Rapid Screening of COVID-19 Postive cases using Ultrasonography and Artificial intelligence

Executive Summary

India has been under lockdown since March 24th to as a preventive measure against the 2020 coronavirus pandemic in India and recently announced an extension of this lockdown for further three weeks. These preventive measures have been effective in keeping the spread of the pandemic under check. As the country moves closer towards the end of lockdown, there is an urgent need for a solution to do rapid screening of people moving across district/state and country borders. Thermal scanning – while rapid – has poor detection accuracy. Recent studies have shown great potential in imaging modalities for detection of the COVID-19 disease. We are proposing to combine handheld portable ultrasonic machines with artificial intellgemce(AI) algorithm to observe peri pulmonary lesions of COVID-19 in the lungs, to enable a rapid screening. The use of portable ultrasounds will have huge advantages over existing techniques, for rapid detection due to its higher accuracy and easier disinfection needs. These portable ultrasound systems also allow triage of patients in remote areas and quarantine zones where most imaging modalities are not available. The Deep Learning based AI Algorithm will enable clinicians diagnose and evaluate the severity of the infection in the COVID-19 infected patients by measuring various biomarkers like the number of A and B lines, thickening of the pleural wall and locating areas of consolidation inside the lungs.

Background

The recent pneumonia outbreak spreading from Wuhan, China, in December 2019 is caused by the 2019 novel coronavirus, also called COVID-19, which has turned out to be among the fastest community-spreading disease the world has seen recently. The Corona Virus attacks two types of cells in the lungs - goblet cells that produce mucus and cilia cells which have the hairs follicles on them to prevent the lungs from filling up with debris, fluid, pathogens such as virus and bacteria, and particles of dust and pollen.
The virus attacks these cells and starts to kill them – causing the lungs to fill with a fluid, making it harder to breathe.

Till today, 2 million people have been diagnosed with COVID-19 infection across the globe. It resulted in 100k+ deaths, growing exponentially with a growth rate of 1.6. In India, due to early preventive action, we are able to flatten the curve with little more than 10000 cases and roughly 3% mortality rate.

The current COVID-19 test kits using throat or nasal swabs or antibody based blood tests are 60-80% sensitive, resulting in a lot of false-negative cases. Test kits are also expensive (Rs2-3K for antibody testing kits and Rs 4-5K per kit for RT-PCR tests) and in limited supply. Medical imaging techniques such as CT and X-rays have been proven to have more sensitivity to the detection of this disease. But these imaging techniques come with their own sets of challenges, a few of them being their high cost, non-portable, take up huge spaces, ionizing in nature, limited supply of the equipment and well-trained radiologists to operate on them. There are other clinical challenges to it as well, the major one being the entire imaging room needs to be disinfected every time it is used by an active patient, which takes up a minimum of 2 hrs, which at a time of crisis like this, can be considered as great deal.

Our Proposal

We propose a novel smartphone-based point-of-care ultrasonography system, which is cost-effective, portable, comes with Artificial Intelligence (AI) algorithms to help healthcare frontliners to conduct effective and accurate screening of COVID-19 patients. These mobile devices will enable POC screener with minimal knowledge of ultrasound scanning to perfrom the screening. The data and preliminary results may be furthur validated with radiology experts to furthur improve the system.

Today, small portable handheld ultrasound equipment is readiliy available in the market, companies like GE, Phillips, Butterfly IQ [6] have penetrated these portable ultrasounds to the grass-root level in few African Countries. Small handheld Butterfly IQ devices are being used by doctors in the United States to diagnose the COVID-19 infection. Few General Practitioners in Italy are using standard ultrasound monitoring against COVID-19.

Scaling the above solution in the country of 1.3 billion will not be easy, as we lack the number of expert radiologists and many more challenges which we have mentioned below. Hence, we propose to create a deep learning-based algorithmic model that will evaluate the location of biomarkers and their status using segmentation masks. The system will guide the rapid ultrasound scanning of people and identifying potential carriers for further confirmation using RT-PCR techniques. The evaluation of the screens by radiology experts and data from RT-PCR tests.

