Introduction

Apollo Hospitals and Google Research collaborated to develop a deep-learning system to identify abnormal Chest X-rays. This system has been built using over 200k data points and further validated with DS-1, CXR-14, and four de-identified datasets from three countries, including two tuberculosis datasets and two COVID-19 datasets from Northwestern Medicine. The methodology stratifies each Chest radiograph and assigns a label of either “normal” or “abnormal” using a regular expression–based natural language processing approach on the associated radiology reports. The system showcases an AUC of 0.87 on the Apollo Hospitals dataset (DS-1) and 0.94 on the ChestX-ray14 (CXR-14) dataset.

Why is Chest X-ray anomaly Detection AI different?

1) Machine Learning Model developed with Indian Data & other Countries' de-identified datasets having Higher AUCROC than a conventional risk score.
    a) Deep Learning System
    b) Model Built over 2,00,000 data and Validated with DS-1, CXR-14, and four de-identified datasets from three countries, including two publicly available tuberculosis datasets and two COVID-19 datasets from North-western Medicine.
    c) Apollo Hospitals dataset (DS-1) and ChestX-ray14 (CXR-14) dataset have AUCROC of 0.87 and 0.94, respectively
2. Feedback Loop from the prospective use in patients
3. Comprehensive & Holistic chest radiographs Anomaly Detection
4. Validated at different National and international Institutions (What Next to do)

Interpretation & Adoption Message

1. AI Algorithm + Clinicians – The Chest X-ray Anomaly detection AI model has been built as an adjunct tool for Clinicians to detect the chest radiograph as "normal" or "abnormal". When the Model is simulated, the system reduces the turnaround time for abnormal cases by up to 28%.
2. Risk Identification and Prevention - This Chest X-ray anomaly detection AI Model helps improve the accuracy, and consistency of chest X-ray interpretation. Which aids in case prioritization and rapid triaging in case of Anomaly & streamlining clinical workflow. However, it is not to be used as the sole method for the diagnosis of Anomaly in chest radiographs.

3. Where to use - Physicians can use the Chest X-ray anomaly Detection AI tool in various settings where a quick and accurate evaluation of chest X-rays is required. This could include preventive health screenings, Emergency rooms for case prioritization & rapid Triaging, or in areas with limited access to trained radiologists and provide the opportunity to batch negative CXRs for streamlined review.

How to Use (For Clinicians Only) –

1. Provide Appropriate –
    a. Chest X Rays
    b. Obtain Patient Consent
2. Risk Factors Included –
    It is a computer vision model hence the digital images of chest radiographs are included as input.
3. Output
    a. Predicting the Image as Abnormal/Normal
    b. Abnormality of the X-Ray

