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## Research Report

# Design Principles of Clinical Dashboards Incorporating PROMs: Crafting and Elaborating the Potential of Clinical Dashboards Incorporating PROMs

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**Design Principles of Clinical Dashboards Incorporating PROMs:  
Crafting and Elaborating the Potential of Clinical Dashboards In-  
corporating PROMs**

**Anja Bischof, Irene Salvi, David Kuklinski, Justus Vogel, Alexander  
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# **Design Principles of Clinical Dashboards Incorporating PROMs: Crafting and Elaborating the Potential of Clinical Dashboards In-corporating PROMs**

**Keywords:** Clinical dashboards; Patient-reported outcome measures; PROMs

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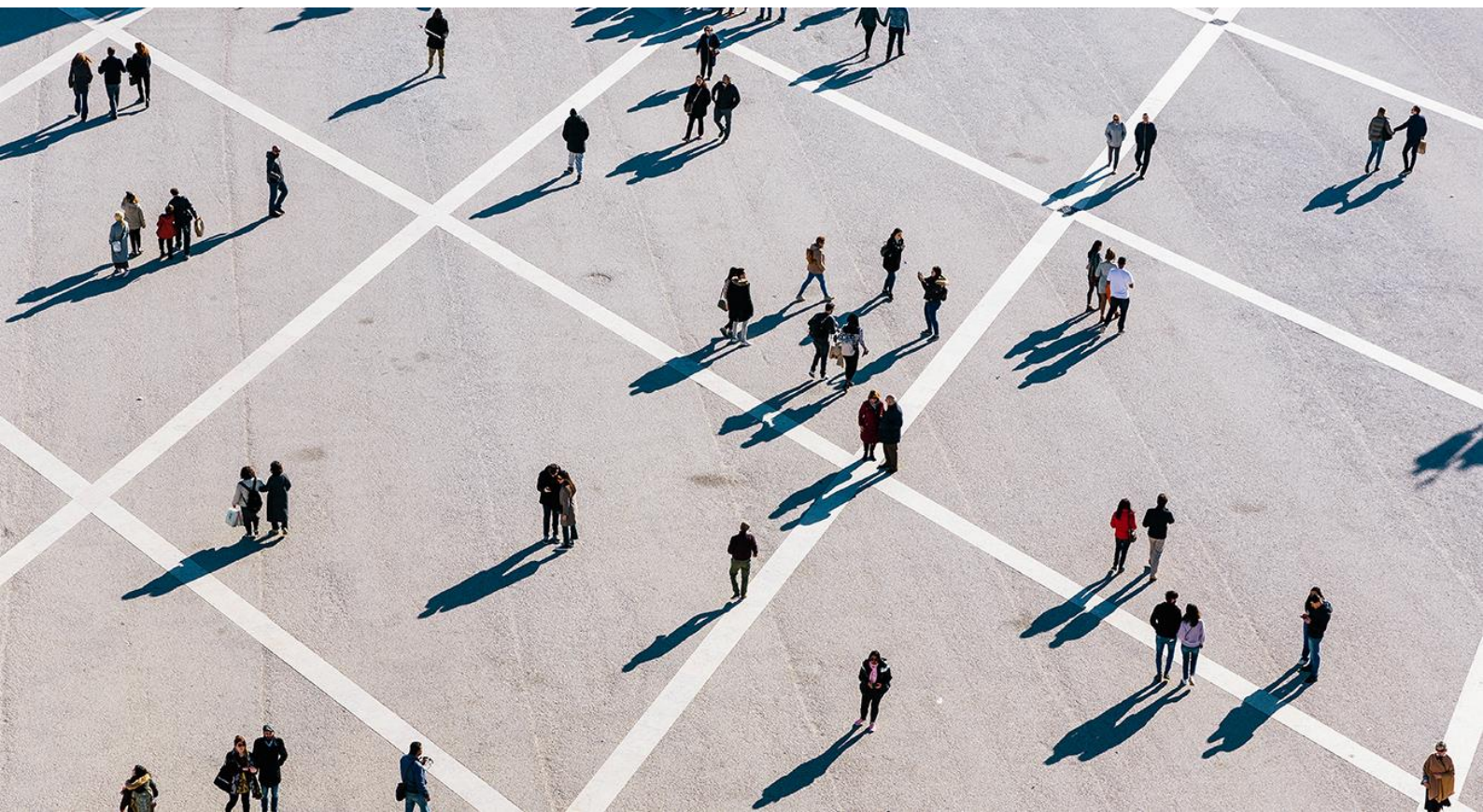
# Design Principles of Clinical Dashboards Incorporating PROMs

Crafting and Elaborating the Potential of Clinical Dashboards Incorporating PROMs

Schriftenreihe in Health Economics, Management and Policy  
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# Abstract

**Objectives:** A clinical dashboard is a data-driven clinical decision support tool visualizing multiple key performance indicators in a single report while minimizing time and effort for data gathering. Evidence showed that including patient-reported outcome measures (PROMs) in clinical dashboards supports the clinician's understanding of how treatments impact patients' health status and helps identifying health-related quality of life changes at an early stage. While existing literature mainly focused on the benefits of using disease-specific PROMs in clinical dashboards, the EQ-5D has rarely been investigated despite its potential to assess the patient's overall health status and mental well-being. To address this gap, we aimed to determine design principles for clinical dashboards incorporating generic – i.e., the EQ-5D – and disease-specific PROMs.

**Methods:** We used a three-step approach. First, a scoping literature review summarized the evidence of relevant design principles for clinical dashboards in general. Second, insights from interviews with both software producers and users of clinical dashboards validated and enhanced the results of the literature review. Third, we built dashboard prototype using the knowledge gathered in the first two steps, which was finally evaluated by a focus group discussion.

**Results:** We found that the design principles for clinical dashboards do not have to change between different episodes of care. The scoping literature review highlighted to incorporate various relevant design principles into clinical dashboards, such as patient data, clinical metrics, past PRO assessment scores, or peer-group comparison. Interviews showed that both software producers and users had similar views on clinical dashboard use, primarily for patient monitoring and interpretation support of PRO data. However, their opinions diverged on the key users, while users favored specialists, dashboard producer expressed their favor for a broader user base. During the focus group discussion, participants found clinical dashboards incorporating PROMs valuable, highlighting the importance getting the possibility of finally considering patients' self-reported health status during consultations. Design principles derived from literature and interviews aligned with the views expressed during focus group discussions, emphasizing the use of both generic and disease-specific PROMs.

**Conclusion:** The chosen three-step approach permitted cross-checking the state-of-the-art in literature and detecting white spots where users and software producers showed diverging tendencies for certain design principles. Our research confirmed that the design principles for different disease areas do not differ. The past score PROM assessment and peer-group comparison were rated, by both the software producers and the users, as the most valuable design principles. Ultimately, this research aims to inform the development of clinical dashboards incorporating PROMs.

# Table of Contents

Abstract	III
List of Abbreviations	V
List of Figures	V
List of Tables	VI
Appendix	VI
1 Introduction	1
1.1 Subject matter, objectives and structure of the study	1
1.2 Definition of scope	2
1.2.1 Episodes of care	3
1.2.2 Definition of clinical dashboards	3
2 Methods	5
3 Results	8
3.1 Scoping Literature Review	8
3.2 Interviews	10
3.3 Focus group – Testing and evaluation of clinical dashboard prototype	15
4 Discussion and implications	21
4.1 Practical implications   General implications	23
4.2 Implications for EuroQol	24
5 Limitations	27
6 Conclusion and outlook	28
References	29
Appendix	35



# List of Abbreviations

CAT	COPD Assessment Test
COPD	Chronic obstructive pulmonary disease
EMR	Electronic medical record
GP	General practitioner
HOOS	Hip disability and Osteoarthritis Outcome Score
HRQoL	Health-related quality of life
KOOS	Knee injury and Osteoarthritis Outcome Score
JAMAR	Juvenile Arthritis Multidimensional Assessment Report
EQ-5D	EuroQol 5 Dimension
OHS	Oxford Hip Scores
OKS	Oxford Knee Scores
PROM	Patient-reported outcome measure
SF-16	12-Item Short Form Survey
SF-36	36-Item Short Form Survey
SGRQ-C	St. Georges Respiratory Questionnaire - COPD
HA	Hip arthroplasty
KA	Knee arthroplasty

# List of Figures

<b>Figure 1. Research approach compiling the design principles of clinical dashboards incorporating PROMs</b>	5
<b>Figure 2. Overview of the screening process</b>	6
<b>Figure 3. Overview of software producer and user responses on general information</b>	10
<b>Figure 4. Overview of responses from software producers and users concerning the dashboard features</b>	14
<b>Figure 5. Clinical dashboard prototype according to the design principles collected in the scoping review and interviews</b>	15
<b>Figure 6: Clinical dashboard prototype – subpage function test</b>	16
<b>Figure 7: Clinical dashboard prototype – subpage laboratory</b>	16
<b>Figure 8: Clinical dashboard prototype – subpage imaging</b>	17
<b>Figure 9: Clinical dashboard prototype – subpage EQ-5D per dimension</b>	17
<b>Figure 10: Clinical dashboard prototype – subpage CAT scores per dimension</b>	18

# List of Tables

<b>Table 1. Overview of features to be tested in user and software producer interviews based on scoping literature review and expert interviews.....</b>	<b>9</b>
<b>Table 2. Overview of software producer and user responses on data collection.....</b>	<b>11</b>

# Appendix

<b>Appendix I: Selected papers from scoping literature review .....</b>	<b>35</b>
<b>Appendix II. Consolidated criteria for reporting qualitative studies (COREQ): 32-item checklist.....</b>	<b>41</b>
<b>Appendix III: Introduction slides presented before each interview .....</b>	<b>43</b>
<b>Appendix IV. Interview guide for software producers and users .....</b>	<b>44</b>
<b>Appendix V: Codebook with deductive codes.....</b>	<b>48</b>
<b>Appendix VI. Overview of software producer and user interviewees' characteristics .....</b>	<b>51</b>
<b>Appendix VII: All codes used during coding attached to the individual interviews .....</b>	<b>52</b>

# 1 Introduction

## 1.1 Subject matter, objectives and structure of the study

Recent medical advances have created a multitude of innovative prevention and treatment options that considerably improved healthcare quality. Despite providing obvious benefits to the patients, this evolution has had, on the other hand, the effect of complicating medical decision-making [1] and distancing the physicians from their patients [2]. As treatments get more complex, the need for reliable medical data and care quality information becomes increasingly important for improving health outcomes [3]. Moreover, incorporating the patient perspective into health care systems has been shown to offer considerable potential to enhance patient outcomes and quality of life [4–7]. The use of patient-generated health-related data, such as patient-reported outcome measures (PROMs), allow patients to engage in their health, enables healthcare providers to monitor more closely how their patients are doing, and establishes more meaningful, standardized, and structured communication between patients and physicians [7–11]. PROMs complement traditional clinical data by representing a patient’s assessment of symptoms, physical function, and health-related quality of life (HRQoL), independently from the interpretation given by physicians or caregivers [12, 13], and their use in health care is key to the transition towards patient-centered care [14]. Growing evidence demonstrates that collecting patient-reported quality of life increases health care providers’ awareness of patients’ concerns [6, 15] and enhances patient-physician communication without increasing visit length [16, 17].

In this context, clinical dashboards can be a supportive tool as they facilitate drawing information from several sources during clinical appointments. A proper visualization of data on clinical dashboards has shown to decrease time spent on data gathering, cognitive overload, time to task completion, and to improve situation awareness and compliance with evidence-based safety guidelines [18]. Furthermore, including PROMs into clinical dashboards enhances the physician’s understanding of the patient’s disease-specific symptoms in the context of the overall health status. Clinical dashboards incorporating PROMs have been shown to potentially improve the clinical workflow due to the possibility of displaying routine medical data and the self-reported health status together [9]. The use of PROMs in clinical dashboards was also shown to support the physician’s understanding of how treatment impacts symptoms scores [10], or enables the identification of HRQoL deterioration at an early stage [9]. This results in a more patient-centered approach, improved care processes, and better patient outcomes [10, 19].

However, physicians will only use clinical dashboards if they perceive an additional value [20]. Thus, the literature highlights the need to define the design principles of clinical dashboards [21]. Accordingly, recent literature has elaborated on potential success factors of clinical dashboards incorporating PROMs. LeRouge et al. [22] showed that the output of such dashboards should be accurate and easily understandable, and it should allow information to be absorbed quickly from the visualization. Further studies have pointed out that information should be used either to provide feedback to physicians to evaluate the treatment, or to support the shared decision-making process in coordination with the patient [8, 19]. Hartzler et al. [23] emphasized the use of different levels of analysis, where one screen view should focus respectively

on a) a general overview of the health status, b) more granular information on the treatment provision and c) operational dashboards for tracking overall treatment activities. Additionally, the authors showed that visualization mechanisms that allow for longitudinal comparison across peer groups with age- and treatment-matched patients work best, and that patients and physicians favor line graphs or bar charts [28].

Nevertheless, most of the existing literature focused on disease-specific PROMs in the respective disease areas [20, 22, 24–26]. Accordingly, the potential of incorporating a generic PROM, such as the EQ-5D, into a dashboard has not been investigated yet. Incorporating a generic PROM enables comparability across disease areas and an overall assessment of the patient's health status and mental well-being. This allows for insights into patients' different recovery paths and stimulates shared decision-making. With our research, we aim at determining meaningful design principles for clinical dashboards that incorporate generic and disease-specific PROMs and are used in the daily clinical practice to improve the communication between the physician and the patient. Furthermore, we analyze whether the design principles differ for acute conditions with a one-time intervention versus chronic conditions.

In our study, we therefore investigate the following two research questions:

- *What are meaningful design principles of clinical dashboards incorporating generic and disease-specific PROMs?*
- *Do the design principles differ for acute conditions with a one-time intervention versus chronic conditions?*

This report is structured as follows: Section 2 reflects on the research approach and the three-step methodology of this study, comprising of a scoping literature review, interviews with software users and producers of clinical dashboards incorporating PROMs, the development of a clinical dashboard prototype incorporating PROMs and its evaluation through a focus group discussion. In section 3, the three sets of results, from the literature review, expert interviews, and focus group, are presented in detail. In section 4, potential practical implications of this research as well as the most relevant implications for the EuroQol group are discussed. Section 5 discusses potential limitations of this study. Section 6 presents some concluding remarks as well as some suggestions for potential future avenues of research.

## 1.2 Definition of scope

In this study, we focus on the investigation of design principles for clinical dashboards incorporating disease-specific and generic PROMs for physician-patient communication. While clinical dashboards have applications in several different episodes of care, we are interested in understanding whether the design principles of clinical dashboards incorporating PROMs change with contact points to patients undergoing a one-time intervention or patients affected by a chronic illness. For this reason, we chose to focus on two specific treatment areas: a one-time intervention represented by hip and knee arthroplasty (HA and KA), and the management of a chronic disease, represented by chronic obstructive pulmonary disease (COPD).

### 1.2.1 Episodes of care

**Hip and knee arthroplasty (HA/KA):** First, the elective one-time interventions HA and KA are considered for patients suffering from coxarthrosis or gonarthrosis. HA and KA provide effective relief for patients with osteoarthritis to increase the functionality of the joint and reduce pain. Both procedures have shown steady increases in the number of cases worldwide, which are likely to rise further over the next decades [27, 28]. In Switzerland, 20,753 patients received a knee replacement, and 24,901 patients underwent hip arthroplasty in 2019 [29]. The reason for choosing this patient group is to investigate the use of a clinical dashboard for tracking short-term outcomes and follow-up developments.

**Chronic obstructive pulmonary disease (COPD):** The second proposed area is COPD, a chronic disease for which treatment changes might be based on a patient's PROM trajectory diverging from her peer group's. COPD is usually caused by exposure to noxious particles (most commonly smoking), which is characterized by respiratory symptoms (i.e., dyspnea, cough, and sputum) and airflow obstruction. Patients experience persistent respiratory symptoms with periods of acute worsening – so-called exacerbations [30]. Worldwide, two out of three deaths are caused by non-communicable diseases, and COPD is the third leading cause of death at global level [30, 31]. In Switzerland, around 400,000 people suffer from COPD [32]. Treatments aim at relieving symptoms and preventing exacerbations. Major interventions are medication, smoking cessation, and physical activity. The reason for choosing this patient group is to investigate the use of a clinical dashboard for chronic disease management.

