SEQUOIA (Sending Emergency Queries Utilizing Online Interactive Aid)

See a Demo of Sequoia here.

Try it yourself!

User: Text HELLO to 618-643-9906

Provider: After a user submits a triage request, triage users here http://159.89.236.70/

1. Problem Overview / Relevant Clinical Background

We are addressing the problem of healthcare resources being overwhelmed by an exponential patient influx to clinical entry points during the COVID-19 pandemic. Emerging research from the CDC, NCBI, and UptoDate states that the clinical presentation of COVID-19 can greatly vary in terms of clinical manifestations and disease severity, meaning different patients are best treated at different care facilities that best fit their needs.[10,12,13] Without a way to get the right patients to the right facilities at the right times, the massive influx will create hospital backlogs that will hasten the spread of COVID-19, divert valuable time away from in person care, and needlessly overburden care facilities.

We have spoken with several physicians and innovation leaders across emergency medicine, internal medicine, and intensive care at Washington University in St. Louis and Barnes-Jewish Hospital who have validated this need. Our competitive analysis has revealed some related solutions, such as high-powered AI screening/diagnostic tools, that handle the complexity of their given problems well. However, these are still only solving isolated resource problems, and there remains a need for a resource connection tool that quickly links patients to the appropriate facilities for their needed level of care. With 41 states predicted to have insufficient ICU beds (11 of which are expected to require a >50% boost in capacity) to handle the upcoming COVID-19 patient influx, this tool needs to be rapidly deployable.[2]

That means it must have simplicity and flexibility as its hallmarks, allowing both easy access/use while also being customizable to fit the needs of different health systems. To ensure effectiveness and patient adherence, the tool would also need to include some form of provider input to make the resource connection. A recent meta-analysis of pure machine based "symptom checkers" indicates such tools exhibit their greatest failure rates in the context of triage.[3,4] The best such tools studied demonstrated a 78% accuracy in triage advice - with others as low as 33%.[4] Additionally, such machine based tools also err on the side of suggesting patients seek further in-person care[4] This could significantly exacerbate the current problem of overflow at clinical entry points. Finally, a 2019 survey of students in Boston and New York showed a 53% greater adherence rate for care suggestions when medical information was provided by a human in comparison to a solely AI-based tool.[1]

Thus, a simple, flexible tool that can provide an automated match between patients and care facilities while still allowing provider input has the potential to greatly reduce the strain on our healthcare system as we battle COVID-19.

2. Proposed Solution

Sequoia is an SMS-based platform based on simplicity and flexibility that connects users to a list of appropriate care facilities by utilizing remote provider input. It gathers the user's responses to automated questions regarding COVID-19 symptoms into a request, which is placed onto a queue. Authorized healthcare providers (including any provider able to do basic triage) can log on to a web interface to view each queued request. Using their clinical judgement, they select from a list of types of care facilities that the patient can be directed to (there is also an option to direct the patient to stay at home). Sequoia's algorithm then takes in the provider's selection alongside data on care facility location and available resources to deliver a list of best-fit facilities near the patient via SMS.

Sequoia is based on crowdsourcing available providers during the crisis, which would allow full utilization of the changing population of available providers (this is not limited to physicians and could include nurses, physician assistants, residents, fourth year medical students, and other allied health professionals). There have been increasing recent cancellations of elective and outpatient clinical procedures - 2019 AAMC data indicates this could affect 25.7% of physicians in New York (similar numbers exist in many other states, as seen in **Table 1**).[7] CMS's recent national recommendations also include limiting and/or delaying non-essential medical, surgical, and dental procedures.[14,15] Reports coming out of hard-hit areas like New York also reveal that medical schools are granting their fourth year students the option of early graduation in order to join the COVID-19 fight.[16] This creates an increasing pool of providers who may not necessarily have years of emergency room or critical care experience, but are in a great position to help in other ways, such as by triaging via Sequoia's platform. This will buy time for those with emergency/critical care experience to focus on in-person care. Thus, Sequoia can increase clinical capacity and efficiency by sourcing all available providers within a certain health system. If a cross-health system is adopted (see Use Case section), an even larger pool of providers becomes accessible, such as retired doctors and rural practitioners, further increasing capacity and efficiency.

