

# Region of interest tuberculosis screening

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# Outline

- Background on Tuberculosis
- Options for screening
- Proposed x-ray system
- Medical study objective
- Materials and Methods
- Results
- Conclusion

# Background on Tuberculosis

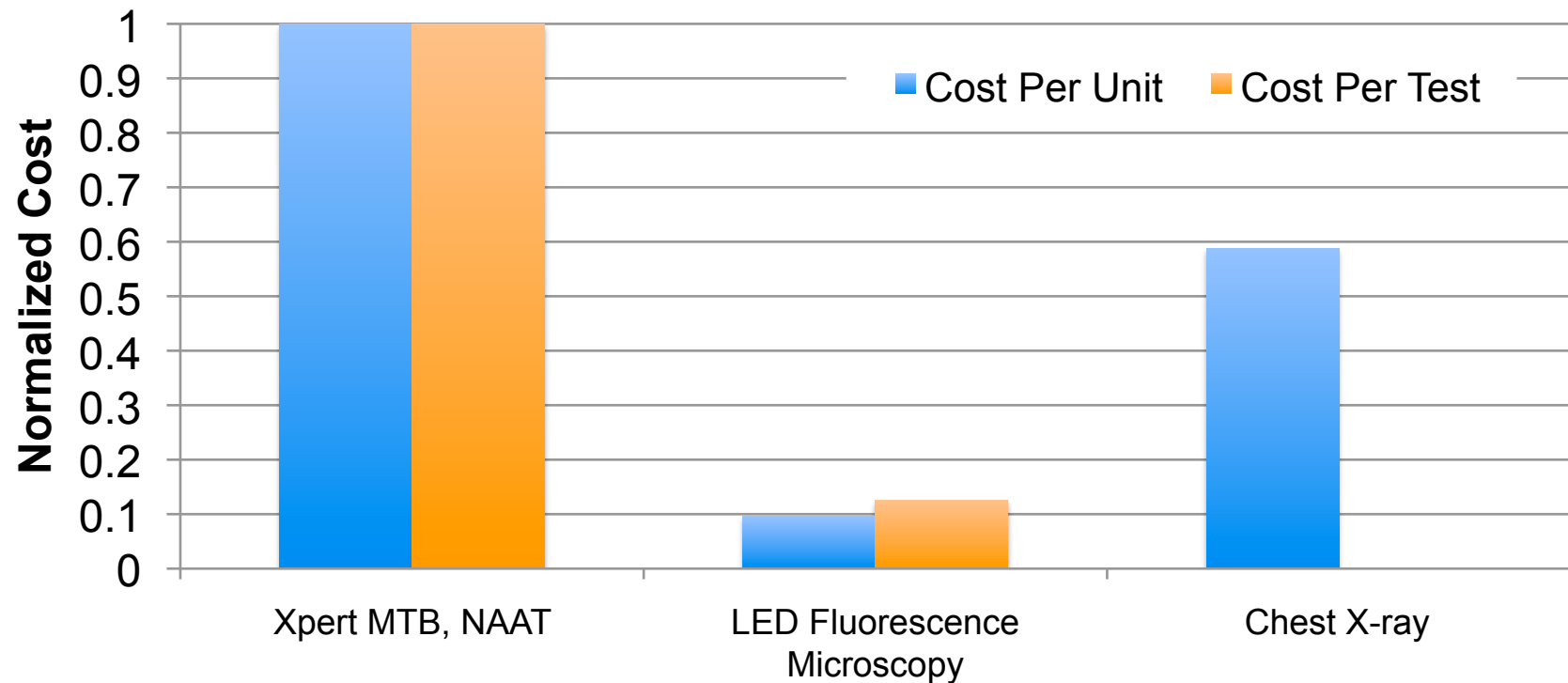
- 1.4 million died in 2011 as a result of TB
- 60% of TB cases were in S-E Asia and W Pacific, 25% in Africa
- <2% of TB-related deaths were in the Americas
- TB is treatable but must be determined preferably at an early stage

# TB diagnostics options

- Symptom questionnaires
- Cartridge-based DNA tests – NAAT (Xpert MTB/RIF)
- Sputum/smear microscopy (LED Fluorescence Microscopy)
- Digital chest x-ray (CXR) (Recommended by World Health Organization, StopTB Partnership)<sup>1</sup>

