Investigating Analytics Dashboards' Support for the Value-based Healthcare Delivery Model

Mona Isazad Mashinchi[1,2,3,4], Adegboyega Ojo[1,2,5], Francis J. Sullivan[2,3,4]
Insight Centre for Data Analytics[1], NUI Galway[2]
Prostate Cancer Institute[3], Galway Clinic[4],
Department pf Applied Informatics in Management, Faculty of Management and Economics, Gdańsk University of Technology, Poland[5]
{Mona.Isazad, adegboyega.ojo}@insight-centre.org, Frank.sullivan@galwayclinic.com

Abstract

Improving the value of care is one of the essential aspects of Value-Based Healthcare (VBHC) model today. VBHC is a new HC delivery model which is centered on patient health outcomes and improvements. There is anecdotal evidence that the use of decision aid tools like dashboards can play a significant role in the successful implementation of VBHC models. However, there has been little or no systematic studies and reviews to establish the extent to which analytics dashboards are used to support patient care in a VBHC delivery context. This paper bridges this knowledge gap through a systematic review of the existing literature on dashboards in the HC domain. Our study reveals dashboard capabilities as an enabling tool for value improvements and provides insight into the design of dashboards. This study concludes by highlighting a few gaps, question, and need for research in the future.

1. Introduction

Healthcare (HC) industry all around the world is struggling with many challenges including: demographic changes, increase in complex chronic disease, limited funding, and limited capacity in managing large volumes of operational and clinical data to make smarter decisions [1]. The models and techniques that have been introduced and developed over the last decades to cope with some of these challenges include evidence-based decision making to quality improvement and cost reduction. Value-based Healthcare (VBHC) as one of the recent developments in the HC domain has emerged to address some of the challenges in this domain. The VBHC model aims to enhance the value (neither an abstract ideal nor a code word for cost reduction) that is driven by the resources available for patients [1]. In this model, value is defined as the patients' health outcomes achieved, relative to the cost of delivering the required outcomes. VBHC systems aim to align patients, providers, and funders' interests toward the shared goal of improving quality and outcome at lower costs. Based on the principles underpinning this model, providers need to collect, monitor and analyse large amounts of data to evaluate and report value and have more value-driven outcomes [2], [3]. So, in the context of VBHC the use of information technologies and decision aid tools such as dashboard [4] which comprise visual displays of the essential data/information can be very useful tools for making sense of the large amount of clinical and operational data. Dashboards can allow clinicians to interpret information from multiple sources to inform decision-making on treatment options in real time. They enable tracking, monitoring, and analyzing different types of data [5]. Dashboards can enhance hospitals' performance and could provide better communication among medical experts and patients [5]–[7]. In this study, we aim to analyse dashboard use in HC delivery domain to establish the extent to which existing dashboards provide support for VBHC delivery model. In our opinion, this study is crucial as it is the first to assess the role of dashboards in HC value improvement to our knowledge.

The remainder of the paper is organized as follows; the next section includes the background, section 3 expands on the research methodology. Section 4 analysis, and section 5 examines the results. The discussion is presented in section 6, and finally, section 7 presents the conclusion.

2. Background

2.1. Value-based Healthcare

The need for HC services is rising due to growing global demand and population, the burden of increasingly complicated chronic disease [8]. With

URI: https://hdl.handle.net/10125/64190
978-0-9981331-3-3

limited HC budgets, actors in this domain need to ensure that available resources are judiciously employed for interventions which have been shown to produce more valuable outcomes for patients. Putting value (in particular for patients) at the centre of any decision in the HC domain is a defining feature of the VBHC model [8], [9]. VBHC was introduced by Porter and Teisberg (2006) [3] and later further developed by Porter (2010) [2] and Porter and Lee (2013) [10] resulting in a "value agenda" that made the following suggestions: (1) organize into integrated practice units; (2) measure outcomes and costs for every patient; (3) move to bundled payments for full care cycles; (4) integrate care delivery across separate facilities; (5) expand excellent services across geography (e.g., compete on value outcomes); and (6) build an enabling information technology platform [11]. In this new model, decision-makers' strategies in the health domain are largely about adding value for patients[2], [12]. Most importantly, VBHC seeks to avoid unnecessary diagnostic and therapeutic interventions. It supports the cost-effective delivery of care while still being compliant with evidence-based guidelines. *In contrast to the traditional fee-for-service model* or capitated approach in which patients have to pay every time they see a doctor or undergo a medical test or procedure regardless of whether a diagnosis or procedure was successful or not, VBHC providers are paid based on patient health outcomes improvements.

VBHC delivery model provides benefits to patients, providers, payers, suppliers, and society as a whole. For example, through VBHC, patients' recovery from illness is quicker. They face fewer doctor's visit, test, and procedure. So, they spend less money on medication as both short-term and long-term health improve. Although providers might have to spend fewer more time on prevention-based patient services, the time that they need to spend on managing chronic disease is less. Furthermore, quality and patient engagement measures increase, as the focus of this model is on value rather than volume, and providers would achieve better care efficiency. Besides, payers in the HC domain would have stronger control over cost, and suppliers gain profits from being able to align the created products and services with positive patients' outcomes and reduced cost. Therefore, society becomes healthier while overall HC spending is less than the traditional models [2], [13]