Sequoia is designed to integrate seamlessly into both the user's and provider's workflow. Anyone who wants medical guidance on whether to get in-person care (and if so, where to receive care) can simply text Sequoia's hotline number and receive a response, all through their phone screens. In times of crisis, there are likely to be many people who want such advice for any symptoms they may have, and Sequoia allows them to bypass calls to overburdened phone lines with massive delays (such as those causing 911 operators to put callers on hold).[17] Any crowdsourced providers who want to triage don't have to go through lengthy training to learn how to use a complex technology. They simply log on to the web interface, view a patient request from the queue, and select where to send the patient from an automated list of care facility types/levels. The final selection is converted to a list of nearby appropriate facilities via Sequoia's algorithm and sent back to the user. Only if needed, a provider can contact a user for more information via telephone or teleconference. Our discussions with providers gave us an estimate that fulfilling a single patient request would take at most five minutes.

Finally, the platform is very flexible: the automated questions sent to patients, the automated care facility suggestions providers can choose from, and the variables going into the algorithm (location and care facility data) can be easily adjusted by different health systems to fit their unique requirements. This fulfills the primary goal: linking patients to the appropriate facilities through remote provider input in a way that can function smoothly across our healthcare system.

3. Use Case

On the user side, as seen in **Figure 1**, individuals use SMS to enter symptoms and basic biometrics. This information is sent to a provider viewing a web app, as seen in **Figure 2**, to determine what type of care facility, if any, is needed. Our back-end algorithm adds this information into existing locational and care facility data to return a list of most appropriate care facilities to the user. **We envision two primary implementations of Sequoia:**

Intra-system Use: Individual health systems can implement Sequoia to efficiently direct patients between their existing care facilities. Instead of crowding the emergency departments or overwhelming phone lines, users within a certain health system's radius of operation simply text Sequoia's hotline number with a request when they need basic advice on whether to seek in-person care and, if needed, where to receive that care. All providers assisting that health system with triage can open Sequoia's web interface, view a request from the queue, and pick a care facility option. Individual health systems can program their own list of care facility options and care facility data (number of providers, beds, ventilators, etc.) into the Sequoia platform. In essence, Sequoia would allow health systems to rapidly stand-up their own service directing patients to appropriate care facilities via remote provider input amid the COVID-19 crisis.

Inter-system Use: In the situation where a pandemic is so severe that individual health systems cannot handle the massive patient influx on their own, Sequoia provides a great alternate option. Neighboring health systems can have vastly differing care facilities, data sets, and provider availability. However, if they have both adopted our tool into their systems, they will both possess Sequoia's basic framework. Thus, the two health systems needing additional support can connect their Sequoia platforms and combine their programmed list of care facility options and available care facility data. Now users will receive an expanded list of care facilities and patient influx will be efficiently distributed between facilities at both health systems, with providers also being crowdsourced from both health systems.

4. Evidence for Functionality/Efficacy.

Core functionality of the platform has been validated with rapid, streamlined transfer of information between a user via SMS and a provider via web application (see demo on page 1). Due to the prevalence of SMS technology (96% of Americans own some kind of phone with at least 2G capability), Sequoia's platform technology is already distributed across the intended market.[6] To model Sequoia's use, we denote traditional triage within one health system as "intra-hospital triage" and cross-health system triage as "inter-hospital triage". We can then model intra-hospital triage as a single-server, single-phase system, and model inter-hospital triage as a multi-server, single-line, single-phase system (**Figure 3**). A comparison of the average wait times per patient shows two key results. First, as the arrival rate of patients increases, the average waiting time per patient remains constant in the case of inter-hospital triage, while it increases exponentially in the case of intra-state triage (**Figure 4**). Second, as the number of hospitals increases (modeling the reality of urban centers such as NYC), the difference in average wait time increases significantly during periods of high patient influx (**Figure 5**). Together, these points suggest that densely populated areas experiencing a high number of Coronavirus cases can expect to benefit the most by adopting a system that can function across health systems.

In addition to waiting times, modeling patient distribution across a multi-hospital system demonstrates the drastic impact that capacity-informed triaging has on increasing both time until a center reaches overload and the number of total patients that can be helped before said overload occurs (**Figure 6**). A system by which patients utilize total capacity of hospitals (i.e. static CMS-derived data on bed number) doubles the number of patients that can be helped while a model incorporating live capacity data in hospitals further increases total patient volume until overload by 25% (**Figure 6**).