Workflow for CXR Anomaly App

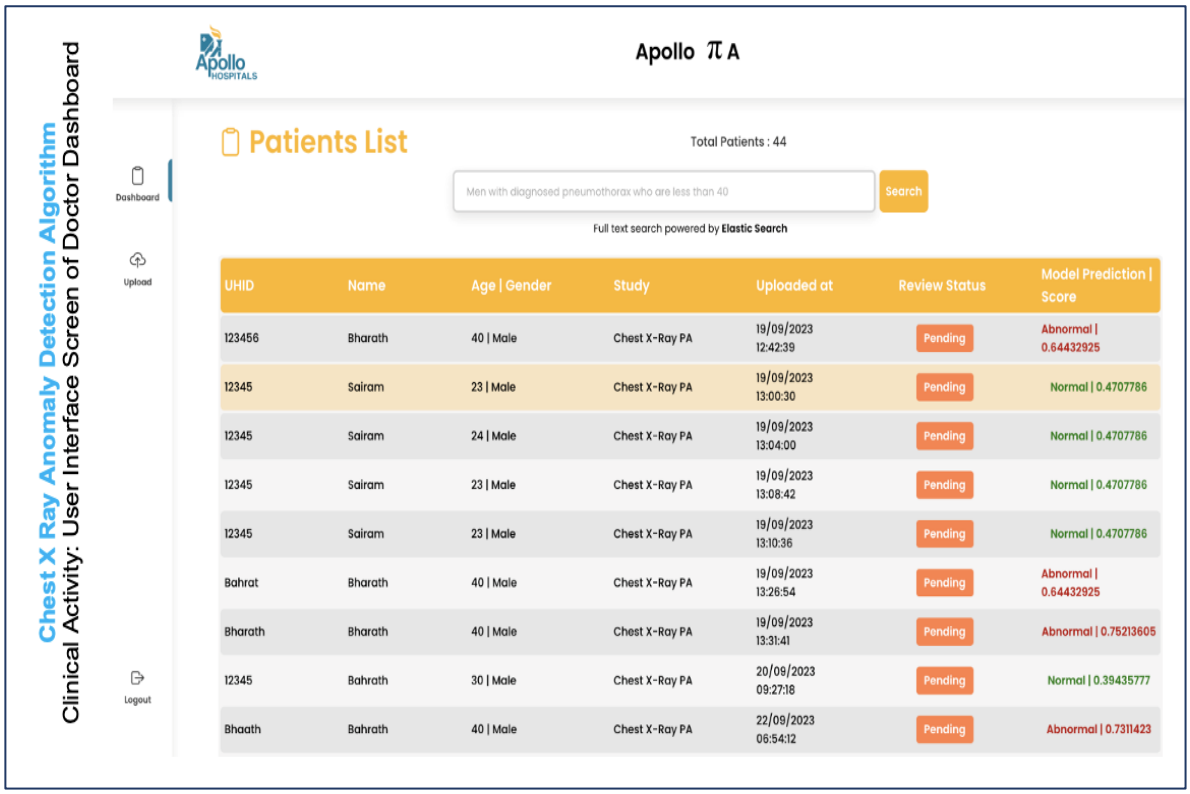

Figure 1. Doctor Dashboard

Doctor Dashboard: The first step to using the Chest X-Ray AI Anomaly Detection App is to log into the Doctor Dashboard using your unique credentials. Here, you will find an overview of your patient cases, both past and present. You can sort and filter cases by patient name, date, or anomaly detection status.

