Visual Exploration of Pairwise Meta-Analysis Results in Real Time

Huan He [1] *, Irbaz Bin Riaz [2,4,5] *, Syed Arsalan Ahmed Naqvi [2], Rabbia Siddiqi [3], Noureen Asghar [3], Mahnoor Islam [3], M. Hassan Murad [4], and Hongfang Liu [1, †]

[1] Department of AI and Informatics, Mayo Clinic, Rochester, MN, USA
[2] Department of Oncology, Mayo Clinic, Phoenix, AZ, USA
[3] Dow University of Health Sciences, Karachi, Pakistan
[4] Mayo Clinic Evidence Based Practice Center, Mayo Clinic, Rochester, MN, USA
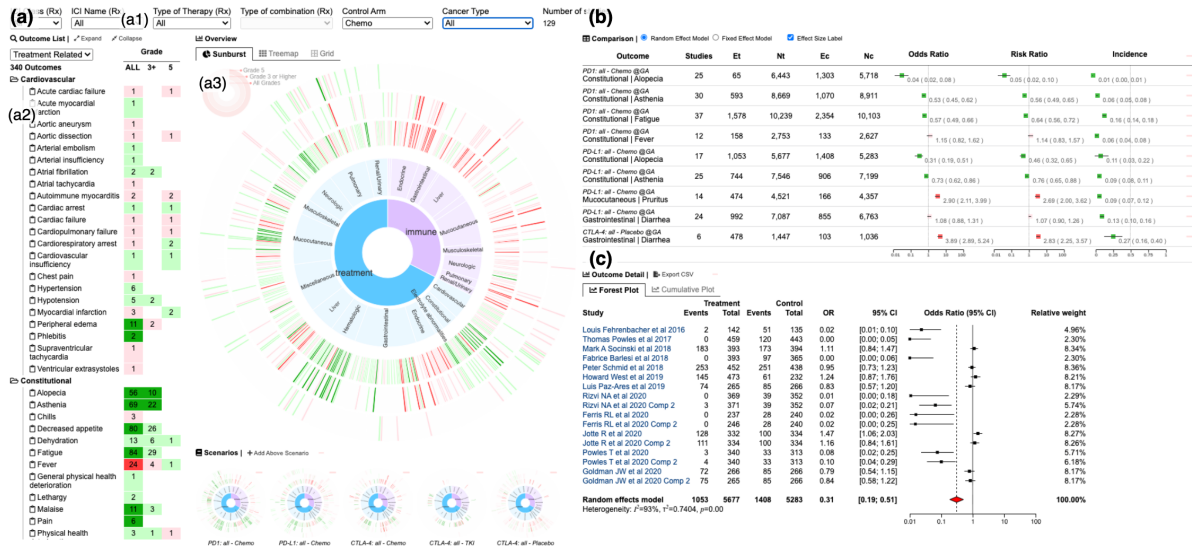[5] Mass General Brigham Hospital, Harvard Medical School, Boston, MA, USA

Figure 1: An interactive visual analytics system for exploring massive pairwise meta-analysis results. (a) The Overview shows the macro-level distribution of the pooled effects of all the outcomes of a specific scenario (a3). The user can customize analysis scenarios with a filter panel (a1), and the filtered outcomes are listed in the outcome list (a2). (b) The Comparison View lists the selected outcomes and how they differ from each other. (c) The Detailed View shows forest plots to help users to examine the spread of the studies included for a specific

ABSTRACT

An interactive and balanced presentation and interpretation of results from a pairwise meta-analysis (PWMA) can immensely facilitate evidence synthesizing in clinical research and practice. However, exploring the PWMA results for clinicians and researchers is challenging as the complexity of clinical questions increases and the vast number of involved studies and outcomes. In response, we proposed a web-based visual analytics system to facilitate the real-time exploration of massive PWMA results.

1 INTRODUCTION

Pairwise meta-analyses (PWMAs) are widely used to summarize precise estimates of treatment effects by pooling evidence from randomized controlled trials that compare two interventions [1]. PWMA can help guideline makers and clinicians to understand the potential benefits and harms using the totality of existing evidence for critical clinical questions. However, presenting the PWMA results from many trials and across many patient-important outcomes can be challenging.

First, the existing tools, such as R packages of meta and metafor [2], are primarily focused on local analytics and producing results

for publications (e.g., static tables and figures). The published static PWMA results cannot be leveraged easily for further exploration. Second, while web services can be leveraged to serve PWMA calculation through the internet, the delayed feedback caused by data transmission and computation cost limit in-depth exploration. Moreover, as the number of users and requests increases, the increasing computation demands of web services will increase the server load and cause delays, which affects the usability and further limits the exploration.

To address the above challenges, we developed a web-based visual analytics system based on a customized JavaScript PWMA module to facilitate real-time exploration of massive PWMA results. The major contributions are as follows:

1. A JavaScript PWMA module that supports PWMA calculation and enables a serverless web-based system for real-time exploration of massive PWMA results in a web browser.

2. An interactive visual analytics system for real-time exploring massive PWMA results based on our proposed PWMA module.

2 RELATED WORK

A variety of commercial and open-source software and packages are available to perform PWMA, such as meta, metafor, and dmetar [2]. And there are a few studies focusing on PWMA visualization designs, such as forest plots and funnel plots, which mainly focus on producing static figures for publications. On the contrary, our proposed visual analytics system aims to provide a more interactive way to help users further explore multiple outcomes of dynamic scenarios in a web browser in real-time.