We are also be creating a biomarkers based scanning assitive algorithm, so that the untrain professionals/healthcare frontliners can easily take quality scans. Morevover we wish to deploy a continous online learning feature on entire AI algorithm, in which system will get more accruate as the time passes by, resulting in improvement of the scores on low confidence cases.

Algorithmic Steps

Step 0: Get the data;

20 confirmed covid19 cases; 10 normal non covid cases; 10 abnormal non covid cases

Step 1: Pre-processing Data;

Yet to be decided, it'll depend on data

Step 2: Deep Learning Model;

Edge device compatibility: mobilenet v2 architecture (less number of parameters)

Significance testing: Based on the consistency of prediction on all the temporal frames

Step 3: Check feature maps:

Visualize feature maps or GradCAM maps to confirm on the features what the model is looking at

Step 4: Assistive Tech for Ultrasound;

Get template ultrasound data: fixed image

Try to provide alert for non aligned acquisition

Step 5: On-line learning (Active learning);

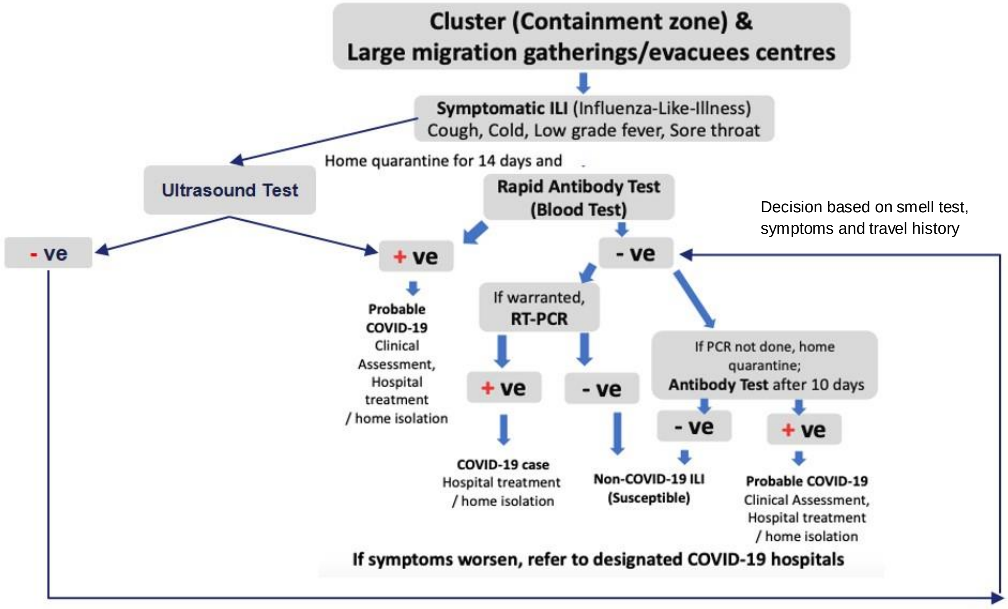
To make use of continuous inflow of data, and also improve on low confidence cases