In addition, it is argued that the best and perhaps the only way to improve the equity of care is to measure value, make it transparent and reward providers based on value improvement [2], [13]. Consequently, based on the VB model, patients' health outcomes need to be measured based on their medical condition along with the cost [8]. In this model, outcomes cover the full cycle of cares (short and long term) including acute care, related complications, rehabilitation, reoccurrences, health-related quality of life (HRQOL), well-being, etc. [2], [14]. Additionally, outcomes must be risk-adjusted or stratified by patients' population (based on their initial conditions) and be based on what patients value [8]. Furthermore, to align processes in this model, one of the essential steps towards VBHC is the standardized measurement of outcomes associated with costs per capita. The International Consortium for Health Outcomes Measurement (ICHOM) - a non-profit organization uses the VB model to define standard sets for various types of medical conditions based on what matters to different groups of patients. This organization report all the required measurement to providers across the world. These sets of outcomes guide providers in different parts of the world to collect similar sets of data and to make decisions based on standard criteria. Furthermore, they facilitate comparable outcome measures across the globe among providers and patients. To date, they have published 28 standard sets covering different conditions and for specific patient populations and still working to establish new standards sets. As an example, the ICHOM standard sets for adults who live with type 1 and 2 diabetes include*;* ***PATIENT-REPORTED OUTCOMES*** *(PSYCHOLOGICAL WELL-BEING*[1]*, DIABETES DISTRESS*[2]*, DEPRESSION*[3]*);* ***ACUTE EVENTS*** *(DIABETIC KETOACIDOSIS, HYPERGLYCEMIC HYPEROSMOLAR SYNDROME, HYPOGLYCEMIA);* ***CHRONIC COMPLICATION*** *(MICRO AND MACROVASCULAR COMPLICATION, NERVOUS SYSTEM COMPLICATIONS, TREATMENT COMPLICATIONS);* ***SURVIVAL*** *(VITAL STATUS);* ***HEALTH SERVICES*** *(FINANCIAL BARRIERS TO TREATMENT, HEALTHCARE UTILIZATION);* ***DIABETES CONTROL*** *(GLYCEMIC CONTROL)* [15].

Considering the various types of data to be extracted and evaluated for value measurement, the success of VB decision making is depending on the availability of a mechanism to simplify the consumption and sense-making of the data for both patients and providers. This availability of such mechanism is expected to positively impact the quality of choices/decisions around treatments or medication type for patients, and decision around teamwork and communication for providers. In addition, information about value and outcomes is beneficial for other external actors such as the insurance

[1] Evaluated via world health organization (WHO-5)

[2] Evaluated via problem areas in diabetes (PAID)

[3] Evaluated via patient health questionnaire (PHQ-9)

company. In summary, for making value-driven decisions, decision-makers require access to precise, actionable, reliable and comprehensive data on the two elements driving the value: 1) health outcome and 2) cost.

2.2. Dashboard in Value-based Healthcare

Visualization has the potential to become an essential part of the HC field [4]. Today, the visualization of patients' health record is one of the primary topics of interest [4] in the HC field. Dashboards as one of the important visualization tools can represent data and information in the HC organizations in a user-friendly style and can help several users in decision making to expose the most insightful information at a glance [12]. HC organizations are introducing dashboards as a means of evaluating and promoting the quality of provided care [16]. It can be mentioned that designing an informative display like dashboards which enable HC professionals to longitudinally follow patients' health outcomes and costs could be very helpful and valuable [9]. Dashboards can enable providers and other stakeholders in the HC domain to track and monitor diverse types of data [12]. Dashboards can quickly communicate information about decision alternatives by presenting factors which might matter to make decisions for its end users. In the context of VBHC, the use of the dashboard to display different health outcomes and costs can help health workers to provide better care [17]–[19] and make more value-driven decisions. Furthermore, it would let patients see various treatments' outcomes/costs (value), and it allows them to see their short and long-term health status in a user-friendly format. Consequently, the use of dashboards can increase patients' satisfaction, self-efficacy and involvement in decision making (decisions concern to treatments types and follow up care) [4], [17], [19]–[21].

Table 1. Required elements for dashboard to support value-based healthcare

Required elements for dashboards decision aid tools to support VBHC delivery model
Providing information about full cycle of care
Providing information about various types of data
Enabling access and communication among parties
Allowing value measurement
Enable transparency about health outcomes and cost
providing interoperability standards to enable communication among providers

Guided by the VBHC principle, the design and use of information technology and decision aid tools, such as dashboards need to support the following elements. They are required to provide information on both long- and short-term health outcomes and cost and also allow access by all involved parties, including patients. They should enable easy extraction of the outcome, process, and activity-based cost measures for each patient and medical condition; and they should support interoperability standards enabling communication among different provider organizations (Table 1) [8], [10].

2.3. Human-Data Interaction and Visualization tools

During the last decades, most of the activities such as problem-solving, decision making and planning that human is involved with, are information-intensive and require complex human cognition [22]–[24]. Additionally, human activities are mediated by various types of tools such as interactive visualizations which are capable of visualizing data in a way that users can interactively manipulate data through them to get answers for several questions which might be driven from data [25]–[27]. Users interaction through visualization tool can be described as users' actions on the interface and responses which they receive from it [24], [26].Interaction is critical as it has a direct effect on users' engagement with data and interface [26], [28]. So, before designing a proper interactive visualization tool such as a dashboard, designers need to consider different users characteristics, such as cognitive styles, knowledge, perceptual capacities, and visual task [26], [29]. For example, according to cognitive fit theory, using graphs could be an excellent way to display the data if the user's task is to identify a relationship in data or to make a comparison. In addition, tables are useful for those tasks which need extracting specific values from data and making decisions [29]. So, it is necessary that the level of interactions, format types (tables vs graphs), functional and visual features of visualization [29] tools to be designed in such a manner that it fits with the types of tasks and users' characteristics to enable their effective use [26], [27].

Furthermore, regarding the importance of human-data interaction and the role of computational tools, Sedig and Parsons [26], defined that "human-data interaction mediated by visualization tools at four levels of granularity: 1) Events, 2) Actions, 3) Tasks, and 4) Cognitive activities" (***EATC***). They defined these four levels of granularity as follows: *Events*: Events are physical occurrences that users perform on the visualization (e.g., clicking, swiping, dragging, tapping), *Actions*: Performance of a series of events gives emergence to epistemic actions (e.g., filtering, linking,

measuring, drilling, annotating), *Tasks*: Tasks can be thought of as having three aspects: cognitive (e.g., generating hypotheses, chaining items), interactive (e.g., browsing, categorizing,), and visual (e.g., scanning, tracing boundaries). Different tasks require different degrees of visual, cognitive, and interactive processing, *Cognitive activities*: Performance of a sequence of tasks give emergence to cognitive activities (e.g., sense making, decision making, problem-solving, learning, planning). Cognitive activities are made up of not only interactive tasks but also visual and cognitive tasks.

