N95 masks and ventilators, particularly at community hospitals. Traditional Chinese medications should also be considered, as they have a profound role in Chinese society and may help relieve mild respiratory symptoms.

It is our view that mainland China should consider changing stepwise from the zero-COVID approach in April or May 2022. By this time, vaccination immunity will not have declined much and most parts of the country will be warm. There is some evidence that SARS-CoV-2 is less transmissable in warmer months[8], when co-infection with other respiratory pathogens will also be less frequent.

Regardless of when the zero-COVID policy changes, preparations should be implemented in advance to confront the challenges. ❐

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Author contributions

J.-M.C. and Y.-Q.C. conceived and conducted this analysis and drafted the manuscript. J.-M.C. supported this work.

Competing interests

The authors declare no competing interests.

Check for updates

A web-based app to provide personalized recommendations for COVID-19

To the Editor — So far, there have been more than 395 million SARS-CoV-2 infections, leading to at least 6 million deaths from COVID-19. The Omicron variant has caused a record surge in cases, with numbers still rising in 45 countries (as of 23 March 2022). COVID-19 testing, immunization and guidelines for nonpharmaceutical interventions are available to mitigate the pandemic, but there is some resistance to these interventions, due to a perceived lack of relevant and trustworthy information[1–3]. We developed a digital recommendation system named CovApp with the following aims: personalized recommendations based on survey answers; ease of use; high scalability to millions of users; fast updates to react to rapidly changing pandemic conditions; and the ability to transfer data to hospital information systems. CovApp was implemented as a web app accessible by internet-enabled devices such as PCs, tablets and especially smartphones. CovApp and its specifications were released as open source[4].

As a multidisciplinary panel of physicians, epidemiologists, computer and data scientists at Charité–Universitätsmedizin Berlin and the Robert Koch Institute (German National Center for Disease Control), we developed a survey with 27 items regarding symptoms, chronic diseases, social environment, COVID-19 test results and vaccination status. Logical expressions are used to estimate the user's risk of infection, severe COVID-19 and secondary infections. On the basis of these estimated risks, CovApp creates personalized recommendations for testing, vaccination and boosters, self-isolation, and possible eligibility for treatments, such as monoclonal antibodies, or inclusion in COVID-19 studies, such as those on vaccine breakthrough infections. CovApp can be used in a wide variety of clinical situations, including false-negative antigen tests, immunosuppression[5], breakthrough infections[6] and very high-risk patients, such as those receiving cancer treatment[7]. Data transfer to hospital information systems is implemented using QR codes that can be scanned at hospitals or testing sites, allowing rapid, standardized electronic documentation and transfer of patient history and clinical data[8] (Fig. 1). CovApp users can volunteer to donate their survey answers for research purposes.

The CovApp instance of Charité Berlin has served up to 2.5 million users in Germany on a monthly basis. It is supported by a variety of German institutions, including the National Center for Disease Control, the Federal Ministry of Health and the Federal Center for Health Education, and has received more than 14,000 backlinks from other websites. CovApp has also received significant media coverage, with more than 1,500 news articles mentioning the term. The authors are aware of more than 100 CovApp instances, in which third parties have adapted the app based on the publicly available code and documentation.

Recommendations need to be updated frequently in line with new emerging variants, novel scientific findings and government policies. Therefore, we developed a secondary tool, named CovQuestions, as a prototyping environment for rapid updates. Using a web-based editor, questions, logical expressions and recommendations can be edited and changes can be immediately assessed. For logical evaluations, a script language with basic syntax has been developed. The tool also contains a testing environment to verify the consistency of the logical expressions by defining test patient cases. CovQuestions can be used as an application programming interface to deliver up-to-date surveys to CovApp. CovApp uses the same rule engine as CovQuestions to evaluate logical expressions on the user's smartphone and to compose recommendations, without the need to send data to external servers. In consequence, these design decisions resulted in maximum data protection and confidentiality for users, in addition to high scalability, as the smartphone's resources are used for computing-intensive workloads.

