Scoping review of dashboards in health care: why, how, and for whom they have been developed, implemented, and evaluated

Danielle Helminski, Jeremy B Sussman, Paul N Pfeiffer, Alex N Kokaly, Allison Ranusch, Anjana Deep Renji, Laura J Damschroder, Zach Landis-Lewis, Jacob E Kurlander

Submitted to: Journal of Medical Internet Research
on: May 08, 2024

Table of Contents

Scoping review of dashboards in health care: why, how, and for whom they have been developed, implemented, and evaluated

Danielle Helminski[1] MPH; Jeremy B Sussman[1, 2, 3] MD, MS; Paul N Pfeiffer[2, 3, 4] MD, MS; Alex N Kokaly[5] MD, MHSA; Allison Ranusch[2] MA; Anjana Deep Renji[6] MBA, MS; Laura J Damschroder[2] MPH, MS; Zach Landis-Lewis[6] PhD, MLiS; Jacob E Kurlander[1, 2, 3]

[1]Department of Internal Medicine, University of Michigan Ann Arbor US
[2]Veterans Affairs Ann Arbor Center for Clinical Management Research Ann Arbor US
[3]Institute for Healthcare Policy and Innovation University of Michigan Ann Arbor US
[4]Department of Psychiatry University of Michigan Ann Arbor US
[5]Department of Medicine University of California Los Angeles Health Los Angeles US
[6]Department of Learning Health Sciences University of Michigan Ann Arbor US

Corresponding Author:
Danielle Helminski MPH
Department of Internal Medicine, University of Michigan
2800 Plymouth Road, NCRC Building 14
Ann Arbor
US

Abstract

Background: While dashboards are frequently used by health systems to monitor and improve performance, little is known about their characteristics and the processes used to incorporate them into practice.

Objective: This scoping review aimed to explore published literature on health care dashboards to summarize why, how, and for whom they have been developed, implemented, and evaluated.

Methods: MEDLINE, EMBASE, Web of Science and the Cochrane Library were searched from inception through July 2020. Studies were included if they described the development or evaluation of a health care dashboard with publication since 2015. Clinical setting, purpose (categorized as clinical, administrative, or both), and end-user were extracted for all studies. Data on dashboard development, design characteristics, implementation strategies, and evaluation were extracted only for studies published from 2018-2020.

Results: Data was extracted for 199 dashboards described in 193 publications. The most common settings in which dashboards were used were inpatient (n=81/199, 40.7%) and outpatient clinics (n=68/199, 34.2%). Most dashboards had ?2 stated purposes (n=142/199, 71.4%); of these, 97/199 (48.7%) were administrative, 68/199 (34.2%) were clinical, and 31/199 (15.6%) met both criteria. Most dashboards included front-line clinical staff as end-users (n=154/199, 77.4%). In the 118 dashboards published from 2018-2020, half involved end-users in the design process (n=59/118, 50.0%); fewer described formative usability testing (n=26/118, 22.0%) or use of any theory or framework to guide development, implementation, or evaluation (n=24/118, 20.3%). Dashboards tended to be web-based (n=41/118, 34.7%) or embedded directly into the electronic health record (n=17/118, 14.4%). Common implementation strategies used alongside dashboards included education (n=60/118, 50.8%), audit and feedback (n=59/118, 50.0%), and advisory boards (n=54/118, 45.8%). Evaluations of dashboards (n=84/118, 71.2%) were mostly quantitative (n=60/118, 50.8%), or mixed methods, combining dashboard or health record data with qualitative findings (n=18/118, 15.2%).

Conclusions: Dashboards in health care have been used in diverse settings, for multiple purposes and varied end users. The complexity of many dashboards – serving many purposes and end users at once – and the frequent expectation that clinicians will use them underscores the importance of systematic design and evaluation to ensure they are having the intended outcomes. Future work is needed to identify best practices for the development, implementation, and evaluation of health care dashboards.

(JMIR Preprints 08/05/2024:59828)
DOI: https://doi.org/10.2196/preprints.59828

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Review Title
Scoping review of dashboards in health care: why, how, and for whom they have been developed, implemented, and evaluated

Authors
Danielle Helminski, MPH [1]; Jeremy B. Sussman, MD, MS [1, 2, 3]; Paul N. Pfeiffer, MD, MS [2, 3, 4]; Alex N. Kokaly, MD, MHSA [5]; Allison Ranusch, MA [3]; Anjana Deep Renji, MBA, MS[6]; Laura J. Damschroder, MS, MPH [3]; Zach Landis-Lewis, PhD, MLIS [6]; Jacob E. Kurlander, MD, MS [1, 2, 3]

Affiliations
1. Department of Internal Medicine, University of Michigan, Ann Arbor, MI
2. Institute for Health care Policy and Innovation, University of Michigan, Ann Arbor, MI
3. Veterans Affairs Ann Arbor Center for Clinical Management Research (CCMR), Ann Arbor, MI
4. Department of Psychiatry, University of Michigan, Ann Arbor, MI
5. Department of Medicine, University of California Los Angeles Health, Los Angeles, CA
6. Department of Learning Health Sciences, University of Michigan, Ann Arbor, MI

Corresponding Author
Danielle Helminski
Department of Internal Medicine
University of Michigan
2800 Plymouth Rd, NCRC Building 14
Ann Arbor, MI 48109-2800, USA
Email: daniellehelminski@gmail.com

Word Count: 3,608

Keywords
Dashboard; mHealth; Medical Informatics; Quality Improvement; Scoping Review

Disclosures
Jacob Kurlander has received speaking fees from the Anticoagulation Forum.

Conflicts of Interest
None to report.

Funding
This scoping review was funded by the National Institute of Diabetes and Digestive and Kidney Diseases through a K23 award (K23DK118179) (JEK), and the U.S. Department of Veterans Affairs (1 I50 HX003251-01) Maintaining Implementation Through Dynamic Adaptations (MIDAS) (QUE 20-025). The funders played no role in the study design, decision to publish, or drafting of the manuscript.

Author Contributions
DH – Study concept and design, database management, screening of identified articles, data extraction, data analysis, project management, drafting of manuscript.
JBS – Study concept and design, project management, drafting of manuscript.
PNP – Study concept and design and critical revision of the manuscript.

ANK – Screening of identified articles, data extraction, and critical revision of the manuscript.
AR – Screening of identified articles, data extraction, and critical revision of the manuscript.
ADR – Screening of identified articles, and critical revision of the manuscript.
LJD – Study concept and design and critical revision of the manuscript.
ZLL – Study concept and design and critical revision of the manuscript.
JEK – Study concept and design, data analysis, project management, drafting of manuscript.

Abstract

Background

While dashboards are frequently used by health systems to monitor and improve performance, little is known about their characteristics and the processes used to incorporate them into practice.

Objective

This scoping review aimed to explore published literature on health care dashboards to summarize why, how, and for whom they have been developed, implemented, and evaluated.

Methods

MEDLINE, EMBASE, Web of Science and the Cochrane Library were searched from inception through July 2020. Studies were included if they described the development or evaluation of a health care dashboard with publication since 2015. Clinical setting, purpose (categorized as clinical, administrative, or both), and end-user were extracted for all studies. Data on dashboard development, design characteristics, implementation strategies, and evaluation were extracted only for studies published from 2018-2020.

Results

Data was extracted for 199 dashboards described in 193 publications. The most common settings in which dashboards were used were inpatient (n=81/199, 40.7%) and outpatient clinics (n=68/199, 34.2%). Most dashboards had ≥2 stated purposes (n=142/199, 71.4%); of these, 97/199 (48.7%) were administrative, 68/199 (34.2%) were clinical, and 31/199 (15.6%) met both criteria. Most dashboards included front-line clinical staff as end-users (n=154/199, 77.4%). In the 118 dashboards published from 2018-2020, half involved end-users in the design process (n=59/118, 50.0%); fewer described formative usability testing (n=26/118, 22.0%) or use of any theory or framework to guide development, implementation, or evaluation (n=24/118, 20.3%). Dashboards tended to be web-based (n=41/118, 34.7%) or embedded directly into the electronic health record (n=17/118, 14.4%). Common implementation strategies used alongside dashboards included education (n=60/118,

50.8%), audit and feedback (n=59/118, 50.0%), and advisory boards (n=54/118, 45.8%). Evaluations of dashboards (n=84/118, 71.2%) were mostly quantitative (n=60/118, 50.8%), or mixed methods, combining dashboard or health record data with qualitative findings (n=18/118, 15.2%).

Conclusions

Dashboards in health care have been used in diverse settings, for multiple purposes and varied end users. The complexity of many dashboards – serving many purposes and end users at once – and the frequent expectation that clinicians will use them underscores the importance of systematic design and evaluation to ensure they are having the intended outcomes. Future work is needed to identify best practices for the development, implementation, and evaluation of health care dashboards.

1. Introduction

Health care systems must process and make sense of more incoming data than ever before. Understanding and acting on these data are essential to almost every aspect of the health care enterprise, from direct patient care and clinical research, in which real-time data are critical to safe, appropriate, and timely care, to the c-suite, where health systems are held financially accountable for the outcomes of their patients[1–4]. This process can be resource intensive. One large academic medical center reported expending roughly 180,000 person-hours and $5 million dollars to prepare and report 162 quality metrics on inpatient and emergency department performance in a single year[5]. Increasingly, business intelligence tools are used in an attempt to reduce this burden by streamlining data aggregation and reporting to facilitate continuous monitoring and improvement of key metrics[6–8].

Health care “dashboards,” which analyze and present dynamic data about individuals and systems in readily interpretable ways to provide high-level and current snapshots of important metrics, have become one of the most common tools in this armamentarium. In modern health systems, they are widely seen as indispensable and are commonly used for clinical management, population health management, and quality improvement[6,9,10]. Despite dashboards’ ubiquity in health care, there is little research on them and how they have been used in practice[11,12]. Basic questions such as their purpose, end users, and design characteristics have relatively little empiric or theoretic explanation[6,13–15].

To address these gaps, here we performed a scoping review of dashboards used in health care settings to understand why, how, and for whom they have been developed, implemented, and evaluated. By identifying common practices, we hope to foster more systematic approaches to dashboard creation and deployment and to accelerate the science of dashboards.

2. Methods

In this scoping review, we followed Arksey and O'Malley's[16] and Levac et al.'s frameworks for scoping review methodology[17] to identify and map relevant literature. Methods and results are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist[18]. The key research objectives were to explore why, how, and for whom dashboards have been developed, implemented, and evaluated.

2.1. Study selection and screening

The search strategy was developed with a research librarian and previously reported[19]. Briefly, in July 2020 we searched MEDLINE, Embase, Web of Science, and the Cochrane Library databases from inception through July 2020, using key terms, medical subject headings (MeSH), and Boolean operators, with no date, language or other restrictions applied. All records were uploaded into Covidence screening software for deduplication and dual reviewer screening of titles and abstracts. All studies describing use of a dashboard within a health care setting were included for full-text review in duplicate (DH, ADR, AR, ANK, RG, MLC, OJG).

Studies were eligible if they described how a dashboard was developed, implemented, or evaluated in a health care setting, were published in English since 2015, and were used successfully in routine workflow or outside of a practice environment[19]. Exclusion criteria were implementation of the dashboard only in a pre-testing environment and use solely for public health disease tracking or undergraduate medical education. Any disagreements on eligibility were resolved through discussion, with adjudication by a third author when needed. In the full-text screening stage, for any clinical trial registrations (e.g., clinicaltrials.gov NCT number), clinicaltrials.gov was visited and reviewed for linked publications, which were imported into Covidence for deduplication and full-text screening.

2.2. Data extraction and coding

A data extraction form was developed a priori[19]. In meetings, the extraction form was iteratively refined and a codebook of response options for categorical variables (e.g., health care setting, dashboard purpose) was developed (Supplement 1). Data was abstracted using Qualtrics (Qualtrics, Provo, UT).

For all included dashboards, data were extracted on health care setting, dashboard purpose, and intended end-user using a select-all-that-apply checklist of pre-defined attributes (see Table 1 for definitions of common purposes, and Supplement 1 for full codebook definitions). Because of the large number of studies identified, detailed data extraction was completed only for studies published from 2018-2020 (DH, AR, ANK), including the development process, design characteristics, and details of dashboard implementation and evaluation.

Table 1. Top Reported Dashboard Purpose Definitions from Study Codebook*

Dashboard Purpose	Codebook Definition
Clinical Purposes	
Direct Patient Care	A dashboard used when providing direct, immediate care to a patient in any health care setting.
Population Health Management	A dashboard used to identify patients in a clinic panel, department, or unit who are at risk for an adverse event or in need of intervention (i.e., dashboard identifies patients with potentially unsafe prescribing).
Care Coordination	A dashboard that supports care coordination by pulling information from multiple data sources and allowing both the patient and a health care provider to view the dashboard, and/or allowing the patient to enter self-reported health data into the dashboard to complement EHR information for the clinician to use for care planning and decision-making.
Administrative Purposes	
Performance Monitoring	A dashboard that provides data on individual provider or unit/site level performance. These dashboards often show performance trends over time as well as offer the user the ability to compare their performance to that of peers or to averages within their department.
Utilization	A dashboard used to provide data on health care utilization, either at the level of

Tracking	the patient (e.g., how often they visit, how long visits take, where the patient is seen) or at the level of the department or organization (e.g., services per day/month/year, services by category or unit, top services provided by cost or in a given time period).
Resource Management	A dashboard used to support resource management by providing data to support adequate staffing, ensure appropriate and adequate supplies are available, and monitor bed management and/or patient transfers.

*Definitions for the most commonly reported dashboard purposes are displayed here. All codebook definitions are reported in Supplement 1.

2.3. Analysis

Because of the large number categories for dashboard purposes and end-users, we created larger super-categories for these domains so data could be summarized at a higher level. For both domains, these super-categories were “administrative/non-clinical,” “clinical,” “both administrative/non-clinical and clinical,” or “research” (Supplementary Tables 1 and 2).

For dashboard purpose, the following attributes were considered (1) clinical: direct patient care, population health management, and care coordination; (2) administrative: performance monitoring, utilization tracking, resource management, financial tracking, alert or best practice advisory (BPA) tracking, facilitating clinical or quality registry use, supporting education or training, and facility management. Some dashboards were categorized as both clinical and administrative (e.g., used for performance monitoring and population health management). Dashboards used solely to support clinical research activities were categorized as research.

For end-users, the following attributes were considered (1) non-clinical: leadership, administrators, and individuals involved in quality improvement efforts, or (2) clinical: front-line clinicians, pharmacists, clinician trainees, remote monitoring staff, and clinical research teams. Some dashboards were categorized as having both non-clinical and clinical end users (e.g., used by leadership or administration and front-line clinicians).

Abstracted data for variables of interest are reported as counts and percentages. We present both the prevalence with which each individual response option was selected, and the top combinations of attributes to allow for better interpretation of why, how, and for whom dashboards have been developed, implemented and evaluated. Data on dashboard development and design characteristics are described narratively in online appendices and summarized in the text.

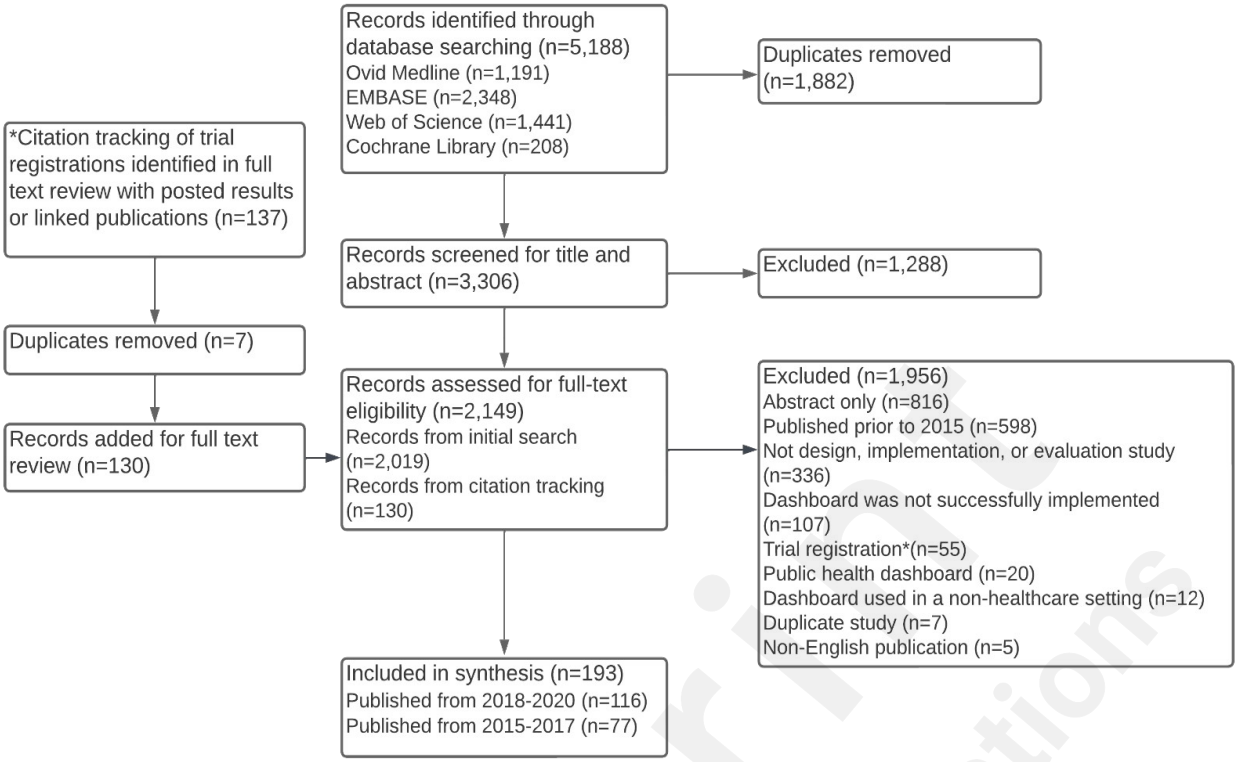
2.4. Data availability statement

Abstracted data from published results is available as an online supplement (Supplement 2).