3. Methodology

3.1. Research objectives and questions

In this study, a systematic literature review was employed to identify the extent of the use of analytics dashboard for VBHC delivery model. Specifically, the study aims to assess the use of analytics dashboards for VBHC in the HC domain. Following the objective of this study, it answers the following questions:

i. *What are the goals of HC organizations in adopting dashboards?*
ii. *Who are the users of dashboards, and to what extent are dashboards targeted at patients?*
iii. *What are the functional and visual features of dashboards?*
iv. *What are the impacts/outcomes of dashboards utilization in the HC domain?*
v. *To what extent do dashboards provide support for value-based HC delivery model? (support means, to what extent dashboards have been designed to support identified elements in section 2.2, which are necessary for VB decision)*

3.2. Selection criteria and method

To carry out the systematic literature review we employed Mathiassen et al. [30] approach (see figure 1). In this study, the Scopus database was used to search for English documents. **In step one**, the "dashboard," as a keyword was used in step one to search relevant documents between 2005 to Jun 2018 and then the search was limited to following subject area: "Medicine, Nursing, Health professional, Immunology and Microbiology, Computer Science and Engineering", and we excluded those paper which was not in the HC domain. **In step two**, we went through the title of identified articles in step 1 to select the relevant articles in ranked journals. Relevant articles are those which could helped us to answer the research questions, considering the following criteria's: ***1)*** *The articles required to be case studies which are reporting the application of dashboard in the HC domain, e.g., hospitals, national HC organizations.* ***2)*** *Report on the aim of HC organizations to use dashboard.* ***3)*** *Report on the targeted end-users of dashboards.* ***4)*** *Report on the functional and visual features of the dashboard and availability of a link or screen shot/figure of the dashboard.* ***5)*** *Report on outcomes of using dashboard.* **In step three**, firstly, some articles were excluded from our repository as they were not relevant (after skimming abstract). Secondly, some were removed as full texts were not available, or the quality was not good, or the document was irrelevant. Thirdly, after full-texts analyses, some other papers were excluded because of the lack of coverage of necessary elements, concrete methodology, or their relevance to the aim of this study. **In step four**, we identified a few references through the reference list. **In step five**, we selected relevant papers from step four. Finally, **in step six**, we combined all the results which identified from previous steps. We ended up with 41 documents which cover 37 unique cases (since multiple papers were found for the two case studies) (figure 1).

4. Analysis

Each case was *coded* based on the following aspects. 1) determining the users of dashboards in the HC organizations; 2) objects/aims or reasons that motivated the HC organizations to apply dashboard solution; 3) the nature of the tools employed as dashboard, its functional, visual and human-data interaction features, and 4) outcomes of applying dashboards solutions in the HC organizations. Coding procedure was done as follows. *At the first step*, the first author of this paper analyzed the background regarding the aim of using dashboard, users of dashboard, features of dashboard, rules, and outcomes to construct a simple annotation framework. *Secondly*, the second author of this paper checked and examined the created framework before the real coding procedure began. Thirdly, the first authors went through each paper and tried to start real coding based on the defined framework (in earlier steps), and if it was necessary, the new terms were added to the framework. Finally, all the coding which was done by the first author was verified by the second author independently, and disagreements were resolved through discussion in a meeting to arrive at unanimous decisions. More specifically, *to answer the first question* of this study (the aims of applying dashboard), first, we tried to extract the information regarding the aims and those factors which motivated HC organizations to choose dashboard solution, and then we code those reasons into five classes. *To answer the second question*, the same approached was applied. We identified the

users, and then we classified them into ten groups. *To examine the types of users' interaction with dashboards*, we used Sedig and Parsons hierarchical model of human-data interaction as a lens. We tried to match the identified interactions to the hierarchical model, considering the definition for EATC. Furthermore, we investigated and analyzed the types of colors and graphs for each case. *For question number 4*, first, we examined the results section of each paper and identified the outcomes, and in the second stage, we grouped them based on their effect on patients and providers. Finally, *for the fifth question*, considering the elements mentioned in table 1 and the analysis of the first four questions, we tried to analyze and answer to what extent dashboards support VBHC.

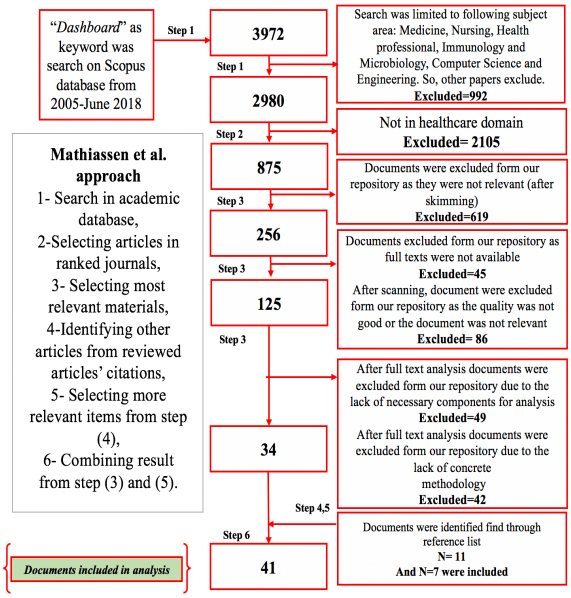

Figure. 1. Flow diagram of included and excluded studies

5. Results

This section summarizes the results of the study concerning the research questions and based on the data analysis method, explained in section 4. Section 5.1 examines the purpose of studies applying dashboards; section 5.2 attempts to determine the end-users of dashboards. Section 5.3 focuses on dashboards' visual and functional features, while outcomes (results) of dashboards application are highlighted in section 5.4, and finally, section 5.5 explains to what extent dashboards support VBHC delivery model.