In the case where inter-system triage across state lines can be facilitated, the temporal shift of COVID-19 epidemic peaks across different states can be leveraged. For example, current modeling predicts New York state peak resource and provider usage to occur on April 6th, 2020 while Wisconsin is expected to peak on May 24th, 2020.[5] Thus, as the pandemic spreads, certain areas will likely maintain excess provider pools. As COVID-19 worsens, we predict more states will follow trends set by Washington and activate UEVHPA legislation allowing for providers out-of-state in good-standing to provide the same level of service as in-state providers.[8] In this situation, Sequoia's utility increases yet again as available providers across the entire country can easily log-in and direct patients to the appropriate care facilities, greatly increasing the efficiency of patient handling and distribution.

5. Further Design / Testing Work Required

Sequoia's technology refinement has two broad purposes. The first is to ensure our tool complies with the complex legal standards regarding basic clinical triage. Before deployment, Sequoia's platform must comply with all HIPAA and PHI standards and allows providers to legally triage both within and between health systems. We need assistance with this step as it requires input from those with legal and/or government expertise.

The second refinement is that Sequoia's clinical workflow would need further vetting through discussions with government and public health agencies. On the front-end, we want to de-risk mis-triaging by verifying that the automated questions from which users can submit information are the ones that give providers the necessary information to make an effective triage decision. On the backend, we want to refine our sorting algorithm that sends a list of appropriate care centers back to users. This would be done by verifying inclusion of the most important static factors present in CMS and other public health databases to predict whether a certain facility has the capacity to provide a certain level of care. We would similarly want to optimize how our algorithm includes real-time (or as close to real-time as possible) factors about the availability of resources (beds, equipment, providers) that could also potentially impact care facility suggestions.

Despite these needed refinements to ensure maximal safety and effectiveness, Sequoia's main platform is already functional and running. Sequoia bypasses the need for FDA Class II clearance as a diagnostic by letting a trained, human provider make the triage decision. We are not predicting that ensuring legality and safety should be too difficult, especially as regulations around telemedicine are laxing based on policy trends already enacted at the federal and state levels (e.g. the state of Washington declaring emergency and activating UEVHPA).

6. Implementation Plan

Once this platform has been legally and clinically verified, we will interface with two primary players: hospital systems/academic centers and government/public health systems. As seen in **Figure 7**, we expect to first pilot Sequoia at a single locale (whether hospital or public health center based) to test efficacy. We have already affirmed with leaders of clinical care excellence and innovation at our affiliated teaching hospital Barnes-Jewish Hospital to see this can be achieved. We hope to complete a beta-prototype for potential IRB approval by April 10th. With that being said, we are cognizant of the bottlenecks associated with academic/hospital vetting of such a study in relation to the time course of the pandemic and are committed to making as much of a timely impact as we can.

Thus, we also plan to reach out to county and state municipality public health organizations. Here, the approach would be to provide this service for free to users within the catchment area of the county/state and work with the relevant public health department to source doctors and hospital data. Discussions with physicians who advise our state Social Services agency have indicated that this tool is of need and could be supported by state funding in Missouri. Adoption at state level could also help develop an incentivization structure for sharing of data regarding available equipment, providers, and patient load.

7. Resources Needed for Completion

In order to meet our implementation timeline and positively impact the COVID-19 pandemic, we need to rapidly assemble the public health/clinical expertise needed to develop a safe product that is approved for deployment. Guidance is also required on navigating the legal process associated with electronically transmitting medical information. Access to governmental groups outside of Missouri to better understand the scalability of Sequoia is also critical in nationwide support. Much of the support we require will be in-kind given that our platform is entirely software-driven with the only projected costs stemming from server usage.