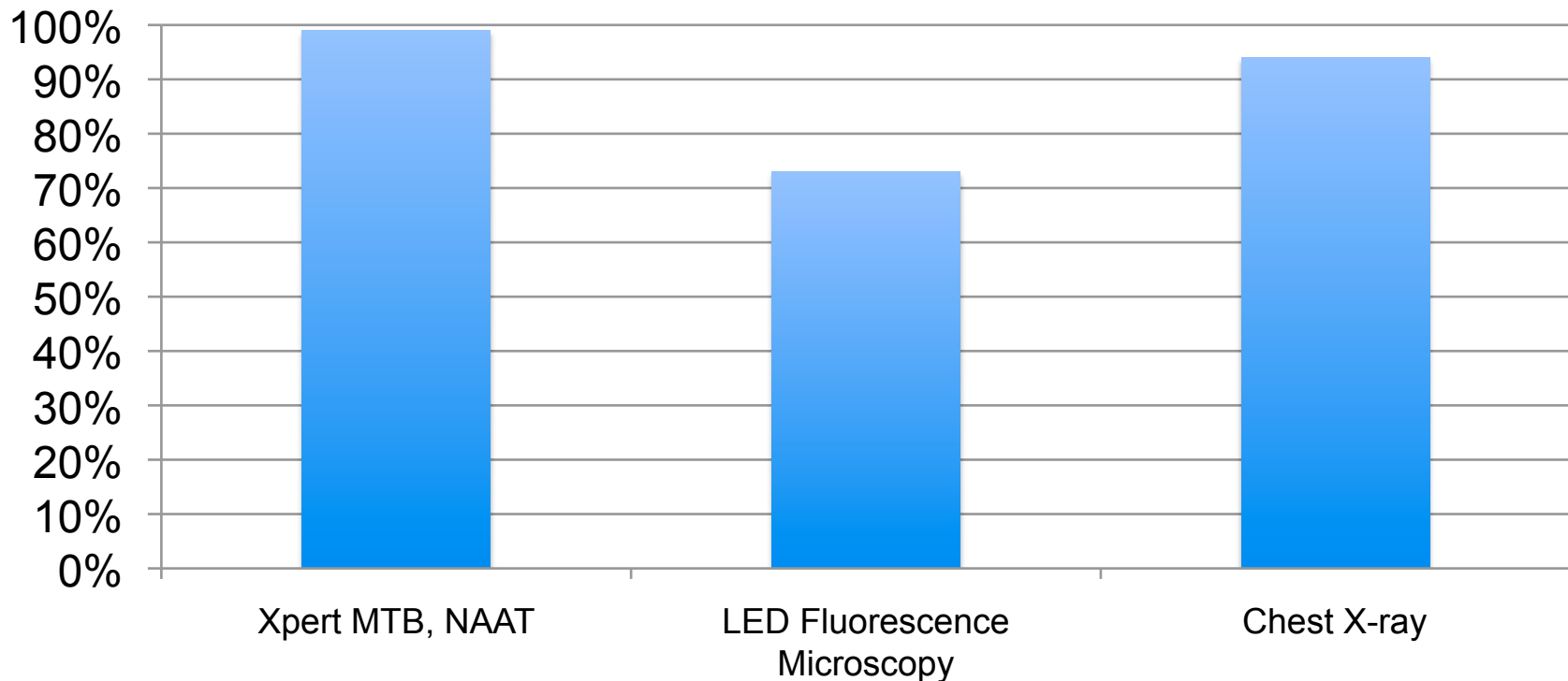
# TB diagnostics options

## Relative Costs of TB Diagnostics



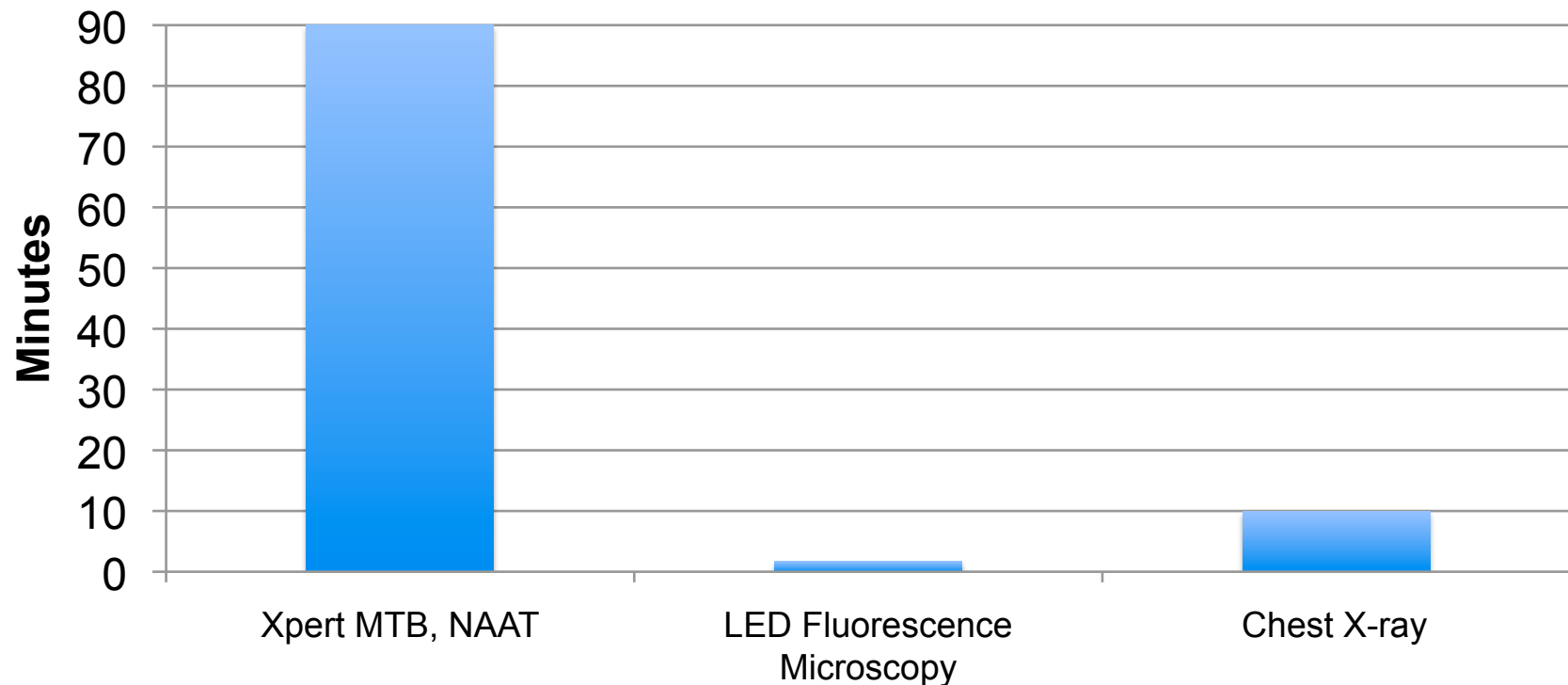
# TB diagnostics options

Sensitivity of TB Diagnostics



# TB diagnostics options

Time to Results for TB Diagnostics

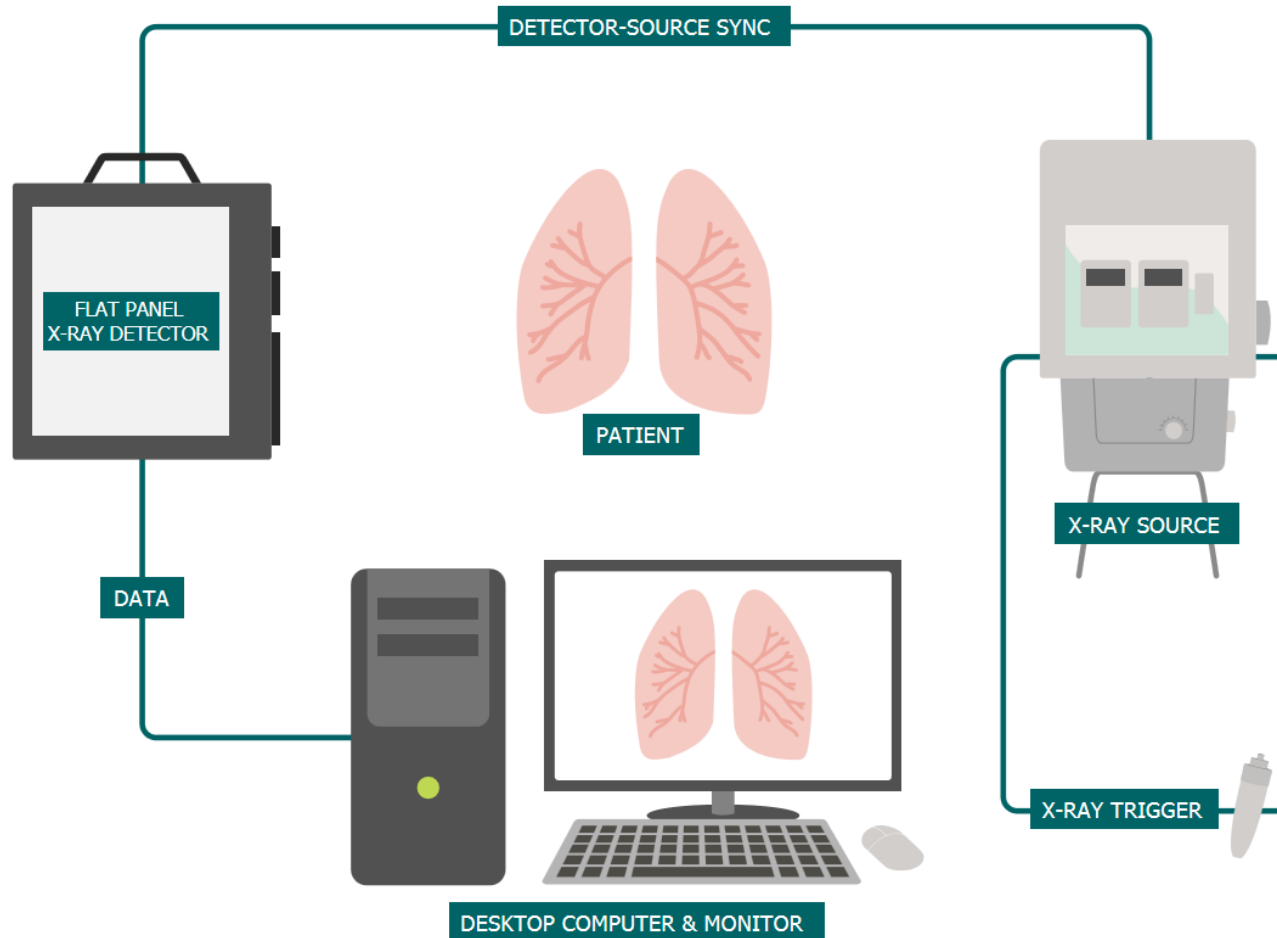


# TB diagnostics options

- CXR alone is more sensitive to TB than symptom surveys alone<sup>1,2</sup>
- 60% of culture confirmed cases are undetected by LED FM (smear negative)<sup>2</sup>
- Digital CXR has value added: tele-radiology, Computer Aided Diagnosis<sup>2</sup>



# Digital x-ray system



# Detector size cost reduction

- Using a small-area detector reduces cost
- Relevant for pediatric imaging or single lung instead of full chest radiography
- **Can radiologists accurately diagnose tuberculosis given two separate lung images rather than a full chest x-ray?**