### 1.2.2 Definition of clinical dashboards

A clinical dashboard is a data-driven clinical decision support tool capable of querying multiple databases and visually representing key performance indicators in a single report. The added value of a dashboard comes from its ability to provide a concise overview of key information with the option to drill-down to detailed information [33]. Clinical dashboards present different use cases, as they can be used in the context of:

- physician-physician communication (for consultation by the physician only, as a clinical decision support tool) [34]
- patient-physician communication (during clinical consultations, where the physician shows the patient their evolution in terms of PROMs to enhance communication and shared decision-making)[24]
- patient-patient communication (patient's independent consultation, for example through access to a patient platform) [35]

In this project, we are interested in the context of patient-physician communication, where the clinical dashboard can be used as a tool to improve the physician's understanding of the patient's current health status during the consultations.

### 1.2.3 Design principles and features

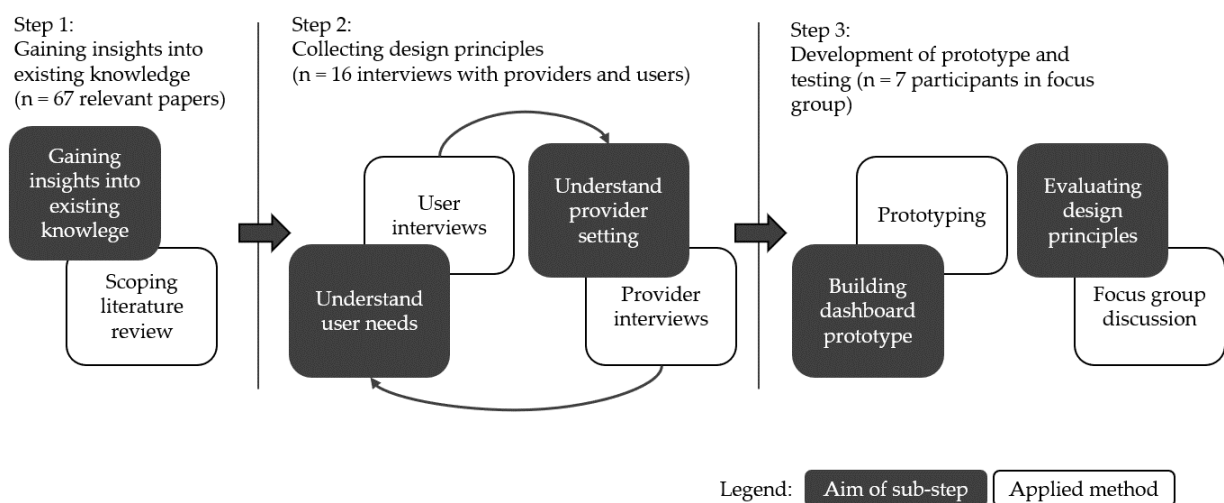
In this study, we derive both design principles and design features. Design principles are prescriptive statements formulating normative design knowledge to show how to do

something in order to achieve a goal [36, 37]. Hence, they provide guidance on what needs to be considered when building clinical dashboards capable of realizing their intended benefits. Design features, on the other hand, refer to the specific functionalities of the individual design principles. For example, showing past assessment PRO scores on the dashboard is defined as design principle, while the exact visualization of the past assessment score is the design feature to the corresponding design principle.

## 2 Methods

To answer our research questions, we followed a three-step approach (see **Figure 1**). First, a scoping literature review was conducted to capture the current knowledge in research (*Step 1*). Second, software producers and users were interviewed to strengthen the understanding of the needs and requirements of clinical dashboards incorporating PROMs, and thereby deriving design principles (*Step 2*). Third, a prototype of the clinical dashboard incorporating PROMs was developed and tested through a focus group discussion with physicians (*Step 3*). The following sub-sections elaborate on the individual steps and the corresponding procedures.

**Figure 1. Research approach compiling the design principles of clinical dashboards incorporating PROMs**



### Step 1. Scoping Literature Review

Given the explorative nature of this project, a scoping literature review was conducted to gather insights on the current state of research. Scoping reviews aim to synthesize literature findings and assess the scope of academic knowledge on a given topic [38]. To report the findings, we used the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [39]. For the search, we consulted four databases: PubMed (MEDLINE), PsychINFO (EBSCO), Cochrane, and Science Direct. In our search, we included studies published between January 1<sup>st</sup>, 2015 to May 27<sup>th</sup>, 2022.

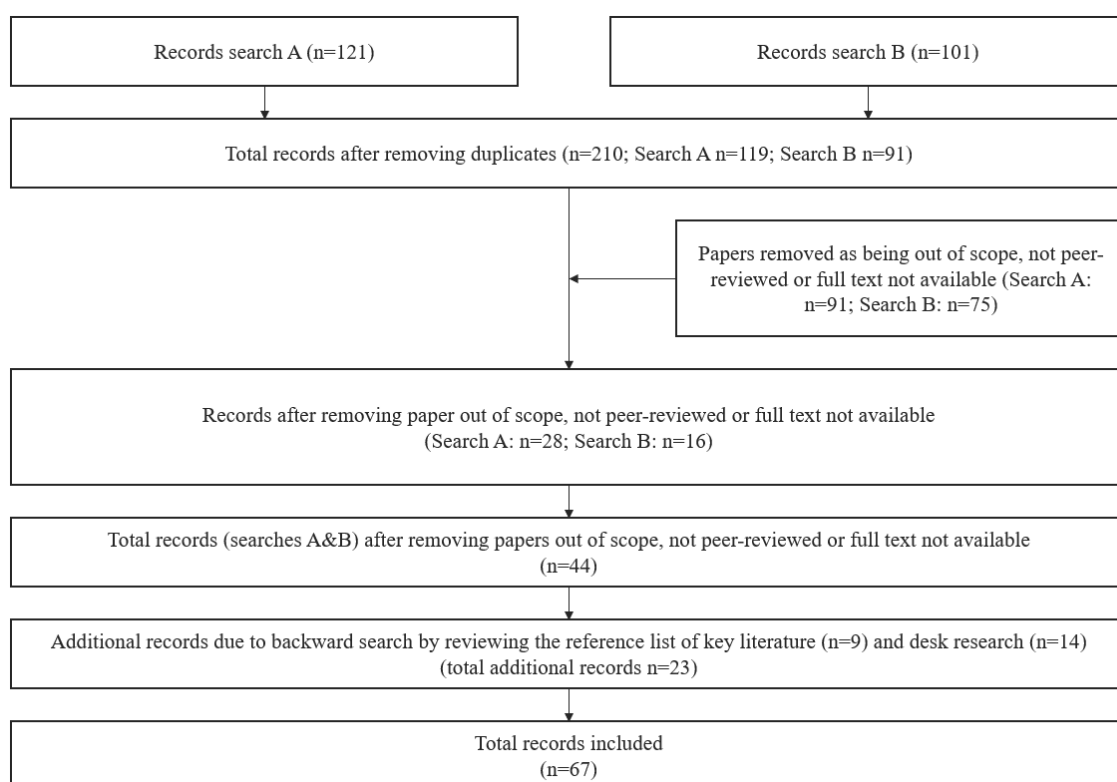
We conducted the database search in two steps. The initial search (Search A) aimed at getting a focused overview of the core area of research: using PROMs in clinical dashboards. The follow-up search (Search B) was needed to gather information on which generic and disease-specific PROMs should be included in the clinical dashboard according to the episodes of care of HA/KA and COPD. The following search terms were used: Search A: ((*PROM dashboard*) OR (*PRO dashboard*) OR (*patient-reported outcomes dashboard*) OR (*patient-reported outcomes measures dashboard*)); Search B: ((*EQ-5D-5L*) AND ((*COPD*) OR (*chronic obstructive pulmonary disease*) OR (*hip or knee replacement*) OR (*hip or knee arthroplasty*))) AND ((*age* OR *culture* OR *geography* OR *language*) OR (*responsiveness* OR *accuracy* OR *validity*)). Two pre-conditions needed to be met by each paper to be considered in the search: 1) originality, and 2) English language. Additionally, desk research and cross-referencing were used to complement the primary literature collection.



For selecting relevant papers, first, the title and abstract of each paper were screened. Next, a thorough second screening of the complete articles was conducted to evaluate relevant insights for this research. The inclusion of papers was evaluated based on the fit of title and abstract. In event of uncertainty as to whether a particular work fell in the scope of this research, the entire text was read.

The two-step search through the databases yielded 212 publications (Search A n=121, Search B n=101). After having screened all papers, 44 publications were considered relevant for this review. With cross-referencing and desk research, we added 23 papers, leading to a total of 67 papers (see **Figure 2**, all selected papers are listed in **Appendix I**).

**Figure 2. Overview of the screening process**



## Step 2. Software producer and user interviews

As second step, we adopted an explorative human-centered research design. Engaging software producers and users is a crucial step towards designing user-friendly clinical dashboards that are accepted, functional, and potentially enhance the quality of care and patient outcomes [15]. Thus, we conducted interviews with software producers and users of clinical dashboards incorporating PROMs. Interviews with software producers strengthened the understanding of current products, whereas the user interviews mainly focused on identifying user needs. This allowed us to gain well-founded insights about potentials, experiences and challenges for clinical dashboards incorporating PROMs. We report the details of the study in accordance with the Consolidated Criteria for Reporting Qualitative Research (COREQ) 32-item checklist to ensure transparency and reliability (**Appendix II**) [40].

The recruitment of the interviewees started in our own network, and through a snowballing technique, we were able to contact software producers and users outside of the network. The interviews were semi-structured, and the relevant literature findings guided the interview questionnaire's development. Afterward, the interview questions were iteratively adapted according to the responses of the already conducted interviews to enhance the inductive explanatory value gained.

Prior to each interview, introductory slides were shown to all interviewees to ensure a common understanding of clinical dashboards, and content-related questions were clarified (see **Appendix III**). All interviews covered the following main areas: 1) general questions on dashboards and PROM usage, 2) questions about the market (penetration) (software producers only), 3) usage of the dashboard, 4) dashboard development and data collection, 5) feature assessment, 6) role of the patient (see **Appendix IV**).

According to grounded theory by Corbin and Strauss [21], the conduction of interviews ended once thematic saturation was reached, i.e., when no additional information was gained from further interviews. All interviews were conducted by two authors – both research – to ensure that the same content was covered. Both interviewers had gained experience in qualitative methods as part of their doctoral research training. The interviews were conducted in English or German and digitally recorded and transcribed verbatim to perform data analysis by coding. For all interviews, also field notes were taken. According to grounded theory, the findings formed the data pool for generating explanations [22]. To identify relevant information for the design principles, first, deductive coding was used to cross-validate the findings from the scoping literature review (for deductive codes, see the codebook in **Appendix V**). Second, inductive coding allowed us to identify and classify information not covered by the scoping literature review. All interviews were coded by two authors independently and afterwards analyzed and compared together. In case the two authors did not find agreement for the applicability of a code, a third author joined the discussion to find consensus on unresolved aspects. All interview analyses were conducted with Atlas.ti Windows (Version 22) [23].

### Step 3. Prototype and evaluation of clinical dashboard

After conducting and evaluating the interviews, a clinical dashboard prototype incorporating PROMs was developed for further evaluation by physicians in a focus group discussion. Features incorporated in our prototype were based on our findings from the literature and the insights gained during the interviews and the subsequent coding.

In the focus group discussion, first, the project and the previous research steps were presented. Second, the clinical dashboard prototype was introduced. Third, the participants had the chance to test the prototype on their devices. Fourth, a feedback discussion occurred which followed a semi-structured guide including six main topics: 1) positive aspects of the dashboard, 2) areas of improvement, 3) design principles that need to be overworked, 4) time of data collection, 5) alert function, 6) likelihood of collecting and using PROMs in the future.

The focus group discussion was audio-recorded, and two note takers documented key insights.

## 3 Results

This chapter summarizes the findings from our three-step approach. The subchapters are structured accordingly. The scoping literature review and the conducted interviews served as the basis for the development of the clinical dashboard prototype and the subsequent focus group.

### 3.1 Scoping Literature Review

#### *Results of Scoping Literature Review Search A: Dashboard focus*

The scoping literature review revealed that research focuses considerably more often on dashboards for chronic diseases, such as endometriosis [21], depression [24], overactive bladder [41], cancer [25, 42–47], asthma [26], Parkinson [48], or rheumatoid arthritis [20, 49, 50] compared to one-time acute care interventions such as spine surgery [51] or HA/KA [52]. Concerning the main episodes of care in this study, only one paper dealt with HA/KA [51], while none targeted a dashboard for COPD (for the full list of episodes of care see **Appendix I**).

#### *Results of Scoping Literature Review Search B: PROM focus*

We only included papers focusing on either COPD or HA/KA to identify relevant disease-specific PROMs. Concerning COPD, the EQ-5D was included in most cases for collecting information about the patient's health-related quality of life [53–57]. Only Smith et al. [57] additionally included the SF-36 as a generic PROM. Commonly used disease-specific PROMs for COPD are the COPD Assessment Test (CAT) [53–55], the St. Georges Respiratory Questionnaire - COPD (SGRQ-C) [53, 54, 56, 57] and the Clinical COPD Questionnaire [53]. When referring to the collection of HRQoL in HA/KA patients, several studies indicated using the EQ-5D [52, 58–66]. As an alternative to the EQ-5D, SF-12 [61, 62, 67] and SF-36 [65, 67] were used as a generic instrument. As suitable disease-specific PROMs for HA/KA patients the Western Ontario and McMaster Universities Arthritis Index (WOMAC) [58–60, 67], the Oxford Hip and Knee Scores (OHS/OKS) [52, 61, 62, 64], or the Knee injury/Hip disability and Osteoarthritis Outcome Score (KOOS/HOOS) [52] were identified.

#### *Results of Scoping Literature Review Searches A and B on design principles*

The scoping literature review revealed relevant insights for design principles of complementary data such as patient information [26, 46, 68] or clinical data [26, 46, 49, 50]. Further, the inclusion of additional features such as past assessment scores [20, 25, 43, 49], peer-group comparisons [42, 45, 49], goals over time [24, 49], alerts [25, 41], and free-write in features [25, 43], and dashboards customizability [24, 46, 51] were perceived as relevant. All these principles are recommended to be incorporated into a clinical dashboard to ensure a perceived additional value through its use.

Based on the findings from the scoping literature review, we developed a listing of essential design principles to be considered when building a clinical dashboard incorporating PROMs (**Table 1**). The table includes three grouping areas: general information, data collection, and dashboard content. Each grouping area includes main design principles and potential attributes. For example, in the grouping area of “general information”, the design principle of

“setting” covers application areas of clinical dashboards in in- or outpatient settings or a combination of both.

