A brief Survey of Recent Clinical Dashboards

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Abstract. Application of data analytics and visual analytics to the medical domain, and specifically to support clinical activities is more and more both a need and an opportunity. For example, as reported by the US Institute of Medicine, positive transformation of current health systems to make them cost-sustainable and providing higher care quality, requires to capture more clinical data and generate knowledge for better healthcare management and enhancement of medical research. In this brief survey we review recent papers (since 2013 on) describing innovative clinical dashboards which promise better support of clinical and medical research activities. We also explain how in some of these tools analytics features are implemented to cope with clinical dataset and get insights from them. We try therefore to identify for each considered tool a set of features concerning data sources, tasks/workflows supported, indicators and their graphical representation, analytics support, target users and data processing approaches.

Keywords: Clinical Decision Support Systems, Clinical Dashboards, Data analytics, Big data for healthcare

1 Introduction

Business dashboards are mostly used to gather summary data and provide necessary information to take critical decisions for the management of single business processes and overall organizations, that are decision support systems. Clinical dashboards specialize this concept to healthcare management but also to everyday clinical and research activities.

Some recent clinical dashboards provide also, often as visual and interactive data visualization features, data analytics and inference capabilities in order to extend the usual capabilities of visualizing key performance indicators (KPI) and summarized data. Actually, application of data and visual analytics to the medical domain and specifically to support clinical activities is currently considered both a need and an opportunity. In fact, as described in a report [8] of the U.S. Institute of Medicine (IOM), transformation of current health systems is needed in order to contain the costs of the systems becoming too complex to manage and to provide high care quality especially for patients with chronic

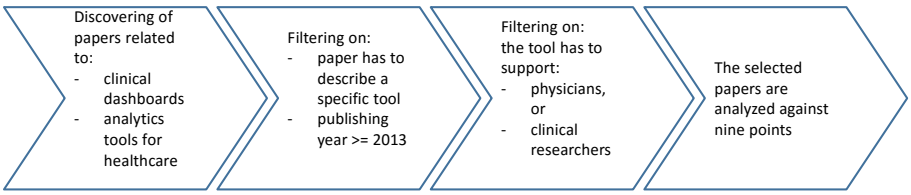

Fig. 1. Selection method for the reviewed tools

diseases that require better coordination in patient data sharing and management among healthcare institutions. One consequent recommendation given in the report, is to gather more clinical data and generate knowledge for better coordination and management, for improving care practices and enhancement of medical knowledge.

As well as, analytics is also an opportunity. The cited IOM report envisions the idea of US healthcare as *continuous learning system* where data produced by healthcare processes is used to improve coordination of these processes and focusing on activities that improve patient health. And to accelerate integration of the best clinical knowledge into care decisions. In this perspective, we notice how the recent evolution of the healthcare interoperabilty standard HL7, that is FHIR, [1] can support the spread of analytics tools by providing models and methods for decoupling data sources and analytics applications operating on this data thus permitting reuse of advanced applications on various data sources.

Other surveys on clinical dashboards have been previously published, for example [4] and the more recent one [3]. In our brief survey we use a more specific perspective by describing innovative clinical dashboards that promise to better support clinical and medical research activities. Moreover, we explain how some of these tools provide analytics features that are implemented to deal with large clinical datasets and in order to get insights from them. For each considered tool we describe a set of features concerning: data sources used by the tool, types of tasks/workflows supported, indicators and their graphical representation, analytics support, target users and adopted data processing approach.

2 Method of selection and analysis of the literature

Reviewed papers have been selected according the criteria reported in the first three steps in Fig. 1 and analyzed according to nine points reported in the following section. Concerning the papers selection process we used as sources: (i) Google Scholar; (ii) Google; (iii) The Proc. of the 2014 Workshop VAHC 2014 [2]. For example, in Google Scholar we made searches based on combinations of groups of terms *tool clinical dashboard* and *medical healthcare analytics*. Even restricting these searches to the range of years 2013-2016 we got thousands of results. Thus, for each search we set in Google Scholar the option of ordering the result by relevance and inspected title and abstract of the first 50 results.