Timeline

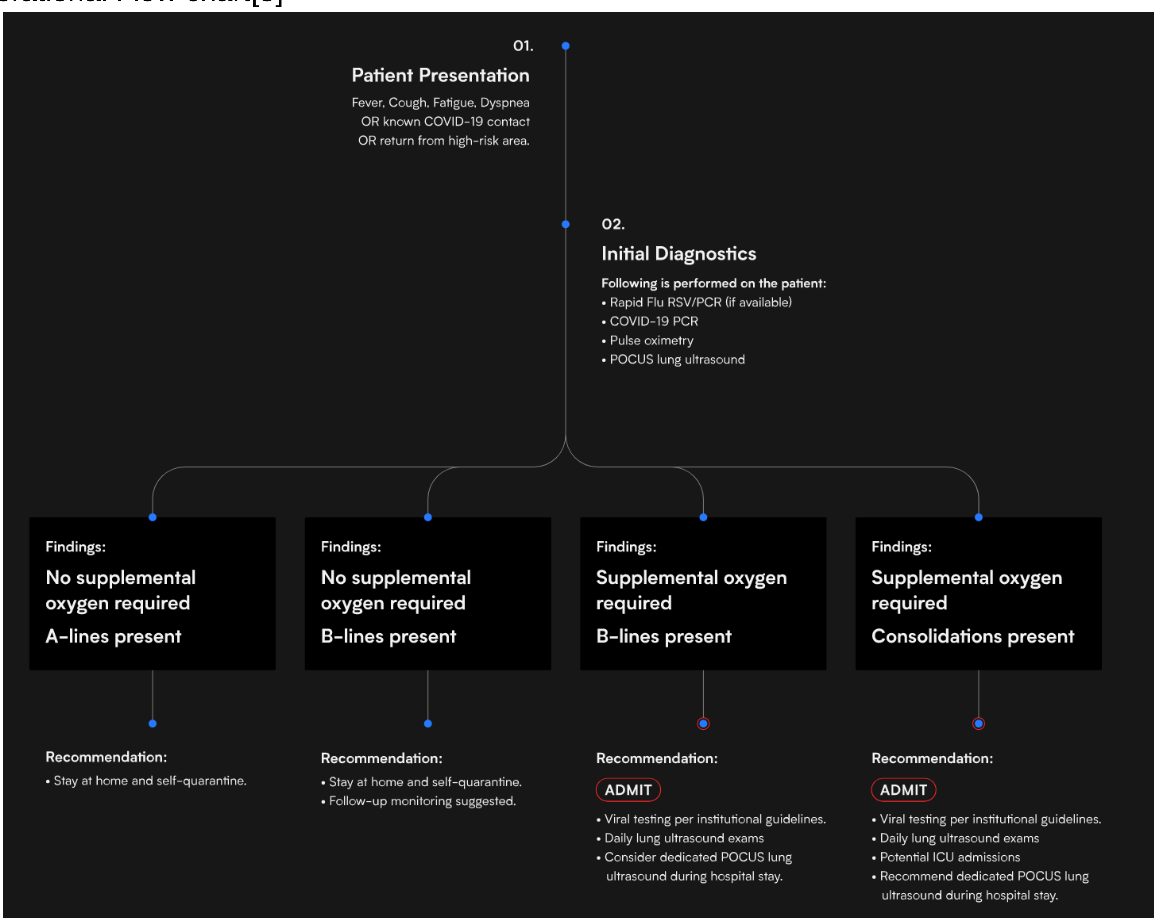
Days	Milestones
T	Received the ultrasound scan data
T+3	Initial results on Deep Learning based algorithm
T+5	Validation of Model on unseen US data
T+8	Retrain on GE handheld POCUS and fix on biomarkers
T+10	Results on Assitive Guidance based algorithm
T+15	Validation of AG system on ground
T+18	Creating an Online Learning based system
	Few days to scale the algorithms demograpically

Working Flowchart

Integration into existing ICMR test protocol



Operational Flow chart[8]



Advantages

	Smell Test	Ultrasound	Antibody test (Blood)	RT-PCR	Thermal Scanning
Capital Cost	Very Low	1L-2L	Lab Setup and Logistic cost	Lab Setup and Logistic cost	Rs 5 - 6K
Opex (excluding personnel, PPE and sanitiation costs)	Negligible	Negligible	Rs 2-3K per Test	Rs4-5K Per Test	Negligible
Storage and Transportation of Sample	Nil	Nil	Room Temperature	Cold Storage	Nil
Sample Collection Time	1-2 min	10-15 Min	<5 Min	5-10 Min (Swab)	< 1Min
Time to Results	Immediate	< 5 Min Using AI system	10-15 Min	Few Hrs to Few Days	Immediate
False Positives	Not Specific Test	Other diseases that affect the lungs including asthma, smokinf etc product similar patterns.	Not Specific Test	Specific Test	Not Specific Test
False Negatives	1 in 3 (Germany) 70% (South Korea)	Comparable to CTs*	10%	10-30%	70%

