl Øyri and Ole Jacob Elle who became co-supervisors for this diploma. They introduced me to the context and put me in contact with other people to talk to. Fangen (2010) explains that it can be beneficial to get a "gate keeper". She explains that a gate keeper is a contact person that can establish contact with potential subjects for the study. A gate keeper is someone who has a lot of influence and contacts within a certain environment.



**Fig 40:** Observations have been done both in the operating room and from the observation room. The advantage of observing from the observation room was that it was easier to take notes and get a better overview. Observing in the operating room was more hectic, but gave me a better understanding of the details, as well as the actual user situation.

# Prototyping - Control Panel

## From Low-Fi to Hi-Fi

After a few observations, I started doing sketches on a conceptual level. I started out sketching on paper and got feedback on these from peers and supervisors. The sketches were rough and far from detailed, as I wanted feedback on the concept as a whole, rather than details. As I made iterations to these sketches, more and more details came in to place. I then began making digital wireframes and low fidelity prototypes to test navigation and content. This gave me something to test and discuss with users, which again gave me a lot of new ideas for the next iterations.

When I got to the higher fidelity prototypes, I got more feedback on details and less on the overall concept. Satisfied with the user test results and feedback, I could focus on the detailing of the control panel. Even though I am satisfied with the result, I see how the solution could benefit from a few more rounds of user testing and iterations.

Below is excerpts from the evolution of fidelity.

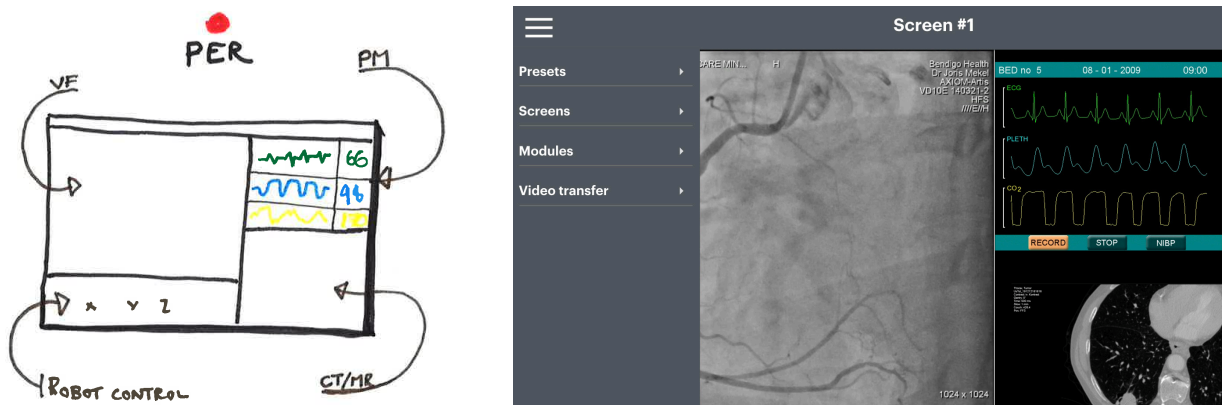
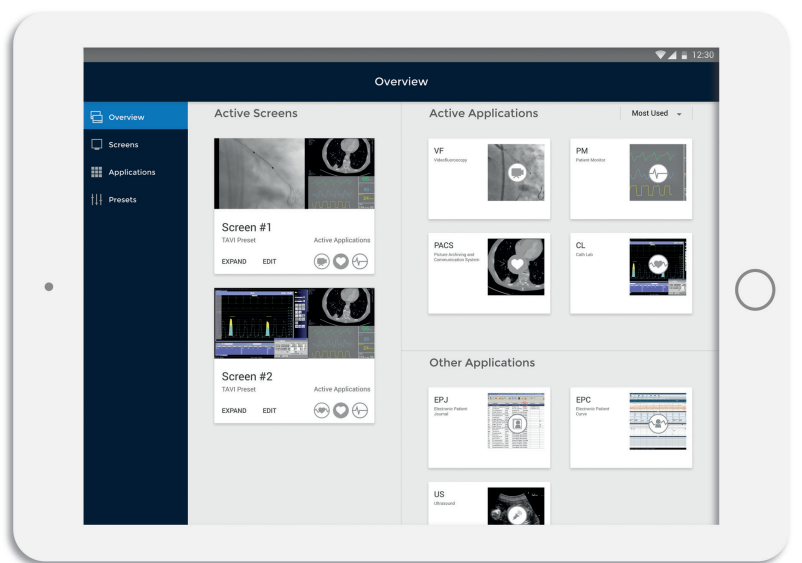
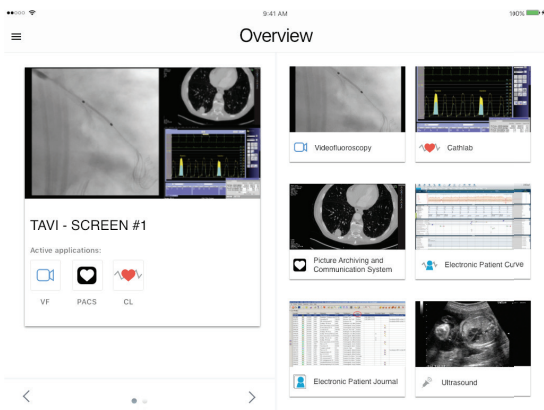