5.1. Objects of dashboards use in healthcare

Our analyses shows that in several cases dashboards were used as to ***monitor the trend of the data and to improve the HC services and quality of care*** [31]–[38]. Desantis et al. (2016) [31] in their study to monitor and improve the quality of life among patients with overactive bladder used a dashboard to track patients' quality of life longitudinally. In Germany at the University Hospital Leipzig, dashboard employed on head and neck tumour board for real-time monitoring and improving the care of patients [35], the designed dashboards had information regarding patient metric (e.g. name, gender, BMI), disease metrics (e.g. clinical and paralogical stages) and therapy metrics (e.g. examination details). In some other cases, dashboards were employed in hospitals to ***enhance the efficiency of care*** [19], [39]–[43]. Bahl et al. (2013) [39] to reduce and better monitoring the inpatient pharmacy cost applied dashboard. They put different types of data related to the cost on dashboard [39]. In another case, Welch et al. (2015) [42] adopted a diabetic dashboard to promote HC efficiency in diabetic care, in the designed dashboard they put different data, such as patient demographic data, medication types etc. In eight other studies, dashboards were used **to *improve the adherence to various guidelines in HC organizations*** [6], [7], [44]–[49]. For example, dashboards were used to monitor adherence to ventilator bundle in intensive care unit [6], [49] and to prevent infection in the adult Intensive Care [7]. Some other groups of HC organizations applied dashboards to fulfil their needs for ***real-time tracking and access to data*** [4], [50]–[53]. For example, Morgan et al. (2008) [52], Nagy et al. (2009) [51], and Huber et al. (2018) [53] employed dashboard-based solutions for real-time monitoring and accessing data for better practice in the radiology department. Furthermore, our analysis revealed *HC **transparency*** as necessity for re-designing a quality HC system. So, regarding its importance, some studies aimed to find a way to report their health outcomes, cost, and quality of care to patients to help them to ***make more informed and valuable decisions*** [5], [9], [17], [18], [20], [21], [54]–[60]. For example, National prostate cancer registry of Sweden, to record and indicate the performance of prostate cancer care in their country developed a comprehensive dashboard which is publicly available, and people and care provider can see and compare the results with together [18], [58].

Analyses show that HC organization use dashboard as decision aid tools for five main reasons to provide better services and care to patients: 1) monitoring and improving HC services and quality; 2) improving the efficiency of care; 3) improving adherence to guidelines; 4) real-time monitoring and tracking of data; 5) improving HC transparency.

5.2. The users of dashboards

Based on our analysis we classified the users of dashboards in ten groups: 1) primary care practitioner; 2) general practitioner; 3) clinician; 4) physicians; 5) nurse; 6) medical staff; 7) pharmacist; 8) administrator and managers, 9) patients and 10) others (e.g., network leaders, mental health professionals, patient safety officers, regulatory agencies, pharmaceutical companies). More specifically, by focusing on patients as end-users, we found that among 37 unique cases, only in 8 cases (table 2) were patients one of the targeted users of dashboards. In few of these cases, providers were trying to provide decision aid tools for patients to help them to see different types of data and information in user-friendly formats to track data and to make more informed decisions. In others, providers aimed to improve the transparency of HC by providing the data in the right format to patients.

Table 2. Dashboard users

Users	Source
Primary care practitioner	[40]–[42], [45], [47]–[49], [52]
General Practitioner	[34]
Clinician	[9], [17]–[21], [31], [46], [50], [55], [56], [58], [59]
Physician	[5], [35], [39], [42], [44], [53]
Nurse	[4], [33], [36], [38], [42], [50]
Medical Staff	[4], [6], [7], [19], [21], [33], [37], [39], [43], [50], [51], [57]
Pharmacist	[40], [60]
Administrator and Managers	[36], [53], [57]
Patient	[4], [17]–[21], [52], [54], [56]–[58]
Others	[4], [5], [32], [33], [60]

5.3. Dashboards

In this section, we report the findings and results of the user's interaction supported by dashboards based on the hierarchical model of human-data interaction (section 2.3). For each case, we have analyzed the dashboard design. In a few cases, links were available to the dashboards which enabled us to visually inspect, use and examine various functional and visual features of dashboards. In some other cases, the screenshots of dashboards and explanations of types of interactivity and functional and visual features allowed us to extract necessary information from cases. Subsequently, these analyses helped us to code the human-data interaction based on events, actions, task, and types of cognitive activity, which can be seen in the table below (see table 3). From the visual perspective, the use of colour in design is significant, and designers need to choose those colours which have semantic meaning. Colours enable end-users to compare different groups and cases easily; for example, comparing high-risk patients with low risk.

Furthermore, for a useful design, not only colours needs to be selected based on the medical experts' suggestions regarding colour semantics of the domain, but also needs be chosen based on other users' characteristics (such as colour-blind users) [4]. In our analysis in some cases the traffic light colour coding principle was adopted in dashboards' design [7], [18], [38], [39], [41], [42], [44], [47], [50]–[52]. As an example, Starmer et al. (2008), [7] used a simple color scheme of (red, yellow and green) to indicate several conditions compliance with processes.

Additionally, different studies used different types of graphs, charts, and tables considering their goals, types of data and users' interest and task. Hartzler et al. in their study on designing a dashboard to display the quality of life for patients with prostate cancer highlighted that patients prefer bar chart to other types of visualization such as line graph, table, and pictograph. On the other hand, in this study providers preferred tables to other kinds of visualizations for the same data set (this difference is related to users' task, preference, and cognitive styles). By considering the cognitive fit theory (section 2-4) in our analysis, Bahl et al. [39] in their case study about designing a dashboard for inpatient pharmacy costs used a line graph to show monthly average costs per patient day for the service against the average for all services to identify relationships in data and to make comparisons. Daley et al. preferred using tables in their dashboard to show the availability of beds. The use of tables in this case could help users to extract specific values from data and make decisions based on the task that they were responsible.

Table. 3. Conceptualization of human-data interaction on dashboards

Name	Source
Identified Cognitive Activities	
Analytical reasoning	[6], [39], [41], [53]
Decision Making	[31], [37], [40], [42], [44]–[46], [54], [55]
Knowledge discovery	[51]
Planning	[5]
Problem Solving	[50]
Sense Making	[33]
Identified Tasks	
Assessing	[50]
Categorising	[50]
Discriminating	[6], [34]
Exploring	[5], [51]
Generating hypothesis	[53]
Triaging	[37]

Identified Actions	
Comparing	[5], [36], [45], [46], [49], [54]
Drilling	[41], [45], [48], [51]
Filtering	[17], [33]–[35], [40], [41], [50], [54]
Selecting	[17], [35], [36], [40], [48], [50], [51]
Zooming	[33]–[35]
Translating	[17]
Identified Events	
Clicking	[37], [41], [44], [50], [51]
Double click	[44]
Hovering	[50]
Scrolling	[33], [35]

5.4. Impacts of dashboards utilization in the healthcare domain

In this section, we analyzed the outcome (results) of utilizing dashboards as mediating tools in the HC domain. First, we tried to identify the results and impacts of using the dashboard in the selected studies (which were mentioned in the result section of each case). For example, Anderson et al. [48] reported that by the use of dashboard adherence to guidelines for opioid practice improved and they experienced more efficient teamwork and better communication among staff. In another study, the use of dashboards enabled patients to easily follow the changes in their health status and quality of life, in comparison to other patients with similar health conditions [17]. In the study by Dolan et al. [54] dashboard's use helped patients to make better decisions regarding their treatment options and care process and enhanced patients' satisfaction and communication with providers. Potentially, dashboards improved shared decision making, because HC professionals could provide various information to patients, and patients could be more involved and informed.

