A Dashboard for Visualizing Health Data of Children with Aortic Valve Disease

Anna Kleinau, Joon Bong Au, Jan Ulmer, Eliane Charbonnier, Mohamed Yaseen Jabarulla, Sarah Elizabeth Long, Dagmar Hohmann, Dietmar Böthig, Hannah Brower-Rabinowitsch, Alexander Horke, Murat Avsar, Philipp Beerbaum, Steffen Oeltze-Jafra, Theodor Uden

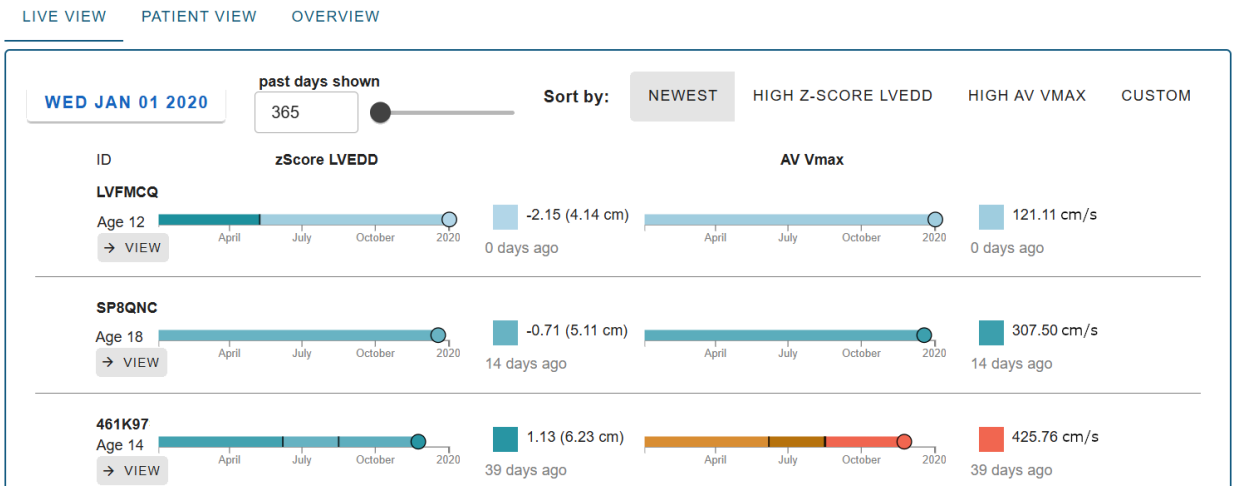

Fig. 1: The live view dashboard simulates a real-time monitoring situation of all relevant patients in a clinic, focusing on echocardiographic parameters and aims to include individual risks and predictions in future. Color-coded time series indicate when a patient's values are normal or abnormal.

Abstract—Children with aortic valve diseases are often observed over decades and might receive multiple interventions. The collected data is rich in information, however, as the patients are highly heterogeneous and few in number, automatic approaches or the strict application of guidelines is not feasible. Therefore, efficient visualization and interaction with the data and looking at each patient in the context of a larger patient cohort is essential for making individualized, patient-centric decisions. We employ a range of visualization and visual analytics techniques, as well as a human-centered design process, to develop a dashboard that visualizes the patient data at both individual and global levels across all patients. The dashboard is specifically tailored to its clinical context using presets, color scales and helper lines, while allowing data exploration in both clinical and research contexts. Our dashboard supports clinicians in their treatment decisions, including for example a determination of the optimal timing for aortic valve replacement surgery, as well as retrospectively analyzing the long-term outcomes of operated cases.

Index Terms—clinical dashboards, personalized health care, health systems, visual analytics, aortic valve disease

1 Introduction

The treatment of children with aortic valve diseases is a highly personalized process, requiring individualized decisions. In addition to selecting the best treatment option [3], aortic valve interventions demand precise timing [4]. Performing interventions too late might result in long-lasting damage to the left ventricle. Too early interventions should be avoided, as the patients are still growing and implanted prostheses—if needed—have limited durability. For these and other patient groups in pediatric cardiology, a visualization is needed that clarifies long and complex treatment pathways and places patients in the context of a larger patient cohort.