**Table 1. Overview of design principles to be tested in user and software producer interviews based on scoping literature review and expert interviews**

<b>General information</b>  <b>Type of disease:</b> chronic, acute  <b>Setting:</b> inpatient, outpatient, combination  <b>Type of PROM:</b> Disease-specific, generic, combination  <b>Key user:</b> Specialist, GP, all kinds of physicians, other health care professionals (e.g., physiotherapist, nurse, etc.), patient, relatives	<b>Sources</b>  [20, 21, 24, 26, 41, 42, 48, 51, 52]  [21, 26, 43, 69, 70]  [52–67]  [26, 51, 71]
<b>Data collection</b>  <b>Level of reporting:</b> micro (patient-physician communication and intra-patient comparison), meso (comparison of patient groups within departments or institutions), macro (comparison of patient groups across departments or institutions)  <b>Purpose of reporting:</b> shared decision-making (for patient and physician), better basis for decision (for physician), interpretation support of data  <b>Data collection:</b> digital, analog  <b>Time of data collection:</b> directly during appointment, before the appointment (in waiting room), independent at home	<b>Sources</b>  [47]  [72–74]  [21, 41, 47]  [21, 41]
<b>Dashboard features</b>  <b>Patient information:</b> 5-point Likert scale on usefulness of feature <b>Clinical data:</b> 5-point Likert scale on usefulness of feature <b>Free write-in space:</b> 5-point Likert scale on usefulness of feature <b>Past assessment PROM score:</b> 5-point Likert scale on usefulness of feature <b>Peer-group comparison:</b> 5-point Likert scale on usefulness of feature <b>PROM-related goals:</b> 5-point Likert scale on usefulness of feature <b>Overall health-related goals:</b> 5-point Likert scale on usefulness of feature <b>Alerts:</b> Immediately when critical value appears, during appointment, no <b>Customizability:</b> To individual needs, from a standard set, no	<b>Sources</b>  [26, 46, 68] [26, 46, 49, 50] [25, 43] [20, 25, 43, 49] [42, 45, 49] [24, 49] [25, 41] [24, 46, 51]

## 3.2 Interviews

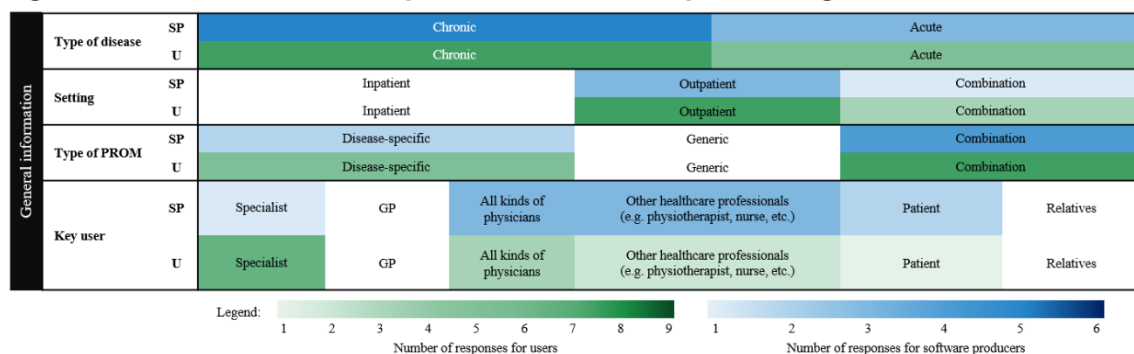
In total, we conducted 16 online interviews with six software producers and ten users ( $m=10$ ,  $f=6$ ) until thematic saturation was reached. All software producer interviewees represented different companies and different positions. All user interviewees were chief physicians with different specialties such as pneumology, cancer care, pediatrics, or orthopedics. This allowed us to analyze distinctive needs for design principles in clinical dashboards according to the episodes of care. All interviews lasted between 20 and 45 minutes (see **Appendix V**).

The interviews with software producers and users revealed that they perceived a differentiation in design depending on disease (one-time intervention vs. chronic disease) as not essential. Therefore, we did not distinguish between design requirements of different disease types but instead focused on the design principles for clinical dashboards incorporating PROMs in general.

### General information

To evaluate the importance of the key design principles, we asked both interview groups to outline the type of disease, the setting, the type of PROM used, and the targeted key user for their clinical dashboard (see **Figure 3**). Both software producers and users preferred a dashboard for tracking the evolution of chronic diseases over time (11/16) and using it in an outpatient setting (9/16). Both interview groups mentioned using a disease-specific PROM only (6/16) or combining generic and disease-specific PROM types (10/16). However, none of the interviewees preferred to use a generic PROM such as the EQ-5D only. Concerning the key users, slight discrepancies were observed. Software producers aimed to target all kinds of physicians (3/6) and other healthcare professionals as key users (3/6), whereas the users favored the specialist as a key user (5/10). Nevertheless, we only interviewed specialized healthcare professionals instead of GPs, which might have influenced their perception of the ideal key user (for the full list of codes, see **Appendix VII**).

**Figure 3. Overview of software producer and user responses on general information**



Legend: The boxes' coloring indicates the individual items' response intensity by software producers (SP; blue) and users (U; green). The more intense the coloring, the more often it was mentioned during the interviews.

### Data collection

The most frequently mentioned use case for data collection was for micro (i.e., patient-physician communication and intra-patient comparison) (11/16), especially by users (7/10), followed by macro perspectives (i.e., comparison of patient groups across departments or institutions) for both interview groups (4/16). Furthermore, the most often mentioned purposes of reporting

were “moderation of data through physicians” (10/16) and “better basis for decision (for physician)” (5/16) (see **Table 2**).

The interviews also covered the point-in-time and the type of data collection. Interviewees distinguished for both categories between the first time of data collection and follow-ups. For the point-in-time of data collection, there was a slight tendency (60%) of users to fill in the questionnaires for the first time in the waiting room prior to the appointment. I2 mentioned that in this way “[patients] get an explanation by a physician or a nurse, but after that, it is on their own.” However, for the follow-ups, 75% of the interviewees preferred that the filling of the questionnaires is done independently at home. For the type of data collection, a strong tendency towards a digital collection was reported (14/16). Some users (4/10) reported that data collection is still conducted on paper and sent to patients before appointments.

**Table 2. Overview of software producer and user responses on data collection**

Data collection	
Level of reporting	
<b>Software producer</b>	<b>User</b>
1. Micro (4/6)	1. Micro (7/10)
2. Macro (2/6)	2. Meso (3/10)
3. Meso (1/6)	3. Macro (2/10)
Purpose of reporting	
<b>Software producer</b>	<b>User</b>
1. Moderation of data through the physician (3/6)   Better basis for decision (for physician) (3/6)	1. Moderation of data through the physician (7/10)
2. Shared decision making (for patient and physician) (1/6)   Interpretation support of data (1/6)   Real-time tracking (1/6)	2. Expectation management (3/10)
3. Expectation management (0/6)	3. Better basis for decision (for physician) (2/10)   Interpretation support of data (2/10)
	4. Shared decision making (for patient and physician) (0/10)   Real-time tracking (0/10)
Data collection (1 <sup>st</sup> time)	
<b>Software producer</b>	<b>User</b>
1. Digital (6/6)	1. Digital (8/10)
2. Analog (0/6)	2. Analog (4/10)
Time of data collection (1 <sup>st</sup> time)	
<b>Software producer</b>	<b>User</b>
1. Independent at home (4/6)	1. Before the appointment (in the waiting room) (6/10)
2. Before the appointment (in the waiting room) (2/6)	2. Independent at home (5/10)
3. Directly during the appointment (0/6)	3. Directly during the appointment (0/10)
Data collection (follow-up)	
<b>Software producer</b>	<b>User</b>
1. Digital (6/6)	1. Digital (8/10)

2. Analog (0/6)	2. Analog (4/10)
<b>Time of data collection (follow-up)</b>	
<b>Software producer</b> 1. Independent at home (4/6) 2. Before the appointment (in the waiting room) (2/6) 3. Directly during the appointment (0/6)	<b>User</b> 1. Independent at home (8/10) 2. Before the appointment (in the waiting room) (4/10) 3. Directly during the appointment (0/10)

Legend: The table shows the ranking of design principles' attributes according to the number of mentions by software producers and users. Behind the attributes, the share of interviewees mentioning this design feature is indicated. As the interviewees could provide more than one answer for each design principle of data collection, shares can add up to more than 100%. The level of reporting represents the main purpose of the dashboard – which we distinguish into three categories: micro, meso, and macro. Micro stands for the patient-physician communication and intra-patient comparison. Meso allows for the comparison of patient groups within departments or institutions. Macro focuses on the comparison of patient groups across departments or institutions.

### Dashboard components

Concerning the dashboard components, especially users (4/10) mentioned that some patient information (such as patient photograph, demographic information or contact details of other care team members) needs to be presented on the dashboard (see **Figure 4**). However, only interviewee I16 emphasized precisely what she expects the patient information to include “*key events. So, surgeries need to be shown. For example, in cancer, the start of chemotherapy, completion of chemotherapy, started radiation, that you can understand what is going on in the background of those patients.*”

Except for I1 and I5, all other software producers rated clinical data (e.g., lab results or medication data) as meaningful information that must be included in the clinical dashboard. In contrast, users tended rather not to include clinical data in the dashboard, as I8 mentioned: “[...] and then if they [the physicians] want to have the clinical information on the patient, they just open up the EMR and check it, which is another tab in the Chrome app.”

The free write-in space did not resonate well in either of the two groups. While half of the software producers replied that a free write-in space is useful for specific questions, only one user perceived this design feature as very beneficial. Nevertheless, when having such a free write-in box included, users (3/10) wanted it as an additional source of information for some specific variables. This indicates that a free write-in space should be treated as an add-on to specific variables where the user can note further information that is important for patient treatment.

Software producers and users rated the past assessment PROM score (10/16) as one of the most crucial features in a clinical dashboard incorporating PROMs. From the software producer perspective, I6 mentioned: “*This [past assessment PROM score] is very well received, simply the score progression up and down visually, so to speak.*” A similar perception presented I9: “*This [past assessment PROM score] is absolutely relevant because it is about all changes in these questionnaires that are significant. In any case, it is very important to look at the progression, not just the individual value.*”

Another well-perceived feature was the peer-group comparison. All software producer interviewees agreed on the inclusion of this design principle. The users acknowledged the inclusion, too (7/10). Only two users, I9 and I12, did not perceive an added value in the peer-group comparison due to the interpretation possibilities of the applied PROM (I9) and the missing

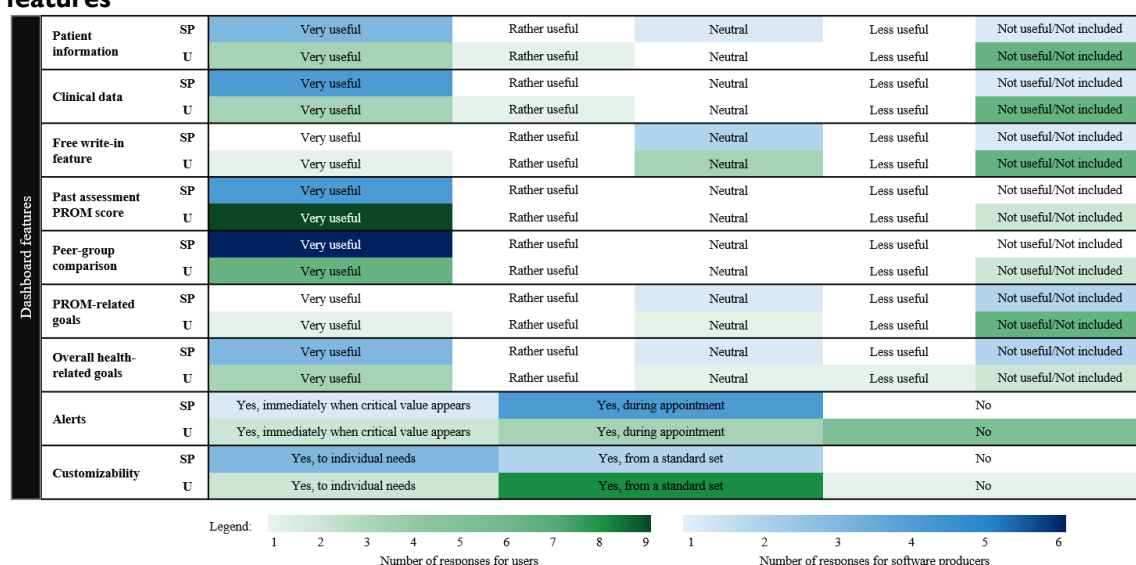


guidance on the relevant factors to compare different patient groups concerning their PROMs (I12).

Although only one user emphasized applying PROM-related goals (especially for the EQ-5D), overall health-related goals were discussed more controversially within both groups. Software producer I4 reported that their dashboard includes a feature where the physician can develop overall health goals together with the patient and check goal achievement, whereas I6 stated that this is not part of their dashboard. From the user perspective, this feature could add value to the patient-physician communication, as the goal statement makes the aim or expectations of the patients explicit (I9, I11).

For alerts, software producers and users have different perceptions on whether alerts should be included in the dashboard. Software producers mentioned that an alert function needs to be included (5/6). However, they were indifferent on whether the alert is real-time (4/6) or only appears during the appointment (4/6). I4 mentioned in this context that, however, the real-time tracking leverages the potential for legal consequences, especially when sending real-time notifications on critical values because *“if [a score is for] three days red or is really critical and no push notification is sent, the error is on our side. However, if a push notification is sent and the doctor does not react, the error lies with the doctor. And that is a bit of a grey area, where we still have to figure out how it’s actually done.”* In contrast, users rather preferred not to include alerts into the dashboard (3/10). I8 and I11 mentioned that this feature was previously built in the dashboard, but the acceptance was not high enough in their teams, which made them stop using it. Further, I12 raised the issue that additional interpretations for physicians are required to ensure that they completely understand what the deterioration or improvement in a score means. I10 favored the alerts during the appointment to highlight critical factors and to facilitate comparison over time. I13 and I16 preferred real-time alerts allowing the treating physician to react directly to the patient’s issues.

The last feature to be elaborated was the degree of customizability. All interviewees agreed that customizability is required to meet the different needs. Although more users preferred customizability from a standard set (4/10) compared to individual needs (3/10) – software producers still seemed undecided whether a clinical dashboard should be adapted to individual needs (3/6) or “off the shelf” (2/6). Nevertheless, the software producers agreed that scalability is only achievable in case clinical dashboards equipped with features defined in a standard set are provided.

**Figure 4. Overview of responses from software producers and users concerning the dashboard features**

Legend: The boxes' coloring indicates the individual items' response intensity by software producers (SP; blue) and users (U; green). The more intense the coloring, the more often it was mentioned during the interviews.

### Findings from inductive coding

We derived the above-presented results from the deductive procedure guided by the findings from the scoping literature review. The subsequent inductive procedure allowed us to identify the potential of dashboards to enhance workflows and various barriers, reducing the impact of the clinical dashboard.

Although the visualization of the PROM scores was not extensively discussed in the literature, we asked our interviewees about their preferences. Software producers indicated that the index and dimensional scores are always provided in their dashboards. Users did not indicate such a clear tendency. Exemplary, I7 voted for the visualization of dimensional scores by stating, “we must of course know the dimensionality and different aspects.” In contrast, I11 argued: “I like [index] scores better, as I said, but because we have these individual questions like there are ten questions, and you can have a summary score of it and the system plots every question on a trend. I think that is rather messy because then you have like ten different color graphs just projected over each other, and you can click them on, or off. So it's easy, but for me it's less informative.” This finding implies that the visualization of PROMs – i.e., by index or dimensional scores – is highly dependent on personal preferences.

Concerning the enhanced workflow enabled through the clinical dashboard, software producers emphasized the increased efficiency (4/6), improved overview of data (3/6), and better basis for decision (2/6). Users perceived the biggest advantages of a clinical dashboard the improved overview of data (6/10), PROMs comparability such as of the EQ-5D (5/10), and increased efficiency (5/10).

Potential barriers to implementing the full potential of clinical dashboards are interoperability between various systems (11/16) and the consultation of different sources (5/10). Exemplary, I11 stated: “[...] one of the problems is now that it [the clinical dashboard] feeds from multiple databases. And one of the problems is that we have research projects. They have also PROMs and they are on different data sets. And we are not able to get them out. And I know that they [the patients] completed that

JAMAR [Juvenile Arthritis Multidimensional Assessment Report], and I will not ask them [the patients] to do it again because that is silly, but then I'm not able to see it and it will ruin my trends in the clinical dashboard. [...] So now I have that clinical dashboard, but I need another screen. We have two screens in our office. One is for the clinical dashboard and on the other one I open the EMR."