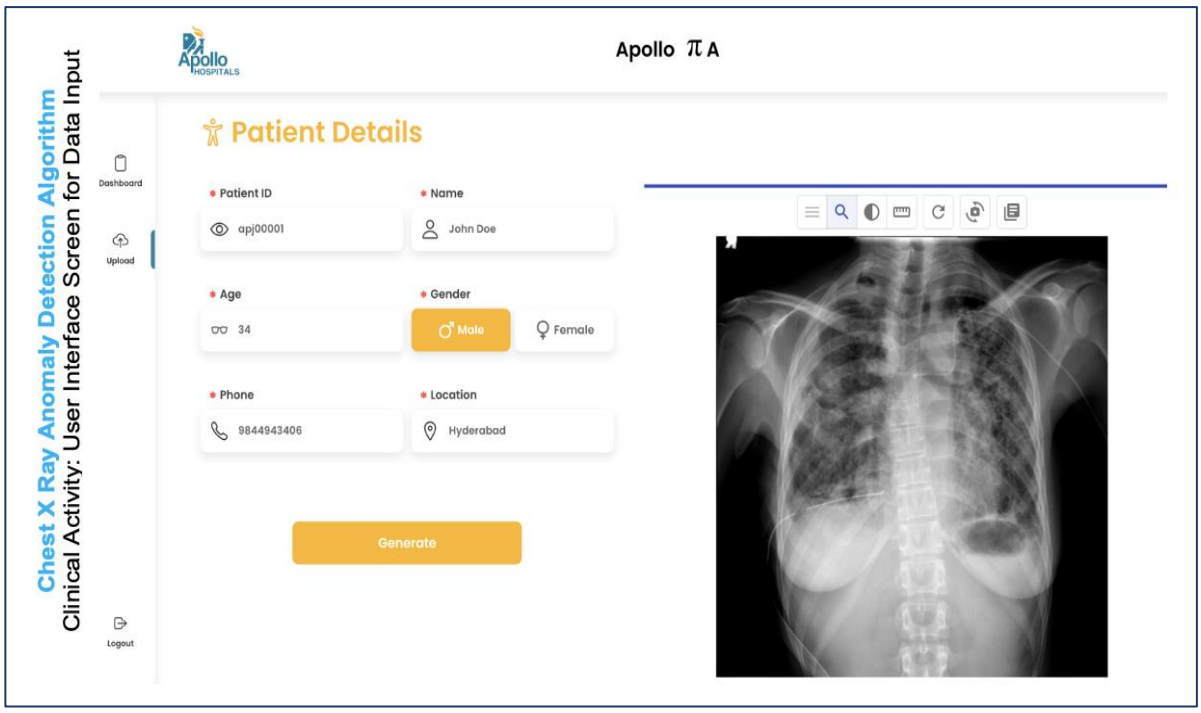

Figure 2. Uploading new CXR DICOM

Uploading New CXR DICOM: To upload a new Chest X-Ray (CXR) DICOM image, click on the "Upload" button, usually located at the top right corner of the dashboard. Browse through your computer's files and select the DICOM image you wish to upload. The file name should end with a DCM extension. Once you've selected the image, click "Open" and the image will start uploading to the app. You should see a progress bar indicating the upload status. Once the upload is complete, the new case will appear in your dashboard.