Appendix (Figures/Data/Tables)

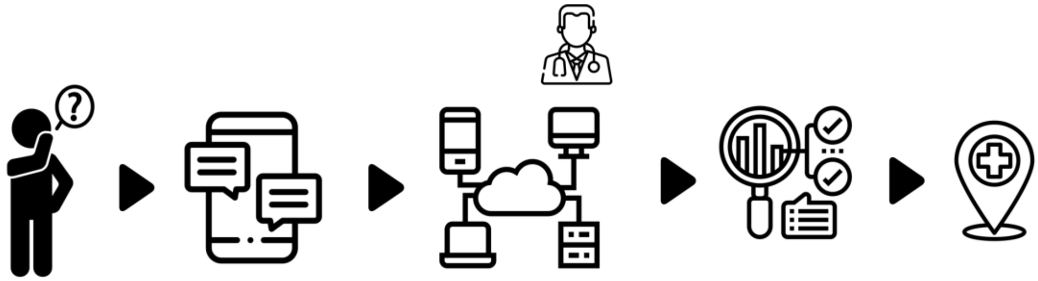

Figure 1: A schematic illustrating a user unsure of whether they are infected with SARS-CoV-2 first interacts with an SMS-based chatbot. This information is then translated into a web app for provider decision-making. Once appropriate level of care has been determined, a matching algorithm incorporates local, level of care, and bed availability to best guide the user to the appropriate care facility location given wait times and type of care needed.

Figure 2: A schematic illustrating the conversion of patient data into a web portal that reduces provider interaction to the critical and last step of triage: decision-making. Once a provider makes a decision regarding level of care, our back-end services take care of providing the full list of available and appropriate care facility locations to the user.

State	Percentage of Providers Performing Elective Procedures and Surgeries
California	22.2
Florida	20.6
Illinois	20.3
Maryland	23.4
Missouri	21.0
New York	25.7

Table 1: Percentage of providers in a series of states that primarily perform elective procedures and surgeries.[9]

Figure 3 depicts the differences between a single-server single-phase waiting line model and a multi-server, single-phase, single-line model.

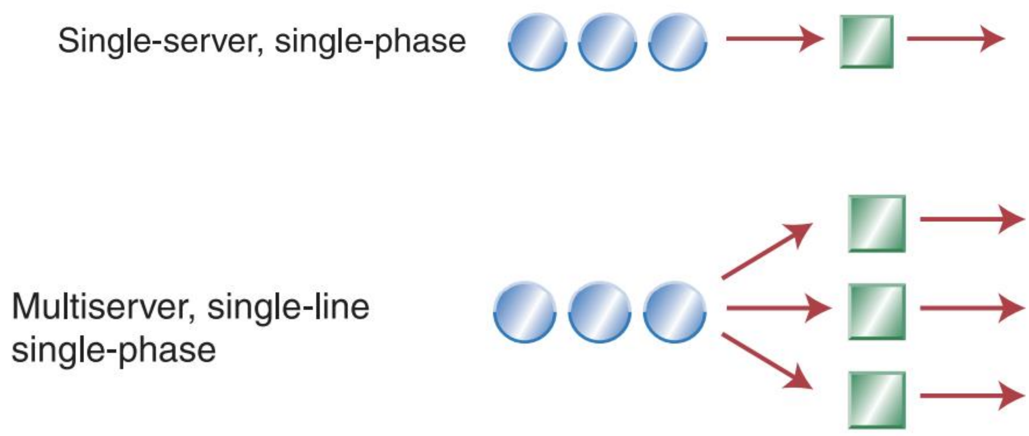

Figure 3: Single-server, single-phase waiting line model (top) and multi-server, single-line, single-phase waiting line model (bottom). They are used to represent intra-system and inter-system triage, respectively.[11]

Figure 4 and **Figure 5** show that inter-hospital triaging outperforms intra-hospital triaging by decreasing average patient wait time in both a pre-pandemic (**Figure 5, top**) and pandemic (**Figure 5, bottom**) setting. Intra-hospital triaging is based on a single-server waiting line model and inter-hospital triaging is based on a multi-server waiting line model.[11]

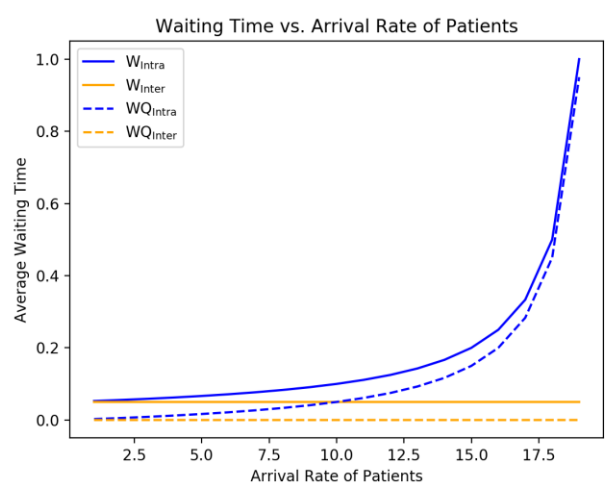

Figure 4: Inter-hospital triage outperforms intra-hospital triage. As the arrival rate of patients increases, the average wait time for inter-hospital triaging remains constant while the average wait time for intra-hospital triaging grows exponentially. W represents average time spent waiting in the system, including service, while WQ represents the average time spent waiting in line/Sequoia's queue.