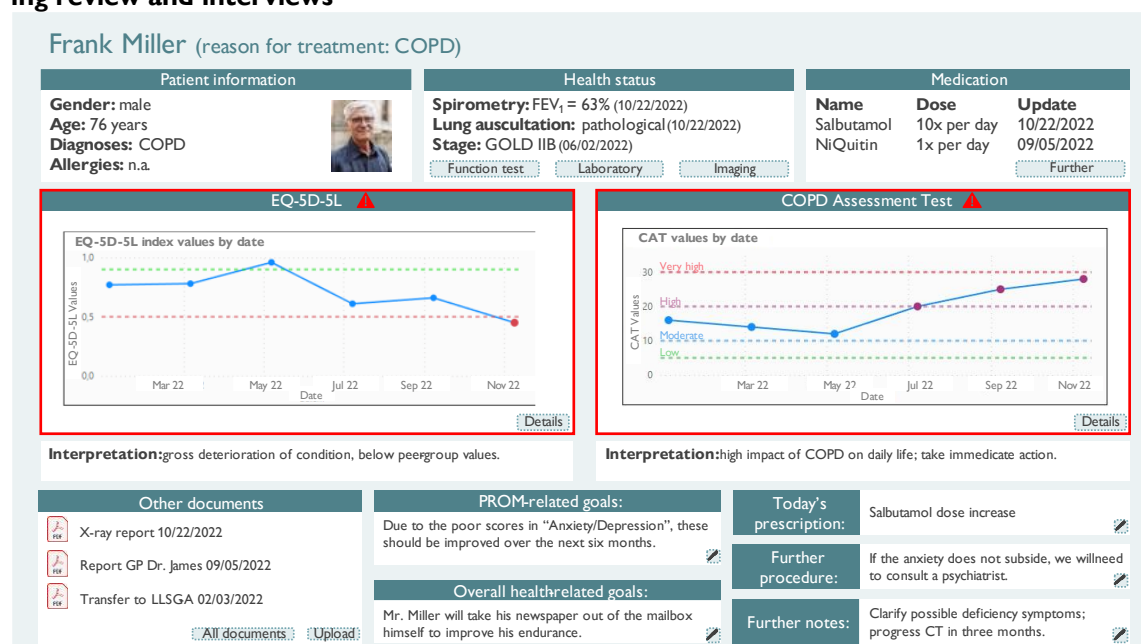
Further, software producers mentioned legal consequences in case of displaying inadequate information (4/6), and the licensing of the PROM questionnaires (3/6) as potential barriers. Users rather perceived the burdensome collection of PROM data (4/10), and non-intuitive use (3/10) as additional barriers.

### 3.3 Design, testing, and evaluation of clinical dashboard prototype

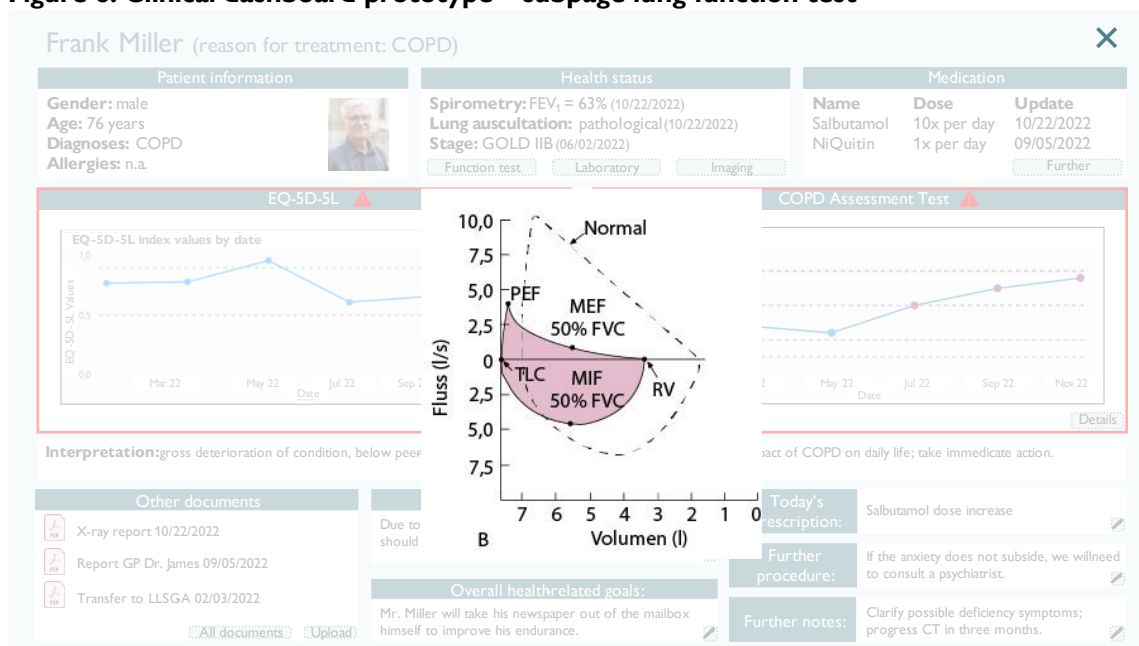
#### 3.3.1 Design: Prototype based on literature review and interviews

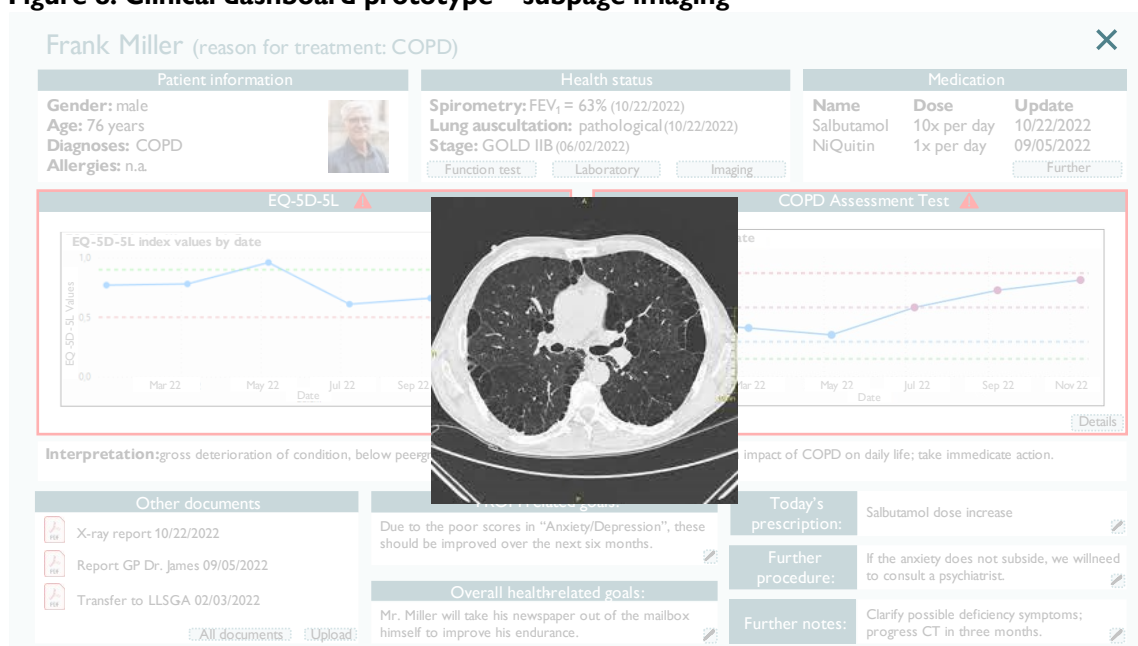
The interviews revealed that the design principles of clinical dashboards do not differ by different episodes of care – except for the inclusion of the disease-specific PROM. Therefore, we developed a clinical dashboard prototype incorporating PROMs only for COPD (see **Figure 5**). Following our literature review, the CAT was used as the disease-specific PROM [53–55].

**Figure 5. Clinical dashboard prototype according to the design principles collected in the scoping review and interviews**

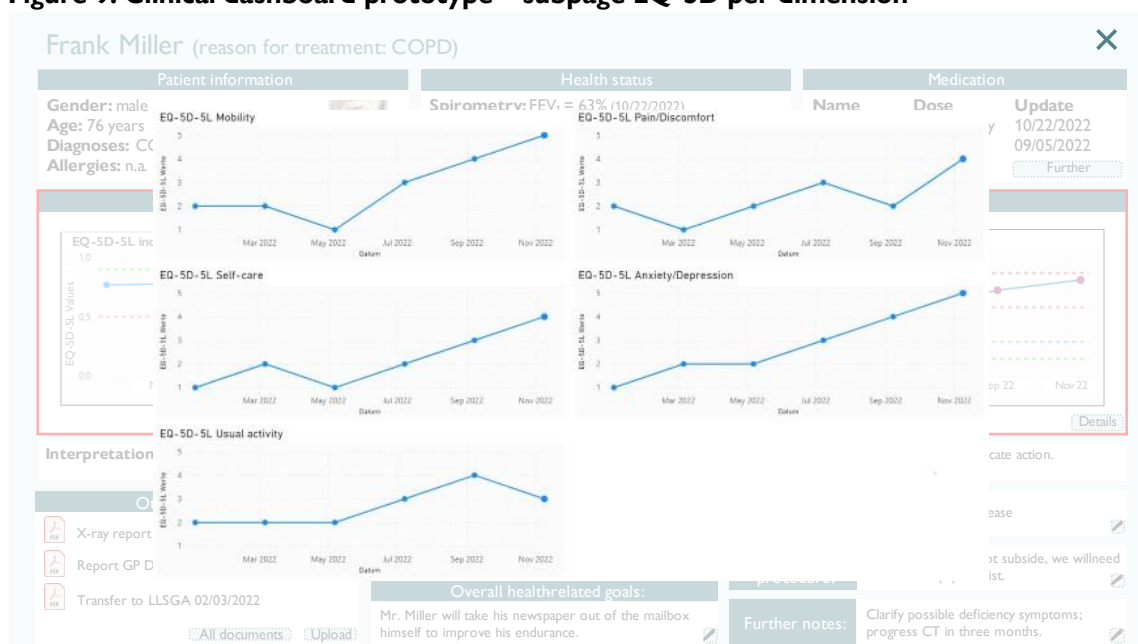


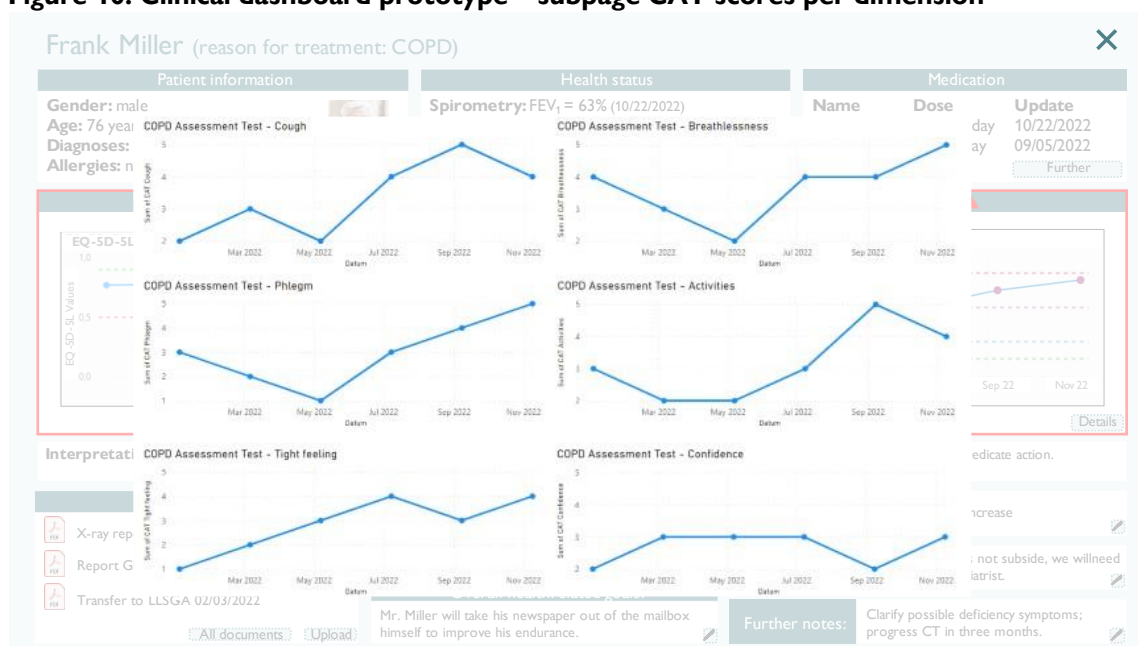
The dashboard contains the design principles and possible features presented and evaluated in the interviews. At the top of the dashboard, there are patient information, clinical data (categorized as "health status"), and information on medication intake. These features only include the most relevant information for the physician to get a quick overview of the patient's status. If the physician is interested in detailed information regarding the lung function test (see **Figure 6**), laboratory test results (see **Figure 7**), or imaging (see **Figure 8**), a new window with the respective information will open by clicking on the corresponding box.

**Figure 6: Clinical dashboard prototype – subpage lung function test****Figure 7: Clinical dashboard prototype – subpage laboratory test results**

**Figure 8: Clinical dashboard prototype – subpage imaging**

The generic and disease-specific PROM are shown in the center of the dashboard underlining their importance for treatment progression. The attention of the physician should be directed to this part of the dashboard through bigger PROM boxes (see **Figure 5**). The dashboard displays the index scores over time accounting for the evaluation of past assessment PROM scores. Furthermore, the EQ-5D allows for a peer-group comparison through the two lines. If the index value falls below the peer group range, an alert appears during the appointment, represented by the red frame and the red warning sign. Similarly, the red box and warning sign appear in case the index value of the CAT is above 20 – defined as the critical threshold by the CAT. Below the PROM scores, an interpretation is provided to support the physician's understanding and their moderation to the patient. Clicking on details, the physician reaches a subpage where scores for each dimension are presented over time (see **Figure 9** and **Figure 10**).

**Figure 9: Clinical dashboard prototype – subpage EQ-5D per dimension**

**Figure 10: Clinical dashboard prototype – subpage CAT scores per dimension**

Coming back to the main overview of the patient (Figure 5), in the lower left-hand corner of the dashboard, additional documents can be uploaded. Moreover, PROM-related and overall health-related goals can be defined. Lastly, in the lower right-hand corner, appointment notes and agreed next steps can be posted. The information about the appointment and next steps are free write-in spaces. Additionally, the box for further notes is also a free write-in space. As proposed by our interviewees, the purpose of the free write-in spaces must be clearly defined and thereby the free write-in spaces function as add-on to specific variables which are important for patient treatment.

### 3.3.2 Testing and evaluation: Results of focus group discussion

The focus group consisted of seven participants (m=3, f=4). Five participants worked in a Swiss cantonal hospital representing the specialties oncology, nephrology, cardiology, and/ or surgery. Additionally, one of the participants was a GP. The remaining two participants were medical students in the first semester of their Medical Master program. This diverse group composition allowed us to evaluate the clinical dashboard across episodes of care and to receive input from various perspectives (different roles, specialties, and qualifications; see **Appendix VIII** for further information). The focus group discussion lasted for one hour.

Concerning the **positive aspects of the dashboard**, responses were diverse. Various times, participants mentioned that a good overview is provided and that the dashboard is not overcrowded by text. Furthermore, the EQ-5D is well presented and visualized due to its placement in the middle of the screen. The past assessment scores and the benchmarking were well-perceived by the participants. Especially highlighted was the patient's picture. Physicians working in the hospital mentioned that the picture can provide a point of orientation of how the patient looked, e.g., at the beginning of the treatment and whether an extreme improvement or deterioration is observed over time. Furthermore, one participant mentioned that a picture of a patient helps remind him how this person was doing before the disease and that it might be a goal

to get back to the status before the outbreak or deterioration of the disease. Another beneficial aspect of the patient picture goes along with patient security. In hospitals, the wrong patient might enter the consultation due to a misunderstanding, e.g., hearing impairments, and a picture helps the physician to check whether the right patient is present. On the other hand, the GP mentioned that he does not need pictures of his patients as he knows how they look, as he has accompanied them for several years. All participants agreed that the design principle of setting goals is beneficial for patient-physician communication to raise awareness on what the treatment should focus on. In general, the participants liked the illustration of the design principles on the clinical dashboards.

Further, the participants discussed **areas of improvement** within the clinical dashboard prototype. Most discussed was the visualization of clinical data, such as the medication dose adaptation, or clinical values, such as spirometry outcomes over time. Participants wished for the possibility to merge the process curve of clinical data with the PROM graphs to identify correlations between the objective measurements (i.e., by clinical data) and patients' self-reported health status (i.e., by PROMs). Additionally, clicking on one measurement point in the PROM curve and having the clinical values opened in a small window would support a faster assessment of the patient's health status for the physician. Furthermore, the space for the lowest part with the free write-in space should be increased, and therefore, the upper part with patient information and clinical data should be decreased.