* Those authors contributed equally to this work.
  e-mail: He.Huan@mayo.edu
  e-mail: riaz.dr@mayo.edu
† e-mail: Liu.Hongfang@mayo.edu

3 DESIGN TASKS

Our design process began with a series of informal discussions and interviews with five domain experts on PWMA at Mayo Clinic. Two of them are our internal collaborators and the other three collaborators are likewise engaged in a variety of PWMAs. We have developed a prototype system to collect task requirements and summarized the task requirements based on feedback as follows:

R1: Presentation of results for a given outcome. It is important to present the effect estimates at the level of each individual outcome to get a better understanding of the treatment effect.

R2: Summary of the evidence across a range of outcomes to assess the overall safety of a drug. For patients diagnosed with certain cancer, it is necessary to get a summary of available adverse events for a certain treatment plan.

R3: Comparison of safety between selected outcomes under different scenarios. The relative effect of treatment with regards to the risk of an adverse event might vary with the choice of comparators. Therefore, the focused outcomes should be presented in a comparable way for shared decision-making.

Based on the summarized requirements (R1-R3) coupled with the system feedback from our domain experts, we have derived the following design tasks (T1-T4).

T1: Show the PWMA result of a specific outcome. Users should be able to check the detailed PWMA results of a given outcome to get understating of how the results are generated (R1).

T2: Show the overall PWMA results of multiple outcomes. The design needs to provide the overall distribution of the PWMA results of multiple outcomes to facilitate the evaluation of treatment at a glance (R2).

T3: Support between outcome comparisons. The design should support users in understanding the differences among multiple outcomes (R3).

T4: Facilitate the exploration of various clinical scenarios. Our design should provide flexible options to customize the scenario and allow users to interactively explore the PWMA results (R2 and R3).

4 REAL-TIME PAIRWISE META-ANALYSIS

To facilitate real-time exploration and reduce the time spent on computation and transmission, we developed a JavaScript PWMA module based on Math.js and implemented the commonly used PWMA indicators such as the DerSimonian-Laird estimator, the Cochran's Q, and the Higgins & Thompson's I^2 statistic.

The preliminary test results and our prototype system show significant performance improvements which enable users to check multiple effects (e.g., odds ratio, risk ratio, etc.) at the same time and compare the results between different cohorts, clinical scenarios, and treatment plans. The source code and tests of our JavaScript PWMA module and an online demo of our system with sample data are available at https://ohnlp.github.io/Meta.js/.

5 PRESENTED VISUALIZATION SYSTEM

As shown in Figure 1, the Overview (Fig. 1a) shows the macro-level distribution of the pooled effects of the outcomes in a specific scenario (**T2**). This view has three panels. **Filter panel** (Fig.1(a1)) provides a set of associated filters for users to customize clinical scenarios for conducting PWMA (**T4**), **Outcome panel** (Fig.1(a2)) shows the available outcomes and the summary of the PWMA results of a specific scenario in a tree-like table, and **Distribution panel** (Fig.1(a3)) shows a sunburst plot that presents the overall pooled effects of all outcomes of three grades in three rings.

In this view, the green color represents relative benefit while the red color represents relative harm, and the darker color represents statistically significant results while the lighter color represents non-significant results.
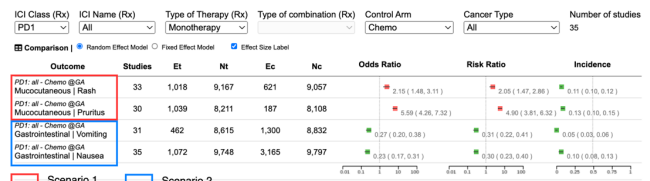

Figure 2: A screenshot for case study

The Comparison View (Fig. 1b) aims to support the comparison between selected outcomes to answer clinical questions (**T3**). The major PWMA results of selected outcomes are listed and color-encoded row by row. The user can add outcomes by clicking the arc or cell in the Overview. Same outcomes from different scenarios can be added for comparison. Users can click on each cell to check more information in the Detailed View.

The Detailed View (Fig. 1c) provides a customized forest plot to help users to examine the precision and spread of the studies included for a specific outcome, and how the pooled effect related to the observed effect sizes (**T1**).

6 CASE STUDY

To investigate the effectiveness of our system, two domain experts from our institution performed a case study on an ongoing PWMA project "Toxicity of Immune Checkpoint Inhibitors". Both experts followed the same sequence of steps, first selecting the conditions and checking the overall PWMA results in the Overview, and then comparing the selected outcomes in the Comparison View and the Detailed View. After an initial assessment of the results, they decided to add more adverse events to get a better sense of treatment safety in the following clinical scenarios.

Scenario 1: What is the risk of all-grade rash and pruritus with PD1 inhibitor monotherapy as compared to chemotherapy in patients with cancer (type not specified)? The experts found an increased risk of rash and pruritus associated with the use of PD1 inhibitor monotherapy when compared to chemotherapy based on evidence from >30 trials with >15000 patients (red box in Fig. 2).

Scenario 2: What is the risk of all-grade nausea and vomiting with PD1 inhibitor monotherapy as compared to chemotherapy in patients with cancer (type not specified)? The experts found a decreased risk of nausea and vomiting with the use of PD1 inhibitor monotherapy when compared to chemotherapy based on evidence from >30 trials with >15000 patients (blue box in Fig. 2).

Both experts commented that the ability to simulate a clinical scenario is helpful and being able to check several outcomes in one view is also helpful for the assessment of the relative safety of treatment. They suggested that it would be better to have different ways to locate outcomes in the Overview, especially when there are many outcomes in some clinical scenarios and the labels on the sunburst plot are too small to identify.

7 CONCLUSION

This poster presented a visual analytics system aiming to support a real-time exploration of PWMA results. The preliminary study shows that our work has the potential to transform how synthesized evidence is presented to patients for shared decision-making. As the next step, we will keep developing the PWMA module and the visual design for further exploration of large-scale PWMA results.

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