*Depends on quality of scans and expertise of operator

Technical and Feasibility Challenges

Feasibility challenges

1. **Legal challenges:** Point-of-care ultrasonography (PoCUS) is banned in India due to its misuse for fetal sex-determination
   ***Solution*:** If the device is used in government hospitals (PHCs, CHCs etc.) under supervision (using security or “silent observers”) only for the pandemic duration, there would not be any legal issues
2. **Lack of equipment:** Good quality ultrasound machines and other equipment is not available in most government hospitals
   ***Solution*:** If companies like GE and Philips can provide with the equipment, this challenge can be overcome
3. **Lack of training:** Most physicians in PHCs and CHCs are only MBBS graduates and do not have specialized ultrasound training, especially in rural India
   ***Solution*:** Automated AI models can be used to assist the physicians to make accurate diagnosis. Automated models, along with tele-ultrasound services and online video lectures, can eliminate the need to have an extensive training

Challenges in applying AI

Deep learning (DL) and other artificial intelligence (AI) models rely highly on the effectiveness of the data it is trained on. The following are a few challenges that we will have to tackle:

1. **Lack of dataset:** Efficient DL models require massive data sets to prepare on. In other words, the larger the data, the better the DL model. A dataset comprises the ultrasound images and their annotations. The challenge will be to get the required number of lung ultrasound images and their annotations of COVID-19 patients
2. **Lack of radiologists:** Annotations are marking that will inform us about all the relevant biomarkers which can be located in the picture. All the images in the dataset have to be annotated to use them for training. This requires medical expertise and can only be done by the medical professionals. We see it will be difficult to get the professionals onboard right now because they will be very busy with the clinical work
3. **Common biomarkers:** It is shown that biomarkers of COVID-19 are very similar to biomarkers of other respiratory diseases like pneumonia and other lung infections. Detecting COVID-19 biomarkers might not guarantee the presence of the disease; it could be a bacterial infection. We will need a dataset of patients suffering from other respiratory disorders so that we can train our model to differentiate them from COVID-19
4. **Geographical differences:** There are anatomical differences among people based on geographic locations. Also, there are variations in the ultrasound machines being used as well. It makes it difficult to generalize one DL model for all. To overcome this, we will need location-specific datasets which include images from all types of ultrasound machines

***Solution*:** If we can get the images from hospitals of different states, medical expertise for making the annotations, and that dataset includes biomarkers of all types of respiratory diseases, we believe we can overcome these challenges.

Clinical relevance

Study 1 [1]

There was a study done on 20 patients who were tested positive for COVID-19. The purpose of this study was to explore more about the ultrasonic manifestations of COVID-19.

Key Findings of the study

The following are the observations in images obtained from ultrasound scans of the COVID-19 patients

1. Lesions were mostly located in the posterior fields of both lungs.
2. The B lines had blurred edges and no bifurcation signs. Multiple discontinuous or continuous fused B lines (waterfall sign) or diffused B lines (white lung sign) under the pleural line were visible
3. The A-lines disappeared
4. High-frequency ultrasound showed that the pleural line was unsmooth, rough and interrupted
5. Multiple small patchy and strip consolidations were observed in the subpleural lesion
6. High-frequency ultrasound also showed the localized pleural thickening and local pleural effusion around the subpleural lesion. Linear array probe clearly showed that most patients' pleural thickening was about 1–2mm, and the subpleural effusion was about 2–3mm, which changed with the progress of the disease

   (Please find all the corresponding images in their research paper (page 12 to 36 here).)

This research study also compared CT and ultrasound images from the same patient. The key findings of the same are:

1. CT and ultrasound were highly consistent
2. CT showed more precise and complete intrapulmonary and apical lesions when compared to ultrasound
3. CT is inferior to ultrasound in showing the smaller peri pulmonary lesions and pleural and peri pulmonary effusion
4. Ultrasound can produce real-time and dynamic images, and is, therefore, more advantageous in distinguishing interstitial lesions and showing the distribution of blood flow and angiogenesis in inflammatory lesions.