To support individualized treatment decisions and offer new insights on treatment timing, we have developed a dashboard visualizing the heterogeneous data available for pediatric patients with aortic valve diseases. It presents the data both at the individual patient level, and globally across all patients. We use visual analytics tools to present this data to clinicians in an intuitive and easy-to-use way, integrating it within its clinical context. We employ presets to manage heterogeneous data in quantities relevant to the current task or scenario. Through linked views, filtering techniques and focus-and-context visualizations, we enable seamless data exploration.

- *Anna Kleinau is with Hannover Medical School, Hannover, Germany and Otto-von-Guericke University, Magdeburg, Germany.*
- *all other authors are with Hannover Medical School, Hannover, Germany.*

Manuscript received xx xxx. 201x; accepted xx xxx. 201x. Date of Publication xx xxx. 201x; date of current version xx xxx. 201x. For information on obtaining reprints of this article, please send e-mail to: reprints@ieee.org. Digital Object Identifier: xx.xxxx/TVCG.201x.xxxxxxx

2 Methods

We designed our dashboard in close cooperation with pediatricians in a human-centered design process. We began by collecting requirements, then iteratively created prototypes and used them to collect feedback from pediatricians, which we used to subsequently improve the tool.

2.1 Data Set

Our data set contains the anonymized data from 186 children who underwent aortic valve interventions. The data set comprises 193 textual and numerical time-dependent and time-independent features.

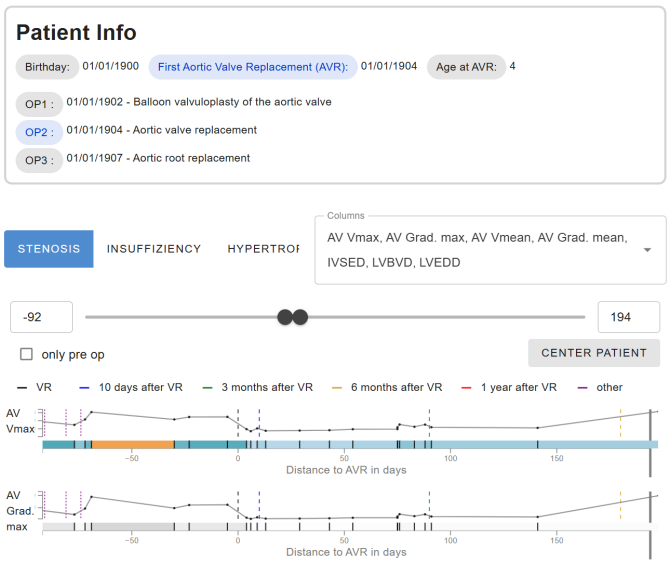

Fig. 2: The patient view, here for a fictional patient, displays demographic data as well as time series data for one individual patient.

Two highly relevant features are the left ventricular diameter (*LVEDD*) and the maximum flow velocity behind the aortic valve (*AV Vmax*).

2.2 Requirements

In multiple sessions with one pediatrician experienced in pediatric cardiology, we defined the following requirements that were subsequently approved by four pediatric cardiologists/ cardiac surgeons.

- Display patient data over the span of multiple years to show changes over time.
- Provide an overview of the clinical status of patients currently being treated in a pediatric cardiology outpatient clinic.
- For a single patient, support intervention decisions through displaying demographic data, interventions and measurements.
- Provide an aggregated view of the data to identify (sub-) collectives and gain new insights into the data for research.

2.3 Distinguishing Use Cases

As the requirements specify distinct use cases ranging from individual patient data to aggregated cohort views, we structured our dashboard into three linked views. When first opening the dashboard, it defaults to the *live view* simulating an overview of all patients currently being in treatment in a department. To examine a specific patient in more detail, the clinician can select the patient and switch over to the *patient view*. Here, the clinician can investigate the available data for that patient further. For exploring trends across similar cases or for research purposes, the clinician can access the *overview*. This view aggregates all available data, aligned by surgery date, to highlight temporal patterns.

3 Results

We developed our dashboard in the JavaScript framework Vue[1], using Vuetify[2] for the user interface and D3 for visualizations [1]. The dashboard is open-source and available on GitHub[3]. The data is imported in CSV format. As the data is retrospective, the live view is simulated by selecting the last available date in the data set as the current date. For demonstration purposes, users can select alternative dates.