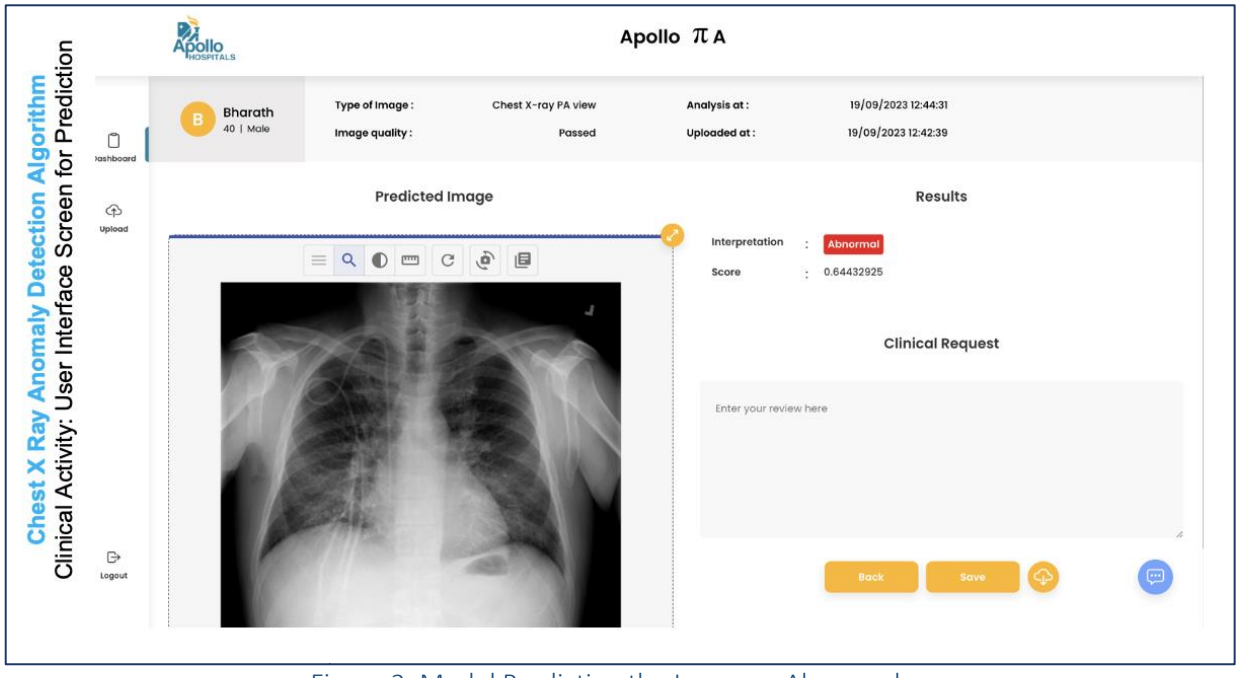

Figure 3. Model Predicting the Image as Abnormal

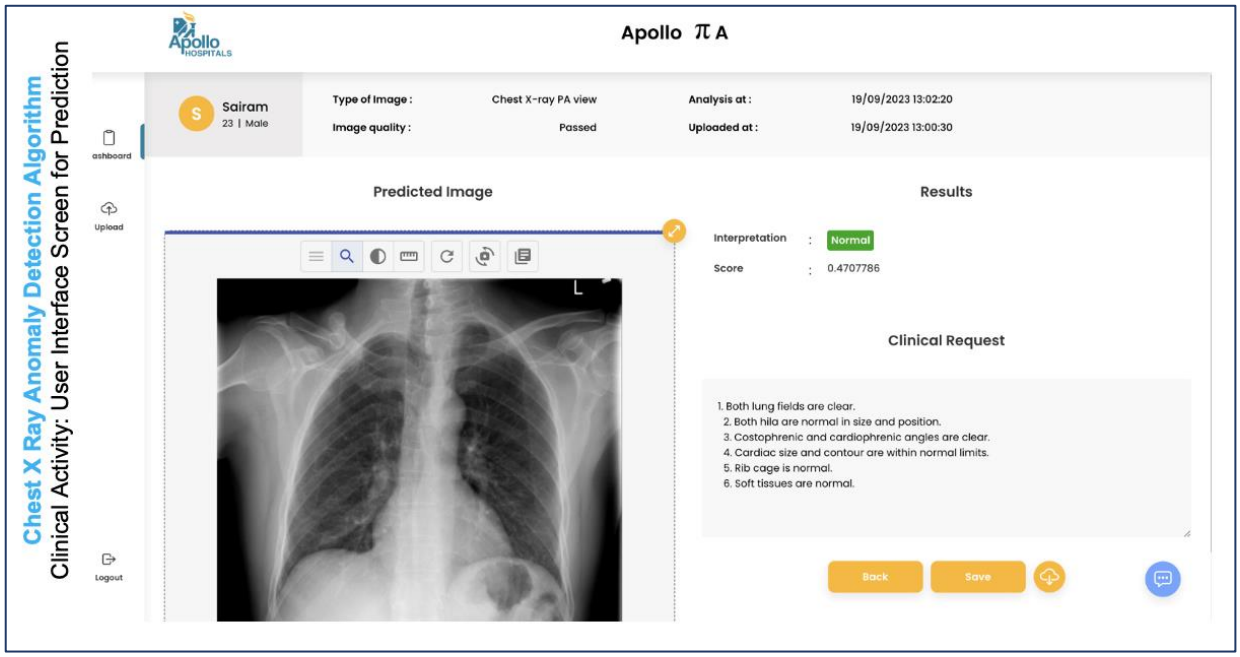

Figure 4. Model Predicting the Image as Normal

AI Model Predicting the Image as Abnormal/Normal and Doctor reviewing it: Upon successful upload, the AI model will automatically analyze the DICOM image. Once the analysis is complete, the AI will categorize the image as either Normal or Abnormal, based on the detected anomalies. This result will be shown in the dashboard next to the respective DICOM image. To review the AI's analysis, click on the specific case. You will be taken to a detailed view of the image. This AI model serves as a tool to assist doctors and does not replace a professional diagnosis.

