

Reconfiguring health services to cope with COVID19-related bed shortage using an open-source scalable platform for remote digital monitoring and coordination of care through hospital Command Centers

Philippe Ravaud^{1,2}, Franck le Ouay^{3*}, Etienne Depaulis³, Alexandre Huckert³, Bruno Vegreville⁴, Viet-Thi Tran^{1,2}

¹ University of Paris, CRESS, INSERM, INRA, F-75004 Paris, France

² Assistance Publique Hôpitaux de Paris, F-75004 Paris France

³ Lifen, Paris France

⁴ Inato, Paris, France

Words: 1075

Corresponding author:

Frank le Ouay
Lifen
franck@lifen.fr

Abstract (100 words)

The Covid-19 outbreak threatens to saturate healthcare systems in most Western countries. It is critical to set up alternative solutions to hospital quarantine for all patients with confirmed Covid-19. We described precise steps utilizing digital technologies to remotely monitor patients at home and only hospitalize patients with signs of severity. Data from remote monitoring of patients are transmitted to a Command Center in the nearest reference hospital, and are automatically filtered so that physicians can focus on patients with early warning signs. Open-source code of all software components required to deploy the remote digital monitoring platform is available.

Context

The coronavirus disease 2019 (Covid-19) has been declared a public health emergency of international concern¹. On the 6th of March 2020, 97 993 cases were confirmed in 87 countries, with 3 381 deaths². The Covid-19 outbreak threatens to saturate healthcare systems in most Western countries -which are already at breaking point dealing with the routine demands placed on them³. First, Covid-19 transmits easily, with risk of a global epidemic (R_0 between 1.4 and 3.9)⁴. Some experts estimate that up to 70% of the world population could be affected⁵. Secondly, the current management of patients with confirmed Covid-19 involves hospital quarantine and surveillance for 14 days, independently of their clinical presentation, despite the fact that most patients who will contract the virus will have few or no long term effects³. Naïve calculations show that this strategy will not be sustainable as the epidemic progresses⁶. Thus, setting-up alternative solutions to universal hospital quarantine is critical.

Our proposal is to exploit digital technologies to remotely monitor patients at home and to hospitalize only those patients with signs of severity. Data from remote monitoring of patients are transmitted to a Command Center in the nearest reference hospital, and are automatically filtered so that physicians can focus on patients with early warning signs (**Figure, Supplementary Material 1**). Remote monitoring of patients with Covid-19 could 1) reduce contacts with care professionals, thus reducing risks of contamination.; 2) delay the expected disorganization of care structures; and 3) free-up hospital beds, especially beds in intensive care units.

In 3 days, a team of public health researchers and clinicians from the Assistance Publique Hôpitaux de Paris and University of Paris, and software architects and developers co-constructed a prototype for the remote monitoring platform (**Supplementary Material 2**). Open-source code of all software components required to deploy the platform was developed by Lifen and is available at: <https://github.com/lifen-labs/covid>.

Remote monitoring for patients in quarantine

Patients with confirmed Covid-19 are assessed by clinicians for: 1) absence of initial signs of severity (based on their age, comorbidities, initial presentation of the disease); 2) their ability to be quarantined at home (e.g., absence of a psychiatric disorder or of a loss of autonomy); and 3) their ability to perform the remote monitoring at home (e.g., basic computer literacy, smartphone availability). If all criteria are fulfilled, the patient is considered eligible for the remote monitoring and sent home with instructions for quarantine ⁷. Information is automatically sent to the patient's general practitioner, informing them that one of their patients has been confirmed with Covid-19 and is now being monitored at home.

Remote follow-up of patients at home was designed to be minimally disruptive. It consists of a self-reported questionnaire, once or twice a day. Patients receive a text-message with a direct secure link to an online questionnaire. No login is required. Questionnaires involve <10 items and collect self-reported symptoms with validated tools (e.g., temperature, dyspnea, pain) and quarantine information (e.g., psychological state regarding the quarantine and the disease, change of the people who are at home with them). In case of emergency, patients can contact the Command Center or the National emergency number.