# Medical study objective

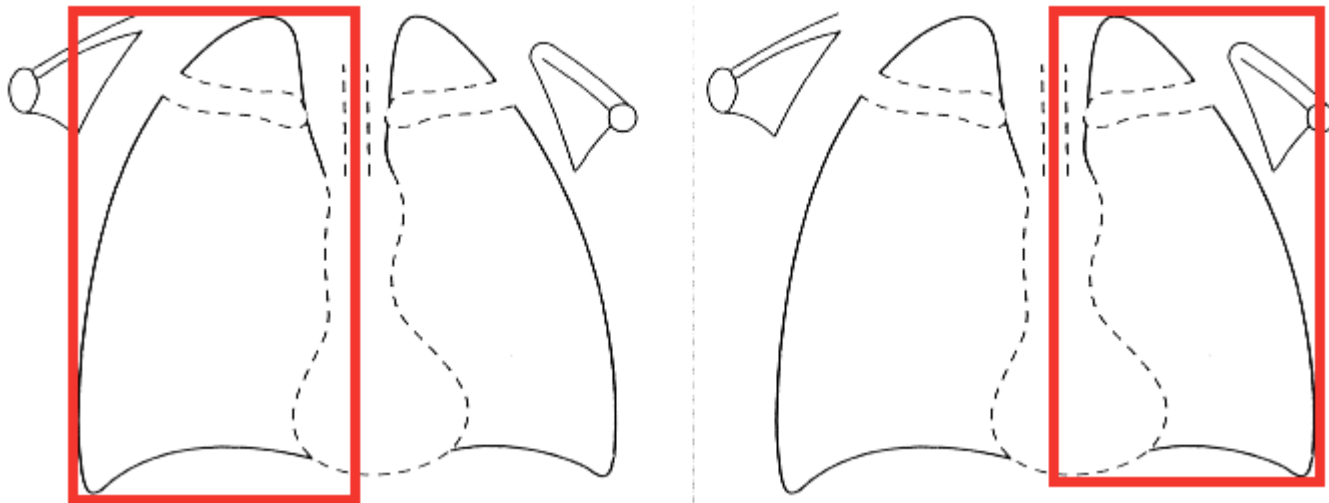
- To determine whether a smaller-area x-ray detector could be used for screening tuberculosis
- Hypothesis: there is no difference in diagnostic accuracy of two single-lung images compared to a full chest x-ray.
- This study is **not** intended to examine correct screening procedures, but to compare **two types of images** as apples to apples.

# Materials

- 570 DR and CR chest x-ray images were collected retrospectively from Aga Khan University Hospital in Karachi, Pakistan
  - 370 of confirmed TB patients
  - 200 of TB-free patients (“non-TB”)
- Used in an online survey of TB-expert radiologists

# Image cropping

- Full chest x-rays were each cropped into two 5" x 9" separate lung images



# Web survey

- Images were randomly selected from the collection to be used in an online survey
- Each radiologist saw half of the cases in the survey as a full chest x-ray, and half as cropped, split-lung x-rays
- Two versions of the survey were created (as below)

Cases	Survey version A	Survey version B
Cases 1-10 ( $\frac{1}{2}$ TB, $\frac{1}{2}$ none)	Full chest x-rays	Split-lung, cropped x-rays
Cases 11-20 ( $\frac{1}{2}$ TB, $\frac{1}{2}$ none)	Split-lung, cropped x-rays	Full chest x-rays

# Web survey

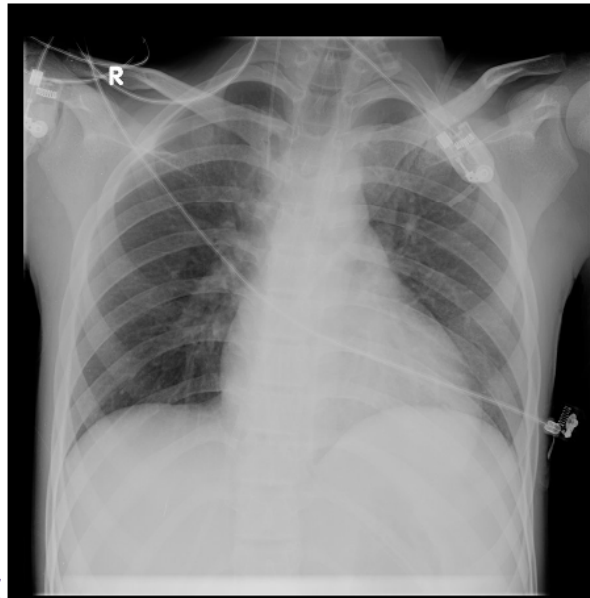
- Radiologists were asked if there were any signs of TB in the images.

## Investigation Into Chest X-ray Region of Interest Tuberculosis Diagnosis

Question 6: Determine if there are any signs of TB, or no signs at all.