3. Results

A total of 3,306 unique studies were identified and underwent title and abstract review; 1288 articles were excluded, and the remaining 2,149 studies were screened in full text (Figure 1). Ultimately, 193 studies were included, with 118 dashboards described in 116 studies published from 2018-July 2020, and 81 dashboards described in 77 studies published from 2015-2017.

Figure 1. PRISMA-ScR Flow Diagram



3.1. *Why and for Whom Dashboards have been Developed in Health Care (n=199, 2015-2020)*

Most dashboards were used in North America (n=140/199, 70.4%) or Europe (n=30/199, 15.1%, predominantly the United Kingdom; Table 2 and Supplementary Table 3). Twelve US dashboards originated from the Veterans Affairs (VA) Health System[32,50,60,61,66,68,89,100,119,121,122,134]. The most prevalent settings were inpatient (n=81, 40.7%), outpatient clinics (n=68, 34.2%), and emergency services (n=28, 14.1%)[32–34,41,45,54,58,69,72,74,88,91,103,112,126,127, 132,138,141,145,155–162] (Table 2); 21/199 (10.5%) were used in >1 health care setting[33,34,45,58,72,74,79,88,91,101,126,145,155–157,159,160,163–166] (Table 2). Supplementary Tables 4 and 5 provide more granular data on the specific types of inpatient and outpatient settings. Front-line clinicians (n=154, 77.4%, predominantly physicians), and leadership or administrators (n=81/199, 40.7%) were frequent end-users (Table 2), often in combination (n=41/199, 20.6%) (Supplementary Table 2). Patients were sometimes included as end-users (n=18/199, 9.0%; Table 2)[22,46,67,78,83,90,104,115,147,167–

175].

The purpose(s) of 68/199 (34.2%) dashboards were categorized as solely clinical, and 97/199 (48.7%) were categorized as solely administrative, and 31/199 (15.6%) [24,26,36,49,60,69,73,79,81,94, 101,121,123,128,137,141,144,148,149,156,157,162,168,176–183] were categorized as both clinical and administrative (Table 3). The most prevalent purposes of dashboards were performance monitoring (n=88, 44.2%), direct patient care (n=75, 37.7%), utilization tracking (n=57, 28.6%), and population health management (n=54, 27.1%) (Table 2, definitions in Table 1). However, the majority of dashboards (n=142, 71.4%) met criteria for 2 or more purposes (Table 2). In dashboards whose purpose(s) were categorized as solely administrative (n=97), most included clinical end-users (n=74/97, 76.3%); few were used solely by non-clinical staff (n=21/97, 21.6%)[34,37,41,58,62,65,80,89,105,114,130,142, 146,159,182,184–188]; clinical users were almost always included as end-users regardless of *why* or *where* the dashboard was being used (Table 3, cross tab of purpose x user group in Supplementary Table 6).

Of dashboards used exclusively in inpatient settings (n=63), most were used for administrative purposes (n=33/63, 52.4%)[22,30,31,37,53,61,71,75,82,86,87,95,98,108,110,116,124,130, 131,133,137,142,143,151,170,189–196], followed by clinical purposes (n=22/63, 34.9%) [23,29,38,46,51,55–57,63,70,78,84,96,102,111,113,125,129,140,197–199]. Prevalent uses for solely inpatient dashboards included performance monitoring (n=30/63, 47.6%)[22,30,31,53,61, 71,75,82,86,95,98,108,110,116,124,130,131,133,142,143,151,176,189–196], direct patient care (n=26/63, 41.3%)[23,29,38,46,49,51,55–57,60,63,70,78,84,96,102,111,113,125, 129,137,140,180,197–199], utilization tracking (n=19/63, 30.2%)[22,31,53,60,61,86,98, 108,124,131, 137,151,170,180,189,190,192,195], and population health management (n=19/63, 30.2%)[23,29,38,51,56,57,63,70,73,96,102,111,125,129,140,176,197–199](Table 3). When used solely in outpatient clinics (n=58), dashboards nearly always had some clinical purpose (n=49/58,

84.5%)[20,21,24,26,28,40,43,48,66–68,76,81,83,94,97,100,104,109,115,119,121–123,135,144,147,148,152,154,167,168,171–173,175,177–179,183,200–208]; few were developed solely for administrative purposes (n=9/58, 15.5%)[25,64,77,85,89,105,136,146,209] (Table 3). Prevalent purposes of outpatient dashboards were direct patient care (n=31/58, 53.4%) [20,21,26,40,43,48,67, 68,76,83,97,104,115,147,152,154,167,168,171–173,175,177,183,201–207], population health management (n=25/58, 43.1%)[21,24,26,28,66,81,94,100,109,119,121–123,135,144,148,177–179,183,200,203,204,206,208], and care coordination (n=25/58, 43.1%) [20,21,28,40,43,48,67,68,76,83, 97,104,115,135,147,152,167,168,171–173,175,201,202,207](Table 3). Details on why and by whom dashboards in inpatient settings and outpatient clinics are used are available in Supplementary Tables 4 and 5.

The characteristics of dashboards used in emergency, surgical, radiology, and laboratory settings can be found in Table 3. Notably, in radiology or laboratory departments, dashboards were almost always used for administrative purposes (n=16/17, 94.1%)[35,36,47,59,65,120,128,149,150,153,186–188,210], including resource management (n=8/17, 47.1%)[59,65,120,128,150,153], performance monitoring (n=7/17, 41.2%)[35,47,65,120,187,188,210], and utilization tracking (n=6/17, 35.3%) [36,59,120, 128,150,210]. Emergency department dashboards were often used clinically for direct patient care activities (n=7/13, 53.8%)[69,127,141,158,161,162]. Common administrative purposes of emergency department dashboards included performance monitoring (n=5/13, 38.5%) [32,41,112,132,138] and utilization tracking (n=4/13, 30.8%)[41,54,69,138]. In surgical departments, dashboards were predominantly used for administrative purposes, most often performance monitoring (n=10/11, 90.9%)[27,39,106,107,117,118,169,182,184] and utilization tracking (n=5/11, 45.5%)[27,39,118,182,184].

Table 2. Why and by Whom Dashboards have been Used (n=199, from 2015-2020)

Characteristic	**All Dashboards** (n=199)	**2018-2020 Dashboards** (n=118)	**2015-2017 Dashboards** (n=81)

Publication Year – n (% of column)			
2015[*]	25 (12.6%)	--	25 (30.9%)
2016	22 (11.1%)	--	22 (27.2%)
2017	34 (17.1%)	--	34 (41.9%)
2018	38 (19.1%)	38 (32.2%)	--
2019[**]	39 (19.6%)	39 (33.0%)	--
2020[†‡]	41 (20.6%)	41 (34.7%)	--
Health care Setting – n[µ] (% of column)			
Inpatient Setting	81 (40.7%)	45 (38.1%)	36 (44.4%)
Outpatient Clinic	68 (34.2%)	42 (35.6%)	26 (32.1%)
Emergency Services	28 (14.1%)	18 (15.2%)	10 (12.3%)
Other Setting or Unclear	17 (8.5%)	12 (10.2%)	5 (6.2%)
Imaging or Radiology Facility	14 (7.0%)	10 (8.5%)	4 (4.9%)
Surgical Departments	13 (6.5%)	7 (5.9%)	6 (7.4%)
Clinical Laboratory	10 (5.0%)	5 (4.2%)	5 (6.2%)
Settings Reported – n (% of column)			
1 Setting	178 (89.4%)	106 (89.8%)	72 (88.9%)
>1 Settings	21 (10.6%)	12 (10.1%)	9 (11.1%)
Geographic Location[€] – n (% of column)			
North America	140 (70.4%)	79 (66.9%)	61 (75.3%)
Europe	30 (15.1%)	18 (15.2%)	12 (14.8%)
Asia	14 (7.0%)	11 (9.3%)	3 (3.7%)
Africa	8 (4.0%)	6 (5.1%)	2 (2.5%)
Australia	5 (2.5%)	4 (3.4%)	1 (1.2%)
South America	2 (1.0%)	0 (0.0%)	2 (2.5%)
Purpose [µ¥] – n (% of column)			
Clinical Purposes			
Direct Patient Care	75 (37.7%)	47 (39.8%)	28 (34.6%)
Population Health Management	54 (27.1%)	37 (31.3%)	17 (21.0%)
Care Coordination	33 (16.6%)	22 (18.6%)	11 (13.6%)
Administrative Purposes			
Performance Monitoring	88 (44.2%)	51 (43.2%)	37 (45.7%)
Utilization Tracking	57 (28.6%)	30 (25.4%)	27 (33.3%)
Resource Management	37 (18.6%)	22 (18.6%)	15 (18.5%)
Financial Tracking	9 (4.5%)	4 (3.4%)	5 (6.2%)
Facility Management	3 (1.5%)	0 (0.0%)	3 (3.7%)
Other Non-Clinical Purpose[₹]	7 (3.5%	6 (5.1%)	1 (1.2%)
Other Purposes			
Clinical Trial Support Tool	3 (1.5%)	1 (0.8%)	2 (2.5%)
Other/Unclear	2 (1.0%)	0 (0.0%)	2 (2.5%)
Number of Purposes– n (% of column)			
1 Purpose	57 (28.6%)	34 (28.8%)	23 (28.4%)
2 or More Purposes	142 (71.4%)	84 (71.2%)	58 (71.6%)
Intended End-User [µ¥] – n (% of column)			
Clinical End-Users			
Front-line Clinicians	154 (77.4%)	97 (82.2%)	57 (70.4%)
MD or APP	136 (68.3%)	87 (73.7%)	49 (60.5%)
RN or MA	65 (32.6%)	35 (29.7%)	30 (37.0%)
Other or Not Specified	63 (31.6%)	38 (32.2%)	25 (30.9%)

Pharmacists or Pharmacy Staff	18 (9.0%)	12 (10.2%)	6 (7.4%)
Patients	18 (9.0%)	12 (10.2%)	6 (7.4%)
Clinician Trainees	9 (4.5%)	5 (4.2%)	4 (4.9%)
Remote Monitoring Staff	5 (2.5%)	4 (3.4%)	1 (1.2%)
Clinical Research Teams	4 (2.0%)	2 (1.7%)	2 (2.5%)
Non-Clinical End-Users			
Leaders and/or Administrators	81 (40.7%)	50 (42.4%)	31 (38.3%)
QI Stakeholders	9 (4.5%)	3 (2.5%)	6 (7.4%)
Other	13 (6.5%)	8 (6.8%)	5 (6.2%)
End-User Not Reported	4 (2.0%)	2 (1.7%)	2 (2.5%)
Number of End-Users– n (% of column)			
1 End-User	104 (52.3%)	54 (45.8%)	50 (61.7%)
>1 End-Users	95 (47.7%)	64 (54.2%)	31 (38.3%)

MD=Medical doctor; APP=Advanced practice provider; RN=Registered nurse; MA=Medical assistant; QI=Quality improvement.

*Four included studies from 2015 described 2 distinct dashboards and underwent 2 extractions (Gomez – 316, Nouei – 4027, Ratwani – 303, Wang – 345)

**One included study from 2019 described 2 dashboards (Woo – 2019)

†One included study from 2020 described 2 dashboards (Stevens – 3478)

‡Databases were searched in July 2020 and only studies published and indexed in the databases searched by this date were screened for inclusion

€Geographic location by Country is available in supplementary table 3.

µCharacteristics are reported by prevalence of selection of each response across dashboards without missing data for the variable of interest. As characteristics are reported by prevalence of selection, totals may be greater than 100%.

¥Mapping of all purpose and user responses from data extraction to non-clinical, clinical, or both non-clinical and clinical groups are available in Supplementary Tables 1 and 2, respectively.

?Non-clinical purposes of education or training, facilitate use of clinical or quality registries, and tracking of alerts or best practice advisories (BPAs) were grouped as other. Definitions for all dashboard purposes are available in supplement 1.

Table 3. Intended End-Users and Purposes of Dashboards by Health care Setting (n=199, 2015-2020)

Characteristic	Overall (n=199)*	Inpatient Settings Only (n=63)	Outpatient Clinics Only (n=58)	Radiology or Laboratory Only (n=17)	Emergency Only (n=13)	Surgery Only (n=11)	Dashboards in Other Setting or >1 Setting (n=37)
Purpose Group € – n (% of column)							
Administrative	97 (48.7%)	33 (52.4%)	9 (15.5%)	13 (76.5%)	6 (46.2%)	10 (90.9%)	26 (70.3%)
Clinical	68 (34.2%)	22 (34.9%)	36 (62.0%)	1 (5.9%)	3 (23.1%)	0 (0.0%)	6 (16.2%)
Both Administrative & Clinical	31 (15.6%)	6 (9.5%)	13 (22.4%)	3 (17.6%)	3 (23.1%)	1 (9.1%)	5 (13.5%)
Research	3 (1.5%)	2 (3.2%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	0 (0.0%)	0 (0.0%)
Purpose ‡– n (% of column)							
Performance Monitoring	86 (43.2%)	30 (47.6%)	17 (29.3%)	7 (41.2%)	5 (38.5%)	10 (90.9%)	19 (51.4%)
Direct Patient Care	76 (38.2%)	26 (41.3%)	31 (53.4%)	3 (17.6%)	6 (46.2%)	1 (9.1%)	8 (21.6%)
Utilization Tracking	56 (28.1%)	19 (30.2%)	6 (10.3%)	6 (35.3%)	4 (30.8%)	5 (45.5%)	17 (45.9%)
Population Health Management	55 (27.6%)	19 (30.2%)	25 (43.1%)	0 (0.0%)	4 (30.8%)	0 (0.0%)	6 (16.2%)
Resource Management	37 (18.6%)	11 (17.5%)	3 (5.2%)	8 (47.1%)	2 (15.4%)	2 (18.2%)	11 (29.7%)
Care Coordination	33 (16.6%)	2 (3.2%)	25 (43.1%)	0 (0.0%)	1 (7.7%)	0 (0.0%)	5 (13.5%)
Financial Tracking	9 (4.5%)	3 (4.8%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	3 (27.3%)	2 (5.4%)
Other Purpose Selected?	15 (7.5%)	3 (4.8%)	1 (1.7%)	4 (23.5%)	2 (15.4%)	2 (18.2%)	3 (8.1%)
End User Group€ – n (% of column)							
Non-Clinical	23 (11.6%)	3 (4.8%)	4 (6.9%)	5 (29.4%)	1 (7.7%)	2 (18.2%)	8 (21.6%)

Characteristic	Overall (n=199)*	Inpatient Settings Only (n=63)	Outpatient Clinics Only (n=58)	Radiology or Laboratory Only (n=17)	Emergency Only (n=13)	Surgery Only (n=11)	Dashboards in Other Setting or >1 Setting (n=37)
Clinical	109 (54.8%)	33 (52.4%)	42 (72.4%)	7 (41.2%)	8 (61.5%)	5 (45.5%)	14 (37.8%)
Both Non-Clinical & Clinical	63 (31.6%)	24 (38.1%)	11 (19.0%)	5 (29.4%)	4 (30.8%)	4 (36.4%)	15 (40.5%)
User Not Reported	4 (2.0%)	3 (4.8%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Intended End-User ‡– n, % of column							
Front-line clinicians	154 (77.4%)	47 (74.6%)	52 (89.7%)	11 (64.7%)	10 (76.9%)	9 (81.8%)	25 (67.6%)
MD or APP	136 (68.3%)	44 (69.8%)	44 (75.9%)	6 (35.3%)	12 (92.3%)	11 (100.0%)	19 (51.4%)
RN or MA	65 (32.7%)	27 (42.9%)	22 (37.9%)	0 (0.0%)	5 (38.5%)	1 (9.1%)	10 (27.0%)
Other or Not Specified	63 (31.6%)	20 (31.7%)	19 (32.8%)	7 (41.2%)	2 (15.4%)	1 (9.1%)	14 (37.8%)
Leadership and/ or Administrators	81 (40.7%)	27 (42.9%)	13 (22.4%)	9 (52.9%)	4 (30.8%)	6 (54.5%)	22 (59.5%)
Pharmacists or Pharmacy Staff	18 (9.0%)	8 (12.7%)	8 (13.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.4%)
Patients	18 (9.0%)	4 (6.3%)	11 (19.0%)	0 (0.0%)	0 (0.0%)	1 (9.1%)	2 (5.4%)
Other or Support Staff	13 (6.5%)	2 (3.2%)	4 (6.9%)	2 (11.8%)	1 (7.7%)	1 (9.1%)	3 (8.1%)
Clinician Trainees	9 (4.5%)	4 (6.3%)	0 (0.0%)	2 (11.8%)	0 (0.0%)	1 (9.1%)	2 (5.4%)
QI Stakeholders	9 (4.5%)	2 (3.2%)	3 (5.2%)	1 (5.9%)	1 (7.7%)	0 (0.0%)	2 (5.4%)
Remote Monitoring Staff	5 (2.5%)	2 (3.2%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	0 (0.0%)	2 (5.4%)
Clinical Research Teams	4 (2.0%)	2 (3.2%)	1 (1.7%)	0 (0.0%)	1 (7.7%)	0 (0.0%)	0 (0.0%)

Characteristic	Overall (n=199)*	Inpatient Settings Only (n=63)	Outpatient Clinics Only (n=58)	Radiology or Laboratory Only (n=17)	Emergency Only (n=13)	Surgery Only (n=11)	Dashboards in Other Setting or >1 Setting (n=37)
Not Reported	4 (2.0%)	3 (4.8%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

MD=Medical doctor; APP=Advanced practice provider; RN=Registered nurse; MA=Medical assistant; QI=Quality improvement.

