COVID-I: A Causal Dynamic Bayesian Network Calculator for Informing Hospital COVID-19 Progression

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1 EXTENDED ABSTRACT

1.1 INTRODUCTION

The COVID-19 disease caused by the SARS-CoV-2 virus has had a significant impact on hospital resourcing and in many cases has impacted the mortality rates of hospital patients [Soria et al., 2021]. Given the recency of the SARS-CoV-2 as well as the speed at which the situation changes between dominant strains, clinicians are left with a great deal of uncertainty on how best to maximise the health outcomes of individual patients. We have built a causal Bayesian Network (BN) that models COVID-19 disease progression in patients from time of presentation at hospital as well as a methodology for rapidly evolving the underlying BN models [Mascaro et al., 2022]. However, supporting clinicians with evidence based decision-making, informed by models such as our COVID-19 BN, at the point of hospitalisation is a different challenge [Sendak et al., 2020, Moxey et al., 2010]. Web based calculators offer a path forward as they have demonstrated success in making BN models accessible to non BN experts in providing decision support around COVID-19 [Lau et al., 2021, Mayfield et al., 2022].

COVID-I is a consortium of research organisations brought together under the CDAP initiative of the Australian Digital Health CRC[1] to research how artificial intelligence can help with the management of the COVID-19 pandemic. The COVID-I patient progression calculator uses Dynamic Bayesian networks (DBN) trained on real-world data from hospitalised cohorts to predict the likely progression of hospitalised patients with COVID-19. While details of the underlying model and methodology have already been documented [Mascaro et al., 2022], the mechanism to deliver this capability to clinicians remains a topic of interest. To this end, the COVID-I team developed a web based calculator.[2]

1.2 METHODOLOGY

The calculator was realised through an Agile project methodology [Cockburn and Highsmith, 2001, Bass et al., 2015] while implementing DevOps toolchains and principles (Bass et al., 2015). Agile sprints were conducted each 2 weeks concluding with a product showcase. UI/UX was deemed critical to the success of this solution due to the initial uncertainty as to how best summarise and portray BN COVID-19 information to clinicians. The development of the calculator faced the additional challenge of having been developed during pandemic lockdowns with traditional in-person usability testing being infeasible. Representation of uncertainty is a very active research area [Van der Bles et al., 2019]. The design of the UI/UX was performed by an industry consultant and was not part of the project's research effort, therefore validating (and potentially improving) the useability of the calculator presents an opportunity for future research.

1.3 ARCHITECTURE

The architecture of the COVID-I patient progression calculator consists of three parts: (1) a React and Node.js driven front end; (2) a Node.js back end server with MongoDB NoSQL database; and (3) a Python Flask API server that serves queries to the BN model(s). Each module is containerised using Docker. The BN models reside within the API container as Netica .DNE files. The initial development of the Node.js modules was developed within AWS infrastructure while the Python API container was on a third party virtual server. The main rationale for this separation was that separate teams with different skill sets were independently maintaining these modules. GitHub was used for source control and management while Travis CI provided Continuous Integration & Continuous Development (CI/CD) functionality.