For the question of what should be **changed entirely**, the physicians from the hospital agreed that a button for "further documents" would be enough to redirect to another platform, and no PDFs should be uploaded on the clinical dashboard. PDF documents do not add informative value as inconsistent storing does not allow for fast information collection out of the documents during the consultation.

When discussing **data collection**, all participants agreed that PROMs should be filled independently at home. PROMs should be sent out via e-mail or link with the reminder for the appointment. If PROMs have not been filled out until one day before the appointment, a second reminder for filling the PROMs should be sent. Regarding the collection of PROMs, one participant raised the question of whether a therapeutic effect would be observable when having PROMs filled before and after the appointment. He justified his question by arguing that consultations might have a placebo effect on patient's well-being, which might also be observable in PROMs.

Concerning **alerts**, similar issues were raised during the interviews. Legal consequences were mentioned if the physicians ignored the alerts, and patients suffered greatly. This might also correspond with alert fatigue or information overflow, as the physicians mentioned that they do not have time to check all individual alerts. They would need the support of another professional, e.g., a nurse, who takes up contact with the patient in case of an alert. Also, defining suitable thresholds for sending alerts and how to assess peer-group values correctly were discussed. In theory, the participants liked both approaches. However, they questioned their current real-world applicability due to reasons mentioned above.

As a last question, we asked the participants whether they would be willing to **collect and use PROMs in and for their daily practice**. The participants agreed that they would only use PROMs in case a clear benefit is perceivable and if it is not an add-on to their workflow and workload. Participants agreed that the use of PROMs would be especially insightful for patients



with chronic conditions. Collecting PROMs regularly could facilitate communication with the patient during the consultation, as PROMs represent relevant information on the patient's health status that would otherwise need to be asked in the consultation itself. Thus, PROMs would allow the physicians to focus more on the adaption of the treatment instead of first having to collect all relevant information. Two physicians mentioned that they would want to use the dashboard to show the PROMs directly to the patient and discuss the curve's progress over time with them. Therefore, the visualization of PROM results needs to be easy-understandable and informative. Having these PROMs in place could allow for a more profound communication of health-related goals with the patient. However, all participants agreed that the use of PROMs needs to be promoted by healthcare professionals themselves and not by registries or healthcare insurers. One participant labeled them as "community influencers" who share their positive experiences with PROMs and motivate their colleagues to use PROMs for their daily practice as well.

## 4 Discussion and implications

### 4.1 Summary of findings

The three-step approach followed in this study allowed for a holistic analysis of the design principles for clinical dashboards incorporating PROMs.

The scoping literature review focused on two search queries. Search A focused on clinical dashboards and their application areas, whereas search B collected the different PROMs for evaluating the HRQoL of HA/KA and COPD patients. Information was collected regarding the inclusion of relevant items into the clinical dashboard, such as general patient information or clinical data. Especially features such as past assessment scores, peer-group comparisons, goals over time, and free-write in features were considered relevant for testing in the following interviews.

The interviews revealed that software producers and users have a similar perception of the use case of a clinical dashboard incorporating PROMs. The dashboard should be used foremost for tracking and observing patients, applied in an outpatient setting, and include a combination of disease-specific and generic PROMs (e.g., the EQ-5D-5L). However, concerning the users, opinions differed between the two interview groups. Dashboard users indicated that specialists should be considered key users, whereas software producers indicated a wider range of users, including all kinds of physicians and other healthcare software users such as physiotherapists or nurses. These different preferences might be owed due to the two interview groups' fundamental interests. While interviewed specialists rather imagine themselves using the dashboard and getting the highest benefit, software producers want to increase their customer base and revenue.

The focus group participants deemed the use of clinical dashboards incorporating PROMs meaningful. The participants particularly liked the idea of paying more attention to the quality of life in treating chronic patients. They mentioned that a shift in mindset should take place within the medical area so that physicians not only focus on adapting the treatment according to clinical data but also consider patients' self-reported health status. The patient photo and setting goals were highlighted as beneficial apart from the inclusion of (generic) PROMs. Participants pointed out that patient photos are a reminder for physicians of what the patient looked like when starting the treatment. Moreover, setting goals allows physicians to develop concrete aims to clarify what the patient wants to achieve with a (long-term) treatment.

Furthermore, the participants mentioned that one possibility for intensifying the use of PROMs would be a "community influencer," who motivates peers to apply PROMs. However, if registries and health insurances put effort into motivating physicians to use PROMs, this will have the opposite effect. The focus group discussion revealed that the participants could use the presented clinical dashboard incorporating PROMs to discuss the patient's health status better.

The design principles extracted from the literature reviews, which were tested in the interviews, are mostly in line with their evaluations during focus group discussions. The complementary use of generic and disease-specific PROMs is only slightly highlighted in the literature, while interviewees and participants in the focus group discussion appreciated the presence of both instruments. Although in the literature review the included papers only focused on specific episodes of

care when building clinical dashboards, our research has shown that design principles do not have to differ between episodes of care – only the disease-specific PROM must be adapted. The scoping literature review also revealed that various design principles must be respected when building such a clinical dashboard. However, no study analyzed in the literature review presented a conclusive list of design principles. By collecting and testing the design principles, we were able to create such a list of essential design principles and build a dashboard prototype that might serve as a point of orientation for the future development of clinical dashboards incorporating PROMs.

## 4.2 Research in context

An enhanced visualization of the patient's PROMs over time can facilitate the moderation role of the physician [41, 47, 75]. The displayed level of detail of PROM scores led to controversial responses on whether the index or dimensional scores should be shown. Furthermore, software producers and users indicated that the dashboard content should not vary between diseases, except that the disease-specific PROM needs to be adapted according to the episode of care.

Studies show that it is common to use generic PROMs, particularly the EQ-5D, to track the health status of patients. Notably, researchers see the standardized format and content as a major benefit that facilitates its usability across different diseases and patient groups [76]. Further, the multi-lingual questionnaire allows for large-scale analysis [66, 77]. Not only were disease-specific PROMs complementing generic PROMs, but their combined value was also seen as even more significant than their sum in the case of the EQ-5D and CAT combination [54]. Interestingly, similar findings emerged from studies developing PROM dashboards for various episodes of care. Baeksted et al. [43] and Hassett et al. [25] found it relevant to include the cancer-care-specific PRO-CTCAE in their dashboard, and Nicolas-Boluda et al. [21] incorporated endometriosis-specific indicators into their dashboard. Also, the interviews revealed that the combination of generic and disease-specific PROMs is considered valuable (10/16). The remaining interviewees (6/16) mentioned that they only use disease-specific PROMs. These statements provide insight that generic PROMs such as the EQ-5D gain enormous value if the information is also presented on the disease-specific condition. This combination allows the physician to take a more holistic view of the patient's health status by linking the disease-specific condition to the overall health condition.

Additionally, the advantages of the dashboard and potential barriers of implementing clinical dashboards were discussed in the interviews. Software producers and users perceived the most significant benefits of using a dashboard as increased workflow efficiency and an improved overview of data. Similar facilitators for implementation are also promoted by literature [34, 78]. However, the two interview groups highlighted different barriers: Software producers focused on legal consequences in case of displaying inadequate information, whereas users considered the consultation of various data sources or the burdensome collection of PROMs as a barrier. Both groups agreed on interoperability as one of the major barriers to implementing clinical dashboards. The barrier of interoperability is also recognized in the literature [79].

According to users, the primary reason for reporting is the moderation of data through the physician. Similarly, Desantis et al. [41] found that using a clinical dashboard improves the workflow and communication of changes in the HRQoL, i.e., data moderation, between the patient and physician. The dashboard features of patient information and clinical data were included, as the literature highlighted this additional information [26, 46, 68]. However, we kept this information to

a minimum as not all users rated these features as highly relevant. Some write-in features were placed in the dashboard represented by “today’s prescription”, “further procedure”, and “further notes”. This allows the physician to note changes in treatment, the procedure for the follow-up months, or other symptoms of the patient [25, 43].

As software producers and users rated the past assessment score and the peer-group comparison as highly relevant features in the dashboard, they were also included in the dashboard. A graphical illustration connecting the scores over time implemented the past assessment score. Baeksted et al. [43] and Watson et al. [47] proposed a similar approach. The peer-group comparison was only implemented in the EQ-5D index score as the CAT already provides an interpretation basis for the index scores. Generally, peer-group comparison should match patients in age and treatment [42] and indicate a “normal” range [49].

Both interview groups had an ambiguous tendency to include PROM-related and overall health-related goals in the dashboard. The overall health-related goals were often favored over the PROM-related goals. Both goal types were included in the dashboard (as a free write-in space). Cronin et al. [24] found that patients want to set and evaluate goals over time, which could be supported by a clinical dashboard. However, Liu et al. [50] warned that setting goals might further pressure the patient.

As a last feature, alerts were included in the dashboard prototype. Users indicated to prefer alerts during appointments over real-time alerts. Also, the software producers favored alerts during the appointment as “inadequate” or “non-appearing” alarms in real-time might lead to legal consequences, as mentioned by I4. The challenge of including alerts is to decide on the appropriate alert level [44] and thereby avoiding “alert fatigue” of physicians [26]. Currently, thresholds for PROM alerts are often not defined yet, as they need to be data-driven and medically sound. Additionally, they often depend on patient characteristics [80], and need to be adequately sensitive.

To visualize the data, the opportunity of tailoring the dashboard to user needs and preferences should exist [50]. Additionally, Engelbrecht et al. [81] formulated some guidelines for visualizing information, such as removing distracting or extraneous information, placing a minimal cognitive load on the users, or consistently applying design choices. These guidelines were considered when building the clinical dashboard prototypes.

## 4.3 Practical implications | General implications

This research project uncovered various implications for the future development of clinical dashboards incorporating PROMs.

*Embedding additional patient information next to PRO scores enhances the value of clinical dashboards*

The trend towards patient-centered care enhances the use of clinical dashboards incorporating PROMs. Such dashboards allow treating physicians to trace the patient’s health status over time, thereby retrieving information that would not be systematically available without the use of PROMs. Furthermore, the use of clinical dashboards in daily practice further strengthens patient-physician communication [72–74] and can be used as a moderation tool. Furthermore, the scoping literature review and the interviews revealed the importance of including additional information in the clinical dashboard, such as patient information and clinical data, to provide diverse content to the user – i.e., the physician – to consider when interpreting the PROM results. Thus, the clinical

dashboard does not provide added value if only PROM results are represented without additional information. Furthermore, no visualization difference for dashboards focusing on various episodes of care is required – except for the adaption of the disease-specific PROM.

*Ensuring interoperability is a key driver for the successful implementation of clinical dashboards*

Additionally, interviewees mentioned interoperability as a challenge. Although interoperability is not in this project's scope, we nevertheless wanted to raise this concern. As mentioned above, certain interviewees perceived additional features such as patient information or clinical data as valuable. However, interoperability of various systems often does not allow for transferring information across systems. Hence, it is currently the case that users of clinical dashboards either manually copy information or retrieve it from another system outside of the clinical dashboard. This burdensome collection of information from various sources harms the experience of clinical dashboards and needs to be improved in the future.

*Customizability of dashboard features is desirable based on context*

The design principle of customizability was extensively discussed during the interviews. Thereby, most users preferred customizability from a standard set. In contrast, software producers were indifferent about whether clinical dashboards should be customized to individual clients' needs or whether some standardized solutions are requested. Additionally, customizability can be tackled from various perspectives such as: Should the dashboard be customizable on department or hospital/organizational level? Which disease-specific scores are to be chosen for which episode of care? Which design features (such as patient information or clinical data, alerts) could users get rid-off in case they demand it? To what degree can the individual features on the clinical dashboards be allocated according to personal preferences? This research project did not cover these questions – however, they might guide future research.

*Online data collection is preferred – however, patients might need support for the first time of collection*

Furthermore, we also addressed the collection of data with respect to the point-in-time and type. Collecting PROMs for the first time, interviewees preferred the waiting room, as assistance might be provided by a nurse or a medical assistant. All follow-up collections, the patient should conduct individually, e.g., at home or a place of own preference. The interviewees also reflected on the trend of collecting PROMs digitally. However, depending on the patient characteristics (e.g., for older patients), this collection approach might not be appropriate. Hence, we identified some tendencies for digital data collection which may vary for the first time of collection and the follow-up collection. Nevertheless, implementing such a process will highly depend on the routine care process of the respective health care providers.

## 4.4 Implications for EuroQol

EuroQol holds the potential to significantly impact clinical practice through the effective utilization of EQ-5D in clinical dashboards. By collaborating with diverse stakeholders, refining the instrument's sensitivity, and customizing its application to different medical conditions, EuroQol can empower healthcare providers with valuable patient-reported data and facilitate evidence-based decision-making for improved patient outcomes. In the following, we will further elaborate on these points:

*A combination of generic and disease-specific PROM instruments considerably strengthens a physician's understanding of the patient's health status*

EuroQol's future research and strategic activities should emphasize the value of utilizing both generic and disease-specific PROMs in clinical dashboards. Collaborating with medical specialists identify relevant disease-specific measures and determine optimal combinations with the EQ-5D will enhance the dashboard's effectiveness in real-world data collection and clinical decision-making. We found that physicians highly value the availability of a combination of generic and disease-specific PROMs. Thus, a collaboration with medical specialists can further strengthen EuroQol's understanding of the varying needs between various diseases. Furthermore, a true added value is only achieved if the combination of PROMs reflects the needs of the physicians and provides an appropriate amount of information.

*An increased use of the EQ-5D in clinical dashboards can be enhanced through collaborating with stakeholders*

Second, EuroQol should actively collaborate with software producers to promote the integration of the EQ-5D into clinical dashboards. Providing a compelling case for using the EQ-5D and offering implementation and interpretation support to software providers will facilitate the widespread adoption of the EQ-5D in health care settings. The interviews also covered the dashboard's degree of the customizability. Thereby, the interviewees – especially the users – indicated that they prefer to build their clinical dashboard based on features from a standard set. Furthermore, software producers agreed that scalability is only achievable if the degree of customizability is limited. Hence, if software producers provide standard sets to choose from, it must be of utmost interest for EuroQol to collaborate with these software producers to ensure the EQ-5D being part of the standard set. Furthermore, this collaboration will further provide EuroQol with important insights on what users – foremost physicians and other health care professionals – care most about in their dashboards.

*Refining the EQ-5Ds sensitivity reduces ceiling effects and thus broadens its applicability*

Third, recognizing the ceiling effect of the EQ-5D in certain situations, EuroQol should work towards resolving this limitation to ensure the EQ-5Ds practicality and sensitivity in real-world applications. By refining the instrument to cater to a broader range of patient health states, EuroQol can enhance the EQ-5D's utility in clinical practice. Depleting the ceiling effect raises the EQ-5D's applicability in patients with good to almost perfect health status, as changes in the general health status will become more easily detectable for physicians. Therefore, the EQ-5D gains importance in tracking patients with early-stage diseases with low impact on the generic health status, too.

*Developing disease-specific EQ-5D thresholds allows for better informed decisions*

Fourth, to achieve comparability across different medical conditions, EuroQol should establish disease-specific EQ-5D thresholds. These thresholds will enable physicians to make informed comparisons and decisions based on patient-reported outcomes for specific diseases. The interviews revealed that 8/10 users would highly appreciate peer-group comparison. Additionally, all software producers agreed they want to entail a peer-group comparison feature to enhance the physician's information gain when consulting the dashboard. To catch up with these needs, EuroQol may guide the development of disease-specific thresholds which allow for peer-group comparison or develop these themselves. This could provide an additional competitive advantage compared to other PROM providers to get into closer contact with software producers. Providing disease-specific thresholds permitting for peer-group comparison can function as a lever to ensure

that EuroQol and the EQ-5D remain meaningful players in gathering patients' self-reports, and thus also being part of clinical dashboards in the future.



## 5 Limitations

This project faces three main limitations: First, the study primarily relied on interviews with specialists and chief physicians, potentially limiting the diversity of perspectives. Including a broader range of stakeholders, such as nurses or other medical professionals (e.g., physiotherapists), could have provided a more comprehensive understanding of the requirements and challenges related to clinical dashboards. Also, the interviewees were mainly from Western countries – especially Switzerland and Germany. Furthermore, the user interviewees were most often specialists. We did not include GPs' perspectives in our sample. In total, we included ten male and six female interviewees. However, we did not identify an attitude-gender gap – meaning that we could not observe differences in their answering or attitudes toward clinical dashboards based on gender. Future research should further consider various dashboard stakeholders from different countries to evaluate our proposed design principles in clinical dashboards.