€Responses were categorized into high-level groups for purpose and user according to the select-all-that-apply data available. Purpose responses of direct patient care, population health management and care coordination were categorized as clinical while responses of performance monitoring, utilization tracking, resource management, financial tracking, BPA tracking, facilitate clinical or quality registry use, education or training, and facility management were categorized as administrative purposes. Dashboards that had both purpose responses from clinical and administrative categories (e.g., performance monitoring and population health management) were categorized as both administrative and clinical dashboards. Dashboards used solely to support clinical research activities are categorized as research. End-user responses of front-line clinical staff, pharmacists or pharmacy staff, clinician trainees, remote monitoring staff, and clinical research teams were categorized as clinical users. Responses of leadership or administrators and QI stakeholders were categorized as non-clinical.

⁋Other purpose selected includes dashboards that included facility management, education or training, clinical trial support, facilitate use of clinical or quality registries, BPA tracking, or other selected as a key function of the dashboard.

‡Characteristics are reported by prevalence of selection of each response across dashboards without missing data for the variable of interest. As characteristics are reported by prevalence of selection, totals may be greater than 100%.

3.2. How Dashboards Have Been Developed (n=118, 2018-2020 subset)

Half of included dashboards (59/118, 50.0%; Table 4)[27,29,32,34,42,44,48–51,55–57,62,70,72,84,85,91,97,99,101,120,123,126,127,131,136,139,143,145,147,148,153,158,162,167,171,173–178,181,183,185,188,191–193,195,198,199,201,208,209,211] described steps to engage intended end-users in the design process. User involvement included dashboard metric selection, data validation, and formation of work groups to iteratively review and revise dashboard prototypes, among other strategies (Supplementary Table 7). Fewer dashboards described formative usability testing (26/118, 22.0%; Table 4, Supplementary Table 8) [32,42,44,48–51,55,57,58,72,85,97,101,111,127,139,158,167,171,174,175,192,201,208,212].

The software or coding languages were reported for 46/118 dashboards (39.0%)[27,28,32–35,37,42,44,47,55,61,64,68,74,78,83–85,91,101,104,110,117,128,133,141,145,153, 165,168,171,174,177,187–189,192,194,195, 198,201,208,209,212], with custom coding (n=14/118, 11.9%)[32,33,35,47,55,153,171,174,177,192,198,201,208], Tableau (n=10/118, 8.5%)[27,42,44, 64,74,85,91,117,141,145], Microsoft Excel (n=6/118, 5.1%) [61,165,187,188,195,212] and Qlikview (n=4/118, 3.4%)[34,37,101,110] most commonly used (Table 4, details available in Supplementary Table 9). Dashboards developed using custom coding often described use of specific programs or coding languages, including structured query language (SQL), JavaScript, and Cascading Style Sheets (CSS).

Overall, dashboards were most often available to end-users as websites (n=41/118, 34.7%) [23,28,33,50,52,55,58,61,68,71,83,84,97,99,103,104,109,110,115,116,119,128,147,151,153,163, 167–169,171,173–175,179,181,189,194,204,208,209] or as tools embedded directly into the

EHR (n=17/118, 14.4%)[29,49,51,55–57,69,101,107,111,124,126,127,144,148,199,211] (Table 4, combinations reported in Supplementary Table 10). However, clinical dashboards were more likely to be web-based (n=21/43, 48.8%) [23,28,33,52,55,68,83,84,97,104,109,115,119,147,167,171,173–175,204,208] or embedded in the EHR (n=9/43, 20.9%)[29,51,55–57,111,127,199,211], while dashboards with administrative purposes were more likely to be shared by email (n=11/54, 20.4%) [42,61,91,99,106,117,124,132,187,188,193], available via intranet or Sharepoint (n=10/54, 18.5%)[27,32,35,42,47,74,91,145,191,192], or posted directly within the setting (n=6/54, 11.1%; Table 4)[44,117,120,133,165,212].

Of dashboards that reported on updating frequency (80/118, 67.8%), most were updated in real time (31/118, 26.3%)[23,29,33,35,55–58,62,76,78,102,111,120,124,128,131,132,144,148,153,157,158,162,168,169,175,180,193,211], or near real time (5-60 minutes) (11/118, 9.3%; Table 4) [44,49,51,69,103,116,126,137,151,176,203]. Dashboards used solely for administrative purposes were more likely to take 24 hours or more to update (n=21/43, 48.8%) [27,30,32,47,71,74,99,107,110,133,136,143,145,163,165,185,187,188,191, 194,195,212], while the majority of clinical dashboards updated every 24 hours or less (n=19/43, 44.2%; Table 4) [23,29,33,51,55–57,70,76,78,102,111,139,158,175,199,203,208,211].

3.2.1. Dashboard Data Content (n=118, 2018-2020 subset)

Nearly a third of health care dashboards used payor or accreditation organization reporting standards or professional guidelines as dashboard benchmarks or metrics of interest (43/118,

36.4%; Table 4)[23,32,44,47,50,61,64,68,70–72,74,78,81,91,97,99,102,109,122,123, 132,135,144,145,148,165,167,174,176,178,183,185,187–189,191–194,198,200,209].

Dashboards designed for performance monitoring included metrics related to value-based payment and quality payment programs[71,144,209], and/or state- or national-level reporting mandates or guidelines[99,132,148,176]. When used for direct patient care or population health management, clinical guidelines were often used to identify patients for intervention or guide decision support[23,102,109] (citations are non-exhaustive, see Supplementary Table 11 for complete data). Of dashboards that reported on visual elements, tables (66/118, 55.9%), graphs (64/118, 54.2%), and color coding (61/118, 51.7%) were common display elements, as shown in Table 4.

3.2.2. Theoretical Frameworks (n=118, 2018-2020 subset)

A theoretical or quality improvement framework was used to guide dashboard development, implementation, or evaluation efforts in 24/118 (20.3%) of dashboards (Table 4) [27,34,42,44,47,50,52,57,91,99,103,107,109,110,119,124,127,135,136,163,178,185,198,203].

None of the frameworks was used in more than 2 studies. Reported theories and frameworks varied widely and included behavior change theories (e.g., stages of change model[135], disruptive behavior pyramid theory[136], active choice principles[109]), technical frameworks (UTAUT[127], technology acceptance model[50]), implementation science specific frameworks (e.g., CFIR[178], ERIC[119], RE-AIM[57]), and a clinical governance framework[185], among others (dashboard level details are available in Supplementary Table 12).

Table 4. How Dashboards have been Developed *(n=118, 2018-2020 subset)*

Reported Strategy	Overall (n=118)	Dashboard Purpose Group€		
		Non-Clinical (n=54)	Clinical (n=43)	Both Non-Clinical and Clinical (n=20)
Use Of Theoretical Framework[µ] – n, % of column	24, 20.3%	14, 25.9%	8, 18.6%	1, 5.0%
End-User Involvement In Design[µ] – n, % of column	59, 50.0%	26, 48.1%	23, 43.5%	10, 50.0%
Formative Usability Testing[µ] – n, % of column	26, 22.0%	9, 16.7%	15, 34.9%	2, 10.0%
Benchmarks or Metrics Informed by Regulatory Guidelines[µ] – n, % of column	43, 36.4%	23, 42.6%	13, 30.2%	7, 35.0%
Software Used for Dashboard Development[‡] – n, % of column				
Software Not Reported	72, 61.0%	26, 48.1%	30, 69.8%	15, 75.0%
Custom Coding Build	14, 11.9%	6, 11.1%	7, 16.3%%	1, 5.0%
Tableau	10, 8.5%	9, 16.7%	0, 0.0%	1, 5.0%
Microsoft Excel	6, 5.1%	6, 11.1%	0, 0.0%	0, 0.0%
Qlikview	4, 3.4%	3, 5.6%	0, 0.0%	1, 5.0%
Other Software Reported[†]	21, 17.8%	9, 16.7%	9, 20.9%	3, 15.0%
Dashboard Delivery Channel[‡] – n, % of column				
Website	41, 34.7%	15, 27.8%	21, 48.8%	4, 20.0%
Embedded within the EHR	17, 14.4%	3, 5.6%	9, 20.9%	5, 25.0%
Site intranet or Sharepoint	13, 11.0%	10, 18.5%	2, 4.6%	1, 5.0%
Shared by email	12, 10.2%	11, 20.4%	0, 0.0%	1, 5.0%
Printed And Posted In Setting	12, 10.2%	6, 11.1%	2, 4.6%	4, 20.0%
Software App On Phone, Tablet Or Computer	7, 5.9%	4, 7.4%	2, 4.6%	1, 5.0%
Other	10, 8.5%	5, 9.2%	5, 11.6%	0, 0.0%
Delivery Channel Not Reported	29, 24.6%	13, 24.1%	8, 18.6%	8, 40.0%
Dashboard Data Update Frequency Reported[‡] – n, % of column				
Real Time	31, 26.3%	11, 20.4%	13, 30.2%	7, 35.0%
Near Real Time (5-60 Minutes)	11, 9.3%	4, 7.4%	2, 4.6%	4, 20.0%
Daily	16, 13.6%	10, 18.5%	4, 9.3%	2, 10.0%
Weekly, Monthly or Quarterly	12, 10.2%	11, 20.4%	0, 0.0%	1, 5.0%
Various Update Times	5, 4.2%	2, 3.7%	1, 2.3%	2, 10.0%
Other	5, 4.2%	5, 9.3%	0, 0.0%	0, 0.0%
Update Frequency Not Reported or Unclear	38, 32.2%	11, 20.4%	23, 53.5%	4, 20.0%

Reported Strategy	Overall (n=118)	Dashboard Purpose Group[€]		
		Non-Clinical (n=54)	Clinical (n=43)	Both Non-Clinical and Clinical (n=20)
Dashboard Visual Elements Reported[‡] – n, % of column				
Tables	66, 55.9%	29, 53.7%	26, 60.5%	11, 55.0%
Graphs	64, 54.2%	34, 63.0%	21, 48.8%	9, 45.0%
Color Coding	61, 51.7%	26, 48.1%	23, 53.5%	12, 60.0%
Gauges	8, 6.8%	4, 7.4%	3, 7.0%	1, 5.0%
Other	7, 5.9%	4, 7.4%	2, 4.7%	1, 5.0%
Visual Elements Not Reported	22, 18.6%	11, 20.4%	7, 16.3%	3, 15.0%

EHR=Electronic health record.

*Table limited to dashboards published between 2018-2020 (n=118 dashboards from 116 studies)

[€]One dashboard that was categorized as "other" rather than non-clinical, clinical, or both, is not represented in the table. This dashboard was web-based with data reported in near real-time and reported use of a theoretical framework, but did not report any end-user involvement in design, formative usability testing, benchmarks or metrics informed by regulatory guidelines, software used to develop the dashboard, or any visual elements used in the dashboard display.

[µ]Dashboard level details on use of theory or frameworks, involvement of end-users in dashboard development, formative usability testing, dashboard metrics informed by professional guidelines or by payor- or licensing agency-specific quality metrics, and details on software used to develop dashboards are available in supplementary tables 8-13.

[‡]Characteristics are reported by prevalence of selection of each response across dashboards without missing data for the variable of interest. As characteristics are reported by prevalence of selection, totals may be greater than 100%.

†Software responses selected for 3 or more dashboards are shown here, with software reported to be used for 2 or fewer dashboards reported as "other" in this table. Dashboard level details are available in supplementary table 10.

3.3. How Dashboards Have Been Implemented and Evaluated (n=118, 2018-2020 subset)

3.3.1. Implementation

Most dashboards used at least one adjunct implementation strategy to augment any intended behavior change (114/118, 96.6%; Table 5). Common implementation strategies and representative examples in citation included: (1) educational sessions or educational materials (60/118, 50.8%)[29,37,44,49–

52,55,56,58,61,62,64,72,76,83,84,98,99,102,104,107,111,116,117,119,122,123,131,135,136,141,144,145,148,151,153,158,163,165,167,171,173–176,178,179,181,187,191–194,199,203,208,211,212], which ranged from peer-led clinician education[72,111,199] to patient education on using the dashboard[76,167]. (2) Audit and feedback or relay of clinical data (59/118, 50.0%)[23,29,30,32,44,47,58,61,62,64,68,70,72,81,97,99,101,102,107,109–111,115–117,119,120,123,124,131–133,135–137,141,145,148,153,163,165,169,173,179,181,183,185,187,189,191,193,195,199,203,204,208,209,212], typically through one-on-one discussions between a clinician and a supervisor or academic detailer focused on how to improve performance or reach specific benchmarks[32,61,132,136,148,179,208,212]. (3) Formation of advisory boards or workgroups, or engagement of stakeholders (54/118, 45.8%) [29,30,32,34,42,44,49,50,55, 57,58,61,62,72,85,91,97,101–103,110,111,119,120,131,136,139,141,145,147,148,153,162, 167,171,174–176,178,181,183,185,187–189,193,199,201,208,209,211], which were often multidisciplinary groups of clinical staff, site leaders, and sometimes patients, who participated in dashboard development, implementation, or formative usability testing [29,34,44,49,57,72,85,145,147,201,209]. Other strategies included changing the physical environment or record systems (42/118, 35.6%)[34,37,44,47–49,57,62,64,72,76,78,106,107,111,116,119,123,126,128,131,132,137,139,141,143,145,148,153,157,158,162,167,171,178,189,193,194,199,211] (e.g., placement of physical reminders and/or relevant supplies); and needs assessments or efforts to identify implementation barriers and facilitators (37/118, 31.4%) [23,27,33–35,42,44,49,55,57,58,84,85,91,97,102,106,110,111,123,127,131,139,141,145,148,158,167,174,176,178,185,192,193,198,200]. While many implementation strategies were used at similar rates across dashboards with

clinical and non-clinical purposes, audit and feedback was most often used alongside administrative dashboards (n=34/54, 63.0%; Table 5) [30,32,44,47,58,61,62,64,72,99,107,110,116,117,120,124,131–133,136,137,145,153,163,165,169,185,187,189,191,193,195,209,212], especially those use for performance monitoring or utilization tracking. Conversely, when dashboards were used for clinical purposes, involving patients or families was more commonly reported (n=24/43, 55.8%) [28,29,48,52,57,68,76,83,97,104,115,119,135,139,147,167,171,173–175,200,201,204,211], often to engage patients in shared decision making (Table 5).

3.3.2. Evaluation

Most dashboards included results from an evaluation of either the dashboard's effect, using the dashboard as a tool for measuring change, or of the dashboard as both intervention and measurement tool (84/118, 71.2%; Table 5). Most evaluations were quantitative, using data from the dashboard or EHR alone (41/118, 34.7%)[23,30,37,44,51,71,72,74,76,78,84,91,98,102,106,107,109,110,117,122,124,131–133,136,143–145,148,151,153,165,180,181,183,189,193,199,200,208], from the dashboard or EHR in combination with survey data (10/118, 8.5%)[34,35,55,64,103,104,115,123,157,198], or from surveys alone (9/118, 7.6%) [33,50,81, 83,119,162,168,173,211]. An additional 18 studies reported mixed-methods evaluations which included interviews, focus groups, or analysis of chart notes[27,29,56,57,61,68,116,127,147,161,177–179,187,192,194,204,212]; only 6 reported results of qualitative assessments of end-user perceptions of dashboards without a quantitative evaluation[28,48,52,163,167,203](Table 5). When dashboards had an administrative purpose, evaluations more often were conducted using dashboard/EHR data (n=25/54, 46.3%)

[30,37,44,71,72,74,91,98,106,107,110,117,124,131–133,136,143,145,151,153,165,189,193].