[1] `http://www.hl7.org/fhir/`

[2] Proceedings of the 2014 Workshop on Visual Analytics in Healthcare (VAHC 2014), available at `http://www.visualanalyticshealthcare.org/proceedings.html`.

Table 1. Non analitycs-based clinical dashboards

Short name	Tool class	Main indicators	Main functionalities	Activities supported by the tool	Dimensions	Visualiz. mean
Real-time enrollment dashboard [7]	Web-based dashboard.	Daily enrollment for nine hospitals participating in the study	Manage multi-site clinical trial enrollment.	Conduction of clinical trials.	Hospital and time	Table; Bar-chart
Measuring Quality in Maternal-Newborn Care [9]	Maternal-newborn dashboard	Six clinical performance indicators of quality care.	Visualization and comparison of indicators.	Support hospitals and care providers for quality improvement.	Hospital/ unit and time.	Table

By looking for paper describing software tools and not general discussions or methodologies we identified 12 papers (from all the considered sources). Some of these papers were further removed because they do describe tools aimed at hospital management and not at physicians/researchers.

The nine points we considered for analyzing the chosen tools and the related literature were devoted to determine for each tool: 1) purpose and application, 2) target users, 3) tool class, 4) data sources used by the tool, 5) types of tasks/workflows supported by the tool, 6) indicators the tool is able to display, 7) dimensions associated with the indicators, 8) data processing methodology, 9) Type of information inferable by the analytics functionalities of tool (e.g., the tool discovers and shows correlations among patient features in order to help physicians to identify relevant cohorts of similar patients). For each tool we complete a form with the answers to these questions. These answers were summarized and used to fill in the Tables 1 and 2. These tables focus on six aspects we considered relevant for our survey in order to balance general features and domain-specific ones.

3 Comparison and features of selected clinical dashboards

The first table describes approaches that do not clearly provide data and visual analytics functionalities. In the second table, approaches that have analytics features are listed. The *Main indicators* column describes the clinical dashboard indicators (KPIs) for each approach. Moreover, we tried to understand the use of each tool in clinical or research contexts. Thus, the *Activities supported by the tool* provides information about the tasks or workflows supported. In a perspective of multidimensional data, typical of dashboard tools, the *Dimensions* column explains, when applicable, which dimensions are applied to indicators. Finally, *Visualization means* lists diagram types or visualization approaches used in each tool.

Non Analytics-based tools. The two tools summarized in Table 1 are clinical dashboards without specific analytic or inferential capabilities. The first one [7] offers support for conduction of clinical trials concerning studying pneumonia and helps management of multi-site enrollment. Physicians can use the enrollment dashboard showing various daily enrollment numbers, also represented as

Table 2. Analitycs-based clinical dashboards

Short name	Tool class	Main indicators	Main functionalities	Activities supported by the tool	Dimensions	Visualiz. mean
Patient-Like-Mine A Real Time [6]	Web-based Visual Analytics Tool for Clinical Decision Support.	Summary indicators from electronic medical records (EMR).	Decision support for: formulation of specific care plan, finding patients' cohorts.	Improve Clinical Pathway compliance, recognize patterns.	Time	Graph
An Analytics Approach to Managing Provider Treatment Variety [5]	Analytics tool, Simulation tool.	Proportions of patients successfully treated and cost per patient.	Analytics approach for improving clinical outcomes by identifying successful treatments.	Application of analytics to EHR; simulation of therapies	Number of patient per cluster.	Barchart; Linechart
A Visual Analytics Approach for Care Processes [1]	Clinical dashboard.	Objective data on the patients expressed by KPIs like acuity, health status, total charges.	Creation and comparison of cohorts. Comparison of care processes with pathway guidelines.	Visualization of indicators for a single cohort of patients and two cohorts.	Flexible: one variable can be shown in scatterplots as a function of another one.	Barplot; Scatterplot
Cancer Cohort Visual Analysis [2]	Clinical dashboard based on static and dynamic indicators.	Objective (e.g., PSA values over the time) and subjective (e.g., well being evaluation over a scale) data on the patients.	Visualization of multiple patient histories and identification of similar patient histories.	Creation and evaluation of cohorts as integrated process.	Typical dimensions: time, therapy type.	Barcart; linechart

barcharts, for the nine hospitals participating in the study. The tool in [9] is a dashboard for measuring and monitoring quality care for maternal-newborns. The purpose is increasing awareness about KPIs identified as relevant (e.g., *Proportion of newborn screening samples that are unsatisfactory for testing*). Moreover, other targets are reporting on a selection of performance indicators (feedback), comparing performance to established ideal levels (benchmarking) and providing alerts when performance is sub-optimal to trigger action (warnings). Indicators are represented in tabular form.