Secondly, we summarized and categorized them based on their impacts on patients and providers. On the one hand, from an organizational point of view, we categorized the outcomes in twelve domains; 1) better collaboration and communication, 2) performance improvement, 3) better documentation,4) time improvement, 5) service quality improvement, 6) efficiency improvement, 7) efficient data access, 8) better data monitoring, 9) cost reduction, 10) health outcome improvement, 11) value Improvement, 12) care improvement". On the other hand, we categorized dashboard impacts on patients into five areas, 1) safety improvement, 2) satisfaction improvement, 3) health outcomes improvement, 4) better communication with providers, 5) value Improvement.

Table 4. Outcomes

Outcomes (Providers)	Sources
Better Collaboration and Communication	[5], [7], [17], [31], [32], [38], [48], [51]
Performance Improvement	[5], [7], [18], [19], [36], [37], [41], [44], [51]
Better Documentation	[38], [41]
Time Improvement	[44], [51], [52]
Service Quality Improvement	[6], [7], [31], [33], [38]–[40], [48], [49], [51]
Efficiency Improvement	[19], [21], [43], [54], [58]
Efficient Data Access	[5], [32]–[35], [39], [41], [44], [53]
Better Data Monitoring	[4], [9], [18], [34], [39], [41], [59]
Cost Reduction	[55], [58]
Health Outcome Improvement	[31], [32], [42]–[44]
value Improvement	[5], [9], [39], [54], [55], [59], [60]
Care Improvement	[6], [7], [17], [19], [31], [34], [38], [40], [43], [47]–[49]
Outcomes (Patients)	**Sources**
Safety Improvement	[33], [39], [40]
Satisfaction Improvement	[17], [19], [21], [54]
Health Outcomes Improvement	[31], [32], [42]–[44]
Better Communication with providers	[4], [5], [17], [19], [21]
value Improvement	[5], [9], [39], [54], [55], [59], [60]

5.5. Dashboards support for value-based HC delivery

Considering the results from sections 5.1, 5.4, and elements identified in section 2.2, *we found that in a few cases, dashboards were used to enhance the quality of care and to choose the best treatment with better health outcomes and cost by tracking and monitoring data* [5], [9], [39], [54], [55], [59], [60]. Frequently, in the majority of cases, it appears that HC organizations typically used and applied dashboards to control and monitor the quality of health services [31]–[36] [37][38] and to improve the adherence to guidelines [6], [7], [44]–[49], internal process, and efficiency [19], [39]–[43], rather than tracking health outcomes and cost and enhancing value, and sharing the data about full cycle of care with other stakeholders. However, in few cases they have been used to improve the transparency in the HC. Unfortunately, these findings indicate a significant gap in the literature which needs to be considered by scientists regarding the importance of VBHC and improving value in this section. Consequently, our study support that well-designed dashboards have essential roles in improving the value of the care as they can provide real-time monitoring of quality indicators and cost. Our analysis and findings clearly defined that dashboards have an essential role in VBHC delivery model as can display all types of analysis (descriptive, predictive and prescriptive) in a way that can make sense for different users and assist them in making VB decisions, etc., via the interaction/communication.

6. Discussion

6.1. Dashboard capabilities in the context of VBHC

VBHC not only has changed the way HC organizations used to manage their business and created data but modified the application of technologies and decision support tools. *VBHC needs to be reached with technologies, techniques, and tools to facilitate systematic outcome-based quality improvement (considering the main aim of VBHC). More specifically, dashboards and other types of decision aid tools need to be designed and developed in a way to support the VBHC delivery model.* To improve value in the HC domain, providers need to longitudinally collect data on both health outcomes and cost for each medical condition and make decisions based on the analyses on these two elements. The results of this study are consistent with those of previous studies which generally (not specifically in the context of VBHC) examined the importance and roles of dashboards in HC domain, additionally clarified the important capabilities of dashboard in the context of VBHC as an enabling tool and has highlighted to what extent HC organization are using dashboard, considering VBHC delivery model [16], [54]

We understood, providing better care to patients and improving value is a complicated task which involves integrating, analyzing and interpreting various types of clinical, financial and technical data and information regarding different groups of patients' circumstance and health status. Besides, transparent reporting of all these outcomes to various actors with different roles (such as insurance companies, hospital staffs, government, other hospitals, patients and their families) and objectives in the HC domain is another essential element for value-driven decisions. *We argue that dashboards which can visually display outcomes and cost for various medical conditions can facilitate patient-centered decision making* [21], [59]*by enabling patients to have access to their data and facilitating the communication between providers and patients* [4], [17], [19], [21] *and increasing the safety* [33], [39], [40] *and satisfaction level* [17], [19], [21], [54]*. The use of dashboards enhance HC transparency and can enable patients to choose the best HC practices with better outcomes and cost,* [5], [9], [17], [18], [20], [21], [54]–[60]. All these advantages show that dashboard as a decision aid tool has the potential to improve the value in the HC domain (considering elements in table 1). It indicates that dashboard as a tool can be adopted by various HC organizations to collect data for value measurement, to monitor the created value, and to improve the value.

Furthermore, our analyses have identified few gaps regarding the value improvement in the HC domain by the help of dashboard, which needs to be considered by researchers and providers in the HC domain, if the aim is to improve the value in HC organization. In many cases, providers which aimed to use dashboard to measure and follow value to make more value-driven decision, mostly focused on one aspect of value, either health outcome or cost (considering the value equation= (Quality + Outcomes) / Cost) *rather than improving the cost in relation to outcomes of various treatments or drugs*. In other words, in most cases, dashboards did not provide information regarding the full cycle of care, cost, and health outcomes. Furthermore, dashboards have not been designed to enable communication among various actors in the HC domain. Providers do not have access to information about their collages created value and outcomes. *We argue that for a successful implementation of VBHC delivery model, providers should communicate together with a high level of trust to share data. So, there are fundamental needs to change traditional paradigms in the HC field.*

Another identified issue was related to the availability of data. In many cases, there was no data regarding the patients' short and long-term health outcomes and cost. *So, providers need to collect such data to enable them to measure the created value and present them to various parties in the domain*.