Table 5. How Dashboards have been Implemented and Evaluated *(n=118, 2018-2020 subset)*

Characteristics of Implementation or Evaluation	Overall (n=118)	Purpose Group†		
		Non-Clinical (n=54)	Clinical (n=43)	Clinical *and* Non-Clinical (n=20)
Adjunct Implementation Strategies Used‡ – n, % of column				
Audit and provide feedback, or facilitate relay of clinical data	59, 50.0%	34, 63.0%	16, 37.2%	9, 45.0%
Conduct educational sessions, or disseminate educational materials	60, 50.8%	27, 50.0%	24, 55.8%	9, 45.0%
Conduct a needs assessment, identify barriers and facilitators	37, 31.4%	17, 31.5%	14, 32.6%	6, 30.0%
Form advisory boards or workgroups	54, 45.8%	26, 48.1%	17, 39.5%	10, 50.0%
Identify champions, involve local opinion leaders	23, 19.5%	13, 24.1%	6, 14.0%	4, 20.0%
Mandate change, institute guidelines	33, 28.0%	19, 35.2%	9, 20.9%	5, 25.0%
Change teams or professional roles	22, 18.6%	10, 18.5%	7, 16.3%	5, 25.0%
Change environment or record systems	42, 35.6%	21, 38.9%	12, 27.9%	9, 45.0%
Involve patients and families, prepare patients to be active in care	31, 26.3%	4, 7.4%	24, 55.8%	3, 15.0%
Financial incentives or disincentives	8, 6.8%	4, 7.4%	3, 7.0%	1, 5.0%
Remind clinicians or other stakeholders	12, 10.2%	3, 5.6%	6, 14.0%	3, 15.0%
Other strategy reported	5, 4.2%	2, 3.7%	3, 7.0%	0, 0.0%
No adjunct implementation strategies reported	4, 3.4%	2, 3.7%	1, 2.3%	1, 5.0%
Number of Adjunct Implementation Strategies Reported – n (% of column)				
0 Implementation Strategies	4, 3.4%	2, 3.7%	1, 2.3%	1, 5.0%
1-3 Implementation Strategies†	67, 56.8%	28, 51.8%	26, 60.5%	12, 60.0%
4-6 Implementation Strategies	37, 31.4%	20, 37.0%	13, 30.2%	4, 20.0%
7-10 Implementation Strategies	10, 8.5%	4, 7.4%	3, 7.0%	3, 15.0%
Evaluation Type€ – n, %				
Quantitative Evaluations	60, 50.8%	29, 53.7%	20, 46.5%	10, 50.0%
Using dashboard/EHR data alone	41, 34.7%	25, 46.3%	11,	5, 25.0%

			25.6%	
Using survey alone	9, 7.6%	1, 1.9%	5, 11.6%	3, 15.0%
Using both dashboard/EHR and survey data	10, 8.5%	3, 5.6%	4, 9.3%	2, 10.0%
Mixed-Method Evaluations				
Using both interview or focus group data and dashboard/EHR data or survey data	18, 15.2%	7, 13.0%	8, 18.6%	3, 15.0%
Qualitative Evaluations				
Using interview or focus group data	6, 5.1%	1, 1.9%	5, 11.6%	0, 0.0%
No Evaluation Reported				
No evaluation reported	34, 28.8%	17, 31.5%	10, 23.3%	7, 35.0%

EHR=Electronic health record.

[‡]Implementation strategies are reported by prevalence of selection of each strategy across included dashboards from 2018-2020 (n=118). Reported combinations of adjunct implementation strategies used will be reported separately.

[†]One dashboard that was categorized as "other" rather than non-clinical, clinical, or both, is not represented in the table. This dashboard reported use of one implementation strategy (form advisory boards or workgroups) and included a quantitative evaluation with both EHR or dashboard data and survey data.

[€]Evaluation type is reported as the combination of evaluation types selected for each of the 118 included dashboards from 2018-2020.

4. Discussion

4.1. Principal findings and comparison with prior work

This scoping review of 199 dashboards in health care settings found that they are used throughout health systems, and have a high degree of diversity in purposes, intended end-users, and features both within and across health care settings. Many dashboards included more than 1 purpose and/or end-user. Most prior reviews of dashboards in health care focused narrowly on specific settings[12,213], end-users[214], and purposes[215,216]. By contrast, our inclusion criteria imposed few restrictions, leading to a greater breadth of dashboards used in health care, and broader findings about the relationship between dashboard characteristics, such as purposes, end users, and settings.

A widely cited review of dashboards by Dowding et al. distinguishes two types of dashboards, both of which use “health IT to provide visual displays of quality or productivity,” with either a clinical focus – intended to aid clinicians in decision making to improve quality of patient care – or a quality focus – intended to enable managers to identify areas for practice improvement; the definition also allows for the possibility of overlap[8]. Our results suggest a more complicated relationship between dashboard purpose and end user, which reflect larger trends in health care. For example, nearly 1/3 of dashboards (n=63/199, 31.6%) serve both clinical and non-clinical end users simultaneously. In addition, most administrative dashboards (74/97, 76.3%) include clinicians as end users. This likely reflects that dashboards have become part of the growing burden of administrative responsibilities clinicians face [217,218]. We also found with the growth in dashboards, end users have expanded to include entire clinical teams (e.g., rapid response teams[51,111,157], care teams completing patient rounds[29,56,113]), and even patients, who often input symptoms or vital signs to supplement EHR data[104,115,147,167,171,174], reflecting the growing complexity of health care teams and trends in patient reported outcomes.

Despite the proliferation of dashboards throughout healthcare, we found major opportunities to improve the development process of dashboards. Half of dashboards (n=59/119, 50.0%) did not involve end users in the development process, and even fewer (26/118, 22.0%) included formative usability testing, which are effective strategies to improve usability and adoption [219,220]. This corroborates the findings a prior systematic review of safety dashboards, which

found a minority of dashboards used formative usability testing[221], and another recent scoping review which found that even when completed, usability testing is often incomplete [219]. Usability has been defined as the “extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specific context of use”[222]. The complexity of dashboards, exemplified by the multiplicity of purposes, end users, and settings often incorporated into a single dashboard, heighten the importance of thoughtful and deliberate usability testing in dashboard development. If clinicians, who are often overworked and burned out, are frequently tasked with using dashboards, usability testing will be crucial to making dashboard use as efficient and palatable as possible[223,224]. Physicians are likely to be more engaged if health IT tools provide direct benefit to them in their work[220].

We found a wide range of implementation strategies that have been paired with dashboards, often in used combination: education; audit and feedback or relay of information; engagement of working groups, stakeholders, or advisory boards; conducting local needs assessments; and changing the environment or electronic record systems. Knowledge of possible implementation strategies is essential since the mere existence of a dashboard does not ensure its adoption. Two prior studies of dashboards used in the US VA health care system found most facilities used an array of implementation strategies[119,225]. For example, one VA study assessing implementation strategies associated with a cirrhosis care dashboard identified 8 core implementation strategies, including use of workgroups, dashboard use, reminders, involving patients, tailoring strategies, and rapid testing, though facilities reported use of up to 52 implementation strategies annually[225]. While our findings reveal a smaller array of implementation strategies, we did find use of many distinct strategies. This finding can serve as a

starting point for future studies examining the potential effectiveness of these implementation strategies. Audit and feedback appears to be a common implementation strategy, highlighting the importance of engaging with end-users outside of the dashboard on important metrics. As dashboard developers consider implementation strategies, selection should depend on a thorough understanding of the specific barriers and facilitators of the specific context, in keeping with implementation theory[226,227]. Additionally, better reporting of which implementation strategies have been used in clinical research or health care quality improvement efforts is essential to improve understanding of how and why implementation strategies impact the effectiveness of these efforts[228,229].

4.2. Strengths and limitations

Strengths of our study include the comprehensiveness of the data elements extracted, including basic characteristics, development, implementation, and evaluation components. In addition, we included all studies in which a dashboard was implemented in a health care setting, which allowed us to capture the full scope of health care dashboards. There are also some limitations. First, we excluded non-English publications, potentially limiting generalizability of our findings. Second, our search ended in 2020 and thus, represents a sample of published literature and did not capture more recent trends in dashboards. Since our goals were not primarily quantitative synthesis, this did not prohibit us from achieving the goal of broadly surveying the range of dashboard characteristics. Third, for studies in which the dashboard was not the main focus (e.g., when a dashboard was only a single part of a larger multicomponent intervention), the manuscript may not have included a complete description of the dashboard or the development, implementation, or evaluation process. Thus, these elements may have been underreported.

4.3. Implications

These limitations notwithstanding, our findings have implications for the future design, implementation, and research of dashboards in health care. Given the complexity of many dashboards, often with multiple purposes, settings, and end users simultaneously, usability testing will be critical to ensure smooth and efficient operability for all end users. Usability testing may be particularly important for clinical care dashboards, not only because they have the potential to impact patients, but also because clinicians are already overloaded with administrative and documentation tasks and are increasingly burned out[217,218,230]. Relatively simple usability testing by novices can pay dividends, with the potential to increase adoption and effectiveness[231]. In a similar vein, dashboard evaluations should holistically consider potential impacts, including not only the performance indicator or quality measure of interest, but also those important to end users, like impact on workflow and efficiency. Finally, dashboard designers should be aware of the wide range of implementations strategies that have been used alongside dashboards.

Future research priorities should include a quantitative review of the impact of dashboards on performance indicators, which was not covered in this scoping review; qualitative evaluations of the impact of dashboards on job satisfaction; and comparative research on the effectiveness of different implementation strategies used with dashboards. In the future, the development of best practice statements may be useful.

4.4. Conclusions

Dashboards are used across various settings and by a range of end users to support patient care and drive quality improvement and regulatory reporting. Notably, a majority of dashboards include clinical personnel as end users. Future research should aim to assess the effect of various design processes and the impact of contextual factors on the effectiveness of health care dashboards to identify best practices for developing and implementing these tools.

Funding and acknowledgements

This work was supported by the US Department of Veterans Affairs (1 I50 HX003251-01) Maintaining Implementation Through Dynamic Adaptations (MIDAS; QUE 20-025; DH, JEK, JBS, PNP, AR, LJD) and the National Institutes for Diabetes and Digestive and Kidney Diseases through a K23 award (K23DK118179; JEK). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

We thank Rebecca Goldberg (RG), Marisa L. Conte (MLC), and Oliver Jintha Gadabu (OJG) for their assistance with study screening and selection in the title and abstract and full-text review stages. We also thank Dr. Shari Rogal for her thoughtful and invaluable feedback on use of the ERIC taxonomy to guide categorization of implementation strategies.

References

1. Agency for Healthcare Research and Quality, Rockville, MD. Major Hospital Quality Measurement Sets. AHRQ - Major Hosp Qual Meas Sets. 2023. Available from: https://www.ahrq.gov/talkingquality/measures/setting/hospitals/measurement-sets.html [accessed Jan 11, 2024]

2. Pross C, Geissler A, Busse R. Measuring, Reporting, and Rewarding Quality of Care in 5 Nations: 5 Policy Levers to Enhance Hospital Quality Accountability. Milbank Q 2017;95(1):136–183. doi: 10.1111/1468-0009.12248

3. Quentin W, Partanen V-M, Brownwood I, Klazinga N. Measuring healthcare quality. Improv Healthc Qual Eur Charact Eff Implement Differ Strateg Internet European Observatory on Health Systems and Policies; 2019. Available from: https://www.ncbi.nlm.nih.gov/books/NBK549260/ [accessed Mar 5, 2024]

4. American Hospital Association. Regulatory Overload: Assessing the Regulatory Burden on Health Systems, Hospitals and Post-acute Care Providers. American Hospital Association; 2017 Oct p. 1–33. Available from: https://www.aha.org/system/files/2018-02/regulatory-overload-report.pdf

5. Saraswathula A, Merck SJ, Bai G, Weston CM, Skinner EA, Taylor A, Kachalia A, Demski R, Wu AW, Berry SA. The Volume and Cost of Quality Metric Reporting. JAMA 2023 Jun 6;329(21):1840–1847. PMID:37278813

6. Rabiei R, Almasi S. Requirements and challenges of hospital dashboards: a systematic literature review. BMC Med Inform Decis Mak 2022 Nov 8;22:287. PMID:36348339

7. Khairat SS, Dukkipati A, Lauria HA, Bice T, Travers D, Carson SS. The Impact of Visualization Dashboards on Quality of Care and Clinician Satisfaction: Integrative Literature Review. JMIR Hum Factors 2018 May 31;5(2):e22. PMID:29853440

8. Dowding D, Randell R, Gardner P, Fitzpatrick G, Dykes P, Favela J, Hamer S, Whitewood-Moores Z, Hardiker N, Borycki E, Currie L. Dashboards for improving patient care: review of the literature. Int J Med Inf 2015 Feb;84(2):87–100. PMID:25453274

9. Randell R, Alvarado N, McVey L, Ruddle RA, Doherty P, Gale C, Mamas M, Dowding D. Requirements for a quality dashboard: Lessons from National Clinical Audits. AMIA Annu Symp Proc 2020 Mar 4;2019:735–744. PMID:32308869

10. Xie CX, Chen Q, Hincapié CA, Hofstetter L, Maher CG, Machado GC. Effectiveness of clinical dashboards as audit and feedback or clinical decision support tools on medication use and test ordering: a systematic review of randomized controlled trials. J Am Med Inform Assoc 2022 Oct 1;29(10):1773–1785. doi: 10.1093/jamia/ocac094

11. Baan FC van de, Lambregts S, Bergman E, Most J, Westra D. Involving Health Professionals in the Development of Quality and Safety Dashboards: Qualitative Study. J Med Internet Res 2023 Jun 12;25(1):e42649. doi: 10.2196/42649

12. Kuznetsova M, Frits ML, Dulgarian S, Iannaccone C, Mort E, Bates DW, Salmasian H. An analysis of the structure and content of dashboards used to monitor patient safety in the inpatient setting. JAMIA Open 2021 Oct 1;4(4):ooab096. doi: 10.1093/jamiaopen/ooab096

13. Vazquez-Ingelmo A, Garcia-Penalvo FJ, Theron R. Information Dashboards and Tailoring Capabilities - A Systematic Literature Review. IEEE Access 2019;7:109673–109688. doi: 10.1109/ACCESS.2019.2933472

14. Barnum TJ, Vaez K, Cesarone D, Contributors CTYOJ of NI. Your Data Looks Good on a Dashboard | HIMSS. 2019. Available from: https://www.himss.org/resources/your-data-looks-good-dashboard [accessed Jan 15, 2024]

15. Shenvi E, Boxwala A, Sittig D, Zott C, Lomotan E, Swiger J, Dullabh P. Visualization of Patient-Generated Health Data: A Scoping Review of Dashboard Designs. Appl Clin Inform 2023 Oct;14(5):913–922. PMID:37704021

16. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol Routledge; 2005 Feb 1;8(1):19–32. doi: 10.1080/1364557032000119616

17. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci IS 2010 Sep 20;5:69. PMID:20854677

18. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MDJ, Horsley T, Weeks L, Hempel S, Akl EA, Chang C, McGowan J, Stewart L, Hartling L, Aldcroft A, Wilson MG, Garritty C, Lewin S, Godfrey CM, Macdonald MT, Langlois EV, Soares-Weiser K, Moriarty J, Clifford T, Tunçalp Ö, Straus SE. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med 2018 Oct 2;169(7):467–473. PMID:30178033

19. Helminski D, Kurlander JE, Renji AD, Sussman JB, Pfeiffer PN, Conte ML, Gadabu OJ, Kokaly AN, Goldberg R, Ranusch A, Damschroder LJ, Landis-Lewis Z. Dashboards in Health Care Settings: Protocol for a Scoping Review. JMIR Res Protoc 2022 Mar 2;11(3):e34894. doi: 10.2196/34894

20. Allen NA, Zagarins S, Welch G. Reducing Social Distress for Chronic Disease Patients in Primary Care: An Intervention for Latino Type 2 Diabetes Patients Seen at Community Health Centers. Diabetes Spectr Publ Am Diabetes Assoc United States; 2017;30(4):288–296. doi: 10.2337/ds16-0031

21. Alnosayan N, Chatterjee S, Alluhaidan A, Lee E, Houston Feenstra L. Design and Usability of a Heart Failure mHealth System: A Pilot Study. JMIR Hum Factors Canada; 2017;4(1):e9. doi: 10.2196/humanfactors.6481

22. Anand V, Cave D, McCrady H, Al-Aklabi M, Ross DB, Rebeyka IM, Adatia I. The development of a congenital heart programme quality dashboard to promote transparent reporting of outcomes. Cardiol Young England; 2015;25(8):1579–83. doi: 10.1017/S1047951115002085

23. Anderson BJ, Do D, Chivers C, Choi K, Gitelman Y, Mehta SJ, Panchandam V, Gudowski S, Pierce M, Cereda M, Christie JD, Schweickert WD, Gabrielli A, Huffenberger A, Draugelis M, Fuchs BD. Clinical Impact of an Electronic Dashboard and Alert System for Sedation Minimization and Ventilator Liberation: A Before-After Study. Crit Care Explor United States; 2019;1(10):e0057. doi: 10.1097/CCE.0000000000000057

24. Anderson D, Zlateva I, Khatri K, Ciaburri N. Using health information technology to improve adherence to opioid prescribing guidelines in primary care. Clin J Pain United States; 2015;31(6):573–9. doi: 10.1097/AJP.0000000000000177

25. Azad TD, Kalani M, Wolf T, Kearney A, Lee Y, Flannery L, Chen D, Berroya R, Eisenberg M, Park J, Shuer L, Kerr A, Ratliff JK. Building an electronic health record integrated quality of life outcomes registry for spine surgery. J Neurosurg Spine United States; 2016;24(1):176–85. doi: 10.3171/2015.3.SPINE141127

26. Banerjee D, Thompson C, Kell C, Shetty R, Vetteth Y, Grossman H, DiBiase A, Fowler M. An informatics-based approach to reducing heart failure all-cause readmissions: the Stanford heart failure dashboard. J Am Med Inform Assoc JAMIA England; 2017;24(3):550–555. doi: 10.1093/jamia/ocw150