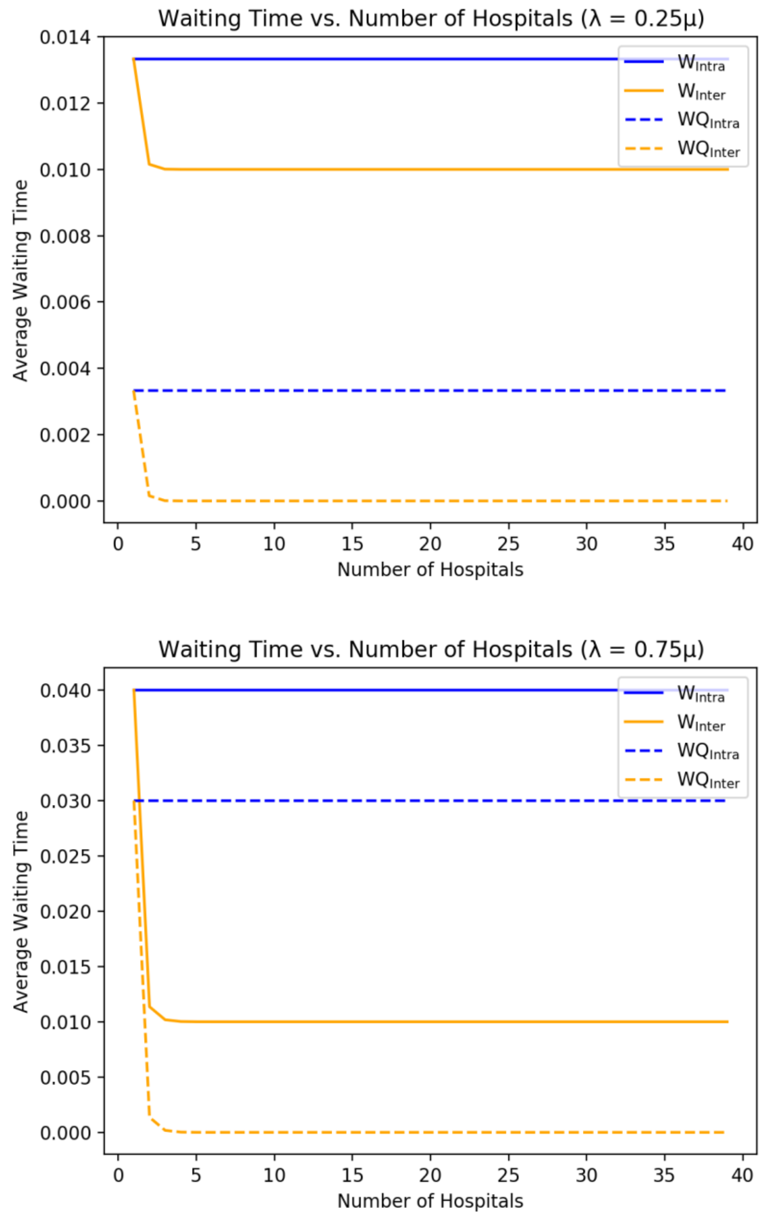

Figure 5: Inter-hospital triage vs. intra-hospital triage in a pre-pandemic and pandemic setting. λ represents mean arrival rate of patients while μ represents mean triage rate, and the λ/μ ratio indicates model similarity to a pandemic setting. As λ/μ approaches 1, the model illustrates hospitals triaging at maximum capacity, a case most applicable to the COVID-19 pandemic. As the ratio of incoming patients to outgoing patients increases, inter-hospital triaging significantly increases in relative efficiency. The top figure has a lower ratio, simulating pre-pandemic days. The bottom figure has a higher ratio, simulating COVID-19 today. W represents average time spent waiting in the system, including service, while WQ represents the average time spent waiting in line/Sequoia's queue.