Fig 41: Evolution of the control panel





# Prototyping - Augmented Reality System

Prototyping AR is an issue. I have tried using the hololens development tool, but this is time consuming and as I don't have a Hololens to test it on it doesn't make much sense in the spatial perception part of the experience. I'm also limited by my technical capabilities. Therefore, I was prototyping with an iPhone, google cardboard and Unity, which is a game engine, and an AR development tool called Vuforia to quicker prototype the augmented reality part of my solution.

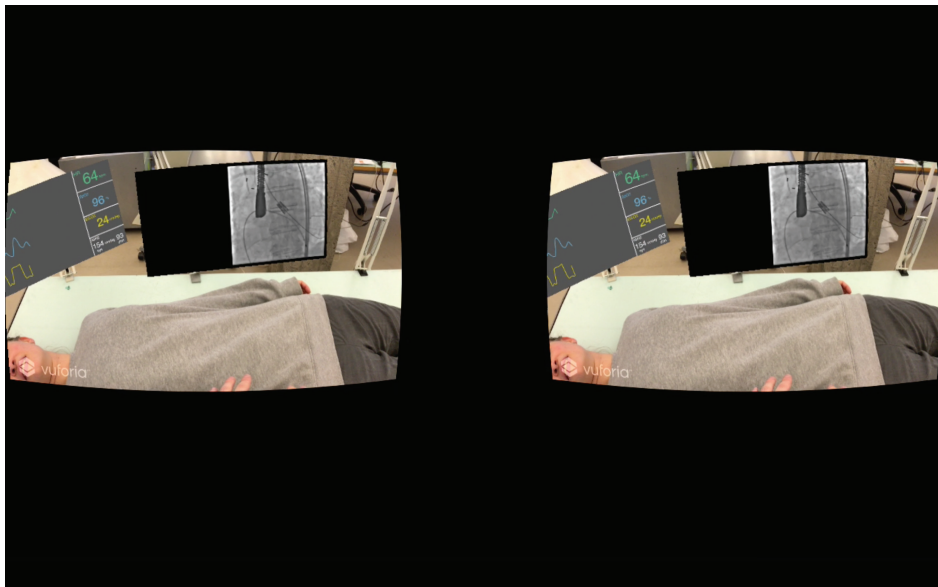
It had the videofluoroscopy, the patient monitor, and a 3D model of the heart in "realtime". I got feedback that the 3D model of the heart was a bit too futuristic, but maybe something to consider for a later time.

At this stage in the process, I was using luxo lamps to position the different modules in the room, as I needed trackers for the prototyping tool. Trackers are images, almost like QR-codes, which the phone camera recognises and replaces with the fake applications.