27. Barbeito A, Segall N. Development and usability testing of an audit and feedback tool for anesthesiologists. JAMIA Open United States; 2019;2(1):29–34. doi: 10.1093/jamiaopen/ooy054

28. Bauer AM, Iles-Shih M, Ghomi RH, Rue T, Grover T, Kincler N, Miller M, Katon WJ. Acceptability of mHealth augmentation of Collaborative Care: A mixed methods pilot study. Gen Hosp Psychiatry United States; 2018;51(fnk, 7905527):22–29. doi: 10.1016/j.genhosppsych.2017.11.010

29. Bersani K, Fuller TE, Garabedian P, Espares J, Mlaver E, Businger A, Chang F, Boxer RB, Schnock KO, Rozenblum R, Dykes PC, Dalal AK, Benneyan JC, Lehmann LS, Gershanik EF, Bates DW, Schnipper JL. Use, Perceived Usability, and Barriers to Implementation of a Patient Safety Dashboard Integrated within a Vendor EHR. Appl Clin Inform Germany; 2020;11(1):34–45. doi: 10.1055/s-0039-3402756

30. Birdas TJ, Rozycki GF, Dunnington GL, Stevens L, Liali V, Schmidt CM. “Show Me the Data”: A Recipe for Quality Improvement Success in an Academic Surgical Department. J Am Coll Surg United States; 2019;228(4):368–373. doi: 10.1016/j.jamcollsurg.2018.12.013

31. Brenn BR, Kim MA, Hilmas E. Development of a computerized monitoring program to identify narcotic diversion in a pediatric anesthesia practice. Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm England; 2015;72(16):1365–72. doi: 10.2146/ajhp140691

32. Burningham Z, Jackson G, Kelleher J, Stevens M, Morris I, Cohen J, Maloney G, Vaughan C. The Enhancing Quality of Prescribing Practices for Older Veterans Discharged From the Emergency Department (EQUIPPED) Potentially Inappropriate Medication

Dashboard: a Suitable Alternative to the In-Person Academic Detailing and Standardized Feedback Rep. 2020; doi: 10.1016/j.clinthera.2020.02.013

33. Burns JL, Hasting D, Gichoya JW, McKibben B 3rd, Shea L, Frank M. Just in Time Radiology Decision Support Using Real-time Data Feeds. J Digit Imaging United States; 2020;33(1):137–142. doi: 10.1007/s10278-019-00268-2

34. Chaparro JD, Hussain C, Lee JA, Hehmeyer J, Nguyen M, Hoffman J. Reducing Interruptive Alert Burden Using Quality Improvement Methodology. Appl Clin Inform Germany; 2020;11(1):46–58. doi: 10.1055/s-0039-3402757

35. Choi HH, Clark J, Jay AK, Filice RW. Minimizing Barriers in Learning for On-Call Radiology Residents-End-to-End Web-Based Resident Feedback System. J Digit Imaging 2018;31(1):117–123. doi: 10.1007/s10278-017-0015-1

36. Chua P, Hill-Kayser C, Ahumada LM, Jalal A, Simpao AF, Lingappan AM, Jawad A, Rehman MA, Galvez JA. Visual analytics dashboard to explore the relationship of unscheduled treatment interruptions and variations in airway management for children undergoing external beam radiation therapy. Pract Radiat Oncol United States; 2017;7(5):e339–e344. doi: 10.1016/j.prro.2017.01.008

37. Connor JP, Raife T, Medow JE, Ehlenfeldt BD, Sipsma K. The blood utilization calculator, a target-based electronic decision support algorithm, increases the use of single-unit transfusions in a large academic medical center. Transfusion (Paris) United States; 2018;58(7):1689–1696. doi: 10.1111/trf.14637

38. Cox ZL, Lewis CM, Lai P, Lenihan DJ. Validation of an automated electronic algorithm and “dashboard” to identify and characterize decompensated heart failure admissions across a medical center. Am Heart J United States; 2017;183(0370465):40–48. doi: 10.1016/j.ahj.2016.10.001

39. Cravero JP, Sriswasdi P, Lekowski R, Carpino E, Blum R, Askins N, Zurakowski D, Sinnott S. Creation of an integrated outcome database for pediatric anesthesia. Paediatr Anaesth France; 2016;26(4):345–55. doi: 10.1111/pan.12857

40. Desantis D, Baverstock RJ, Civitarese A, Crump RT, Carlson KV. A clinical perspective on electronically collecting patient-reported outcomes at the point-of-care for overactive bladder. Can Urol Assoc J J Assoc Urol Can Canada; 2016;10(11–12):E359–E366.

41. Dickson RL, Sumathipala D, Reeves J. Stop Stroke© Acute Care Coordination Medical Application: A Brief Report on Postimplementation Performance at a Primary Stroke Center. J Stroke Cerebrovasc Dis Off J Natl Stroke Assoc United States; 2016;25(5):1275–1279. doi: 10.1016/j.jstrokecerebrovasdis.2015.12.001

42. Dixit RA, Hurst S, Adams KT, Boxley C, Lysen-Hendershot K, Bennett SS, Booker E, Ratwani RM. Case Report: Rapid Development of Visualization Dashboards to Enhance Situation Awareness of COVID-19 Telehealth Initiatives at a Multi-Hospital Healthcare System. J Am Med Inform Assoc JAMIA England; 2020;(b92, 9430800). doi:

10.1093/jamia/ocaa161

43. Dixon BE, Alzeer AH, Phillips EO, Marrero DG. Integration of Provider, Pharmacy, and Patient-Reported Data to Improve Medication Adherence for Type 2 Diabetes: A Controlled Before-After Pilot Study. JMIR Med Inform Canada; 2016;4(1):e4. doi: 10.2196/medinform.4739

44. Dolan JE, Lonsdale H, Ahumada LM, Patel A, Samuel J, Jalali A, Peck J, DeRosa JC, Rehman M, Varughese AM, Fernandez AM. Quality Initiative Using Theory of Change and Visual Analytics to Improve Controlled Substance Documentation Discrepancies in the Operating Room. Appl Clin Inform Germany; 2019;10(3):543–551. doi: 10.1055/s-0039-1693688

45. Ducatman AM, Tacker DH, Ducatman BS, Long D, Perrotta PL, Lawther H, Pennington K, Lander O, Warden M, Failinger C, Halbritter K, Pellegrino R, Treese M, Stead JA, Glass E, Cianciaruso L, Nau KC. Quality Improvement Intervention for Reduction of Redundant Testing. Acad Pathol United States; 2017;4(101698648):2374289517707506. doi: 10.1177/2374289517707506

46. Duckworth M, Leung E, Fuller T, Espares J, Couture B, Chang F, Businger AC, Collins S, Dalal A, Fladger A, Schnipper JL, Schnock KO, Bates DW, Dykes PC. Nurse, Patient, and Care Partner Perceptions of a Personalized Safety Plan Screensaver. J Gerontol Nurs United States; 2017;43(4):15–22. doi: 10.3928/00989134-20170313-05

47. Durojaiye AB, Snyder E, Cohen M, Nagy P, Hong K, Johnson PT. Radiology Resident Assessment and Feedback Dashboard. Radiogr Rev Publ Radiol Soc N Am Inc United States; 2018;38(5):1443–1453. doi: 10.1148/rg.2018170117

48. Elm JJ, Daeschler M, Bataille L, Schneider R, Amara A, Espay AJ, Afek M, Admati C, Teklehaimanot A, Simuni T. Feasibility and utility of a clinician dashboard from wearable and mobile application Parkinson's disease data. NPJ Digit Med England; 2019;2(101731738):95. doi: 10.1038/s41746-019-0169-y

49. Field M, Fong K, Shade C. Use of Electronic Visibility Boards to Improve Patient Care Quality, Safety, and Flow on Inpatient Pediatric Acute Care Units. J Pediatr Nurs 2018;41:69–76. doi: 10.1016/j.pedn.2018.01.015

50. Fischer MJ, Kourany WM, Sovern K, Forrester K, Griffin C, Lightner N, Loftus S, Murphy K, Roth G, Palevsky PM, Crowley ST. Development, implementation and user experience of the Veterans Health Administration (VHA) dialysis dashboard. BMC Nephrol England; 2020;21(1):136. doi: 10.1186/s12882-020-01798-6

51. Fletcher G.S., Aaronson B.A., White A.A., Julka R. Effect of a Real-Time Electronic Dashboard on a Rapid Response System. J Med Syst 2018;42(1). doi: 10.1007/s10916-017-0858-5

52. Fortuna KL, Storm M, Aschbrenner KA, Bartels SJ. Integration of Peer Philosophy into a Standardized Self-Management Mobile Health Intervention. Psychiatr Q United States;

2018;89(4):795–800. doi: 10.1007/s11126-018-9578-3

53. Fox LA, Walsh KE, Schainker EG. The Creation of a Pediatric Hospital Medicine Dashboard: Performance Assessment for Improvement. Hosp Pediatr United States; 2016;6(7):412–9. doi: 10.1542/hpeds.2015-0222

54. Franklin A, Gantela S, Shifarraw S, Johnson TR, Robinson DJ, King BR, Mehta AM, Maddow CL, Hoot NR, Nguyen V, Rubio A, Zhang J, Okafor NG. Dashboard visualizations: Supporting real-time throughput decision-making. J Biomed Inform United States; 2017;71(100970413, d2m):211–221. doi: 10.1016/j.jbi.2017.05.024

55. Frymoyer A, Schwenk HT, Zorn Y, Bio L, Moss JD, Chasmawala B, Faulkenberry J, Goswami S, Keizer RJ, Ghaskari S. Model-Informed Precision Dosing of Vancomycin in Hospitalized Children: Implementation and Adoption at an Academic Children's Hospital. Front Pharmacol Switzerland; 2020;11(101548923):551. doi: 10.3389/fphar.2020.00551

56. Fuller TE, Garabedian PM, Lemonias DP, Joyce E, Schnipper JL, Harry EM, Bates DW, Dalal AK, Benneyan JC. Assessing the cognitive and work load of an inpatient safety dashboard in the context of opioid management. Appl Ergon England; 2020;85(cyz, 0261412):103047. doi: 10.1016/j.apergo.2020.103047

57. Fuller TE, Pong DD, Piniella N, Pardo M, Bessa N, Yoon C, Boxer RB, Schnipper JL, Dalal AK. Interactive Digital Health Tools to Engage Patients and Caregivers in Discharge Preparation: Implementation Study. J Med Internet Res Canada; 2020;22(4):e15573. doi: 10.2196/15573

58. Gardner LA, Bray PJ, Finley E, Sterner C, Ignudo TL 3rd, Stauffer CL, Kincaid SA, Marella WM. Standardizing Falls Reporting: Using Data From Adverse Event Reporting to Drive Quality Improvement. J Patient Saf United States; 2019;15(2):135–142. doi: 10.1097/PTS.0000000000000204

59. Gomez AT, Quinn JG, Doiron DJ, Watson S, Crocker BD, Cheng CK-W. Implementation of a novel real-time platelet inventory management system at a multi-site transfusion service. Transfusion (Paris) United States; 2015;55(9):2070–5. doi: 10.1111/trf.13081

60. Graber CJ, Jones MM, Glassman PA, Weir C, Butler J, Nechodom K, Kay CL, Furman AE, Tran TT, Foltz C, Pollack LA, Samore MH, Goetz MB. Taking an Antibiotic Time-out: Utilization and Usability of a Self-Stewardship Time-out Program for Renewal of Vancomycin and Piperacillin-Tazobactam. Hosp Pharm United States; 2015;50(11):1011–24. doi: 10.1310/hpj5011-1011

61. Graber CJ, Jones MM, Goetz MB, Madaras-Kelly K, Zhang Y, Butler JM, Weir C, Chou AF, Youn SY, Samore MH, Glassman PA. Decreases in antimicrobial use associated with multihospital implementation of electronic antimicrobial stewardship tools. Clin Infect Dis Off Publ Infect Dis Soc Am United States; 2019;(a4j, 9203213). doi: 10.1093/cid/ciz941

62. Grange ES, Neil EJ, Stoffel M, Singh AP, Tseng E, Resco-Summers K, Fellner BJ, Lynch JB, Mathias PC, Mauritz-Miller K, Sutton PR, Leu MG. Responding to COVID-19: The

UW Medicine Information Technology Services Experience. Appl Clin Inform Germany; 2020;11(2):265–275. doi: 10.1055/s-0040-1709715

63. Guo U, Chen L, Mehta PH. Electronic health record innovations: Helping physicians - One less click at a time. Health Inf Manag J Health Inf Manag Assoc Aust Australia; 2017;46(3):140–144. doi: 10.1177/1833358316689481

64. Hagaman DH, Ehrenfeld JM, Terekhov M, Kla KM, Hamm J, Brumley M, Wanderer JP. Compliance Is Contagious: Using Informatics Methods to Measure the Spread of a Documentation Standard From a Preoperative Clinic. J Perianesthesia Nurs Off J Am Soc PeriAnesthesia Nurses United States; 2018;33(4):436–443. doi: 10.1016/j.jopan.2016.08.016

65. Halwani F, Li WC, Banerjee D, Lessard L, Amyot D, Michalowski W, Giffen R. A real-time dashboard for managing pathology processes. J Pathol Inform India; 2016;7(101528849):24. doi: 10.4103/2153-3539.181768

66. Harris AHS, Brown R, Dawes M, Dieperink E, Myrick DH, Gerould H, Wagner TH, Wisdom JP, Hagedorn HJ. Effects of a multifaceted implementation intervention to increase utilization of pharmacological treatments for alcohol use disorders in the US Veterans Health Administration. J Subst Abuse Treat United States; 2017;82(kai, 8500909):107–112. doi: 10.1016/j.jsat.2017.09.002

67. Hartzler AL, Izard JP, Dalkin BL, Mikles SP, Gore JL. Design and feasibility of integrating personalized PRO dashboards into prostate cancer care. J Am Med Inform Assoc JAMIA England; 2016;23(1):38–47. doi: 10.1093/jamia/ocv101

68. Harzand A, Witbrodt B, Davis-Watts ML, Alrohaibani A, Goese D, Wenger NK, Shah AJ, Zafari AM. Feasibility of a Smartphone-enabled Cardiac Rehabilitation Program in Male Veterans With Previous Clinical Evidence of Coronary Heart Disease. Am J Cardiol United States; 2018;122(9):1471–1476. doi: 10.1016/j.amjcard.2018.07.028

69. Heaton HA, Russi CS, Monroe RJ, Thompson KM, Koch KA. Telehealth dashboard: leverage reporting functionality to increase awareness of high-acuity emergency department patients across an enterprise practice. BMJ Health Care Inform England; 2019;26(1). doi: 10.1136/bmjhci-2019-100093

70. Hebert C, Flaherty J, Smyer J, Ding J, Mangino JE. Development and validation of an automated ventilator-associated event electronic surveillance system: A report of a successful implementation. Am J Infect Control United States; 2018;46(3):316–321. doi: 10.1016/j.ajic.2017.09.006

71. Herzke CA, Michtalik HJ, Durkin N, Finkelstein J, Deutschendorf A, Miller J, Leung C, Brotman DJ. A Method for Attributing Patient-Level Metrics to Rotating Providers in an Inpatient Setting. J Hosp Med United States; 2018;13(7):470–475. doi: 10.12788/jhm.2897

72. Hester G, Lang T, Madsen L, Tambyraja R, Zenker P. Timely Data for Targeted Quality

Improvement Interventions: Use of a Visual Analytics Dashboard for Bronchiolitis. Appl Clin Inform Germany; 2019;10(1):168–174. doi: 10.1055/s-0039-1679868

73. Hu PF, Yang S, Li H-C, Stansbury LG, Yang F, Hagegeorge G, Miller C, Rock P, Stein DM, Mackenzie CF. Reliable Collection of Real-Time Patient Physiologic Data from less Reliable Networks: a “Monitor of Monitors” System (MoMs). J Med Syst United States; 2017;41(1):3.

74. Huber TC, Krishnaraj A, Monaghan D, Gaskin CM. Developing an Interactive Data Visualization Tool to Assess the Impact of Decision Support on Clinical Operations. J Digit Imaging United States; 2018;31(5):640–645. doi: 10.1007/s10278-018-0065-z

75. Hyman D, Neiman J, Rannie M, Allen R, Swietlik M, Balzer A. Innovative Use of the Electronic Health Record to Support Harm Reduction Efforts. Pediatrics United States; 2017;139(5). doi: 10.1542/peds.2015-3410

76. Jaimini U, Thirunarayan K, Kalra M, Venkataraman R, Kadariya D, Sheth A. “How Is My Child’s Asthma?” Digital Phenotype and Actionable Insights for Pediatric Asthma. JMIR Pediatr Parent Canada; 2018;1(2):e11988. doi: 10.2196/11988

77. Joshi D, Tanner A. CREATING PEDIATRIC SPECIALTY AMBULATORY CARE DASHBOARDS. Physician Leadersh J United States; 2016;3(6):46–48.