Second, the absence of further iterations after the focus groups might restrict the opportunity to refine the dashboard based on participants' feedback. Continuous iterations will lead to a more refined and user-centered prototype. However, as the project's aim was identifying and evaluating critical design principles for clinical dashboard – not the effective implementation – we renounced from re-designing the dashboard prototype after conducting the focus group. The insights provided during the focus group serve as a basis for recommendations on the direction of future research.

Third, the prototype's implementation in PowerPoint may not have accurately reflected the actual user experience of a functioning clinical dashboard. A real application will provide more realistic insights into users' opinions and potential usability issues. Also, the non-implementation of the prototype into real-world clinical settings might limit the understanding of how it integrates with existing workflows and impacts daily practice. Prototyping under live conditions will further reveal unforeseen challenges or untapped potentials.

## 6 Conclusion and outlook

The holistic approach of a scoping literature review, user, and software producer interviews, and developing and testing a clinical dashboard prototype allowed us to establish relevant design principles for clinical dashboards incorporating PROMs. The semi-structured interview guide was motivated by our findings from the literature. This chosen procedure permitted cross-checking the state-of-the-art in the literature and detecting white spots where users and software producers showed diverging tendencies for certain features. The last step of developing and testing the clinical dashboard in focus groups enabled us to investigate the user experience, motivating another iteration of the design principles.

The contribution of this research project is threefold: First, we determined the design principles for clinical dashboards based on a scoping literature review and interviews conducted with clinical experts and clinical dashboard software producers. Interestingly, the dashboard content should not differ for treating various episodes of care. The only feature that should be case-specifically adapted is the disease-specific PROM. Second, we tested the inclusion of the EQ-5D into the clinical dashboard in combination with disease-specific PROMs, an approach that was rarely considered in recent literature despite its potential to enhance the physician's understanding of the patient's health status and choice of treatment pathway; third, we developed a prototype and discussed it with seven focus group participants, laying the basis for building and developing "real" clinical dashboards in the future.

For future research, we recommend the following: Our goal was to develop design principles of a clinical dashboard incorporating PROMs that empower healthcare providers with a holistic view of patient information, simplifying complex data and enhancing decision-making processes. While our paper's focus centered on the clinical dashboard's design principles, we recognize the crucial importance of two key aspects: accessibility and implementation into existing hospital information systems. Future projects should commit to elaborate on these facets to ensure the successful adoption of PROM dashboards in clinical practice. Addressing these elements will be pivotal in overcoming potential barriers and fostering widespread acceptance among healthcare professionals.

Additionally, expanding the applicability of the developed clinical dashboard prototype to inpatient care presents a tremendous opportunity to revolutionize medical care within hospital settings. To achieve this goal, we recognize the indispensable role of nursing staff in the research process. By incorporating their perspectives through interviews and focus groups in future projects, their needs will be better understood and reflected to create a comprehensive solution that benefits all stakeholders. Furthermore, to better tailor the EQ-5D to relevant episodes of care, a future research project should develop disease- and patient-specific thresholds to make the EQ-5D more actionable for physicians.

Our efforts to elaborate on clinical dashboards incorporating PROMs mark a critical milestone in our quest to enhance patient care. With this project, we set the foundation for a transformative tool that will revolutionize the healthcare landscape. Through collaboration and a commitment to continuous improvement, this project has the potential to contribute to a healthier and more informed society.

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# Appendix

## Appendix I: Selected papers from scoping literature review

Author	Date	Articles' added value and justification for inclusion	Condition	A/C*	Dashbd.	PROMs	EQ-5D
<b>Absolom et al.</b>	2017	1) Visuals of dashboard: 2 tabs: EPR graphical view where 1 symptom = 1 box with graph trended over time + EPR tabular view with detailed scores and possibility to respond to alert (high number marked in red) 2) Integration of information into EPR	Cancer	C	Yes	Yes	Yes
<b>Amini et al.</b>	2021	1) Relevance of PROMs: Dashboard must be visually appealing and physicians see it as needed for better patient care	N/A	N/A	No	Yes	Yes
<b>Ayala et al.</b>	2021	1) Measures complementing EQ-5D: Mapping the WOMAC to EQ-5D shows that one can be translated to the other while not losing too many insights. However, WOMAC stiffness dimension items are not covered by the EQ-5D-5L dimensions (low correlation)	THA/TKA	A	No	Yes	Yes
<b>Baeksted et al.</b>	2017	1) Dashboard example: Bar charts for disease-specific PROM. Items are presented as bars with different colors (for example, red = very severe, orange = severe, yellow = moderate, light green = mild, dark green = none), lengths and numbers (1–5) for each date of treatment visit. 2) Dashboard feature: Free text write-in feature (in case additional symptoms not covered by PROM) 3) PROMs dashboard benefits: Availability of the PRO-CTCAE self-reports during the consultation improved patient-physician communication about side effects	Cancer	C	Yes	Yes	No
<b>Baghbani-Naghadabi et al.</b>	2022	1) EQ-5D biases: Obesity does not make THA more complex, as eventually there are same benefits after 12 months for all BMIs in WOMAC and EQ-5D	THA/TKA	A	No	Yes	Yes
<b>Bansback et al.</b>	2019	1) PROMs benefits: PROM as decision aid to guide shared decision on if operation is the best option (helps decision quality) 2) Collection: 3-4 weeks before, can be done until waiting room+ (if surgery) 6 weeks post surgery	THA/TKA	A	No	Yes	Yes
<b>Bauer et al.</b>	2018	1) PROMs benefits: patients become more mindful of their symptoms (in depression) if PROMs monitored daily 2) PROMs collection: Daily for mental health 2) Customization: patients' desire for personalization	Depression	C	Yes	Yes	No
<b>Bovonratwet et al.</b>	2021	1) EQ-5D biases: found that negative experience during THA/TKA operation is not a biasing factor for evaluating PROM scores, so it does not threaten comparability of patients	THA/TKA	A	No	Yes	No
<b>Breckenridge et al.</b>	2015	1) PROMs collection: For renal registries, the collection is suggested at least once yearly	Renal registry	C	No	Yes	Yes

<b>Canfield et al.</b>	2020	1) Data collection timeframe: Most improvement in PROMs after THA/TKA occurs within the first 6 months. Thus, limiting PROMs collection to 6 months is cost-efficient and is a good indicator of value of the surgical intervention	THA/TKA	A	No	Yes	No
<b>Conner-Spady et al.</b>	2018	1) Measures complementing EQ-5D: 5L better measure than 3L in TKA/THA, but even better in combination with disease-specific measures	THA/TKA	A	No	Yes	Yes
<b>Conner-Spady et al.</b>	2015	1) EQ-5D-5L relevance: 5L better measure than 3L in TKA/THA, especially for dimensions: mobility, usual activities, and pain/discomfort	THA/TKA	A	No	Yes	Yes
<b>Cronin et al.</b>	2018	1) Customization: Need customization of contents (should be limited to what their practice can address) 2) Features: Patients want feature to track health assessment over time 3) Features: Patients want feature to set goals over time (own physicians) 4) PROMs Dashboard benefits: Can improve patient outcomes, shorten appointment times, patient-centred discussions	Depression & Anxiety	C	Yes	Yes	No
<b>Desantis et al.</b>	2016	1) Features: Physicians want flagging system (not too sensitive ones), dynamic display of previous questionnaire scores, date of treatment change, notifications within display 2) Challenges: EHR integration is a must 3) Data collection timeframe: PRO collection not more than monthly over concerns for both patient and physician fatigue in reviewing results.	Overactive bladder	C	Yes	Yes	No
<b>Devlin &amp; Brooks</b>	2017	1) EQ-5D-5L relevance: EQ-5D is gaining importance and thus the need for better integration, yet people still struggle with scale valuation 2) Disease-specific measures: EuroQol is thinking of bolt-ons	N/A	N/A	No	Yes	Yes
<b>Dixon et al.</b>	2016	1) Features: EHR widgets to combine vitals sign trends and PROMs could be explored 2) PROMs dashboard benefits: dashboard can be used to improve medication adherence, thus better management of chronic conditions 3) Challenges: implementation difficult because patients were reluctant to complete questions	Diabetes	C	Yes	No	No
<b>Dumais et al.</b>	2019	1) Implementation challenge: Incorporating patient preferences when designing a dashboard can increase engagement and data quality 2) Collection method: Patients prefer reporting disease symptoms via a smartphone provided by a physician to feel safe sharing their data 3) Collection method: Increasing preference for electronic PROs collection because of their advantages (elimination of errors, increased accuracy and data quality, real-time reporting)	COPD	C	No	Yes	No
<b>Elm et al.</b>	2019	1) PROMs collection: use wearables (and not necessarily only PROMs questionnaires) 2) PROMs benefits: Physicians saw the complementary aspect to clinical assessments 3) Dashboard display: expansion of the Y- axis in certain displays for easier data comprehension, the addition of markers for medication intake across ePROs and sensor-derived data displays, updates to descriptive text and the addition of "info" buttons describing each display	Parkinson	C	Yes	Yes	No
<b>Eneqvist et al.</b>	2020	1) EQ-5D-5L relevance: EQ-5D-5L is better than 3L in THA/TKA 2) PROMs collection: preoperatively and 1-year postoperatively	THA/TKA	A	No	Yes	Yes

<b>Fautrel et al.</b>	2018	1) Features: Data can be trended over time and anomalous results identified 2) Dashboard visual: Single interface in an easy-to-read, easily interpreted format (e.g. graphs) 3) EHR integration: need for EHR integration	Rheumatoid arthritis	C	Yes	Yes	No
<b>Feng et al.</b>	2021	1) EQ-5D relevance: A diseases are expected to have limitations with "self-care" function 2) Complementary measures: EQ-5D was conceptualized to measure deviations from full health (or negative health), thus in some circumstances, should use disease-specific instrument 3) EQ-5D relevance: EQ-5D has excellent psychometric properties	N/A	N/A	No	Yes	Yes
<b>Field et al.</b>	2019	Shows: 1) PROMs benefits: helps patients remember better their past symptoms and hence to bring more awareness on the care needed. Also helps to adapt medication, changing components of care, etc.	N/A	N/A	No	Yes	No
<b>Finch et al.</b>	2022	1) PROMs collection: Explore videoconferencing as valid new EQ-5D collection method	N/A	N/A	No	Yes	Yes
<b>Gandrup et al.</b>	2019	1) Relevance of dashboards: HIT is increasingly used for PROM collection (incl. dashboards) 2) Dashboard contents: Patient's most salient goals, concerns, and experiences	Rheumatoid arthritis	C	Yes	Yes	No
<b>Garcia-Gordillo et al.</b>	2017	1) EQ-5D biases: Men reported better health status than women. As educational level and monthly incomes were higher, gender differences were lower and HRQoL was better	COPD	C	No	Yes	Yes
<b>Greene et al.</b>	2015	1) EQ-5D relevance: 5L better than 3L because it allows to show better patient's mobility and pain/discomfort problems	THA/TKA	A	No	Yes	Yes
<b>Haragus et al.</b>	2018	1) EQ-5D biases: Finds that the translation of a THA-specific PROMs is reliable from one translation to the other	THA/TKA	A	N/A	Yes	Yes
<b>Hartzler et al.</b>	2016	1) PROMs collection: Monthly before each visit 2) Dashboard visuals: Preference for bar charts and line graphs. Pictographs/tables less helpful 2) Customizability: Patients + HCP Need tailoring of content complexity 3) Dashboard design: adapted dashboard could be built for each disease HCD 4) Features: data trended to similar patients (age- and treatment-matched)	Cancer	C	Yes	Yes	No
<b>Hartzler et al.</b>	2015	1) Customization: HCP prefer simple static views of data to share with patients during consultation, differentiates between inside/outside the consultation through three different tabs with different data complexity levels	Spine surgery	A	Yes	Yes	No
<b>Hasset et al.</b>	2022	1) Dashboard contents: see past responses of PROMs and other freely- indicated symptoms 2) Features: Physicians get messages to alert on patient's severe symptoms	Cancer	C	Yes	Yes	No
<b>Heath et al.</b>	2021	1) EQ-5D relevance: that EQ-5D is massively used to THA/TKA but that at the moment it is not incorporated in dashboards 2) Dashboard content: For THA/TKA it makes sense to compare pre-op. and six-month postoperative EQ-5D	THA/TKA	A	No	Yes	Yes
<b>Heath et al.</b>	2022	1) PROMs collection: pre-op and 6 months after 2) Challenges: costs of implementation & PROM collection, frequency of dashboard use	THA/TKA	A	Yes	Yes	No
<b>Hoogendoorn et al.</b>	2021	1) Disease-specific PROMs: Bolt on for COPD led to small improvement in EQ-5D performance	COPD	C	No	Yes	Yes

Huber et al.	2020	1) EQ-5D biases: HRQoL of obese patients with mild to severe COPD might improve following weight reduction. For very severe COPD, a negative association of obesity and HRQoL could not be confirmed.	COPD	C	No	Yes	Yes
Jin et al.	2019	1) EQ-5D relevance: 5L better than 3L in THA/TKA, differentiates patients better based on their mobility	THA/TKA	A	No	Yes	Yes
Khairat et al.	2018	1) Visuals: colour- code to spot patients with severe symptoms 2) Challenges: Alerts may lead to information overload	N/A	N/A	Yes	No	No
LeRouge et al.	2017	1) Dashboard visuals: Heuristics revealed visual characteristics, e.g., Exclude data labels from column; Unified colours, differentiated darker colour is data to emphasize; Greatest interest outcomes on top-left corner; Descriptive graph titles 2) Dashboard design: Use HCD	N/A	N/A	Yes	Yes	No
Leutner et al.	2021	1) Customization: different tabs, Expandable information, possibility of corrections, including and excluding diagnoses and patients, filter by time periods	Rare diseases	Both	Yes	No	No
Liu et al.	2020	1) Dashboard contents: Include key lab results, Some patients did not like the goal function 2) Customization: Add widgets to dashboard, ability to customize is important	Rheumatoid arthritis	C	Yes	Yes	No
Liu et al.	2018	1) Use in practice: Physicians should clearly communicate the importance of PROMs to help generate “buy in” 2) Data collection: Preferences for pre-visit PROMs at home, delivered by email or text message. Technological is still a barrier but text messages seemed to be a good bridge. The message must clearly indicate that it is healthcare-related.	THA/TKA	A	No	Yes	No
Lutz et al.	2022	1) Dashboard design: for success, need for clear and integrated dashboards showing relevant information only	Cancer	C	No	Yes	Yes
Marshall et al.	2021	1) PROMs benefits: dashboard helps patients to have realistic expectations for TKA outcomes and promote shared decision-making with their care provider 2) Data collection timeframe: Before surgery, 3-months, and 12-months post-surgery. Reporting on 3-month results is done in practice since most of the functional improvement is achieved by then 3) Data collection method: Critical success factors for electronic data collection are the availability of staff to assist patients with the technology, WIFI connectivity, and dedicated space for patients to complete their PROMs.	THA/TKA	A	No	Yes	No
Marten et al.	2021	1) Accessibility: elderly may need additional assistance to complete questionnaires	N/A	N/A	No	Yes	Yes
Merino et al.	2019	1) EQ-5D relevance: Uses EQ-5D to evaluate HRQL 2) EQ-5D biases: In COPD: greatest problems in mobility and pain/discomfort 3) EQ-5D biases: having suffered exacerbations in the last year, presenting a higher level of severity, being a woman, and having a low education level are related to worse HRQL in patients with COPD.	COPD	C	No	Yes	Yes
Molloy et al.	2020	1) Data collection method: can ensure PROM completion by sending automated text message reminders to patients (esp. For younger ones) 2) Data collection timeframe: In THA/TKA, suggest to expand the follow-up questionnaire time period to 13 months as completion increased to 46.2% through this.	THA/TKA	A	No	Yes	No
Mooney et al.	2019	1) Dashboard visuals: line graphs, Horizontal lines discriminating mild, moderate, and severe scores 2) Dashboard features: alerts for high severity symptoms, overlay symptom graphs to look at symptom clustering	Cancer	C	Yes	Yes	No