After our successes in Germany, we released CovApp in the United States[9]. We leveraged the rapid prototyping environment of CovQuestions to create, in collaboration with Stanford and Harvard Universities, a US-specific version of CovApp that provides recommendations in accordance with US Centers for Disease Control and other federal and state guidelines. User characteristics and location are used to generate a visual risk score and personalized

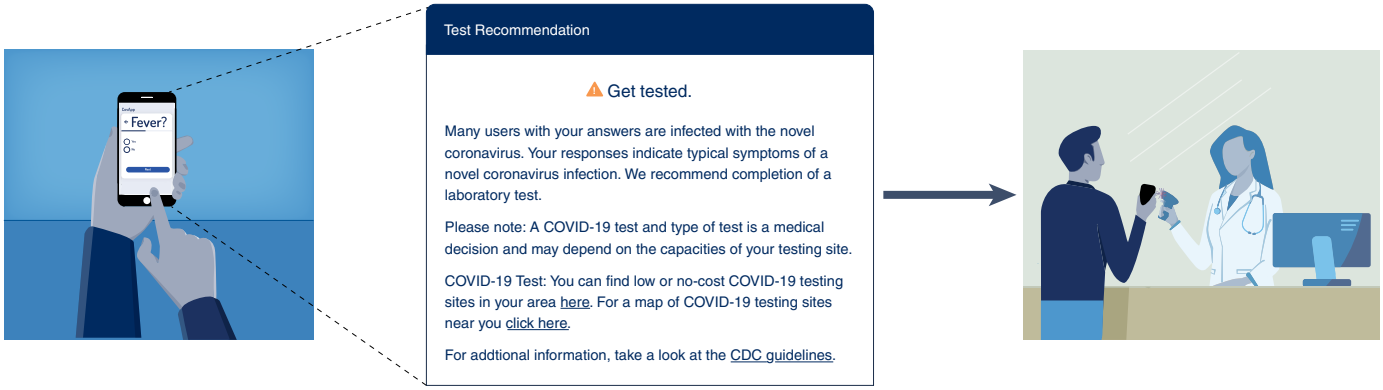

Fig. 1 | Schematic of the CovApp recommendation workflow. A person who suspects they have a SARS-CoV-2 infection can complete a survey at home, receive personalized recommendations and then present a QR code generated during this process at a hospital or COVID-19 testing center, resulting in an accelerated admission process. The medical staff can stay protected behind a glass window to scan the QR code from the smartphone's display.

recommendations (Fig. 1). Real-time information regarding regional infection numbers in the United States is evaluated and translated into easy-to-understand metrics, such as the probability of encountering an infected person. Users are guided through various US health-care offerings, including local sites for low-cost or free COVID-19 testing and vaccination and specialized treatment centers for monoclonal antibodies (Fig. 1). Depending on the course of the pandemic, further country-specific versions might be helpful to address specific countries' needs. For example, our group is currently in contact with the public health authorities in Rwanda to adapt CovApp to the local public health policies there.

Recently, our group demonstrated that the effective reproduction rate of SARS-CoV-2 can be modeled and predicted two weeks ahead via a contact index, a metric that characterizes the contact behavior of the general population and that is derived from deidentified global positioning system (GPS) data of 1.15–1.4 million smartphones[10]. We plan to combine the symptom data from CovApp with GPS data to create an early-warning system that will deploy artificial intelligence methods to detect local outbreaks and predict the spatial and temporal evolution of infection cases.

By translating up-to-date scientific knowledge and the current public health policies into personalized recommendations, CovApp addresses the individual's questions and concerns and provides guidance on next steps after they are exposed to SARS-CoV-2. The large number of CovApp users illustrates the feasibility of employing a web-based survey and recommendation system to educate and engage the public in the pandemic response, while also providing an important source of big data for future research. ❐

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Author contributions

A.H.T. designed and developed CovApp; A.H.T. and O.G. conceived the idea of the manuscript and wrote the first draft. All authors commented on draft versions of the manuscript for important intellectual content and approved the final version.

Competing interests

The authors declare no competing interests.