Downsides of the study:

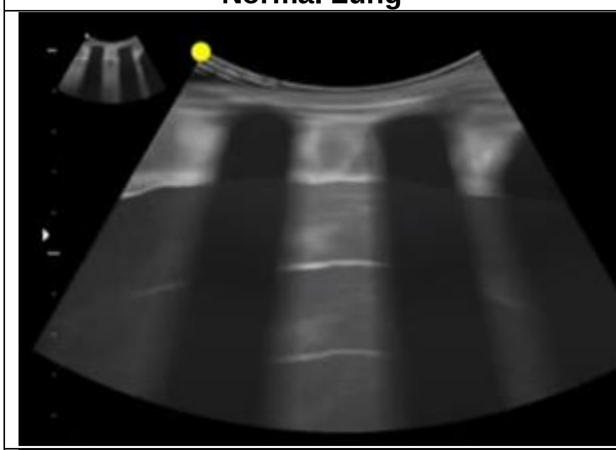
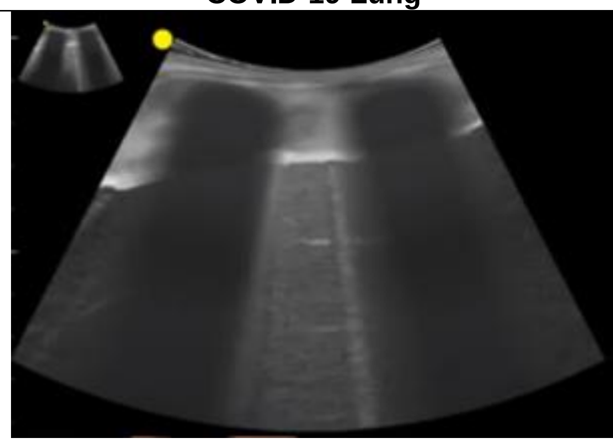
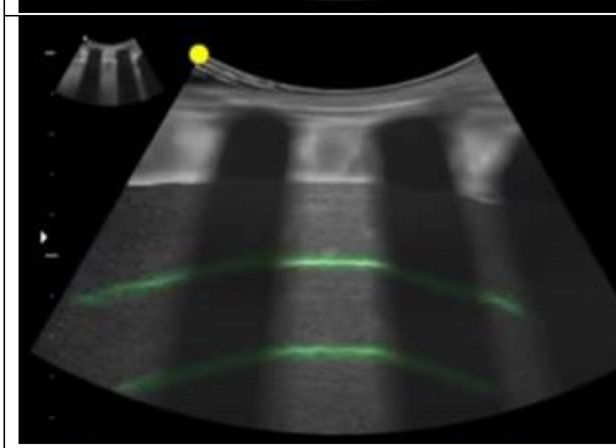
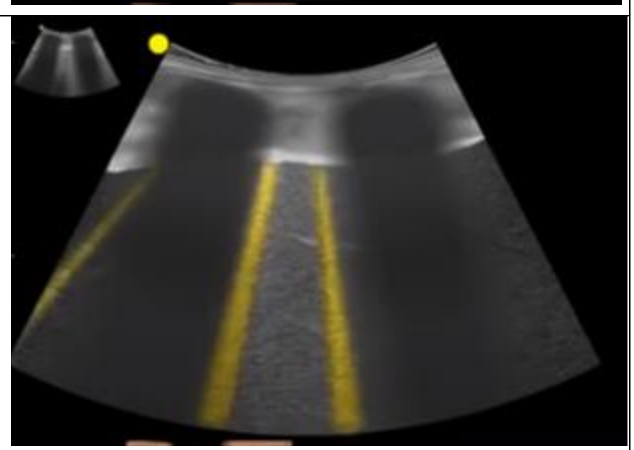
1. The sample size is small.
2. The changes in ultrasonic images are not carefully examined.
3. No control studies are conducted