Analyses on the aims of using dashboard revealed that in most cases aims were monitoring and improving patients' and hospitals' workflow, services, and cost rather than improving the value (improving both health outcomes and cost). Analyzing, assessing, improving, and reporting the value is one of the most critical missing points in the literature, which needs more consideration. There is a need to go towards more value-driven analyses and reports to improve public health outcomes. Furthermore, the clarification about the users of dashboards shows that they are usually designed for the use of HC providers, not patients. So, if the aim of HC organization is going toward more patient-centered care, shared decision making, and value improvement, they should consider patients as one of the essential users of dashboard decision aid tools.

6.2. Dashboards' design considerations

Related studies on the use of dashboard decision aid tools [16], [54]have shown that graphical formats are more effective than numerical information for identifying relationships and comparing the possibilities of different results, minimizing decision biases due to clear anecdotal information, and promoting understanding of information by patients and providers. Subsequently, this study provided evidence supporting

the advantages of visual information formats for supporting the decision-making processes in the HC domain and specifically, to some extent in the context of VBHC.

However, our analysis of the design of dashboards revealed some limitation. For example, we found that only in two cases, hospitals developed particular types of dashboards for patients with prostate cancer based on their need and characteristic and got feedback from them [21][17]. *This finding shows that there is a large gap between users' needs and dashboard design.* Designers and providers need to consider patients' need and features before any dashboard development for a higher level of acceptance of dashboard technology and more significant results.

It means the types of data, selection of the graphs/tables, the color types, the layout, level of interactivity (functional, not functional and visual features), etc., should be chosen based on users' characteristics, needs, and tasks. If dashboards are appropriately designed, they can provide an accurate mean [26] for users with access to relevant and timely information [32] to examine and explore data and to make the right decision [26]. Indeed, a dashboard which is fitted with users' needs, task, and characteristics would highly be accepted by the users and would provide better outcomes. So, considering the relationship between users and a designed tool is an important aspect which needs more attention.

Furthermore, based on our analysis, it is not clear what types of dashboards' characteristics such as graphical features are related to improved outcomes (dashboard's impacts in HC domain) (section 5.4), or if there is any significant relationship between various types of design and outcomes. For example; Will the results/outcomes (mentioned in section 5.4) of using dashboards change if the dashboards' features changes? The answer to this question is critical, as shows the level of importance of various components in the dashboard design. Besides, if designers aim to develop a dashboard to improve value in HC, not only need to focus more on users' need and characteristics but should consider essential elements for a decision aid tool in the context of VBHC delivery model.

Summarizing what has been discussed in this paper, we believe dashboards are useful decision aid tools for reporting different types of data to various users in the HC domain. From the VB perspective, dashboards have vital roles in enabling HC transparency, as they can support an easy, fast, and accurate way for monitoring and analyzing data to improve value. So, if providers in the HC domain aim to go toward VBHC delivery model, a dashboard is one of enabling tools which can facilitate value improvement.

7. Conclusion

In this study, we attempted to analyze dashboards' application in the context of VBHC. We have identified, that dashboard as decision aid tools by providing various types of data in a user-friendly format can enable providers in the HC domain to measure and track the created value. They can improve access to data and facilitate communication between various parties. They also can enable transparency in the HC domain.

Furthermore, our study has revealed few gaps; in most cases dashboard were designed for the use of HC providers; in most cases the access and use to dashboard were limited to one hospital rather than sharing it with other providers in different hospitals (we think, it might be because of the lack of trust); in many cases the focus was on one aspect of value improvements (health outcome or cost) and not both(we believe the reason could be the unavailability of right data, the lack of insight about VBHC, or both); in some cases where patients identified as one of the dashboard's end-users, the designers did not consider their need or characteristics. To our knowledge, by future attempts to fill the identified gaps, and considering the capabilities and effectiveness of dashboards, they can be adopted and used by providers in the HC domain to improve value in this arena.

Acknowledgments

This study is supported by the **Irish Research Council** and **Galway Clinic Hospital**.

8. References

[1] M. Gray, "Value based healthcare," vol. 437, pp. 1–2, 2017.

[2] M. E. Porter, "What is value in health care?," *N. Engl. J. Med.*, vol. 363, no. 26, pp. 2477–81, Dec. 2010.

[3] M. E. Porter and E. Olmsted Teisberg, *Redefining Health Care: Creating Value-Based Competition on Results*. Harvard Business School Press, 2006.

[4] J. Bernard, D. Sessler, J. Kohlhammer, and R. A. Ruddle, "Using Dashboard Networks to Visualize Multiple Patient Histories: A Design Study on Post-operative Prostate Cancer," *IEEE Transactions on Visualization and Computer Graphics*, 2018.

[5] C. E. Ward, L. Morella, J. M. Ashburner, and S. J. Atlas, "An interactive, all-payer, multidomain primary care performance dashboard," *J. Ambul. Care Manage.*, 2014.

[6] V. Zaydfudim, L. A. Dossett, J. M. Starmer, P. G. Arbogast, I. D. Feurer, W. A. Ray, A. K. May, and C. W. Pinson, "Implementation of a real-time compliance dashboard to help reduce SICU ventilator-associated pneumonia with the ventilator bundle," *Arch. Surg.*, 2009.

[7] J. Starmer and D. Giuse, "A real-time ventilator management dashboard: toward hardwiring compliance with evidence-based guidelines," *AMIA Annu. Symp. Proc.*, pp. 702–706, 2008.

[8] Porter, "What is value in health care," *N Engl J Med*, vol. 363:26, no. 1, pp. 1–3, 2010.

[9] N. G. Thaker, T. N. Ali, M. E. Porter, T. W. Feeley, and R. S. Kaplan, "Communicating Value in Health Care Using Radar Charts : A Case Study of Prostate Cancer," vol. 12, no. 9, 2017.

[10] M. E. Porter and T. H. Lee, "The strategy that will fix health care," *Harv. Bus. Rev.*, 2013.