Command Centers

Command Centers are located in hospitals and involve human personnel, including physicians and nurses who will analyze the constant influx of information from the remote monitoring. These people are equipped with real-time and decision-support tools, and assess whether patient care needs to be modified. They take necessary actions (e.g., intensifying monitoring, sending medical assistance, calling the patient for reassurance etc.) or provide feedback to patients and General Practitioners.

Each time a patient sends new information by completing a self-reported questionnaire, their data are updated in real time, and they are automatically flagged, using pre-defined decision rules, in four categories:

- “Green” patients are asymptomatic and have no problems with the quarantine. No action from clinicians is required for these patients. Automatic messages are sent to reassure patients and to remind them to continue completing the regular questionnaires.

- “Yellow” patients are stable with no signs of severity. No action from clinicians is required for these patients. Automatic messages are sent to reassure patients and to remind them to continue completing the regular questionnaires.
- “Orange” patients are those with a recent change of symptoms and who may require closer monitoring. When a patient is flagged “Orange”, the frequency of questionnaires is increased. In addition, an action is required from clinicians.
- “Red” patients are those with rapid evolution of symptoms, signs of severity and/or those who have problems with the quarantine. Rapid action is required from clinicians.
- “Patients who did not complete the questionnaire after 8h”. Patients are highlighted and are called by the Command Center.

Automatically a summary of the patient status and decisions taken is sent to their GP after each assessment.

To manage patients, the human personnel in Command Centers have access to dashboards where they can 1) visualize all patients enrolled in the remote monitoring, their main symptoms, and their flags; 2) examine a given patient’s data and take actions; or 3) zoom out to examine the state of the Command Center regarding specific subgroups of patients (e.g., those requiring actions, severe patients, etc.). A video demonstration of the Platform is available (**Supplementary Material 3**).

Scalability and Future evolutions

The platform was designed to be compatible with nationwide deployment, in various size hospitals.

The remote digital monitoring platform was envisioned being thoughtful of the worst case scenario. First, the platform can be modified to address different needs, beyond the

monitoring of confirmed cases in quarantine. For example, it is possible to propose simple self-reported questionnaires to asymptomatic contact subjects to identify the moment when they develop the disease. Secondly, according to the outbreak progression, the enrollment can be escalated from university hospitals to smaller hospitals, General Practitioners, or even self-recruitment of patients. Thirdly, the platform was thought to be compatible with the potential enrichment of patient-reported information with data from biometric monitoring devices, such as pulse oximeters (these could be either provided to patients or via patients' own smartphones as in a Bring Your Own Device approach⁸). Finally, the remote digital monitoring of patients will provide continuous streams of routinely collected data, directly usable to inform decision-makers at the local or regional levels through dashboards automatically constituted. In addition, data from all command centers can be pooled to provide real-time data visualizations on the state of the epidemic at national level. Furthermore, these routinely collected data could be extracted daily to constitute a research database.

Acknowledgements

We thank greatly Prof Xavier Lescure (Infectious Diseases), Prof Enrique Casalino (Emergency Medicine) and Dr François Grolleau (Intensive Care Medicine) who helped us build the clinical questionnaires and decision rules. We also thank Dr Youri Yordanov (Emergency Medicine) for useful discussions about this paper. We thank Elise Diard for her help in drafting figures.