[1]See `https://www.covidcdap.org/`
[2]See `https://covidi.org/`

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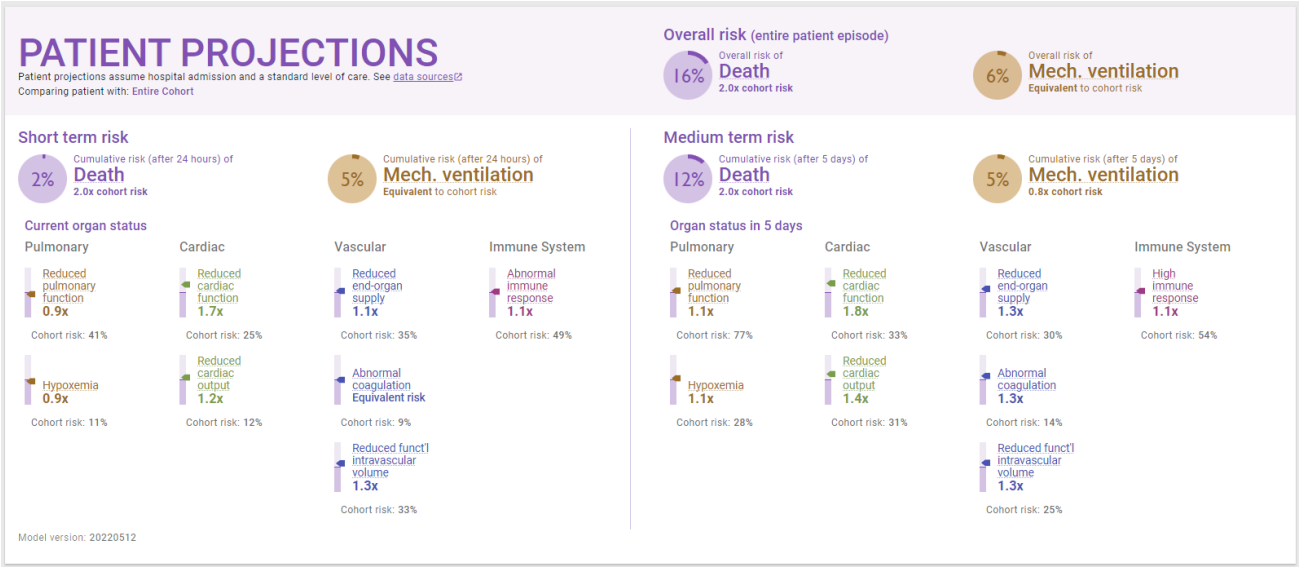

Figure 1: COVID-I patient projection output of main calculator.

1.4 FUNCTIONALITY

The main functional considerations of the calculator include:

- Registration and consent - by providing a barrier to entry we could ameliorate the risk of misinformed use of the calculator furthermore registration provided us insight into the breadth of interest;
- User tips - to ensure overlap in training and education of how the calculator works, users are provided with a tip upon registration;
- Disclaimer and terms and conditions - as the calculator is still under validation and has not been certified as software as a medical device, disclaimers and terms needed to be well considered and front and centre;
- Data sources - to ensure that users understood the limitations of any response from the calculator, the source of the data driving the underlying model needed to be highlighted;
- Instructions for use - are provided in detail as we have not yet tested if the output of the calculator is intuitive to all users;
- Setting evidence - the calculator accepts evidence in the form of patient background, comorbidities and patient indicators which are mapped to variables within the underlying BN's. Mapping logic between the calculator inputs and the BN (such as discretisation and interpolation) is performed within the API layer;
- Patient projections - the API returns multiple sets of responses based on the evidence provided. These responses include output based on the specific evidence set, as well as more generalised outputs that provided cohorts for comparison;

Both setting evidence and the output of patient projections are displayed on a single page. Figure 1 shows the patient projects component as context. The underlying BN is dynamic, with the calculator providing short term, medium term and overall risk projections. It is important to note that these results are for demonstration purposes only and that the indicative figures are for patients that have presented to hospital with COVID-19 not all individuals with COVID-19. Furthermore these are specific to region and strain of the virus. A statement identifies how similar the patient is compared to a cohort of other patients that share similar background factors (such as age).

1.5 CONCLUSION AND FUTURE WORK

The COVID-I patient progression calculator provides a means to rapidly convey BN findings to clinicians. We have not yet empirically determined the effectiveness of this tool however focus groups with stakeholders during development have provided promising anecdotal feedback. The next steps with the calculator are to (1) evaluate the UI/IX in a usability testing lab and revise as needed and (2) commence validation within a hospital district setting. Validation will include both the calculator output as well as the UI/UX. Currently, the calculator is a standalone tool without integration for the evidence, meaning that users must enter patient evidence/data via the web-interface - which is a combination of drop down menus and plain text fields. Following successful validation, an assessment needs to be made as to the Australian Therapeutic Goods Authority (TGA) regulatory requirements (if any) as well as a determination as to what extent integration with Electronic Medical Records (EMRs) is required.

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