[1] https://vuejs.org/
[2] https://vuetifyjs.com/
[3] https://github.com/akleinau/Herzklappen

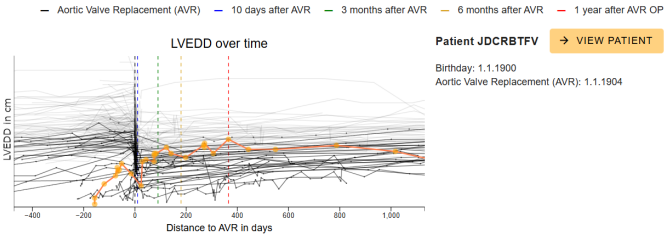

Fig. 3: The overview displays all patients at once. Here, the cohort of patients under five years old is selected, with one patient highlighted.

3.1 Live view

The live view (Fig. 1) is used to monitor current patients, e.g. to identify those who should undergo surgery soon. For each patient, their age and heatmaps displaying the time series for two important parameters *LVEDD* (normalized in the form of z-scores) and *AV VMax* are shown [2]. To the right, the most recent value of both parameters and how many days ago it was recorded is stated. Since both parameters indicate the disease severity, we use a traffic light color scheme. Normal values appear in blue, while abnormal values are shown in yellow, then red as severity increases. Within each color zone, different hues indicate more subtle changes. Patients are sorted through presets that define both the feature and ordering direction. For example, the preset "newest" sorts patients by the time of their last data entry in ascending order. Individual patients can be selected to switch over to the patient view.

3.2 Patient view

The patient view (Fig. 2) provides in-depth information about one individual patient. On top, demographic information and her clinical pathway with a focus on prior surgical interventions are shown. Below, heatmaps show time-dependent data. Markers on top of the heatmap mark the dates of previous operations, and clinically relevant time points after the heart valve replacement. On demand, a detailed line graph of each time series is shown. As there are numerous features, we provide presets showing only the features relevant for a specific diagnosis or medical task. For example, the preset for aortic stenosis focuses primarily on flow velocity measurements, while the preset for aortic insufficiency concentrates on left ventricular dimensions.

3.3 Overview

Lastly, our overview (Fig. 3) shows all patients at once in a line graph, with one feature on the Y axis and the day on the X axis, centered around the operation date [5]. We provide important features as presets for quick selection, including *LVEDD* and *AV Vmax*. Filtering functionality over the different features of the data set allows to observe cohorts of patients. As each patient is associated with multiple time points, the filter must indicate whether the condition should be satisfied at all time points or at least one. The result is visualized using a focus-and-context approach: The filtered subset is emphasized, while the broader context remains visible through semi-transparent lines in the background. Additionally, the currently selected patient is highlighted in orange, as well as a button for proceeding to the patient view.

4 Conclusion and Future Work

Using a human-centered design process, we developed our dashboard that allows exploring the heterogeneous data of children with aortic valve diseases. The interactive dashboard is realized using a coordinated multiple views approach, with all views adapted to their clinical context. Future work includes integrating live data instead of using a retrospective data set, and training and integrating AI models that can predict optimal timing of the aortic valve replacement. We will evaluate the usability and clinical relevance using qualitative user studies.

Acknowledgments

This research project was funded by the German Heart Foundation, Frankfurt.

REFERENCES

[1] M. Bostock, V. Ogievetsky, and J. Heer. D^3 data-driven documents. *IEEE Transactions on visualization and computer graphics*, 17(12):2301–2309, 2011. 2

[2] M. L. Brown, H. V. Schaff, R. M. Suri, L. Zhuo, T. M. Sundt, J. A. Dearani, R. C. Daly, and T. A. Orszulak. Indexed left ventricular dimensions best predict survival after aortic valve replacement in patients with aortic valve regurgitation. *The Annals of thoracic surgery*, 87(4):1170–1176, 2009. 2

[3] J. R. Etnel, L. C. Elmont, E. Ertekin, M. M. Mokhles, H. J. Heuvelman, J. W. Roos-Hesselink, P. L. De Jong, W. A. Helbing, A. J. Bogers, and J. J. Takkenberg. Outcome after aortic valve replacement in children: a systematic review and meta-analysis. *The Journal of thoracic and cardiovascular surgery*, 151(1):143–152, 2016. 1

[4] J. T. Tretter and A. Langsner. Timing of aortic valve intervention in pediatric chronic aortic insufficiency. *Pediatric cardiology*, 35:1321–1326, 2014. 1

[5] T. D. Wang, C. Plaisant, A. J. Quinn, R. Stanchak, S. Murphy, and B. Shneiderman. Aligning temporal data by sentinel events: discovering patterns in electronic health records. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pp. 457–466, 2008. 2