Conflicts of Interest

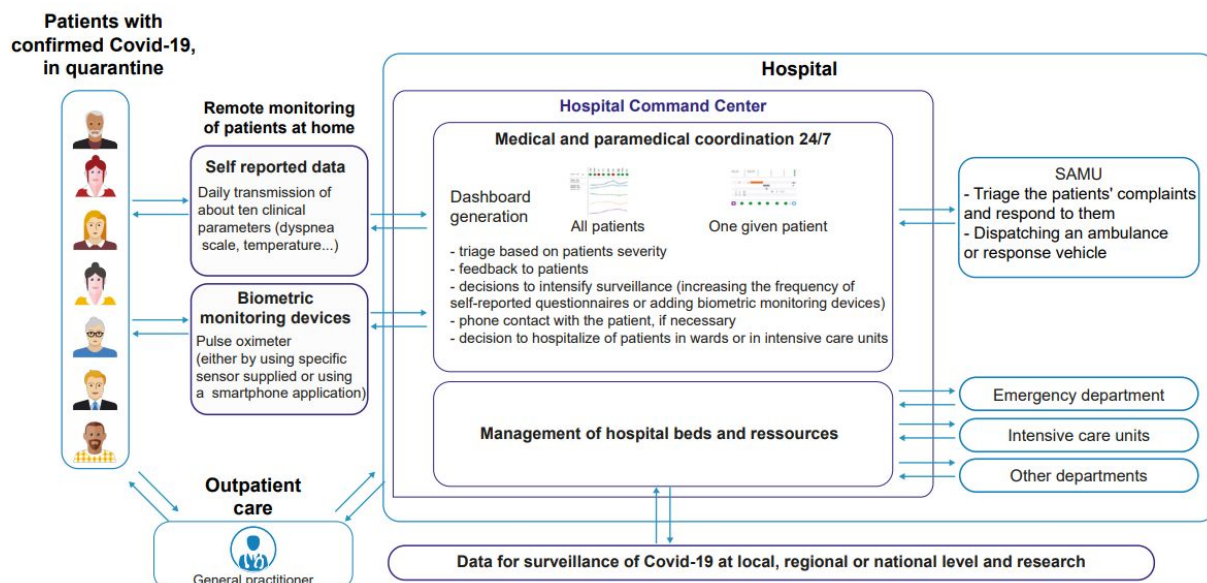
Franck le Ouay, Etienne Depaulis and Alexandre Huckert are co-founders of Lifén. Bruno Vegreville is employed by Inato. Philippe Ravaud holds shares in Inato.

References

1. Guan WJ, Ni ZY, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *The New England journal of medicine* 2020 doi: 10.1056/NEJMoa2002032 [published Online First: 2020/02/29]
2. World Health Organization. Novel coronavirus (COVID-19) Situation 2020 [cited 2020 06/03]. Available from: <https://experience.arcgis.com/experience/685d0ace521648f8a5beeeee1b9125cd> accessed 06/03 2020.
3. Watkins J. Preventing a covid-19 pandemic. *BMJ (Clinical research ed)* 2020;368:m810. doi: 10.1136/bmj.m810 [published Online First: 2020/03/01]
4. Li Q, Guan X, Wu P, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. *The New England journal of medicine* 2020 doi: 10.1056/NEJMoa2001316 [published Online First: 2020/01/30]
5. Axelrod J. Coronavirus may infect up to 70% of world's population, expert warns 2020 [cited 2020 06/03]. Available from: <https://www.cbsnews.com/news/coronavirus-infection-outbreak-worldwide-virus-expert-warning-today-2020-03-02/> accessed 06/03 2020.
6. Lalibre.be. Coronavirus en Belgique, le scénario du pire : "jusqu'à 850 000 personnes infectées et 50 000 morts", vraiment ? : Lalibre.be; 2020 [Available from: https://www.lalibre.be/debats/opinions/coronavirus-sans-mesures-de-precaution-drastiques-on-risque-d-avoir-850-000-personnes-infectees-et-50-000-morts-en-belgique-5e5cf60f9978e23106a0bfd9?fbclid=IwAR3YHFU64eNN0S32OoO-WohxsqYF8xdkmnTEk_dCNwRnL4xG70Dj1b4PPOA accessed 06/03 2020.
7. Santé Publique France. Conduite à tenir France: Santé Publique France, ; 2020 [accessed 06/03 2020.
8. Tayfur I, Afacan MA. Reliability of smartphone measurements of vital parameters: A prospective study using a reference method. *The American journal of emergency medicine* 2019;37(8):1527-30. doi: 10.1016/j.ajem.2019.03.021 [published Online First: 2019/03/25]