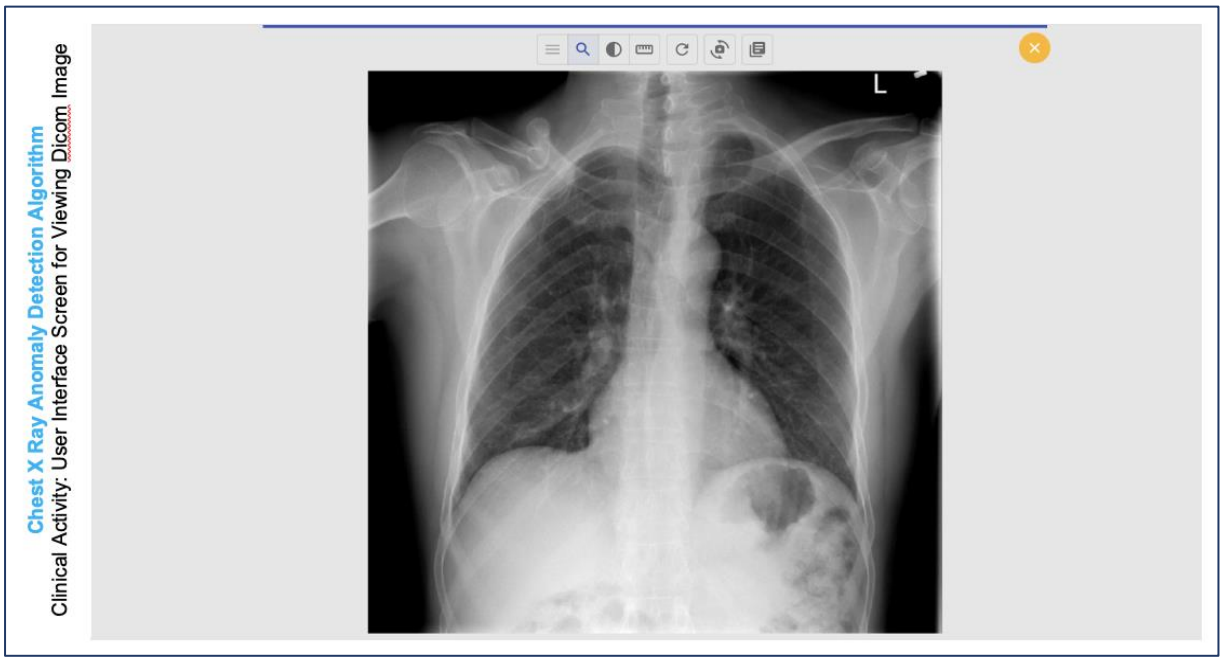

Figure 5. Doctor Reviewing the DICOM Image in a Web Browser with Relevant Tools

Doctor Reviewing the DICOM Image in a Web Browser with Relevant Tools: To review the DICOM image in detail, use the built-in viewing tools provided by the app. You can zoom in and out, adjust brightness

and contrast, and move the image around for a better view of certain areas. You can also manually mark areas of interest. Once you've finished reviewing and annotating the image, you can save it and move on to the next case.

Disclaimer

(a) This tool is designed to assist in anomaly detection and should not be solely relied upon for making a diagnosis. This is not a diagnostic tool and it does not guarantee the accuracy of the result and cannot be independently acted upon.

(b) This Prediction score and Clinical Algorithm is a general guideline for Physicians. Any additional laboratory investigations, Diagnostic Imaging, Treatment, or Patient Education related to lifestyle management is under the Physician's discretion.

(c) To ensure the information in the report is up to date, accurate, and correct, the Doctor shall be consulted for interpretation of the report.

(d) Apollo Hospitals and its Staff do not offer any assurance on the information made available or be liable for any loss or damage as the said report is based on the Chest X-ray anomaly Detection Algorithm without any intervention from their side.

(e) By usage of the Chest X-Ray Anomaly Detection Algorithm, it is deemed that the beneficiary of this service has agreed to get the same done at his/her own risk and further agrees with this disclaimer without any limitation or any clauses or sub-clauses.

Research

The integration of Machine learning (ML) into medical imaging promises improved efficiency and accuracy in chest X-ray (CXR) interpretation. Existing algorithms, tailored for specific conditions, encounter limitations in diverse clinical settings. Recognizing this gap, the development of a general-purpose AI tool for CXR abnormality detection becomes essential for streamlined workflows.

Apollo Hospitals and Google Research collaborated to introduce a deep learning system. Utilizing the EfficientNet-B7 architecture and trained on 200,000 de-identified CXRs, the tool employs a natural language processing approach to adeptly discern between normal and abnormal cases.

Performance evaluations on the Apollo Hospitals dataset (DS-1) and ChestX-ray14 (CXR-14) dataset, annotated by US board-certified radiologists, reveal commendable AUROCs of 0.87 and 0.94, respectively.