Figure 6 represents a series of simulations representing how different methods of load distribution across a multi-system city affects the ability to treat patients.

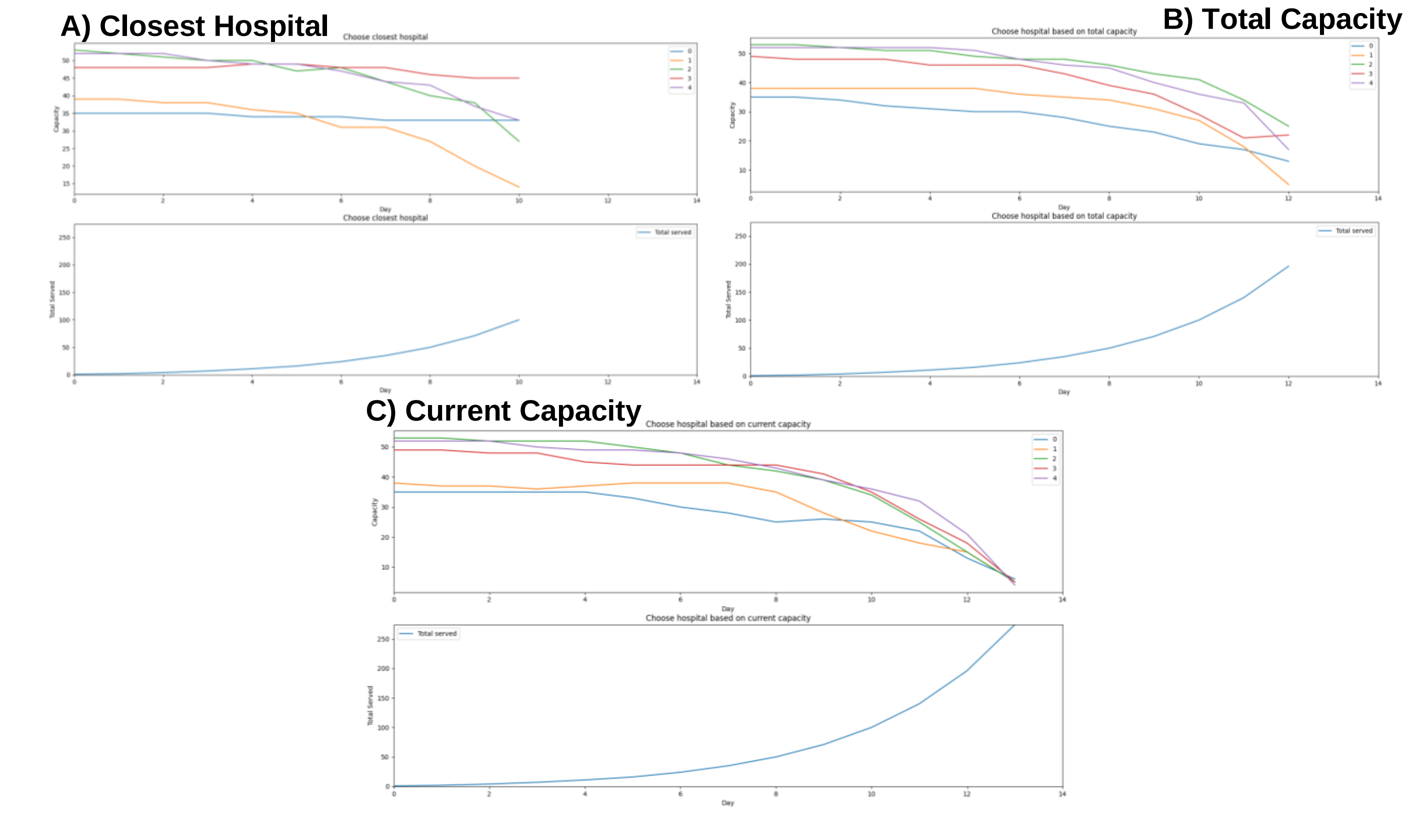

Figure 6: A series of stochastic simulations showing the effect of the Sequoia system on hospital capacities. Each pair of vertical graphs represents simulation with a specific user behavior; behaviors include choosing the closest hospital when infected **(A)**, randomly choosing a hospital weighted on total capacity of the hospital **(B)**, and randomly choosing a hospital weighted on the current open capacity of the hospital **(C)**. In this simulation, there are 50,000 people in the population and the number of infections increases by a factor of 1.4X every day. The capacities of the 5 hospitals are chosen from a normal distribution with mean 50 and standard deviation 10. A treatment time of 4 days was modeled, after which the patient was returned to the population and was no longer able to be infected. The