		3) Dashboard contents: 2) EHR integration: Need for integration in clinical workflow						
<b>Nicolas-Boluda et al.</b>	2021	1) PROMs benefits: patient-centred care, decision making, enable comparisons with peer-group, help to raise concerns	Endometriosis	C	Yes	Yes	Yes	
<b>Nishimura et al.</b>	2019	1) Data collection method: PROMs questionnaire is either self-administered under supervision using a tablet computer at our outpatient clinic or as paper completed at home and returned by mail 2) Data collection method challenge: Cannot use paper and digital version interchangeably because there are big differences in scores reported	COPD	C	No	Yes	No	
<b>Nolan et al.</b>	2016	1) EQ-5D-5L relevance: 5L is good for use in COPD, helps to differentiate between groups defined according to disease severity. 2) Disease-specific measures: EQ-5D-5L is correlated to disease-specific responses (and their changes)	COPD	C	No	Yes	Yes	
<b>Oeser et al.</b>	2018	1) Dashboard contents: 3 classes of data to be displayed: patient, disease and therapy metrics	Cancer	C	Yes	No	No	
<b>Pellizzoni et al.</b>	2020	1) Use in practice: Need for multilingual collection system in some countries (here Brazil)	N/A	N/A	Yes	Yes	Yes	
<b>Ragouzeos et al.</b>	2019	1) Dashboard content: 3 types of data important for patient and physician: lab results, PROs, and medication data 2) Dashboard visuals: lab data should be placed at bottom of page, smaller than PROs because not the focus	Rheumatoid arthritis	C	Yes	Yes	No	
<b>Rolfson et al.</b>	2016	1) EQ-5D biases: Include and adjust for: age, sex, diagnosis at joint, general health status preoperatively, and joint pain and function score for THA/TKA 2) PROMs collection: Immediately before and 1 year after surgery 3) Disease-specific PROMs: should complement EQ-5D with a 1-item pain question and a single-item satisfaction outcome	THA/TKA	A	No	Yes	Yes	
<b>Rudin et al.</b>	2021	1) EHR integration: integrated remote symptom monitoring 2) Dashboard features: data dashboard accessible from the EHR in 1 click + sending EHR inbox message preceding the visit. 3) Dashboard visuals: Divergent opinions between higher=better asthma control OR worse control 4) Dashboard contents: current asthma medications and refill data, recent ED visits or hospitalizations, name of asthma specialist treating patient	Asthma	C	Yes	Yes	No	
<b>Sen et al.</b>	2022	1) EQ-5D biases: women have more disabilities than men in osteoarthritis knee	THA/TKA	A	No	Yes	Yes	
<b>Shewchuk et al.</b>	2021	1) Dashboard features: option to highlight red flags intended to be discussed with an HCP + ease of reading for patients (eg, add a legend, increase contrast and font size, and reduce reading level)	Knee OA	C	Yes	Yes	Yes	
<b>Smith et al.</b>	2019	1) PROMs dashboard benefit: improving recall	COPD	C	No	Yes	Yes	
<b>Spronk et al.</b>	2021	1) Disease-specific PROMs: Adding a burn-specific item to the EQ-5D-5L is possible and has potential.	Burns	A	No	Yes	Yes	
<b>Strachna et al.</b>	2021	1) Dashboard visuals: line graphs most effective to show HRQoL 2) Dashboard contents: Comparison group	Cancer	C	Yes	Yes	No	

<b>Szentes et al.</b>	2020	1) Disease-specific PROMs: Combined use of the EQ-5D and the CAT is seen as a promising approach to best depict HRQL in COPD	COPD	C	No	Yes	Yes
<b>Tai et al.</b>	2020	1) Dashboard benefits: helps patients to understand what clinical factors explain changes in health status	Falls	A	No	Yes	Yes
<b>Taxter et al.</b>	2021	1) Dashboard visuals: Clearly labelled graphs, and vertical orientation to facilitate review and discussion 2) Dashboard content: trending data over time, personalization with patient photo and updates on life before visit	JIA	C	Yes	Partially	No
<b>Tsangaris et al.</b>	2022	1) Dashboard features: Radar allows to see overall picture, Possibility to display item-level responses, PROMs with labels (ie, up/down arrows and equal symbols) showing changes vs. previous score 2) Customization: Enables transferability to other institutions or department 3) Dashboard contents: Photograph of the patient, graph summaries, and recommendations including links to relevant resources	Cancer	C	Yes	Yes	No
<b>Van Citters et al.</b>	2020	1) PROMs dashboard benefits: supported discussions of what matters most 1) Challenges: dashboard was seen by physicians as less comprehensive and timely, more work than their EMR	Cystic fibrosis	C	Yes	Yes	No
<b>Wang et al.</b>	2021	1) EQ-5D relevance: there are other uses of EQ-5D than for economic assessments. It can be used in patient-physician communication 2) Collection frequency: In cancer, EQ-5D usually administered at each chemotherapy cycle	N/A	N/A	No	Yes	Yes
<b>Watson et al.</b>	2021	1) Dashboard contents: patient's six most recent PROMs answers, the patient's priority concern, and clinical actions taken in the encounter 2) Dashboard visuals: Visual flag to identify patients with high number of symptoms/concerns 3) Dashboard features: longitudinal trending and visual cues to easily differentiate mild symptoms from moderate or severe which informed the colour coded trends	Cancer	C	Yes	Yes	Yes
<b>Zhou et al.</b>	2021	1) EQ-5D biases: Discriminative ability of EQ-5D because of the variances depending on characteristics. E.g., sex, age and comorbidities	COPD	C	No	Yes	Yes

\*A/C: Acute vs. Chronic condition. N/A is written in case there was no precise disease in the focus of the study The sections *Dashboard*, *PROM* and *EQ-5D* show which study was focused on which topic.

## Appendix II. Consolidated criteria for reporting qualitative studies (COREQ): 32-item checklist

No. Item	Guide questions/description	Reported on Page #
<b>Domain 1: Research team and reflexivity</b>		
<i>Personal Characteristics</i>		
1. Interviewer/facilitator	Which author/s conducted the interview or focus group?	Page 7
2. Credentials	What were the researcher's credentials? E.g. PhD, MD	Page 7
3. Occupation	What was their occupation at the time of the study?	Page 7
4. Gender	Was the researcher male or female?	n/a
5. Experience and training	What experience or training did the researcher have?	Page 7
<i>Relationship with participants</i>		
6. Relationship established	Was a relationship established prior to study commencement?	Page 7
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	Page 7
8. Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	Page 7
<b>Domain 2: study design</b>		
<i>Theoretical framework</i>		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	Page 7
<i>Participant selection</i>		
10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	Page 7
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	Page 10
12. Sample size	How many participants were in the study?	Page 10
13. Non-participation	How many people refused to participate or dropped out? Reasons?	n/a
<i>Setting</i>		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	Page 10
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	No, only researcher and interviewee

16. Description of sample	What are the important characteristics of the sample? e.g. demographic data, date	Appendix VI
<i>Data collection</i>		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	Page 7 and Appendix IV
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?	No
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	Page 7
20. Field notes	Were field notes made during and/or after the interview or focus group?	Page 7
21. Duration	What was the duration of the interviews or focus group?	Appendix VI
22. Data saturation	Was data saturation discussed?	Page 7
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?	The transcripts were returned to interviewees to get their approval.
<b>Domain 3: analysis and findings</b>		
<i>Data analysis</i>		
24. Number of data coders	How many data coders coded the data?	Page 7
25. Description of the coding tree	Did authors provide a description of the coding tree?	Appendix VII
26. Derivation of themes	Were themes identified in advance or derived from the data?	Page 7
27. Software	What software, if applicable, was used to manage the data?	Page 7
28. Participant checking	Did participants provide feedback on the findings?	No
<i>Reporting</i>		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	Pages 11-15
30. Data and findings consistent	Was there consistency between the data presented and the findings?	Pages 11-15
31. Clarity of major themes	Were major themes clearly presented in the findings?	Appendix VII
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	Appendix VII



### Appendix III: Introduction slides presented before each interview



University of St.Gallen  
School of Medicine

# PROM Dashboards in Practice



From insight to impact.

## What is our aim?

- **Aim of this research:** Exploring **facilitating factors** and **potential barriers** in designing clinical dashboards incorporating PROMs in daily practice
- **Clinical dashboards definition:** *clinical decision support tools capable of providing a concise visual representation of key indicators in a single report, by linking data from multiple databases*
- **Areas of application:** physician-physician communication or **physician-patient** communication
- **Focus on:** a **one-time procedure** (represented by orthopedics) and **treatment of a chronic disease** (represented by COPD)
- **Two types of PROMs:** **generic** (represented by EQ5D-5L) and **disease-specific** (depending on the investigated disease)
  - Reason for generic PROM: overall assessment of the patients health status and mental well-being
  - Shall improve patient-physician communication before, during and after the treatment

## Comparison of generic vs disease-specific PROMs

Both PROMs are **self-reported by the patient** and based on a **standardized questionnaire**— however, a generic PROM focuses on the overall health status (e.g., EQ-5D-5L), while a disease specific PROM reveals information tailored towards the specific health state in relation to the disease (e.g., WOMAC for orthopedics interventions and CAT for COPD treatment)

### Generic PROM (EQ-5D-5L)

Under each heading, please tick the ONE box that best describes your health TODAY

#### MOBILITY

- I have no problems in walking about ☐
- I have slight problems in walking about ☐
- I have moderate problems in walking about ☐
- I have severe problems in walking about ☐
- I am unable to walk about ☐

#### SELF-CARE

- I have no problems washing or dressing myself ☐
- I have slight problems washing or dressing myself ☐
- I have moderate problems washing or dressing myself ☐
- I have severe problems washing or dressing myself ☐
- I am unable to wash or dress myself ☐

#### USUAL ACTIVITIES (e.g. work, study, housework, family or leisure activities)

- I have no problems doing my usual activities ☐
- I have slight problems doing my usual activities ☐
- I have moderate problems doing my usual activities ☐

### Disease-specific PROM (CAT)

I never cough	1 2 3 4 5	I cough all the time
I have no phlegm (mucus) in my chest at all	1 2 3 4 5	My chest is completely full of phlegm (mucus)
My chest does not feel tight at all	1 2 3 4 5	My chest feels very tight
When I walk up a hill or over flight of stairs I am not breathless	1 2 3 4 5	When I walk up a hill or over flight of stairs I am very breathless
I am not limited doing any activities at home	1 2 3 4 5	I am very limited doing activities at home
I am confident leaving my home despite my lung condition	1 2 3 4 5	I am not at all confident leaving my home because of my lung condition

## Goal of the interview

The success of clinical dashboards depends on **suitable offerings customized towards user needs** and the possibility to **integrate the clinical dashboard into the daily workflow**. Therefore, we are very interested in your opinion and experience with clinical dashboards.

→ **Software producers** We appreciate to hear what your perceptions about “the needs in the markets” are and where you **face challenges** (in the market) to make your product reach its full potential | **Users** We are interested in your **opinion, experience and “wishes for the future”** to improve the user experience of clinical dashboards

### Interview flow

- **Duration** about 30 minutes
- **Before:** your consent to record it
- **After:** we will transcribe it and send it to you
- **If you wish**
  - you can make adjustments or note additional information and then send it back
  - we can send you the final report with findings

## Appendix IV. Interview guide for software producers and users

### 1) General questions on dashboards and PROM usage

Software Producer	User
<ul style="list-style-type: none"> <li>- Please describe the dashboard you are producing/designing.</li> <li>- In which countries or regions is your dashboard available?</li> <li>- What is the major goal of your clinical dashboard? <ul style="list-style-type: none"> <li>- For what type of work (e.g., analyzing</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>- What is your motivation for using clinical dashboards? <ul style="list-style-type: none"> <li>- For what type of work (e.g., analyzing outcomes over time, communicating with the patient, comparing to other groups, getting a better overview of all data collected) do you use the</li> </ul> </li> </ul>

<p>outcomes over time, communicating with the patient, comparing to other groups, getting a better overview of all data collected) is the clinical dashboard designed for?</p> <ul style="list-style-type: none"> <li>- What do you think is beneficial about using clinical dashboards?</li> <li>- Where do you see major barriers in using clinical dashboards?</li> </ul> <p>- Do you incorporate PROMs in your clinical dashboard? If yes, which ones (standardized sets vs. own creation)? If no, why not?</p> <ul style="list-style-type: none"> <li>- Does the user have the possibility to choose from a set of available PROMs or is it pre-defined by you?</li> <li>- Do you use generic and disease-specific PROMs, or just one of each? Why?</li> <li>- Why do you think it is beneficial to incorporate PROMs into clinical dashboards?</li> <li>- What do you perceive as challenging when incorporating PROMs into clinical dashboards?</li> </ul>	<p>clinical dashboard?</p> <ul style="list-style-type: none"> <li>- What do you like about the clinical dashboard you currently use?</li> <li>- What don't you like about the clinical dashboard you currently use?</li> </ul> <p>- Do you use PROMs? If yes, which ones (standardized sets vs. own creation)? If no, why not?</p> <ul style="list-style-type: none"> <li>- Do you use generic and disease-specific PROMs, or just one of each? Why?</li> <li>- Are PROMs already integrated into the clinical dashboard?</li> <li>- What is your motivation for using PROMs?</li> <li>- For what type of work (e.g., analyzing outcomes over time, communicating to patients, comparing to other groups) do you use PROMs?</li> <li>- What do you like about using PROMs?</li> <li>- What don't you like about using PROMs?</li> </ul>
<p><b>2) Questions about the market (penetration)</b></p>	
<p><b>Software Producer</b></p> <ul style="list-style-type: none"> <li>- How many clients do already use the clinical dashboards incorporating PROMs to communicate with patients?</li> <li>- How do you feel about the demand for these dashboards?</li> <li>- What designs are requested?</li> <li>- What is the general feedback from customers on your solution? What do they like - what don't they like?</li> <li>- Is there a scientific basis for the design of your dashboards? Are physicians involved in the development process?</li> </ul>	<p><b>User</b></p> <p><i>Not asked to users.</i></p>
<p><b>3) Usage of the dashboard</b></p>	

<p><b>Software Producer</b></p> <ul style="list-style-type: none"> <li>- In how far does your product facilitate the workflow of practitioners?</li> <li>- Who uses and has access to the clinical dashboard? <ul style="list-style-type: none"> <li>- Do you have a special area of expertise, or can the dashboard be used at any discipline?</li> <li>- Can it be used in an outpatient and inpatient setting?</li> <li>- Can it only be used in one department/hospital or is it conceivable that it could also be used, for example, by outpatient care providers such as primary care physicians in parallel?</li> </ul> </li> <li>- What type of data is available in the clinical dashboard? <ul style="list-style-type: none"> <li>- Do you receive regular feedback from your users on how valuable the included data is?</li> <li>- Do you provide support in using the clinical dashboards?</li> <li>- Do your customers own or rent the software of the clinical dashboard?</li> </ul> </li> <li>- Do you think different episodes of care (e.g., orthopedics and COPD, one-time intervention vs chronic disease) require different dashboard capabilities? Why?</li> </ul>	<p><b>User</b></p> <ul style="list-style-type: none"> <li>- To what extent does using the clinical dashboard make your day-to-day work easier?</li> <li>- Who uses and has access to the clinical dashboard? <ul style="list-style-type: none"> <li>- Is it only for use in your department/hospital or is it conceivable that it could also be used, for example, by outpatient care providers such as primary care physicians?</li> </ul> </li> <li>- Is all the data you need in your clinical practice included in the clinical dashboard? <ul style="list-style-type: none"> <li>- What type of data is available in the clinical dashboard?</li> <li>- In your opinion, is there a feature missing that you would find particularly valuable?</li> <li>- What addition did you notice when using the clinical dashboard for the first time?</li> <li>- Did you feel that using a clinical dashboard was complicated and could be made easier in the future?</li> <li>- Do you find that using the clinical dashboard for the first time was intuitive? <ul style="list-style-type: none"> <li>- Have you received any support, or have you familiarized yourself with its use?</li> </ul> </li> </ul> </li> <li>- Do you think different episodes of care (e.g., orthopedics and COPD) require different dashboard capabilities? Why?</li> </ul>
<p><b>4) Dashboard development and data collection</b></p>	
<p><b>Software Producer</b></p> <ul style="list-style-type: none"> <li>- How do you develop a dashboard for a client? Do you have a basic product that is customizable to different needs, or do you develop it every time from scratch according to the needs of your client?</li> </ul>	<p><b>User</b></p> <ul style="list-style-type: none"> <li>- Who provides the dashboard you use? <ul style="list-style-type: none"> <li>- How was it developed?</li> <li>- Is it customizable to individual needs?</li> </ul> </li> <li>- How was the clinical dashboard</li> </ul>