[11] C. Colldén, I. Gremyr, A. Hellström, and D. Sporraeus, "A value-based taxonomy of improvement approaches in healthcare," *J. Heal. Organ. Manag.*, vol. 31, no. 4, pp. 445–458, 2017.

[12] M. I. Mashinchi, A. Ojo, and F. J. Sullivan, "Analysis of Business Intelligence

Applications in Healthcare Organizations," in *Proceedings of the 52nd Hawaii International Conference on System Sciences*, 2019, pp. 4155–4164.
[13] NEJM Catalyst, "What Is Value-Based Healthcare?," *N. Engl. J. Med.*, 2017.
[14] S. Riva and G. Pravettoni, "Value-Based Model: A New Perspective in Medical Decision-making," *Front. Public Heal.*, vol. 4, Jun. 2016.
[15] "The International Consortium for Health Outcomes Measurement (ICHOM)," 2017. [Online]. Available: https://www.ichom.org/portfolio/diabetes/.
[16] D. Dowding, R. Randell, P. Gardner, G. Fitzpatrick, P. Dykes, J. Favela, S. Hamer, Z. Whitewood-Moores, N. Hardiker, E. Borycki, and L. Currie, "Dashboards for improving patient care: Review of the literature," *Int. J. Med. Inform.*, vol. 84, no. 2, pp. 87–100, 2015.
[17] A. L. Hartzler, J. P. Izard, B. L. Dalkin, S. P. Mikles, and J. L. Gore, "Design and feasibility of integrating personalized PRO dashboards into prostate cancer care," *J. Am. Med. Informatics Assoc.*, vol. 23, no. 1, pp. 38–47, 2015.
[18] P. Stattin, F. Sandin, T. Sandbäck, J. E. Damber, I. Franck Lissbrant, D. Robinson, O. Bratt, and M. Lambe, "Dashboard report on performance on select quality indicators to cancer care providers," *Scand. J. Urol.*, 2016.
[19] H. Lin, H. Wu, C. Chang, T. Li, W. Liang, and J. W. Wang, "Development of a real-time clinical decision support system upon the web mvc-based architecture for prostate cancer treatment," 2011.
[20] J. Izard, A. Hartzler, D. I. Avery, C. Shih, B. L. Dalkin, and J. L. Gore, "User-centered design of quality of life reports for clinical care of patients with prostate cancer," *Surg. (United States)*, vol. 155, no. 5, pp. 789–796, 2014.
[21] A. Hakone, L. Harrison, A. Ottley, N. Winters, C. Gutheil, P. K. J. Han, and R. Chang, "PROACT : Iterative Design of a Patient-Centered Visualization for Effective Prostate Cancer Health Risk Communication," vol. 23, no. 1, pp. 601–610, 2017.
[22] Funke J., "Complex Problem Solving: A Case for Complex Cognition?," vol. 11, no. 2, pp. 133–142, 2010.
[23] R. Sternberg, *Complex Cognition: The Psychology of Human Thought.* Oxford University Press., 2001.
[24] K. Sedig and P. Parsons, "Interaction Design for Complex Cognitive Activities with Visual Representations: A Pattern-Based Approach," *AIS Trans. Human-Computer Interact.*, 2013.
[25] I. E. D. Marcelo Dascal, "The impact of cognitive technologies: towards a pragmatic approach," 2005.
[26] O. Ola and K. Sedig, "Discourse with Visual Health Data: Design of Human-Data Interaction," *Multimodal Technol. Interact.*, vol. 2, no. 1, p. 10, Mar. 2018.
[27] L. Yang, "An Activity Theory Evaluation of a User Interface for a Web-based Virtual Research Environment (VRE)," Maynooth University, 2015.
[28] A. Endert, R. Chang, C. North, and M. Zhou, "Semantic Interaction: Coupling Cognition and Computation through Usable Interactive Analytics," *IEEE Comput. Graph. Appl.*, vol. 35, no. 4, pp. 94–99, 2015.
[29] O. M. Yigitbasioglu and O. Velcu, "A review of dashboards in performance management: Implications for design and research," *Int. J. Account. Inf. Syst.*, vol. 13, no. 1, pp. 41–59, 2012.
[30] M. R. L. Mathiassen, T. Saarinen, T. Tuunanen, *Managing requirements engineering risks: an analysis and synthesis of the literature.* 2004.
[31] D. Desantis, R. J. Baverstock, A. Civitarese, R. T. Crump, and K. V. Carlson, "A clinical perspective on electronically collecting patient-reported outcomes at the point-of-care for overactive bladder," *Can. Urol. Assoc. J.*, 2016.
[32] K. Daley, J. Richardson, I. James, A. Chambers, and D. Corbett, "Clinical dashboard: use in older adult mental health wards," *Psychiatrist*, 2013.
[33] R. M. Ratwani and A. Fong, "'Connecting the dots': Leveraging visual analytics to make sense of patient safety event reports," *J. Am. Med. Informatics Assoc.*, 2015.
[34] R. De Croon, J. Klerkx, and E. Duval, "Design and evaluation of an interactive proof-of-concept dashboard for general practitioners," in *Proceedings - 2015 IEEE International Conference on Healthcare Informatics, ICHI 2015*, 2015.
[35] A. Oeser, J. Gaebel, A. Dietz, S. Wiegand, and S. Oeltze-Jafra, "Information architecture for a patient-specific dashboard in head and neck tumor boards," *Int. J. Comput. Assist. Radiol. Surg.*, 2018.
[36] L. Jeffs, S. Beswick, J. Lo, Y. Lai, A. Chhun, and H. Campbell, "Insights from staff nurses and managers on unit-specific nursing performance dashboards: A qualitative study," *BMJ Qual. Saf.*, 2014.
[37] N. Martin, J. Bergs, D. Eerdekens, B. Depaire, and S. Verelst, "Developing an emergency department crowding dashboard: A design science approach," *Int. Emerg. Nurs.*, vol. 39, pp. 68–76, Jul. 2018.
[38] M. Field, K. Fong, and C. Shade, "Use of Electronic Visibility Boards to Improve Patient Care Quality, Safety, and Flow on Inpatient Pediatric Acute Care Units," *J. Pediatr. Nurs.*, 2018.