Further assessments across diverse datasets from three countries demonstrate the tool's efficacy in novel settings, achieving AUCs of 0.95-0.97 for tuberculosis and 0.65-0.68 for COVID-19. Acknowledging potential abnormalities beyond tuberculosis and COVID-19, the system exhibits versatility with AUCs of 0.91-0.93 for tuberculosis and 0.86 for COVID-19 datasets, attesting to its capability to identify a spectrum of abnormalities.

The subsequent collaborative efforts, incorporating diverse datasets, yield an AI tool surpassing performance expectations, marking a notable advancement in medical imaging technology.

Ethics Perspectives

Title	Deep learning for distinguishing normal versus abnormal chest radiographs	Centers	India – Apollo Hospitals -5 Regions(Bangalore, Bhubaneswar, Chennai, Hyderabad, and New Delhi)
Principal Investigators	Dr Raju Kalidindi (Apollo), Rory Pilgrim (Google)	Institutional Ethics Committee Approval	JUNE 2021
Data	Retrospective	Safety	Model distinguishes Normal & Abnormal Chest Radiograph that are interpreted by clinicians through safe Machine (API) – Human (Clinician) Interaction
Sample Size + Missing Data	Train dataset - 248,445 patients Validation/Test dataset - 6 international datasets from India, China, and the United States	Inclusiveness & Fairness	At admission data includes Chest X ray| No socioeconomic discrimination
Personal Health information	De-identified all PHI during analysis, model building, API hosting and Prospective Use	Privacy & Confidentiality	Data secured at Apollo Azure Tenant with all relevant compliance + conforming to laws
Addressing Bias (Geographical / Ethnic / Temporal / Gender etc.)	Multiethnic – All Adult Population Group –Automation Bias addressed at API Clinical Use	Accuracy + Efficacy	AUC Metrics - Apollo Hospitals dataset (DS-1)-AUROCs of 0.87 |ChestX-ray14 (CXR-14) dataset- AUC of 0.94| Tuberculosis datasets (TB-1,2)-AUC of 0.97|COVID 19 datasets- COV1-AUC -0.68, COV1-AUC -0.65
Risk Groups	Normal and abnormal labels for chest Radiographs	Informed Consent	Yes – Template & Protocol (Prototype Attached)
Model Specification	Deep learning model + EfcientNet-B7, pre-trained on ImageNet	API – Ease of Use + Interpretation	Flows to Clinical Algorithm Standard User manual
Clinical Algorithm Update (Version)	Version 1- JUNE 2023	Validation + Peer Review	Radiology; Scientific Reports
Certifications	ISO 13485:2016 Certification | MD 763515	Regulatory Compliance	CDSCO Application No| Apollo-Hyder-TE/M/MD/007509

Frequently Asked Questions

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Where can the physicians use the tool -

Physicians can use the Chest X-Ray Anomaly Detection AI tool in various settings where a quick and accurate evaluation of chest X-rays is required. This could include preventive health screenings, Emergency rooms for case prioritization & rapid Triaging, or in areas with limited access to trained radiologists and provide the opportunity to batch negative CXRs for streamlined review.

What are the Risk Factors Included –

It is a computer vision model hence the digital images of chest radiographs are included as input.

What is the Output and Follow-Up for the Model?

The output is a label of either "normal" or "abnormal" for each chest X-ray. The follow-up would depend on the specific clinical context, but if an abnormality is detected, further diagnostic testing or consultation with a specialist might be required.

Is this a diagnostic tool?

This is not a diagnostic tool. It is more of a decision support tool rather than a standalone diagnostic tool. it does not guarantee the accuracy of the result and cannot be independently acted upon.

Does this contradict the Physician's view?
The tool doesn't contradict a physician's view, rather it augments it. It provides an additional layer of analysis that can help physicians to make better-informed decisions. Any additional laboratory investigations, Diagnostic Imaging, Treatment, or Patient Education related to lifestyle management is at the Physician's or Pulmonologist's discretion.