<ul style="list-style-type: none"> <li>- How would you describe your working mode? Do you work agile or in a waterfall structure?</li> <li>- How many iteration cycles do you go through until the delivery of the final product?</li> <li>- How does the roll-out of a new clinical dashboard work?</li> <li>- How does the data collection work? (Where, when, how, who, ...)</li> <li>- Where do you see difficulties in data collection?</li> <li>- Where is the data stored?</li> <li>- Do you have access to the data collected by your customers?</li> <li>- Is the collected data also used for other purposes than for the improvement in the patient-physician communication?</li> <li>- E.g., aggregation of data and comparison between hospitals, other research purposes, etc.</li> </ul>	<ul style="list-style-type: none"> <li>- implemented in your organization?</li> <li>- How does the data collection work? (Where, when, how, who, ...)</li> <li>- Where are difficulties in the data collection?</li> </ul>
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## 5) Feature Assessment

### Same questions for software producers and users

From the literature, we have extracted some design principles that could be included in clinical dashboards - please provide your opinion on displaying these design principles and whether you already incorporate these design principles in your clinical dashboard:

- Previous PROM assessments (including evolution over time).
  - What kind of scores does the dashboard display? Values for individual dimensions or index scores? Why?
- Future PROM-related goals
- Benchmarking | peer-group comparison
- Alerts on symptom/symptom change warnings
  - If yes, at what time should the alarm/warning appear?
- Patient information (patient photo, demographic information, recent health updates, and contact information for other care team members)
- Clinical data (laboratory results and drug data)
  - What medical data do you use?
- Free write-in space

<ul style="list-style-type: none"> <li>- In your opinion, is a feature missing?</li> </ul>	
<b>6) Role of the patient</b>	
<b>Software Producer</b> <ul style="list-style-type: none"> <li>- What is the role of the patient? <ul style="list-style-type: none"> <li>- Does the patient also have access to the information on the dashboard?</li> <li>- Do you assist the patient in interpreting the data?</li> <li>- Do you think the patient's needs concerning the dashboard differ whether he/she underwent a one-time intervention or whether he/she suffers from a chronic disease?</li> <li>- To what extent is the information different from that displayed to the health professional/physician?</li> </ul> </li> </ul>	<b>User</b> <ul style="list-style-type: none"> <li>- What is the role of the patient? <ul style="list-style-type: none"> <li>- Does the patient also have access to the information on the dashboard?</li> <li>- Should the patient be assisted in interpreting the information?</li> <li>- To what extent is the information different from that displayed to the health professional/physician?</li> </ul> </li> </ul>
<b>End</b>	
Is there anything else you would like to add to conclude the interview?	

#### Appendix V: Codebook with deductive codes

General information
<ul style="list-style-type: none"> <li>- <b>Type of disease: For the observation/tracking of which types of disease/episodes of care is the clinical dashboard used for?</b> <ul style="list-style-type: none"> <li>o <b>Chronic:</b> The clinical dashboard is oriented to collect information on chronic episodes of care (such as COPD, arthritis, cancer, etc).</li> <li>o <b>Acute:</b> The clinical dashboard is oriented to collect information on acute episodes of care (such as stroke, heart attack, etc).</li> </ul> </li> <li>- <b>Setting: In which setting is the clinical dashboard used?</b> <ul style="list-style-type: none"> <li>o <b>Inpatient:</b> The clinical dashboard is mainly used in an inpatient setting – i.e., while the patient is in the hospital.</li> <li>o <b>Outpatient:</b> The clinical dashboard is mainly used in an outpatient setting – i.e., during the consultation with the physician.</li> <li>o <b>Combination:</b> The clinical dashboard can be used in inpatient and outpatient settings.</li> </ul> </li> <li>- <b>Type of PROM: What kind of PROMs are used in the clinical dashboard?</b> <ul style="list-style-type: none"> <li>o <b>Disease-specific:</b> The PROMs which are/can be used by the physician are disease-oriented (such as CAT, WOMAC, HOOS, KOOS, Forgotten Hip/Knee Score etc)</li> </ul> </li> </ul>

- **Generic:** The PROMs which are/can be used by the physician are generic (such as EQ-5D, PROMIS, WHO-5, SF-12, SF-36 etc)
- **Combination:** The PROMs which are/can be used by the physician are a combination of disease-specific and generic PROMs
- **Key user: Who is the key user of the clinical dashboard?**
  - **Specialist:** Only the treating specialist (especially in hospitals or in an outpatient setting) can use the clinical dashboard and the corresponding information on it
  - **GP:** Only the treating GP can use the clinical dashboard and the corresponding information on it
  - **All kind of physicians:** The clinical dashboard is available for all kind of physicians and the data on it can be used in parallel/simultaneously / Various physicians have access to the clinical dashboard and the information of the corresponding patient on it
  - **Other health care professionals (e.g., physiotherapist, nurse, etc.):** All kind of health care professionals that do not belong to the group of physicians.
  - **Patient:** The patient him-/herself should have access to the clinical dashboard.
  - **Relatives:** The patient's relatives have access to the clinical dashboard.

### Data collection

- **Level of reporting: What is the preferred/chosen level of reporting?**
  - **Micro:** The dashboard's main purpose is for patient-physician communication and intra-patient comparison.
  - **Meso:** The dashboard's main purpose is comparison of patient groups within departments or institutions.
  - **Macro:** The dashboard's main purpose is comparison of patient groups across departments or institutions.
- **Purpose of reporting: For which activity is the data collected? What does the clinical dashboard serve for?**
  - **Shared decision-making** (for patient and physician): Through the visualization of the PROM scores, the clinical dashboard should improve the shared decision-making of further treatment and thereby also allow for better, more profound communication.
  - **Better basis for decision:** Through the visualization of the PROM scores, this should give the physician a better understanding of the patient's current health status and thereby provide a better basis for decision on further treatment approaches.
  - **Interpretation support of data:** Through the visualization of the PROM scores and a interpretation directly provided by the clinical dashboard, the physician is supported by the correct interpretation of the collected information.
- **Data collection (1<sup>st</sup> time): How should the data be collected for the first time?**
  - **Digital:** The PROM is filled digital.
  - **Analogue (on paper):** The PROM is filled on paper.



- **Time of data collection (1<sup>st</sup> time): When/Where should the first data collection take place?**
  - o **Directly during the appointment:** The PROMs are filled directly during the appointment; when physician is in the room
  - o **Before the appointment (in the waiting room):** The PROMs are filled right before the appointment, when already being at the physician's place.
  - o **Independent at home:** The PROMs are filled independently at home or a place of the patient's own choice.
- **Data collection (follow-up): How should the data be collected in all follow-ups?**
  - o **Digital:** The PROM is filled digital.
  - o **Analogue (on paper):** The PROM is filled on paper.
- **Time of data collection (follow-up): When/Where should the follow-up data collections take place?**
  - o **Directly during the appointment:** The PROMs are filled directly during the appointment; when physician is in the room
  - o **Before the appointment (in the waiting room):** The PROMs are filled right before the appointment, when already being at the physician's place.
  - o **Independent at home:** The PROMs are filled independently at home or a place of the patient's own choice.

#### Dashboard content

- **Patient information** (5-point Likert scale): very useful to not useful (or not yet included), patient information such as name, age, further diseases, etc.
- **Clinical data** (5-point Likert scale): very useful to not useful (or not yet included), clinical data such as lab results or medical history
- **Free write-in space** (5-point Likert scale): very useful to not useful (or not yet included); space where the user has the opportunity to take further notes
- **Past assessment score** (5-point Likert scale): very useful to not useful (or not yet included); visualization of the PROM scores over time
- **Peer-group comparison** (5-point Likert scale): very useful to not useful (or not yet included); feature to analyse a patient's performance/development of health status with his/her peer group
- **PROM-related goals** (5-point Likert scale): very useful to not useful (or not yet included); establishing goals related to individual PROM items (such as for the EQ-5D "decreasing the impact of bad mobility by getting from 3 to 2")
- **Overall health related goals** (5-point Likert scale): very useful to not useful (or not yet included); establishing goals related to overall health (not related to any item of PROMs such as "getting the newspaper every morning on own's own")
- **Alerts: Should alerts be incorporated in/displayed by the clinical dashboard?**
  - o **Yes, immediately when critical value appears:** An alert should be sent out/appear directly once a PROM value crosses a threshold – like this the physician has the opportunity to immediately contact the patient
  - o **Yes, during appointment:** Alerts are only shown during appointment (e.g. by signaling critical values) – like this, the physician has the opportunity to discuss critical PROM values with the patient during the appointment



- **No:** There are signaling of critical values
- **Customizability: What degree should customizability be possible/allowed?**
  - **Yes, to individual needs:** Everything can be adapted to personal needs of the users while developing the clinical dashboard.
  - **Yes, from a standard set:** The users can choose from a standard set/"off the shelf" – some degree of customizability is possible, but not full
  - **No:** Clinical dashboards cannot be adapted to individual needs.

#### Appendix VI. Overview of software producer and user interviewees' characteristics

Interview ID	Software producer/ User	Function	Country	Inter- view du- ration
I1	Software pro- ducer	Product Owner	Netherlands	45 mins
I2	Software pro- ducer	Product Delivery Manager	Netherlands	43 mins
I3	Software pro- ducer	Digital strategy lead	Switzerland	29 mins
I4	Software pro- ducer	CEO & founder	Germany	36 mins
I5	Software pro- ducer	Director Smart Health Academy & Patient Reported Outcomes	Germany	44 mins
I6	Software pro- ducer	Chief Medical Officer	Germany	33 mins
I7	User	Chief physician at depart- ment of orthopedics	Switzerland	29 mins
I8	User	Chief innovation officer	Switzerland	28 mins
I9	User	Chief physician at depart- ment of pneumology	Switzerland	30 mins
I10	User	Member of hospital quality management	Switzerland	34 mins
I11	User	Chief physician at depart- ment of pediatrics and rheu- matology	Netherlands	36 mins
I12	User	Chief physician at depart- ment of pneumology	Switzerland	35 mins
I13	User	Chief physician at depart- ment of orthopedic surgery and traumatology	Switzerland	34 mins
I14	User	Chief physician at depart- ment of orthopedics	Germany	21 mins

Interview ID	Software producer/ User	Function	Country	Inter- view du- ration
I15	User	Chief physician at department of pneumology	Germany	20 mins
I16	User	Chief physician at department of cancer care	USA	24 mins

#### Appendix VII. All codes used during coding attached to the individual interviews

	Software Producer						User									
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
<b>Alert</b>		X	X	X	X	X		X		X	X	X	X			X
- during appointment		X	X		X	X				X						
- none								X			X	X				
- in real time		X	X	X	X								X			X
<b>Barrier</b>	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
- additional level of abstraction															X	X
- additional source of information that needs to be considered		X				X		X	X	X	X					X
- burdensome collection of PROMs		X						X				X		X		X
- interoperability	X	X		X		X		X	X		X	X		X		X
- lack of intrinsic motivation of users		X														X
- legal consequences	X	X	X	X												
- licensing of questionnaires		X			X	X										
- not intuitive to use								X							X	X
- various interests							X		X							
<b>Before first data collection</b>		X														
- explanation by nurse or physician		X														
<b>Clinical data</b>		X	X	X		X		X	X	X	X	X	X	X		X
- clinical data		X	X	X		X			X				X	X		
- not included								X		X	X	X				X

	Software Producer						User									
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
<b>CROMs not included</b>						X										
<b>Customizability</b>		X		X	X	X	X	X		X		X			X	X
- from a standard set					X	X	X	X		X					X	
- to individual needs		X		X	X		X					X				X
<b>Dashboard development</b>	X	X	X			X		X								X
- iteration	X	X				X		X								X
- market trial			X			X										
<b>Data storage</b>			X	X												
- at producer			X													
- cloud			X	X												
- on premise				X												
<b>Design</b>		X	X			X	X	X		X						
- color coding of results		X	X			X	X			X						
- explanation of results						X										
- filter function for search		X														
- heatmap							X									
- indication of change over time		X														
- lines		X						X								
- radar graphs								X								
<b>Different needs between diseases</b>			X	X	X	X	X		X					X		
- no				X	X	X		X		X				X		
- yes			X													
<b>Different needs in various countries</b>				X												
<b>First data collection</b>		X		X		X	X		X	X	X	X	X	X		X
- mail with link		X		X					X							
- online/QR code						X										X
- paper								X				X	X	X		
- telephone/tablet/app		X		X			X			X	X					X
<b>First time of data collection</b>		X		X		X	X		X	X	X	X	X			X
- in waiting room		X				X	X			X	X	X				X

[illegible]

	Software Producer						User									
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
<b>Patient perspective</b>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<b>Payment</b>			X	X	X	X	X									
- add-on to product (for free)			X				X									
- license				X	X	X	X									
<b>Peer-group comparison</b>	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
- no									X			X				
- yes	X	X	X	X	X	X	X	X					X	X		X
- yes, but not possible						X				X						
<b>Personal data</b>		X		X		X		X			X	X				
- no								X			X	X				
- yes		X		X		X										
<b>Purpose of reporting</b>			X	X		X	X	X			X	X	X			X
- better basis for physician's decision						X					X		X			
- communication				X		X	X	X			X	X	X			X
- expectation management							X	X					X			
- real-time tracking			X	X												
- shared decision-making						X		X								
<b>Roll-out</b>				X		X			X	X				X		
- step by step (in different clinics)				X		X			X	X						
- top down														X		
<b>Scores</b>				X		X	X	X	X	X	X	X	X	X		X
- both				X		X		X						X		
- dimensional							X			X			X			X
- index									X		X	X				
<b>Setting</b>				X	X				X	X					X	X
- in- & outpatient					X					X					X	X
- inpatient																
- outpatient				X					X							
<b>System support</b>	X	X	X	X				X	X			X	X	X		X
- in-house at corresponding institution								X								

	Software Producer						User									
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
- interpretation of PROM scores			X	X						X		X		X		
- with implementation		X	X						X	X						X
- none					X								X			
- remote support			X	X												
- workshops/webinars			X													
<b>Type of disease</b>	X	X	X						X							
- chronic		X	X						X							
- combination	X	X														
- one-time intervention																
<b>Type of PROM</b>	X	X	X	X	X	X	X	X	X	X	X	X	X			X
- combination		X		X	X	X	X			X		X	X			
- disease-specific	X		X					X	X		X					X
- generic - only for research											X					
<b>Improved workflow</b>	X	X		X	X	X	X	X	X	X			X	X	X	X
- better basis for decision		X			X											
- better overview over data		X		X		X	X		X	X				X	X	X
- direct communication to patient					X		X						X			
- efficiency	X	X		X		X		X	X	X					X	X
- facilitates workflow								X								X
- inclusion into preoperative planning													X			
- one platform for all information																X
- patient satisfaction		X				X										X
- program in whole institution the same								X								
- PROMs comparability				X		X	X			X			X	X		X
- PROMs measurability											X					X

	Software Producer						User									
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
- visualisation						X				X			X			

#### Appendix VIII. Overview of focus group participants' characteristics

Partici- pant	Gender	Specialty	Role	Qualification
1	Male	Internal Medicine	General practitioner	Specialist in General Internal Medicine
2	Male	Nephrology	Chief physician	Specialist in Internal Medicine and Nephrology
3	Male	Pediatric and adolescent surgery	Senior physician	Specialist in Pediatric Surgery
4	Female	Cardiology	Senior physician	Specialist in Cardiology
5	Female	Clinical Oncology and Hematology	Senior physician	Specialist in Clinical Oncology and Internal Medicine
6	Female	n.a.	Medical student	n.a.
7	Female	n.a.	Medical student	n.a.