[39] V. Bahl, S. R. McCreadie, and J. G. Stevenson, "Developing dashboards to measure and manage inpatient pharmacy costs," *Am. J. Heal. Pharm.*, 2007.
[40] A. F. Simpao, L. M. Ahumada, B. R. Desai, C. P. Bonafide, J. A. Gï¿½vez, M. A. Rehman, A. F. Jawad, K. L. Palma, and E. D. Shelov, "Optimization of drug-drug interaction alert rules in a pediatric hospital's electronic health record system using a visual analytics dashboard," *J. Am. Med. Informatics Assoc.*, 2015.
[41] D. Zeng, C. C. Yang, V. S. Tseng, C. Xing, H. Chen, F.-Y. Wang, and X. Zheng, "LNCS 8040 - Smart Health," 2013.
[42] G. Welch, S. E. Zagarins, P. Santiago-Kelly, Z. Rodriguez, S. E. Bursell, M. C. Rosal, and R. A. Gabbay, "An internet-based diabetes management platform improves team care and outcomes in an urban latino population," *Diabetes Care*, 2015.
[43] A. Staib, C. Sullivan, M. Jones, B. Griffin, A. Bell, and I. Scott, "The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital," *EMA - Emerg. Med. Australas.*, 2017.
[44] R. J. Koopman, K. M. Kochendorfer, J. L. Moore, D. R. Mehr, D. S. Wakefield, B. Yadamsuren, J. S. Coberly, R. L. Kruse, B. J. Wakefield, and J. L. Belden, "A diabetes dashboard and physician efficiency and accuracy in Accessing data needed for high-quality diabetes care," *Ann. Fam. Med.*, 2011.
[45] B. Linder, J.A., Schnipper, J.L., Tsurikova, R., Yu, D.T., Volk, L.A., Melnikas, A.J., Palchuk, M.B., Olsha-Yehiav, M. and Middleton, "Electronic Health Record Feedback to Improve Antibiotic Prescribing for Acute Respiratory Infections," *Am. J. Manag. Care*, vol. 16, no. 12 Suppl HIT, pp. e311–e319, 2010.
[46] B. E. Dixon, A. M. Jabour, E. O. K. Phillips, and D. G. Marrero, "An informatics approach to medication adherence assessment and improvement using clinical, billing, and patient-entered data," *J. Am. Med. Informatics Assoc.*, 2014.
[47] J. McMenamin, R. Nicholson, and K. Leech, "Patient Dashboard: The use of a colour-coded computerised clinical reminder in Whanganui regional general practices," *J. Prim. Health Care*, vol. 3, no. 4, pp. 307–310, 2011.
[48] D. Anderson, I. Zlateva, K. Khatri, and N. Ciaburri, "Using health information technology to improve adherence to opioid prescribing guidelines in primary care," *Clin. J. Pain*, 2015.
[49] T. R. Talbot, D. Carr, C. Lee Parmley, B. J. Martin, B. Gray, A. Ambrose, and J. Starmer, "Sustained reduction of ventilator-associated pneumonia rates using Real-Time course correction with a ventilator bundle compliance dashboard," *Infect. Control Hosp. Epidemiol.*, 2015.
[50] A. Franklin, S. Gantela, S. Shifarraw, T. R. Johnson, D. J. Robinson, B. R. King, A. M. Mehta, C. L. Maddow, N. R. Hoot, V. Nguyen, A. Rubio, J. Zhang, and N. G. Okafor, "Dashboard visualizations: Supporting real-time throughput decision-making," *J. Biomed. Inform.*, 2017.
[51] P. G. Nagy, M. J. Warnock, M. Daly, C. Toland, C. D. Meenan, and R. S. Mezrich, "Informatics in Radiology: Automated Web-based Graphical Dashboard for Radiology Operational Business Intelligence," *RadioGraphics*, 2009.
[52] M. B. Morgan, B. F. Branstetter IV, D. M. Lionetti, J. S. Richardson, and P. J. Chang, "The radiology digital dashboard: Effects on report turnaround time," *J. Digit. Imaging*, 2008.
[53] T. C. Huber, A. Krishnaraj, D. Monaghan, and C. M. Gaskin, "Developing an Interactive Data Visualization Tool to Assess the Impact of Decision Support on Clinical Operations," *Journal of Digital Imaging*, 2018.
[54] J. G. Dolan, P. J. Veazie, and A. J. Russ, "Development and initial evaluation of a treatment decision dashboard," 2013.
[55] J. R. Robinson, N. H. Carter, C. Gibson, A. S. Brinkman, K. Van Arendonk, K. E. Speck, M. E. Danko, G. P. Jackson, H. N. Lovvorn, and M. L. Blakely, "Improving the value of care for appendectomy through an individual surgeon-specific approach," *J. Pediatr. Surg.*, vol. 53, no. 6, pp. 1181–1186, Jun. 2018.
[56] J. G. Nayak, A. L. Hartzler, L. C. Macleod, J. P. Izard, B. M. Dalkin, and J. L. Gore, "Relevance of graph literacy in the development of patient-centered communication tools," *Patient Educ. Couns.*, 2016.
[57] V. Anand, D. Cave, H. McCrady, M. Al-Aklabi, D. B. Ross, I. M. Rebeyka, and I. Adatia, "The development of a congenital heart programme quality dashboard to promote transparent reporting of outcomes," *Cardiol. Young*, 2015.
[58] P. Stattin, F. Sandin, K. Hellström, D. Robinson, and I. Franck Lissbrant, "The National Prostate Cancer Register of Sweden," *Tijdschr. voor Urol.*, 2017.
[59] N. G. Thaker, T. J. Pugh, U. Mahmood, S. Choi, E. Tracy, N. E. Martin, T. T. Sio, R. J. Kudchadker, R. S. Kaplan, A. Kuban, D. A. Swanson, P. F. Orio, M. J. Zelefsky, B. W. Cox, L. Potters, T. A. Buchholz, T. W. Feeley, and S. J. Frank, "Defining the Value Framework for Prostate Brachytherapy using Patient-Centered Outcome Metrics and Time-Driven Activity-Based Costing," vol. 15, no. 3, pp. 274–282, 2017.
[60] K. Bollaerts, T. De Smedt, K. Donegan, L. Titievsky, and V. Bauchau, "Benefit–Risk Monitoring of Vaccines Using an Interactive Dashboard: A Methodological Proposal from the ADVANCE Project," *Drug Saf.*, 2018.