top graph in each series depicts the capacities of each hospital at each day, and the bottom graph represents the total number of patients admitted to the hospital. The simulation stops when at least one hospital's capacity equals zero; e.g. the hospital becomes overloaded. In this simulation, the "closest hospital" model becomes overloaded after 10 days and ~100 patients **(A)**, the "total capacity" model becomes overloaded after 12 days and ~200 patients **(B)**, and the "current capacity" model becomes overloaded after 13 days and ~250 patients **(C)**. Our current Sequoia prototype corresponds to the "total capacity" model **(B)**, but the full implementation would correspond most closely to the "current capacity" model, taking into account current information provided by health care centers **(C)**.

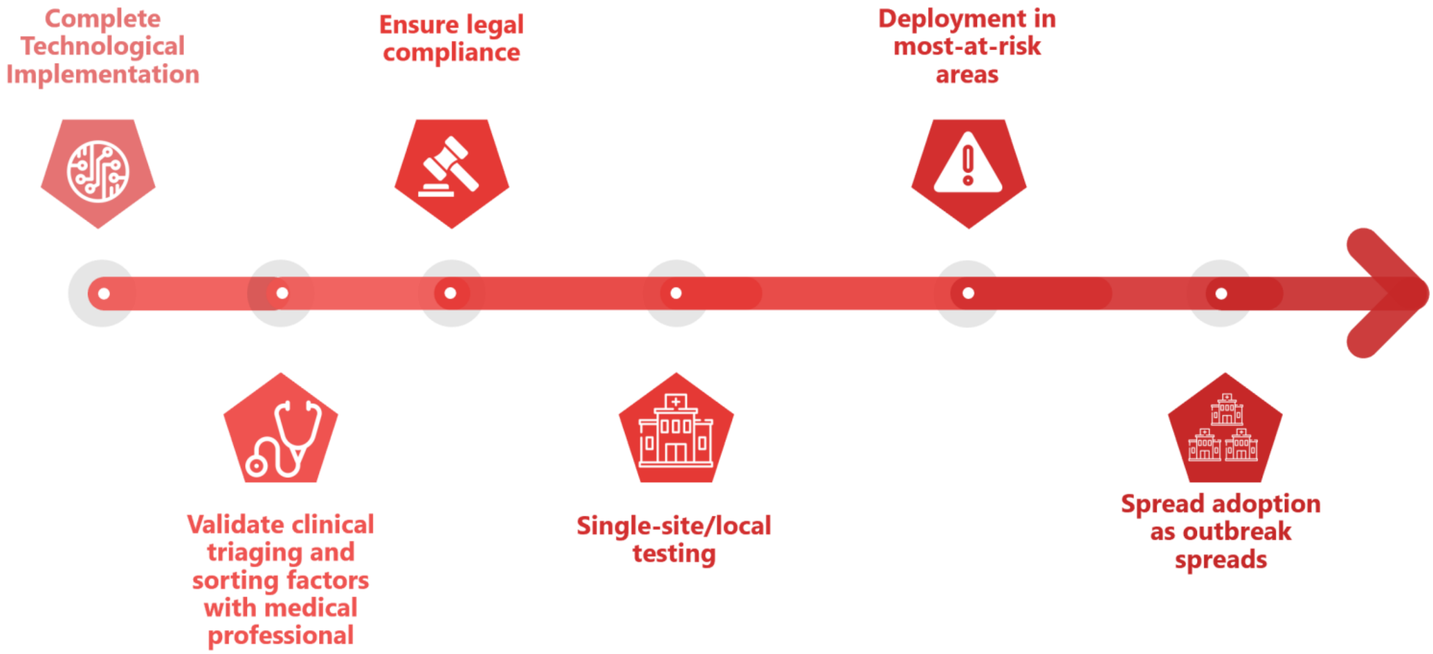

Figure 7: A timeline of key next steps to bring Sequoia in the hands of those that need it most.

References

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