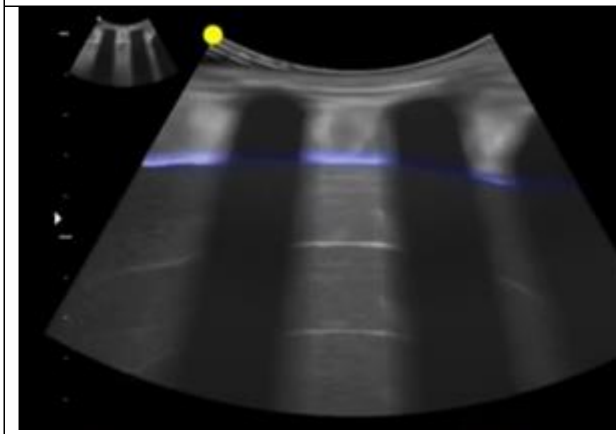
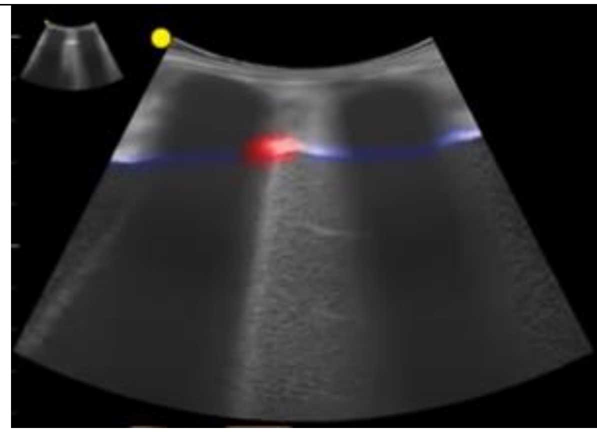
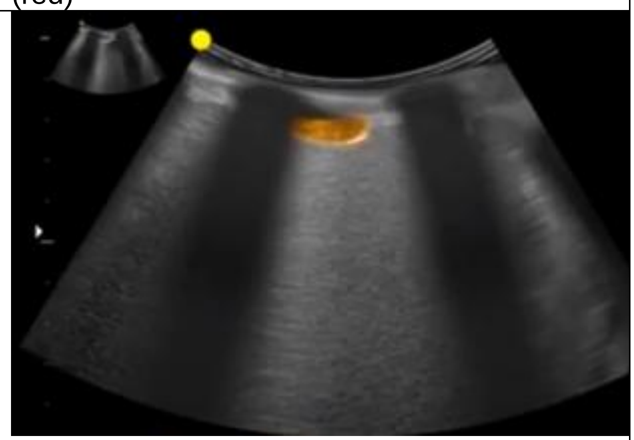
Study 2 [2]

The following diagram compares the observed biomarkers in a CT with that in the ultrasound.

Lung CT	Lung ultrasound
Thickened pleura	Thickened pleural line
Ground glass shadow and effusion	B lines (multifocal, discrete, or confluent)
Pulmonary infiltrating shadow	Confluent B lines
Subpleural consolidation	Small (centomeric) consolidations)
Translobar consolidation	Both non-translobar and translobar consolidation
Pleural effusion is rare.	Pleural effusion is rare
More than two lobes affected	Multilobar distribution of abnormalities
Negative or atypical in lung CT images in the super-early stage, then diffuse scattered or ground glass shadow with the progress of the disease, further lung consolidation	Focal B lines is the main feature in the early stage and in mild infection; alveolar interstitial syndrome is the main feature in the progressive stage and in critically ill patients; A lines can be found in the convalescence; pleural line thickening with uneven B lines can be seen in patients with pulmonary fibrosis

A normal lung vs a COVID-19 lung, for better visualisation [9]:

Normal Lung	**COVID-19 Lung**
	
 A-lines (green)	 B-Lines (yellow)
Here, we cannot see any B-lines	We can clearly see the B-lines here

Here, we can notice the A-lines very clearly	The A-lines fade away as effects of the infection worsen but tend to reappear as they patient recovers
	
Pleural lines (blue) are uniform everywhere	Pleural lines (blue) are irregular and thicker (red)
No consolidation can be seen here	 Consolidations and discontinuous pleural line can be seen here

Conclusion

After accessing through the literature, itIt is clear that ultrasound images of COVID-19 have identifiable features that can be easily spotted by a radiologist. This, combined with ready availability of ultrasound imaging equipment and machine learning algorithms provides us an opportunity to offer a rapid screening technique to efficiently screen people for COVID-19. While there is limited ultrasound scan data for Indian population currently, the system can rapidly learn as it screens people. Hence, Our initial assessment suggested that portable ultrasound tuned with the assistive algorithmic model can be used to diagnose the COVID-19 infection and also to decide the severity of infection in the later stages of the infection. In order to ascertain this, we would need access toInj order to develop this system, we need annotated ultrasonography data from COVID-19 patients and snon-COVID-19 patients as at different stages of their illnessoutlined above.

References

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9. https://www.youtube.com/watch?v=WQBuaLnh_U4&t=2s