78. Jung AD, Baker J, Droege CA, Nomellini V, Johannigman J, Holcomb JB, Goodman MD, Pritts TA. Sooner is better: use of a real-time automated bedside dashboard improves sepsis care. J Surg Res United States; 2018;231(k7b, 0376340):373–379. doi: 10.1016/j.jss.2018.05.078

79. Kannan V., Fish J.S., Mutz J.M., Carrington A.R., Lai K., Davis L.S., Youngblood J.E., Rauschuber M.R., Flores K.A., Sara E.J., Bhat D.G., Willett D.L. Rapid Development of Specialty Population Registries and Quality Measures from Electronic Health Record Data. Methods Inf Med 2017;56(S 01):e74–e83. doi: 10.3414/ME16-02-0031

80. Karralli R, Tipton J, Dumitru D, Scholz L, Masilamani S. Development of a metrics dashboard for monitoring involvement in the 340B Drug Pricing Program. Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm England; 2015;72(17):1489–95. doi: 10.2146/ajhp140567

81. Khanna N, Gritzer L, Klyushnenkova E, Montgomery R, Dark M, Shah S, Shaya F. Practice Transformation Analytics Dashboard for Clinician Engagement. Ann Fam Med United States; 2019;17(Suppl 1):S73–S76. doi: 10.1370/afm.2382

82. Kinney A, Bui Q, Hodding J, Le J. Pharmacy Dashboard: An Innovative Process for Pharmacy Workload and Productivity. Hosp Pharm United States; 2017;52(3):198–206. doi: 10.1310/hpj5203-198

83. Kumar D, Tully LM, Iosif A-M, Zakskorn LN, Nye KE, Zia A, Niendam TA. A Mobile Health Platform for Clinical Monitoring in Early Psychosis: Implementation in

Community-Based Outpatient Early Psychosis Care. JMIR Ment Health Canada; 2018;5(1):e15. doi: 10.2196/mental.8551

84. Kummer BR, Willey JZ, Zelenetz MJ, Hu Y, Sengupta S, Elkind MSV, Hripcsak G. Neurological Dashboards and Consultation Turnaround Time at an Academic Medical Center. Appl Clin Inform Germany; 2019;10(5):849–858. doi: 10.1055/s-0039-1698465

85. Kunjan K, Doebbeling B, Toscos T. Dashboards to Support Operational Decision Making in Health Centers: A Case for Role-Specific Design. Int J Hum-Comput Interact 2019;35(9):742–750. doi: 10.1080/10447318.2018.1488418

86. Kurtzman G, Dine J, Epstein A, Gitelman Y, Leri D, Patel MS, Ryskina K. Internal Medicine Resident Engagement with a Laboratory Utilization Dashboard: Mixed Methods Study. J Hosp Med United States; 2017;12(9):743–746. doi: 10.12788/jhm.2811

87. Leu M.G., Austin E., Foti J.L., Hrachovec J., Popalisky J., Spencer S.M., OHare P., Migita D.S. A framework for evaluating value of new clinical recommendations. Hosp Pediatr 2016;6(10):578–586. doi: 10.1542/hpeds.2016-0009

88. Levin JC, Hron J. Automated Reporting of Trainee Metrics Using Electronic Clinical Systems. J Grad Med Educ United States; 2017;9(3):361–365. doi: 10.4300/JGME-D-16-00469.1

89. Lin LA, Bohnert ASB, Kerns RD, Clay MA, Ganoczy D, Ilgen MA. Impact of the Opioid Safety Initiative on opioid-related prescribing in veterans. Pain United States; 2017;158(5):833–839. doi: 10.1097/j.pain.0000000000000837

90. Martin CK, Gilmore LA, Apolzan JW, Myers CA, Thomas DM, Redman LM. Smartloss: A Personalized Mobile Health Intervention for Weight Management and Health Promotion. JMIR MHealth UHealth Canada; 2016;4(1):e18. doi: 10.2196/mhealth.5027

91. Martinez DA, Kane EM, Jalalpour M, Scheulen J, Rupani H, Toteja R, Barbara C, Bush B, Levin SR. An Electronic Dashboard to Monitor Patient Flow at the Johns Hopkins Hospital: Communication of Key Performance Indicators Using the Donabedian Model. J Med Syst United States; 2018;42(8):133. doi: 10.1007/s10916-018-0988-4

92. Mattingly WA, Kelley RR, Wiemken TL, Chariker JH, Peyrani P, Guinn BE, Binford LE, Buckner K, Ramirez J. Real-Time Enrollment Dashboard For Multisite Clinical Trials. Contemp Clin Trials Commun Netherlands; 2015;1(101671157):17–21.

93. McBain KL, Payne ET, Sharma R, Frndova H, Abend NS, Sanchez SM, Gallentine WB, Cornett KM, Nash KB, Snead OC, Parshuram CS, Hutchison JS, Hahn CD. Strategies to Maximize Enrollment in a Prospective Study of Comatose Children in the PICU. Pediatr Crit Care Med J Soc Crit Care Med World Fed Pediatr Intensive Crit Care Soc United States; 2016;17(3):246–50. doi: 10.1097/PCC.0000000000000642

94. McGough P., Kline S., Simpson L. Team care approach to population health and care management. Int J Health Gov 2017;22(2):93–103. doi: 10.1108/IJHG-11-2016-0048

95. Michtalik HJ, Carolan HT, Haut ER, Lau BD, Streiff MB, Finkelstein J, Pronovost PJ, Durkin N, Brotman DJ. Use of provider-level dashboards and pay-for-performance in venous thromboembolism prophylaxis. J Hosp Med United States; 2015;10(3):172–8. doi: 10.1002/jhm.2303

96. Mlaver E, Schnipper JL, Boxer RB, Breuer DJ, Gershanik EF, Dykes PC, Massaro AF, Benneyan J, Bates DW, Lehmann LS. User-Centered Collaborative Design and Development of an Inpatient Safety Dashboard. Jt Comm J Qual Patient Saf Netherlands; 2017;43(12):676–685. doi: 10.1016/j.jcjq.2017.05.010

97. Mooney K., Whisenant M.S., Beck S.L. Symptom Care at Home: A Comprehensive and Pragmatic PRO System Approach to Improve Cancer Symptom Care. Med Care 2019;57((Mooney K., kathi.mooney@nurs.utah.edu) Huntsman Cancer Institute, University of Utah, 10 South 2000 East, Salt Lake City, UT, United States(Whisenant M.S.) Department of Symptom Research, University of Texas, MD Anderson Cancer Center, Houston, TX, Unite):S66–S72. doi: 10.1097/MLR.0000000000001037

98. Mottes TA, Goldstein SL, Basu RK. Process based quality improvement using a continuous renal replacement therapy dashboard. BMC Nephrol England; 2019;20(1):17. doi: 10.1186/s12882-018-1195-8

99. Mulhall CL, Lam JMC, Rich PS, Dobell LG, Greenberg A. Enhancing Quality Care in Ontario Long-Term Care Homes Through Audit and Feedback for Physicians. J Am Med Dir Assoc United States; 2020;21(3):420–425. doi: 10.1016/j.jamda.2019.11.017

100. Naville-Cook C., Rhea L., Triboletti M., White C. Analyzing the Clinical Outcomes of a Rapid Mass Conversion from Rosuvastatin to Atorvastatin in a VA Medical Center Outpatient Setting. J Pharm Technol 2017;33(5):189–194. doi: 10.1177/8755122517719545

101. Nelson O, Sturgis B, Gilbert K, Henry E, Clegg K, Tan JM, Wasey JO, Simpao AF, Galvez JA. A Visual Analytics Dashboard to Summarize Serial Anesthesia Records in Pediatric Radiation Treatment. Appl Clin Inform Germany; 2019;10(4):563–569. doi: 10.1055/s-0039-1693712

102. Newberry C, Saha A, Siddique SM, Metz DC, Domenico C, Choi K, Gitelman E, Mehta S. A Novel Clinical Decision Support System for Gastrointestinal Bleeding Risk Stratification in the Critically Ill. Jt Comm J Qual Patient Saf Netherlands; 2019;45(6):440–445. doi: 10.1016/j.jcjq.2019.01.001

103. Ni Y, Bermudez M, Kennebeck S, Liddy-Hicks S, Dexheimer J. A Real-Time Automated Patient Screening System for Clinical Trials Eligibility in an Emergency Department: Design and Evaluation. JMIR Med Inform Canada; 2019;7(3):e14185. doi: 10.2196/14185

104. Niendam TA, Tully LM, Iosif A-M, Kumar D, Nye KE, Denton JC, Zakskorn LN, Fedechko TL, Pierce KM. Enhancing early psychosis treatment using smartphone technology: A longitudinal feasibility and validity study. J Psychiatr Res England; 2018;96(jtj, 0376331):239–246. doi: 10.1016/j.jpsychires.2017.10.017

105. Nowalk MP, Lin CJ, Pavlik VN, Brown AE, Zhang S, Moehling KK, Raviotta JM, South-Paul JE, Hawk M, Ricci EM, Middleton DB, Patel SA, Ahmed F, Zimmerman RK. Using the 4 Pillars TM Practice Transformation Program to increase adult Tdap immunization in a randomized controlled cluster trial. Vaccine Netherlands; 2016;34(41):5026–5033. doi: 10.1016/j.vaccine.2016.07.053

106. O'Reilly-Shah VN, Easton GS, Jabaley CS, Lynde GC. Variable effectiveness of stepwise implementation of nudge-type interventions to improve provider compliance with intraoperative low tidal volume ventilation. BMJ Qual Saf England; 2018;27(12):1008–1018. doi: 10.1136/bmjqs-2017-007684

107. Offodile AC 2nd, Sen AP, Holtsmith S, Escalante J, Park A, Terrell J, Bassett R, Perrier ND. Harnessing Behavioral Economics Principles to Promote Better Surgeon Accountability for Operating Room Cost: A Prospective Study. J Am Coll Surg United States; 2020;230(4):585–593. doi: 10.1016/j.jamcollsurg.2019.12.013

108. Patel H, Morduchowicz S, Mourad M. Using a Systematic Framework of Interventions to Improve Early Discharges. Jt Comm J Qual Patient Saf Netherlands; 2017;43(4):189–196. doi: 10.1016/j.jcjq.2016.12.003

109. Patel MS, Kurtzman GW, Kannan S, Small DS, Morris A, Honeywell SJ, Leri D, Rareshide CAL, Day SC, Mahoney KB, Volpp KG, Asch DA. Effect of an Automated Patient Dashboard Using Active Choice and Peer Comparison Performance Feedback to Physicians on Statin Prescribing: The PRESCRIBE Cluster Randomized Clinical Trial. JAMA Netw Open United States; 2018;1(3):e180818. doi: 10.1001/jamanetworkopen.2018.0818

110. Patel S, Rajkomar A, Harrison JD, Prasad PA, Valencia V, Ranji SR, Mourad M. Next-generation audit and feedback for inpatient quality improvement using electronic health record data: a cluster randomised controlled trial. BMJ Qual Saf England; 2018;27(9):691–699. doi: 10.1136/bmjqs-2017-007393

111. Paulson SS, Dummett BA, Green J, Scruth E, Reyes V, Escobar GJ. What Do We Do After the Pilot Is Done? Implementation of a Hospital Early Warning System at Scale. Jt Comm J Qual Patient Saf Netherlands; 2020;46(4):207–216. doi: 10.1016/j.jcjq.2020.01.003

112. Perron C.E., Bachur R.G., Stack A.M. Development, Implementation, and Use of an Emergency Physician Performance Dashboard. Clin Pediatr Emerg Med 2017;18(2):115–123. doi: 10.1016/j.cpem.2017.04.004

113. Pickering BW, Dong Y, Ahmed A, Giri J, Kilickaya O, Gupta A, Gajic O, Herasevich V. The implementation of clinician designed, human-centered electronic medical record viewer in the intensive care unit: a pilot step-wedge cluster randomized trial. Int J Med Inf Ireland; 2015;84(5):299–307. doi: 10.1016/j.ijmedinf.2015.01.017

114. Ratwani RM, Fong A. "Connecting the dots": leveraging visual analytics to make sense of patient safety event reports. J Am Med Inform Assoc JAMIA England; 2015;22(2):312–7. doi: 10.1136/amiajnl-2014-002963

115. Reback CJ, Runger D, Fletcher JB, Swendeman D. Ecological momentary assessments for self-monitoring and counseling to optimize methamphetamine treatment and sexual risk reduction outcomes among gay and bisexual men. J Subst Abuse Treat United States; 2018;92(kai, 8500909):17–26. doi: 10.1016/j.jsat.2018.06.005

116. Reszel J, Dunn SI, Sprague AE, Graham ID, Grimshaw JM, Peterson WE, Ockenden H, Wilding J, Quosdorf A, Darling EK, Fell DB, Harrold J, Lanes A, Smith GN, Taljaard M, Weiss D, Walker MC. Use of a maternal newborn audit and feedback system in Ontario: a collective case study. BMJ Qual Saf England; 2019;28(8):635–644. doi: 10.1136/bmjqs-2018-008354

117. Robinson JR, Carter NH, Gibson C, Brinkman AS, Van Arendonk K, Speck KE, Danko ME, Jackson GP, Lovvorn HN 3rd, Blakely ML. Improving the value of care for appendectomy through an individual surgeon-specific approach. J Pediatr Surg United States; 2018;53(6):1181–1186. doi: 10.1016/j.jpedsurg.2018.02.081

118. Rocchio BJ. Achieving Cost Reduction Through Data Analytics. AORN J United States; 2016;104(4):320–325. doi: 10.1016/j.aorn.2016.07.010

119. Rogal SS, Chinman M, Gellad WF, Mor MK, Zhang H, McCarthy SA, Mauro GT, Hale JA, Lewis ET, Oliva EM, Trafton JA, Yakovchenko V, Gordon AJ, Hausmann LRM. Tracking implementation strategies in the randomized rollout of a Veterans Affairs national opioid risk management initiative. Implement Sci IS England; 2020;15(1):48. doi: 10.1186/s13012-020-01005-y

120. Romero-Brufau S, Kostandy P, Maass KL, Wutthisirisart P, Sir M, Bartholmai B, Stuve M, Pasupathy K. Development of data integration and visualization tools for the Department of Radiology to display operational and strategic metrics. AMIA Annu Symp Proc AMIA Symp United States; 2018;2018(101209213):942–951.

121. Rose AJ, Park A, Gillespie C, Van Deusen Lukas C, Ozonoff A, Petrakis BA, Reisman JI, Borzecki AM, Benedict AJ, Lukesh WN, Schmoke TJ, Jones EA, Morreale AP, Ourth HL, Schlosser JE, Mayo-Smith MF, Allen AL, Witt DM, Helfrich CD, McCullough MB. Results of a Regional Effort to Improve Warfarin Management. Ann Pharmacother 2017;51(5):373–379. doi: 10.1177/1060028016681030

122. Rostata-Pesola H, Olender L, Leon N, Aytaman A, Hoffman R, Pesola GR. Hepatitis C virus screening at a Veterans Administration Hospital in New York City. J Am Assoc Nurse Pract United States; 2020;(101600770). doi: 10.1097/JXX.0000000000000393

123. Ruff JC, Herndon JB, Horton RA, Lynch J, Mathwig DC, Leonard A, Aravamudhan K. Developing a caries risk registry to support caries risk assessment and management for children: A quality improvement initiative. J Public Health Dent United States; 2018;78(2):134–143. doi: 10.1111/jphd.12253

124. Ryskina K, Jessica Dine C, Gitelman Y, Leri D, Patel M, Kurtzman G, Lin LY, Epstein AJ. Effect of Social Comparison Feedback on Laboratory Test Ordering for Hospitalized Patients: A Randomized Controlled Trial. J Gen Intern Med United States;

2018;33(10):1639–1645. doi: 10.1007/s11606-018-4482-y

125. Schall MCJ, Cullen L, Pennathur P, Chen H, Burrell K, Matthews G. Usability Evaluation and Implementation of a Health Information Technology Dashboard of Evidence-Based Quality Indicators. Comput Inform Nurs CIN United States; 2017;35(6):281–288. doi: 10.1097/CIN.0000000000000325

126. Scheinfeld MH, Feltus W, DiMarco P, Rooney K, Goldman IA. The Emergency Radiology Dashboard: Facilitating Workflow With Realtime Data. Curr Probl Diagn Radiol United States; 2020;49(4):231–233. doi: 10.1067/j.cpradiol.2020.02.013

127. Schleyer TKL, Rahurkar S, Baublet AM, Kochmann M, Ning X, Martin DK, Finnell JT, Kelley KW, FHIR Development Team, Schaffer JT. Preliminary evaluation of the Chest Pain Dashboard, a FHIR-based approach for integrating health information exchange information directly into the clinical workflow. AMIA Jt Summits Transl Sci Proc AMIA Jt Summits Transl Sci United States; 2019;2019(101539486):656–664.

128. Shailam R, Botwin A, Stout M, Gee MS. Real-Time Electronic Dashboard Technology and Its Use to Improve Pediatric Radiology Workflow. Curr Probl Diagn Radiol United States; 2018;47(1):3–5. doi: 10.1067/j.cpradiol.2017.03.002

129. Shaw SJ, Jacobs B, Stockwell DC, Futterman C, Spaeder MC. Effect of a Real-Time Pediatric ICU Safety Bundle Dashboard on Quality Improvement Measures. Jt Comm J Qual Patient Saf Netherlands; 2015;41(9):414–20.