With Hololens or like, you would not be dependent on trackers. It scans the room and lets you place the applications in the room. The applications will stay put unless you want it to tag along with your head movement.



**Fig 42:** Using peers, Luxo lamps, a desk, and a primitive augmented reality tool to prototype the experience of augmented reality.



**Fig 43:** Showing the patient monitor and videofluoroscopy seen through Google Cardboard and an iPhone.

# User testing

I did most of the user testing in between procedures and in breaks, in the observation room. This was the time when the users had time to test and talk to me. The average test lasted about 10 minutes. In the beginning, when the prototypes were low fidelity, it was more of a discussion than an actual user test. The more I detailed the solution, the less I had to explain.

The different iterations of the control panel has been tested with users, and the feedback has provided me with knowledge and ideas for new iterations.

The augmented reality system lacks proper user testing due to the technical limitations of my competence and the prototyping tools. However, I have been able to discuss the cardboard prototype, images and movie clips with the users, giving me new ideas for iterations. I have also been ensured that the technical part of the development is possible, by the developers I met with during the Hololens demonstration.



# **4. Sum-up and Conclusion**

## **Risk and Complexity**

To challenge myself and my education, I wanted to work in a complex environment with complex systems. Working in this context has been challenging as a designer without any pre-knowledge about the healthcare system in general, or in more specific, operating rooms, operating teams, and information systems used in this context. However, I believe that being able to adapt to new environments and seeing things from a new perspective are at the core of what it is to be a designer. In retrospect, I don't regret going into this topic, as I have discovered a new field in which I have gained knowledge and experience.

## **The Solution**

With this project I wanted to make a solution that improves the way information is provided to an operating team when performing a procedure. Based on my findings, I found it best to divide the solution in two parts to best suit the individual needs of the team members.

For the cardiologists, I have made a design for a augmented reality system that provides them with the information that they need during the procedure. When using this solution they can keep patient contact and a view of their hands, and still see the information.

The rest of the team can control the information on the screens in the operating room, using a control panel on a tablet in the operating room. This gives them the advantage of not having to leave the operating room to change the information. They also have presets of different layouts that suits the different procedures. Using these, they don't have to spend a lot of time navigating through all of the applications to find the right pieces of information for the screens.

The solution has room for improvement and detailing in both the augmented reality system and the control panel. However, the control panel has come a longer way than the augmented reality system, and it would not be long before this is appropriate for implementation. The augmented reality system would need to be developed and tested on a proper headset before it could be implemented as a finished solution.

## **The Process**

The process has been challenging and engaging. In the beginning, the context was very unfamiliar, and also working with specialists was a new experience for me.

I have had an iterative process, especially with the control panel as this has been easier to prototype than it has been with the augmented reality system. Prototyping augmented reality has been an issue that has forced me to be creative with the prototyping methods.

I hope this project will encourage other designer to explore the professional health care context, as I believe there is a great need for designers in this area.



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# References

[http://www.ivs.no/admin/uploadfiles/ann\\_rep\\_2015.pdf](http://www.ivs.no/admin/uploadfiles/ann_rep_2015.pdf)

<https://material.io/guidelines/resources/roboto-noto-fonts.html>

<http://webaim.org/resources/contrastchecker/>

Cresswell, J. W. (2007) *Qualitative inquiry & research design: Choosing among five approaches*. 2nd edition. Thousand Oaks, CA: Sage

Endsley, M. (1988) Design and evaluation of situation awareness enhancement. Pp. 97-101 in *Proceedings of the Human Factors Society 32nd Annual Meeting*. Santa Monica, CA: Human Factors and Ergonomics Society.

Fangen, K. (2010) *Deltagende observasjon*. 2. utgave. Oslo: Fagbokforlaget.

*Modeling Human and Organizational Behavior (1998): Application to Military Simulations* Richard W. Pew and Anne S. Mavor, Editors; Panel on Modeling Human Behavior and Command Decision Making: Representations for Military Simulations, National Research Council