How does one ensure the accuracy of the Chest X-ray Anomaly Detection AI tool?
The accuracy of the Chest X-ray anomaly Detection AI tool is ensured through rigorous training and validation. The model was trained on over 200,000 de-identified chest X-rays and achieved a high area under the receiver operating characteristic curve (AUROC) in evaluations.

To ensure the information in the report is up to date, accurate, and correct, the Doctor shall be consulted for interpretation of the report.

Is this a substitute for any diagnostic test or clinician's advice?
Absolutely No. This is an adjunct tool developed with Digital Images of Chest Radiographs. It doesn't substitute for any tests or advice. It complements and supports the diagnostic process by providing another perspective on the chest X-ray images.

What are the disclaimers for the use of this tool?

a. Apollo Hospitals and its Staff do not offer any assurance on the information made available or be liable for any loss or damage as the said report is based on the Chest X-ray Anomaly Detection AI tool without any intervention from their side.
b. By usage of the Chest X-ray Anomaly Detection AI Model, it is deemed that the beneficiary of this service has agreed to get the same done at his/her own risk and further agrees with this disclaimer without any limitation or any clauses or sub-clauses.
c. The disclaimers for the use of this tool would likely include statements reminding users that it is not a substitute for professional medical advice, diagnosis, or treatment and that all medical decisions should be made in consultation with a qualified healthcare provider.

Can the report be shared with other clinicians?
Yes, each patient shall get a printed report or PDF copy which can be kept by the patient to maintain privacy and confidentiality.

Is this tool validated for research ethics committees?
Yes. Institutional Ethics Committee Approval for All Centre's and annually followed.

How is Safety addressed?
The model advocates risk scores clinicians interpret through a safe machine (API) – human (clinician) interaction. Informed consent from each individual is obtained before chest x-ray interpretation using chest x-ray Anomaly detection AI score.

How does the Chest X-ray anomaly Detection AI tool keep patient data secure?
The tool uses de-identified datasets to ensure patient data is anonymized and secured.

How does the AI tool differentiate between different types of abnormalities in the chest X-ray?
The tool is designed to distinguish between normal and abnormal chest X-rays and can generalize to unseen diseases such as tuberculosis and COVID-19.

Are there any clinical trials or studies that validate the efficacy of this tool?
Yes, the tool's efficacy was evaluated on diverse datasets from three countries, achieving high AUROCs in detecting general abnormalities as well as specific diseases like tuberculosis and COVID-19.

How does the AI tool deal with false positives or negatives?
The tool may produce some false positives, as highlighted by the cases flagged as "positive" for abnormalities that were negative for COVID-19. However, these still contained abnormal findings requiring attention.

How does the Chest X-ray anomaly Detection AI tool handle unclear or poor-quality chest X-ray images?
The Chest X-ray anomaly Detection AI tool checks image quality before processing and skips poor-quality images. It uses a refined threshold based on extensive data to accommodate various image types. The model is trained for diverse image variations through data augmentation. This quality threshold ensures only high-standard images undergo analysis, enhancing accuracy in anomaly detection.

Are there any limitations or challenges faced by the Chest X-ray anomaly Detection AI tool?
One potential limitation is its ability to generalize to unseen CXR findings, as the study demonstrated its generalizability to unseen diseases, but not necessarily unseen CXR findings.

Is there any training required for physicians to use this tool effectively?
No, the tool is designed with a user-friendly API, eliminating the need for physicians to undergo any specific training for its use.

Can this tool be used in telemedicine or remote patient monitoring?
Given its digital nature, the tool could potentially be used in telemedicine settings or for remote patient monitoring.

What specific anomalies do the labels incorporate in the Study?
The labels in the study encompass a diverse range of chest anomalies, Additionally, the labels involve the binary classification of normal versus abnormal cases, providing a comprehensive coverage of potential chest conditions for analysis.
The labels in the study consist of:

- Atelectasis
- Cardiomegaly
- Effusion
- Infiltration
- Mass
- Nodule
- Pneumonia
- pneumothorax
- Consolidation
- Edema
- Emphysema
- Fibrosis
- Pleural thickening
- Hernia
- Other abnormalities.