130. Simpao AF, Ahumada LM, Desai BR, Bonafide CP, Galvez JA, Rehman MA, Jawad AF, Palma KL, Shelov ED. Optimization of drug-drug interaction alert rules in a pediatric hospital's electronic health record system using a visual analytics dashboard. J Am Med Inform Assoc JAMIA England; 2015;22(2):361–9. doi: 10.1136/amiajnl-2013-002538

131. Sinvani L., Goldin M., Roofeh R., Idriss N., Goldman A., Klein Z., Mendelson D.A., Carney M.T. Implementation of Hip Fracture Co-Management Program (AGS CoCare: Ortho®) in a Large Health System. J Am Geriatr Soc 2020;((Sinvani L.; Goldin M.; Roofeh R.; Idriss N.) Division of Hospital Medicine, Department of Medicine, Northwell Health, Manhasset, NY, United States(Roofeh R.; Carney M.T., mcarney@northwell.edu) Division of Geriatrics and Palliative Medicine, Department o). doi: 10.1111/jgs.16483

132. Smalley CM, Willner MA, Muir MR, Meldon SW, Borden BL, Delgado FJ, Fertel BS. Electronic medical record-based interventions to encourage opioid prescribing best practices in the emergency department. Am J Emerg Med United States; 2019;(aa2, 8309942). doi: 10.1016/j.ajem.2019.158500

133. Smith AJF, Ahern SP, Shermock KM, Feller TT, Hill JD. Assessment of impact of daily huddles and visual displays on medication delivery timeliness in a large academic medical center. Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm England; 2020; (9503023, cbh). doi: 10.1093/ajhp/zxaa210

134. Smith CEP, Kamal AH, Kluger M, Coke P, Kelley MJ. National Trends in End-of-Life

Care for Veterans With Advanced Cancer in the Veterans Health Administration: 2009 to 2016. J Oncol Pract United States; 2019;15(6):e568–e575. doi: 10.1200/JOP.18.00559

135. Srivastava P, Verma A, Geronimo C, Button TM. Behavior stages of a physician- and coach-supported cloud-based diabetes prevention program for people with prediabetes. SAGE Open Med England; 2019;7(101624744):2050312119841986. doi: 10.1177/2050312119841986

136. Stachelek GC, McNutt T, Thompson CB, Smith K, DeWeese TL, Song DY. Improvements in Physician Clinical Workflow Measures After Implementation of a Dashboard Program. Pract Radiat Oncol United States; 2020;10(3):151–157. doi: 10.1016/j.prro.2019.11.014

137. Stevens J.S., Toma K., Tanzi-Pfeifer S., Rao M.K., Mohan S., Gharavi A.G., Radhakrishnan J. Dashboards to Facilitate Nephrology Disaster Planning in the COVID-19 Era. Kidney Int Rep 2020;((Stevens J.S., jss2275@cumc.columbia.edu; Toma K.; Rao M.K.; Mohan S.; Gharavi A.G.; Radhakrishnan J.) Department of Medicine, Division of Nephrology, Columbia University Irving Medical Center, New York, NY, United States(Stevens J.S., jss2275@cumc.columb). doi: 10.1016/j.ekir.2020.06.033

138. Swartz J, Koziatek C, Theobald J, Smith S, Iturrate E. Creation of a simple natural language processing tool to support an imaging utilization quality dashboard. Int J Med Inf Ireland; 2017;101(ct4, 9711057):93–99. doi: 10.1016/j.ijmedinf.2017.02.011

139. Taber DJ, Pilch NA, McGillicuddy JW, Mardis C, Treiber F, Fleming JN. Using informatics and mobile health to improve medication safety monitoring in kidney transplant recipients. Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm England; 2019;76(15):1143–1149. doi: 10.1093/ajhp/zxz115

140. Talbot TR, Carr D, Parmley CL, Martin BJ, Gray B, Ambrose A, Starmer J. Sustained Reduction of Ventilator-Associated Pneumonia Rates Using Real-Time Course Correction With a Ventilator Bundle Compliance Dashboard. Infect Control Hosp Epidemiol United States; 2015;36(11):1261–7. doi: 10.1017/ice.2015.180

141. Tan A, Durbin M, Chung FR, Rubin AL, Cuthel AM, McQuilkin JA, Modrek AS, Jamin C, Gavin N, Mann D, Swartz JL, Austrian JS, Testa PA, Hill JD, Grudzen CR, Group Authorship: Corita R. Grudzen on behalf of the PRIM-ER Clinical Informatics Advisory Board. Design and implementation of a clinical decision support tool for primary palliative Care for Emergency Medicine (PRIM-ER). BMC Med Inform Decis Mak England; 2020;20(1):13. doi: 10.1186/s12911-020-1021-7

142. Trinh LD, Roach EM, Vogan ED, Lam SW, Eggers GG. Impact of a quality-assessment dashboard on the comprehensive review of pharmacist performance. Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm England; 2017;74(17 Supplement 3):S75–S83. doi: 10.2146/ajhp160556

143. Trinh LD, Wong JT, Sullivan PA, Nguyen LH, Pham YT. Impact of a chemotherapy workload and productivity dashboard on pharmacy technician turnover. Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm England; 2019;76(13):992–997. doi:

10.1093/ajhp/zxz081

144. Twohig PA, Rivington JR, Gunzler D, Daprano J, Margolius D. Clinician dashboard views and improvement in preventative health outcome measures: a retrospective analysis. BMC Health Serv Res England; 2019;19(1):475. doi: 10.1186/s12913-019-4327-3

145. Tyler A, Krack P, Bakel LA, O'Hara K, Scudamore D, Topoz I, Freeman J, Moss A, Allen R, Swanson A, Bajaj L. Interventions to Reduce Over-Utilized Tests and Treatments in Bronchiolitis. Pediatrics United States; 2018;141(6). doi: 10.1542/peds.2017-0485

146. Umbreit A, Holm E, Gander K, Davis K, Dittrich K, Jandl V, Odell L, Sweeten P. Developing a dashboard for benchmarking the productivity of a medication therapy management program. J Am Pharm Assoc JAPhA United States; 2017;57(1):95-101.e1. doi: 10.1016/j.japh.2016.09.002

147. Van Citters AD, Gifford AH, Brady C, Dunitz JM, Elmhirst M, Flath J, Laguna TA, Moore B, Prickett ML, Riordan M, Savant AP, Gore W, Jian S, Soper M, Marshall BC, Nelson EC, Sabadosa KA. Formative evaluation of a dashboard to support coproduction of healthcare services in cystic fibrosis. J Cyst Fibros Off J Eur Cyst Fibros Soc Netherlands; 2020;(101128966). doi: 10.1016/j.jcf.2020.03.009

148. Wang EJ, Helgesen R, Johr CR, Lacko HS, Ashburn MA, Merkel PA. A Targeted Program in an Academic Rheumatology Practice to Improve Compliance with Opioid Prescribing Guidelines for the Treatment of Chronic Pain. Arthritis Care Res United States; 2020; (101518086). doi: 10.1002/acr.24354

149. Wang J, Liao J, Zhang J, Cheng W-Y, Hakenberg J, Ma M, Webb BD, Ramasamudram-Chakravarthi R, Karger L, Mehta L, Kornreich R, Diaz GA, Li S, Edelmann L, Chen R. ClinLabGeneticist: a tool for clinical management of genetic variants from whole exome sequencing in clinical genetic laboratories. Genome Med England; 2015;7(101475844):77. doi: 10.1186/s13073-015-0207-6

150. Wang K., Zwart C., Wellnitz C., Wu T., Li J. Integration of multiple health information systems for quality improvement of radiologic care. IISE Trans Healthc Syst Eng 2017;7(3):169–180. doi: 10.1080/24725579.2017.1329241

151. Weiss D, Dunn SI, Sprague AE, Fell DB, Grimshaw JM, Darling E, Graham ID, Harrold J, Smith GN, Peterson WE, Reszel J, Lanes A, Walker MC, Taljaard M. Effect of a population-level performance dashboard intervention on maternal-newborn outcomes: an interrupted time series study. BMJ Qual Saf England; 2018;27(6):425–436. doi: 10.1136/bmjqs-2017-007361

152. Welch G, Zagarins SE, Santiago-Kelly P, Rodriguez Z, Bursell S-E, Rosal MC, Gabbay RA. An internet-based diabetes management platform improves team care and outcomes in an urban Latino population. Diabetes Care United States; 2015;38(4):561–7. doi: 10.2337/dc14-1412

153. Woo JS, Suslow P, Thorsen R, Ma R, Bakhtary S, Moayeri M, Nambiar A. Development

and Implementation of Real-Time Web-Based Dashboards in a Multisite Transfusion Service. J Pathol Inform India; 2019;10(101528849):3. doi: 10.4103/jpi.jpi_36_18

154. Zahanova S, Tsouka A, Palmert MR, Mahmud FH. The iSCREEN Electronic Diabetes Dashboard: A Tool to Improve Knowledge and Implementation of Pediatric Clinical Practice Guidelines. Can J Diabetes Canada; 2017;41(6):603–612. doi: 10.1016/j.jcjd.2016.12.012

155. Hermans MPJ, Velders MA, Smeekes M, Drexhage OS, Hautvast RWM, Ytsma T, Schalij MJ, Umans VAWM. Call-to-balloon time dashboard in patients with ST-segment elevation myocardial infarction results in significant improvement in the logistic chain. EuroIntervention J Eur Collab Work Group Interv Cardiol Eur Soc Cardiol France; 2017;13(5):e564–e571. doi: 10.4244/EIJ-D-16-00124

156. Lee K, Jung SY, Hwang H, Yoo S, Baek HY, Baek R-M, Kim S. A novel concept for integrating and delivering health information using a comprehensive digital dashboard: An analysis of healthcare professionals' intention to adopt a new system and the trend of its real usage. Int J Med Inf Ireland; 2017;97(ct4, 9711057):98–108. doi: 10.1016/j.ijmedinf.2016.10.001

157. Matsumoto S, Koyama H, Nakahara I, Ishii A, Hatano T, Ohta T, Tanaka K, Ando M, Chihara H, Takita W, Tokunaga K, Hashikawa T, Funakoshi Y, Kamata T, Higashi E, Watanabe S, Kondo D, Tsujimoto A, Furuta K, Ishihara T, Hashimoto T, Koge J, Sonoda K, Torii T, Nakagaki H, Yamasaki R, Nagata I, Kira J-I. A Visual Task Management Application for Acute Ischemic Stroke Care. Front Neurol Switzerland; 2019;10(101546899):1118. doi: 10.3389/fneur.2019.01118

158. Schmidt T, Brabrand M, Lassen AT, Wiil UK. Design and Evaluation of a Patient Monitoring Dashboard for Emergency Departments. Stud Health Technol Inform Netherlands; 2019;264(ck1, 9214582):788–792. doi: 10.3233/SHTI190331

159. Smith H, Asfaw AG, Aung KM, Chikoti L, Mgawadere F, d'Aquino L, van den Broek N. Implementing the WHO integrated tool to assess quality of care for mothers, newborns and children: results and lessons learnt from five districts in Malawi. BMC Pregnancy Childbirth England; 2017;17(1):271. doi: 10.1186/s12884-017-1461-y

160. Staib A, Sullivan C, Jones M, Griffin B, Bell A, Scott I. The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. Emerg Med Australas EMA Australia; 2017;29(3):363–366. doi: 10.1111/1742-6723.12661

161. Ulaganathan S, Fatah T, Schmidt T, Nohr C. Utilization of a Novel Patient Monitoring Dashboard in Emergency Departments. Stud Health Technol Inform Netherlands; 2019;262(ck1, 9214582):260–263. doi: 10.3233/SHTI190068

162. Yoo J, Jung KY, Kim T, Lee T, Hwang SY, Yoon H, Shin TG, Sim MS, Jo IJ, Paeng H, Choi JS, Cha WC. A Real-Time Autonomous Dashboard for the Emergency Department: 5-Year Case Study. JMIR MHealth UHealth Canada; 2018;6(11):e10666. doi:

10.2196/10666

163. Begum T, Khan SM, Adamou B, Ferdous J, Parvez MM, Islam MS, Kumkum FA, Rahman A, Anwar I. Perceptions and experiences with district health information system software to collect and utilize health data in Bangladesh: a qualitative exploratory study. BMC Health Serv Res England; 2020;20(1):465. doi: 10.1186/s12913-020-05322-2

164. Kuipers DA, Wartena BO, Dijkstra BH, Terlouw G, van T Veer JTB, van Dijk HW, Prins JT, Pierie JPEN. iLift: A health behavior change support system for lifting and transfer techniques to prevent lower-back injuries in healthcare. Int J Med Inf Ireland; 2016;96(ct4, 9711057):11–23. doi: 10.1016/j.ijmedinf.2015.12.006

165. Patel MS, Rathi B, Tashfeen K, Yarubi MA. Development and Implementation of Maternity Dashboard in Regional Hospital for Quality Improvement at Ground Level: A Pilot Study. Oman Med J Oman; 2019;34(3):194–199. doi: 10.5001/omj.2019.38

166. Wahba K, Shah A, Hill K, Hosni MM. A Novel early pregnancy assessment unit/Gynaecology assessment unit dashboard: An experience from a UK district general hospital. J Obstet Gynaecol J Inst Obstet Gynaecol England; 2015;35(7):703–6. doi: 10.3109/01443615.2014.991296

167. Webers C, Beckers E, Boonen A, van Eijk-Hustings Y, Vonkeman H, van de Laar M, van Tubergen A. Development, usability and acceptability of an integrated eHealth system for spondyloarthritis in the Netherlands (SpA-Net). RMD Open England; 2019;5(1):e000860. doi: 10.1136/rmdopen-2018-000860

168. van Zijl FVWJ, Versnel S, van der Poel EF, Baatenburg de Jong RJ, Datema FR. Use of Routine Prospective Functional and Aesthetic Patient Satisfaction Measurements in Secondary Cleft Lip Rhinoplasty. JAMA Facial Plast Surg United States; 2018;20(6):488–494. doi: 10.1001/jamafacial.2018.0876

169. Stranne J, Axen E, Franck-Lissbrant I, Fransson P, Franlund M, Hugosson J, Khatami A, Koss-Modig K, Lodding P, Nyberg M, Stattin P, Bratt O. Single institution followed by national implementation of systematic surgical quality control and feedback for radical prostatectomy: a 20-year journey. World J Urol Germany; 2020;38(6):1397–1411. doi: 10.1007/s00345-019-02887-4

170. Phull J. Clinical dashboards and their use in an adult mental health inpatient setting, a pilot study. Clin Gov 2015;20(4):199–207. doi: 10.1108/CGIJ-06-2015-0019

171. Hoogeveen IJ, Peeks F, de Boer F, Lubout CMA, de Koning TJ, te Boekhorst S, Zandvoort R-J, Burghard R, van Spronsen FJ, Derks TGJ. A preliminary study of telemedicine for patients with hepatic glycogen storage disease and their healthcare providers: from bedside to home site monitoringKeywords. J Inherit Metab Dis 2018;41(6):929–936. doi: 10.1007/s10545-018-0167-2

172. Datema FR, van Zijl FVWJ, van der Poel EF, Baatenburg de Jong RJ, Lohuis PJFM. Transparency in Functional Rhinoplasty: Benefits of Routine Prospective Outcome

Measurements in a Tertiary Referral Center. Plast Reconstr Surg United States; 2017;140(4):691–702. doi: 10.1097/PRS.0000000000003701

173. Coventry P, Bower P, Blakemore A, Baker E, Hann M, Li J, Paisley A, Gibson M. Satisfaction with a digitally-enabled telephone health coaching intervention for people with non-diabetic hyperglycaemia. NPJ Digit Med England; 2019;2(101731738):5. doi: 10.1038/s41746-019-0080-6

174. Jameie S, Haybar H, Aslani A, Saadat M. Development and Usability Evaluation of Web-Based Telerehabilitation Platform for Patients After Myocardial Infarction. Stud Health Technol Inform Netherlands; 2019;261(ck1, 9214582):68–74.