Analytics-based tools. The Web-based visual analytics tool in [6] provides clinical decision support. It appears to be the only non domain/pathology specific tool we reviewed. In particular, it creates a transparent, interactive environment that enables a physician to formulate more specific plan for a given patient using real world data from a high number of EHRs (i.e., electronic health records). Moreover, it provides support to find patients' cohorts in order to improve clinical pathway compliance. By using a flexible UI, the physician or team can also explore *what-if* scenarios that would have previously required statistical/database skills and effort to develop. For example, use of graphics allows the provider to quickly determine if a patients clinical parameter is within given bounds, based on visual comparison with a cohort of similar patients.

Also the work [5] applies analytics to EHRs in order to improve clinical outcomes. In particular, it utilizes EHR data to identify different types of successful treatments that physicians deliver for different types of patients with Type 2 diabetes. Then a simulated environment is used to assigns patients to physicians for better treatment of type-2 diabetes in a clinic setting. Simulations of a *diabetes clinic* relies on different physician models for treating patients. The simulated clinic comprises models of patients with type 2 diabetes (T2DM) and models of physician decision making processes. The tool clusters patients into groups based on their initial states then assigns a physician model for each cluster of patients. It also permits to evaluate the physician-patient assignments by visualizing indicators of treatment success and cost per patient per year, calculated on the outcomes of simulations.

We focus now on two interesting tools, the ones in the last two row of Table 2. The first one, in [1], provides visualization of indicators mainly oriented to study either a single cohort of patients, that is a group of patients with similar features, or to study and compare two cohorts (i.e., comparing populations of patients). The application domain is care of asthma in children. The main purpose of this system is to permit analysis of care processes in the reference domain. Basically the system provides functions to:

- create/modify patient cohorts based on demographic (age, gender), process (length of stay, number activities), clinical (e.g., acuity, initial clinical respiratory score (CRS)) and others;
- analyze the care processes of single cohort of patients by visualizing indicators values and distributions (e.g., histograms);
- comparing a single cohort of patients by visualizing indicators values and distributions (e.g., histograms);

In general, the system provides multiple and coordinated visualizations. The tool has not statistical inference capabilities. So identification of correlations in cohorts has to be performed visually. However, it is able to perform process mining concerning care processes and presents in a graphical way frequent subprocesses in care therapies by using Sankey diagrams. Target users are clinical physicians who specialize in the research and treatment of children asthma.

The last tool we consider is [2] which permits to visually analyze multi attribute datasets including time dependent data. The dataset concerns patient records of patients suffering from prostate cancer. Visualization of large sets of patient histories as well as aggregate visualization of specific aspect of sets of patient histories are offered. That helps to identify patient cohorts based on a visual and inferential support and permits to make shorter the clinical task of identifying such as cohorts. Statistical inference functionalities are implemented in order to identify correlations between features that help physicians identify patient cohorts. In particular, the system offers a guided analysis of correlations between the current patient cohort and all static attributes provided in the data. The correlations are calculated automatically using statistical dependency measures.

4 Conclusions

In this survey we reviewed clinical dashboards that provide access to information for clinicians and researcher supporting improved care process and quality. Generally, these tools allow to visualize and compare specific profiles of different patients at the same time and help recognizing patients' histories. It is interesting to notice that some recent dashboards either provide analytics features or are based on analytics approaches, like clustering. This may help physicians to make inferences and/or to discover patterns in large EHRs datasets. Concerning visualization approaches, the dashboards here considered adopt simple, and probably familiar to physicians, metaphors like: barcharts, linecharts and tables. Since the growing interest and expectation for applying big data techniques to medical research and practice, we suppose more and more analytic-based medical applications will be soon presented.

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