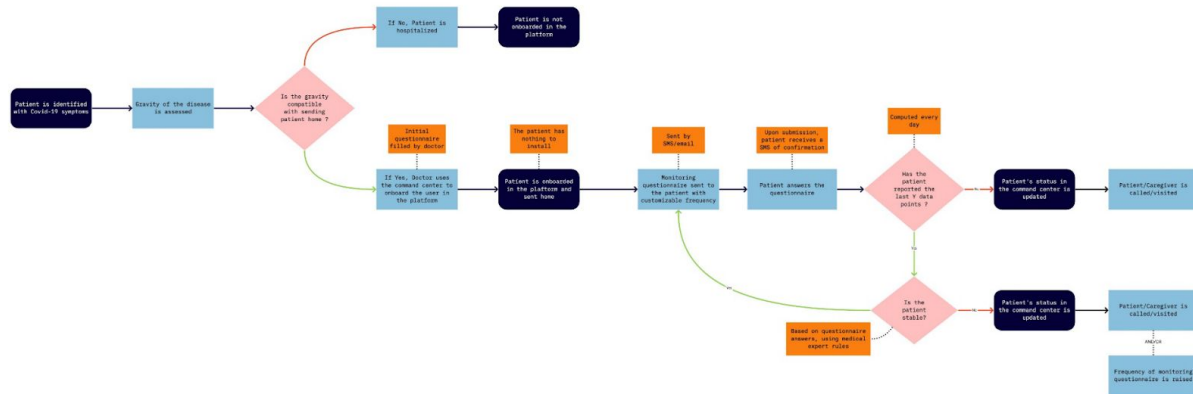
Figures

Figure. Key elements of the remote digital monitoring platform and Command Center



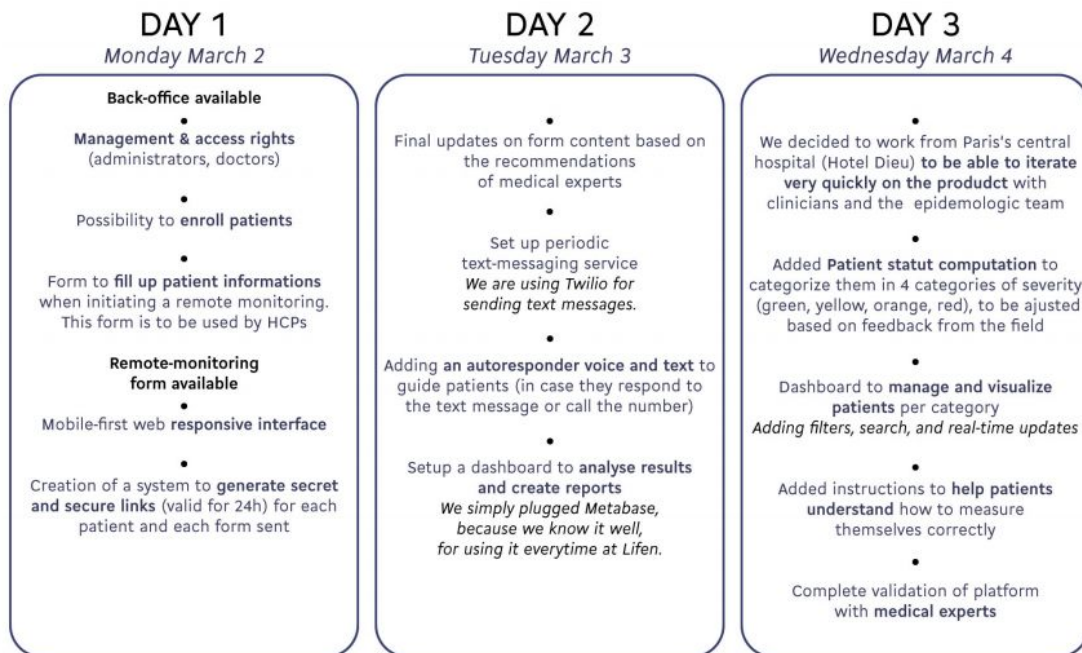
Supplementary Material

Supplementary Material 1. Architecture diagram of the remote digital monitoring platform and Command Center



Supplementary Material 2. Development steps of the remote digital monitoring platform and Command Center

Supplementary Material 2. Development steps of the remote digital monitoring platform and Command Center



Supplementary Material 3. Video demonstration of the remote digital monitoring platform and Command Center