175. Ospina-Pinillos L, Davenport TA, Ricci CS, Milton AC, Scott EM, Hickie IB. Developing a Mental Health eClinic to Improve Access to and Quality of Mental Health Care for Young People: Using Participatory Design as Research Methodologies. J Med Internet Res Canada; 2018;20(5):e188. doi: 10.2196/jmir.9716

176. Barnett A, Winning M, Canaris S, Cleary M, Staib A, Sullivan C. Digital transformation of hospital quality and safety: real-time data for real-time action. Aust Health Rev Publ Aust Hosp Assoc Australia; 2019;43(6):656–661. doi: 10.1071/AH18125

177. Dagliati A, Sacchi L, Tibollo V, Cogni G, Teliti M, Martinez-Millana A, Traver V, Segagni D, Posada J, Ottaviano M, Fico G, Arredondo MT, De Cata P, Chiovato L, Bellazzi R. A dashboard-based system for supporting diabetes care. J Am Med Inform Assoc JAMIA England; 2018;25(5):538–547. doi: 10.1093/jamia/ocx159

178. Findlay M, Rankin NM, Shaw T, White K, Boyer M, Milross C, De Abreu Lourenco R, Brown C, Collett G, Beale P, Bauer JD. Best Evidence to Best Practice: Implementing an Innovative Model of Nutrition Care for Patients with Head and Neck Cancer Improves Outcomes. Nutrients Switzerland; 2020;12(5). doi: 10.3390/nu12051465

179. Jeffries M, Gude WT, Keers RN, Phipps DL, Williams R, Kontopantelis E, Brown B, Avery AJ, Peek N, Ashcroft DM. Understanding the utilisation of a novel interactive electronic medication safety dashboard in general practice: a mixed methods study. BMC Med Inform Decis Mak England; 2020;20(1):69. doi: 10.1186/s12911-020-1084-5

180. Kai-Hsuan Y, Kao W-F, Yen-Kuang L, Pei-Ling W, Tsung-Jen H, Yi-No K, Ray-Jade C, Chun-Chieh C. REDUCING LENGTH OF STAY AND IMPROVING QUALITY OF CARE BY IMPLEMENTATION OF INFORMATICS SYSTEM AND CARE BUNDLE IN THE INTENSIVE CARE UNIT. Rev Investig Clin Organo Hosp Enfermedades Nutr Mexico; 2020;72(1):25–31. doi: 10.24875/RIC.19003183

181. Mabirizi D, Phulu B, Churfo W, Mwinga S, Mazibuko G, Sagwa E, Indongo L, Hafner T. Implementing an Integrated Pharmaceutical Management Information System for Antiretrovirals and Other Medicines: Lessons From Namibia. Glob Health Sci Pract United States; 2018;6(4):723–735. doi: 10.9745/GHSP-D-18-00157

182. Nouei MT, Kamyad AV, Soroush AR, Ghazalbash S. A comprehensive operating room

information system using the Kinect sensors and RFID. J Clin Monit Comp 2015;29(2):251–261. doi: 10.1007/s10877-014-9591-5

183. Rea R.D., Lumb A., Tan G.D., Owen K., Thanabalasingham G., Latif A., Swan P., Scott J., Jones D., Gillott E., Smith R.H. Using data to improve the care of people with diabetes across Oxfordshire. Pract Diabetes 2020;37(1):27–31. doi: 10.1002/pdi.2257

184. Frosini F, Miniati R, Avezzano P, Cecconi G, Dori F, Gentili GB, Belardinelli A. Development of a web based monitoring system for safety and activity analysis in operating theatres. Technol Health Care Off J Eur Soc Eng Med Netherlands; 2016;24(1):99–109. doi: 10.3233/THC-151073

185. Ahern S, Feiler R, Sdrinis S. Maximising the value of clinical registry information through integration with a health service clinical governance framework: a case study. Aust Health Rev Publ Aust Hosp Assoc Australia; 2020;44(3):421–426. doi: 10.1071/AH19004

186. Bustamante C, Pineda J, Rascovsky S, Arango A. Open-Source, Web-Based Dashboard Components for DICOM Connectivity. J Digit Imaging United States; 2016;29(4):455–9. doi: 10.1007/s10278-016-9866-0

187. Cassim N, Coetzee LM, Tepper MEE, Perelson L, Glencross DK. Timely delivery of laboratory efficiency information, Part II: Assessing the impact of a turn-around time dashboard at a high-volume laboratory. Afr J Lab Med South Africa; 2020;9(2):948. doi: 10.4102/ajlm.v9i2.948

188. Cassim N, Tepper ME, Coetzee LM, Glencross DK. Timely delivery of laboratory efficiency information, Part I: Developing an interactive turnaround time dashboard at a high-volume laboratory. Afr J Lab Med South Africa; 2020;9(2):947. doi: 10.4102/ajlm.v9i2.947

189. Staples S, Salisbury RA, King AJ, Polzella P, Bakhishli G, Staves J, Murphy MF. How do we use electronic clinical decision support and feedback to promote good transfusion practice. Transfusion (Paris) United States; 2020;(wdn, 0417360). doi: 10.1111/trf.15864

190. Muhammad S., Chandraharan E. The Maternity Dashboard: how effective is it in improving maternity care? Obstet Gynaecol Reprod Med 2016;26(9):276–279. doi: 10.1016/j.ogrm.2016.06.002

191. Minton O, Ede C, Bass S, Tavabie S, Bourne A, Hiresche A. Hospital deaths dashboard: care indicators. BMJ Support Palliat Care England; 2020;(101565123). doi: 10.1136/bmjspcare-2020-002223

192. Laurent G, Moussa MD, Cirenei C, Tavernier B, Marcilly R, Lamer A. Development, implementation and preliminary evaluation of clinical dashboards in a department of anesthesia. J Clin Monit Comput Netherlands; 2020;(9806357, cyw). doi: 10.1007/s10877-020-00522-x

193. Brink AJ, Messina AP, Maslo C, Swart K, Chunnilall D, van den Bergh D, Netcare

Antimicrobial Stewardship and Infection Prevention Study Alliance. Implementing a multi-faceted framework for proprietorship of hand hygiene compliance in a network of South African hospitals: leveraging the Ubuntu philosophy. J Hosp Infect England; 2020;104(4):404–413. doi: 10.1016/j.jhin.2019.11.004

194. Lenglet A, van Deursen B, Viana R, Abubakar N, Hoare S, Murtala A, Okanlawon M, Osatogbe J, Emeh V, Gray N, Keller S, Masters P, Roolvink D, Davies J, Hickox K, Fotso A, Bil K, Ikenna Nwankwo C, Ahmad B, Caluwaerts A, Lessard I, Dimeglio S, Malou N, Kanapathipillai R, McRae M, Wong S, Hopman J. Inclusion of Real-Time Hand Hygiene Observation and Feedback in a Multimodal Hand Hygiene Improvement Strategy in Low-Resource Settings. JAMA Netw Open United States; 2019;2(8):e199118. doi: 10.1001/jamanetworkopen.2019.9118

195. Pandya ST, Chakravarthy K, Vemareddy A. Obstetric anaesthesia practice: Dashboard as a dynamic audit tool. Indian J Anaesth India; 2018;62(11):838–843. doi: 10.4103/ija.IJA_346_18

196. Raban MS, Bamford C, Joolay Y, Harrison MC. Impact of an educational intervention and clinical performance dashboard on neonatal bloodstream infections. South Afr Med J Suid-Afr Tydskr Vir Geneeskd South Africa; 2015;105(7):564–6. doi: 10.7196/SAMJnew.7764

197. Bourdeaux CP, Thomas MJ, Gould TH, Malhotra G, Jarvstad A, Jones T, Gilchrist ID. Increasing compliance with low tidal volume ventilation in the ICU with two nudge-based interventions: evaluation through intervention time-series analyses. BMJ Open England; 2016;6(5):e010129. doi: 10.1136/bmjopen-2015-010129

198. Rezaei-Hachesu P, Samad-Soltani T, Yaghoubi S, GhaziSaeedi M, Mirnia K, Masoumi-Asl H, Safdari R. The design and evaluation of an antimicrobial resistance surveillance system for neonatal intensive care units in Iran. Int J Med Inf Ireland; 2018;115(ct4, 9711057):24–34. doi: 10.1016/j.ijmedinf.2018.04.007

199. Sheen Y-J, Huang C-C, Huang S-C, Huang M-D, Lin C-H, Lee I-T, Lin S-Y, Sheu WH-H. IMPLEMENTATION OF AN ELECTRONIC DASHBOARD WITH A REMOTE MANAGEMENT SYSTEM TO IMPROVE GLYCEMIC MANAGEMENT AMONG HOSPITALIZED ADULTS. Endocr Pract Off J Am Coll Endocrinol Am Assoc Clin Endocrinol United States; 2020;26(2):179–191. doi: 10.4158/EP-2019-0264

200. Ebbens MM, Errami H, Moes DJAR, van den Bemt PMLA, van der Boog PJM, Gombert-Handoko KB. Prevalence of medication transfer errors in nephrology patients and potential risk factors. Eur J Intern Med Netherlands; 2019;70(9003220):50–53. doi: 10.1016/j.ejim.2019.09.003

201. Giordanengo A, Arsand E, Woldaregay AZ, Bradway M, Grottland A, Hartvigsen G, Granja C, Torsvik T, Hansen AH. Design and Prestudy Assessment of a Dashboard for Presenting Self-Collected Health Data of Patients With Diabetes to Clinicians: Iterative Approach and Qualitative Case Study. JMIR Diabetes Canada; 2019;4(3):e14002. doi: 10.2196/14002

202. Harrison B, Stern L, Chung P, Etemadi M, Kwiat D, Roy S, Harrison MR, Martinez-Ferro M. MyPectus: First-in-human pilot study of remote compliance monitoring of teens using dynamic compression bracing to correct pectus carinatum. J Pediatr Surg United States; 2016;51(4):608–11. doi: 10.1016/j.jpedsurg.2015.11.007

203. Jeffries M, Keers RN, Phipps DL, Williams R, Brown B, Avery AJ, Peek N, Ashcroft DM. Developing a learning health system: Insights from a qualitative process evaluation of a pharmacist-led electronic audit and feedback intervention to improve medication safety in primary care. PloS One United States; 2018;13(10):e0205419. doi: 10.1371/journal.pone.0205419

204. Prabhu A, Agarwal U, Tripathy JP, Singla N, Sagili K, Thekkur P, Sarin R. "99DOTS"techno-supervision for tuberculosis treatment - A boon or a bane? Exploring challenges in its implementation at a tertiary centre in Delhi, India. Indian J Tuberc India; 2020;67(1):46–53. doi: 10.1016/j.ijtb.2019.08.010

205. Riboni D, Bettini C, Civitarese G, Janjua ZH, Helaoui R. SmartFABER: Recognizing fine-grained abnormal behaviors for early detection of mild cognitive impairment. Artif Intell Med Netherlands; 2016;67(bup, 8915031):57–74. doi: 10.1016/j.artmed.2015.12.001

206. Segagni D, Sacchi L, Dagliati A, Tibollo V, Leporati P, De Cata P, Chiovato L, Bellazzi R. Improving Clinical Decisions on T2DM Patients Integrating Clinical, Administrative and Environmental Data. Stud Health Technol Inform Netherlands; 2015;216(ck1, 9214582):682–6.

207. Serrano JA, Holthe H. Development and trial of ePoint.telemed - An open web-based platform for home monitoring of chronic heart failure patients. Stud Health Technol Inform Netherlands; 2015;210(ck1, 9214582):311–5.

208. Williams R, Keers R, Gude WT, Jeffries M, Davies C, Brown B, Kontopantelis E, Avery AJ, Ashcroft DM, Peek N. SMASH! The Salford medication safety dashboard. J Innov Health Inform England; 2018;25(3):183–193. doi: 10.14236/jhi.v25i3.1015

209. Palin V, Tempest E, Mistry C, van Staa TP. Developing the infrastructure to support the optimisation of antibiotic prescribing using the learning healthcare system to improve healthcare services in the provision of primary care in England. BMJ Health Care Inform England; 2020;27(1). doi: 10.1136/bmjhci-2020-100147

210. Jones S, Cournane S, Sheehy N, Hederman L. A Business Analytics Software Tool for Monitoring and Predicting Radiology Throughput Performance. J Digit Imaging 2016;29(6):645–653. doi: 10.1007/s10278-016-9871-3

211. Bae YS, Kim KH, Choi SW, Ko T, Jeong CW, Cho B, Kim MS, Kang E. Information Technology-Based Management of Clinically Healthy COVID-19 Patients: Lessons From a Living and Treatment Support Center Operated by Seoul National University Hospital. J Med Internet Res Canada; 2020;22(6):e19938. doi: 10.2196/19938

212. Whidden C, Kayentao K, Liu JX, Lee S, Keita Y, Diakite D, Keita A, Diarra S, Edwards J,

Yembrick A, Holeman I, Samake S, Plea B, Coumare M, Johnson AD. Improving Community Health Worker performance by using a personalised feedback dashboard for supervision: a randomised controlled trial. J Glob Health Scotland; 2018;8(2):020418. doi: 10.7189/jogh.08.020418

213. Siette J, Dodds L, Sharifi F, Nguyen A, Baysari M, Seaman K, Raban M, Wabe N, Westbrook J. Usability and Acceptability of Clinical Dashboards in Aged Care: Systematic Review. JMIR Aging 2023 Jun 19;6:e42274. PMID:37335599

214. Young L, Vogelsmeier A. Quality Dashboards in Hospital Settings: A Systematic Review With Implications for Nurses. J Nurs Care Qual 2024 Jun 1;39(2):188–194. PMID:37782907

215. Rabiei R, Bastani P, Ahmadi H, Dehghan S, Almasi S. Developing public health surveillance dashboards: a scoping review on the design principles. BMC Public Health 2024 Feb 6;24(1):392. PMID:38321469

216. Wilson AS, Triller DM, Allen A, Burnett A, Gouveia-Pisano JA, Brenner A, Pritchard B, Medico C, Vazquez SR, Witt DM, Barnes GD. Digital dashboards for oral anticoagulation management: a literature scoping review. J Thromb Thrombolysis 2023 Nov;56(4):568–577. PMID:37596426

217. Toscano F, O'Donnell E, Broderick JE, May M, Tucker P, Unruh MA, Messina G, Casalino LP. How Physicians Spend Their Work Time: an Ecological Momentary Assessment. J Gen Intern Med 2020 Nov;35(11):3166–3172. PMID:32808212

218. Gaffney A, Woolhandler S, Cai C, Bor D, Himmelstein J, McCormick D, Himmelstein DU. Medical Documentation Burden Among US Office-Based Physicians in 2019: A National Study. JAMA Intern Med 2022 May 1;182(5):564–566. doi: 10.1001/jamainternmed.2022.0372

219. Almasi S, Bahaadinbeigy K, Ahmadi H, Sohrabei S, Rabiei R. Usability Evaluation of Dashboards: A Systematic Literature Review of Tools. BioMed Res Int 2023;2023:9990933. PMID:36874923

220. Kaplan B, Harris-Salamone KD. Health IT Success and Failure: Recommendations from Literature and an AMIA Workshop. J Am Med Inform Assoc JAMIA 2009;16(3):291–299. PMID:19261935

221. Murphy DR, Savoy A, Satterly T, Sittig DF, Singh H. Dashboards for visual display of patient safety data: a systematic review. BMJ Health Care Inform BMJ Publishing Group Ltd; 2021 Oct 1;28(1):e100437. PMID:34615664

222. Marcilly R, Peute LW, Beuscart-Zephir M-C, Jaspers MW. Towards Evidence Based Usability in Health Informatics? Stud Health Technol Inform IOS Press; 2015; doi: 10.3233/978-1-61499-574-6-55

223. Budd J. Burnout Related to Electronic Health Record Use in Primary Care. J Prim Care

Community Health 2023 Apr 19;14:21501319231166920. PMID:37073905

224. Li C, Parpia C, Sriharan A, Keefe DT. Electronic medical record-related burnout in healthcare providers: a scoping review of outcomes and interventions. BMJ Open British Medical Journal Publishing Group; 2022 Aug 1;12(8):e060865. PMID:35985785

225. Yakovchenko V, Morgan TR, Miech EJ, Neely B, Lamorte C, Gibson S, Beste LA, McCurdy H, Scott D, Gonzalez R, Park A, Powell BJ, Bajaj JS, Dominitz JA, Chartier M, Ross D, Chinman MJ, Rogal SS. Core implementation strategies for improving cirrhosis care in the Veterans Health Administration. Hepatol Baltim Md 2022 Aug;76(2):404–417. PMID:35124820

226. Damschroder LJ, Reardon CM, Widerquist MAO, Lowery J. The updated Consolidated Framework for Implementation Research based on user feedback. Implement Sci 2022 Oct 29;17(1):75. doi: 10.1186/s13012-022-01245-0

227. Fernandez ME, ten Hoor GA, van Lieshout S, Rodriguez SA, Beidas RS, Parcel G, Ruiter RAC, Markham CM, Kok G. Implementation Mapping: Using Intervention Mapping to Develop Implementation Strategies. Front Public Health 2019 Jun 18;7:158. PMID:31275915

228. Rudd BN, Davis M, Beidas RS. Integrating implementation science in clinical research to maximize public health impact: a call for the reporting and alignment of implementation strategy use with implementation outcomes in clinical research. Implement Sci IS 2020 Nov 25;15:103. PMID:33239097

229. Powell BJ, Fernandez ME, Williams NJ, Aarons GA, Beidas RS, Lewis CC, McHugh SM, Weiner BJ. Enhancing the Impact of Implementation Strategies in Healthcare: A Research Agenda. Front Public Health 2019 Jan 22;7:3. PMID:30723713

230. Tai-Seale M, Baxter S, Millen M, Cheung M, Zisook S, Çelebi J, Polston G, Sun B, Gross E, Helsten T, Rosen R, Clay B, Sinsky C, Ziedonis DM, Longhurst CA, Savides TJ. Association of physician burnout with perceived EHR work stress and potentially actionable factors. J Am Med Inform Assoc 2023 Oct 1;30(10):1665–1672. doi: 10.1093/jamia/ocad136

231. Krug S. Rocket Surgery Made Easy: The Do-It-Yourself Guide to Finding and Fixing Usability Problems. 1st ed. 2009. Available from: https://sensible.com/rocket-surgery-made-easy/ [accessed Apr 17, 2024]ISBN:0-321-65729-2

Supplementary Files

Multimedia Appendixes

Supplement 1 study codebook and examples.
URL: http://asset.jmir.pub/assets/a176b3c042430cf969f7e2008b452115.docx

Supplement 2 study data file.
URL: http://asset.jmir.pub/assets/0dd5f6d0671f0e2196050d6d28e7df75.xlsx

Supplement 3 supplementary tables and additional findings.
URL: http://asset.jmir.pub/assets/b454a3a227af3d82fc1f3a66ed921384.docx

CONSORT (or other) checklists

PRISMA-Scr checklist.
URL: http://asset.jmir.pub/assets/767cb66511fe88823c7564fc385f9cfc.pdf

TOC/Feature image for homepages

Untitled.