- No sign of TB
- Sign(s) of TB

Submit



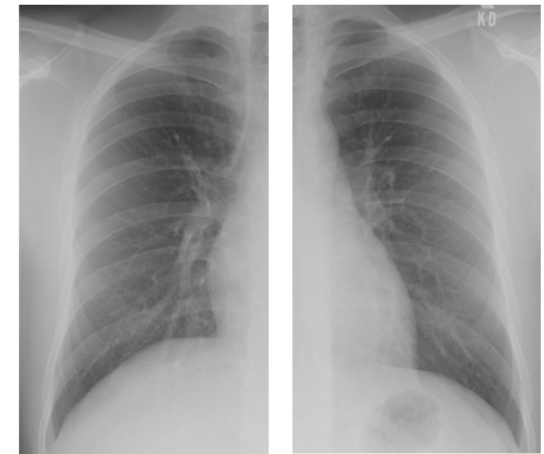
a)

## Investigation Into Chest X-ray Region of Interest Tuberculosis Diagnosis

Question 44: Determine if there are any signs of TB, or no signs at all.

- No sign of TB
- Sign(s) of TB

Submit



b)

# Measurements

- Two different measurements were made with 1480 data points across 21 survey sessions:
  - Sensitivity (correct TB diagnosis)
  - Specificity (correct non-TB diagnosis)
- These were based on the gold standard diagnosis for each case



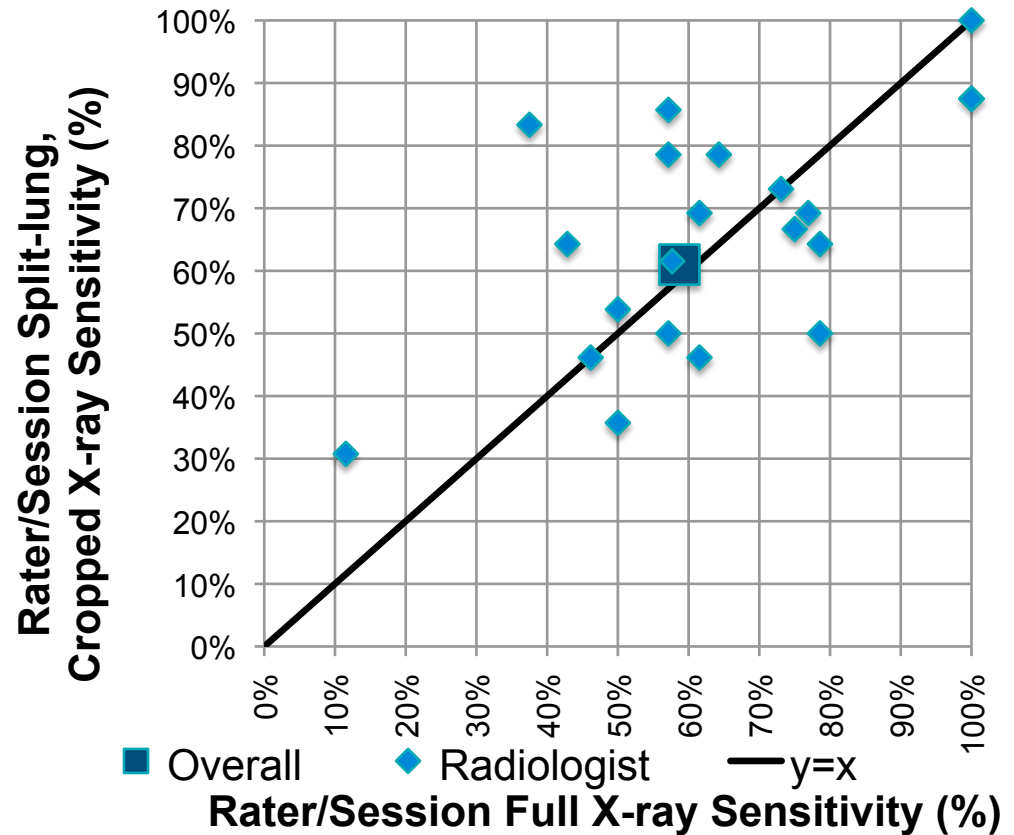
# Results: overall

Overall sensitivity and specificity results for tuberculosis with full chest x-ray and split-lung, cropped x-ray

Full x-ray sensitivity	209/356 = 58.7%
Full x-ray specificity	354/384 = 92.2%
Split-lung, cropped x-ray sensitivity	219/359 = 61.0%
Split-lung, cropped x-ray specificity	335/381 = 87.9%

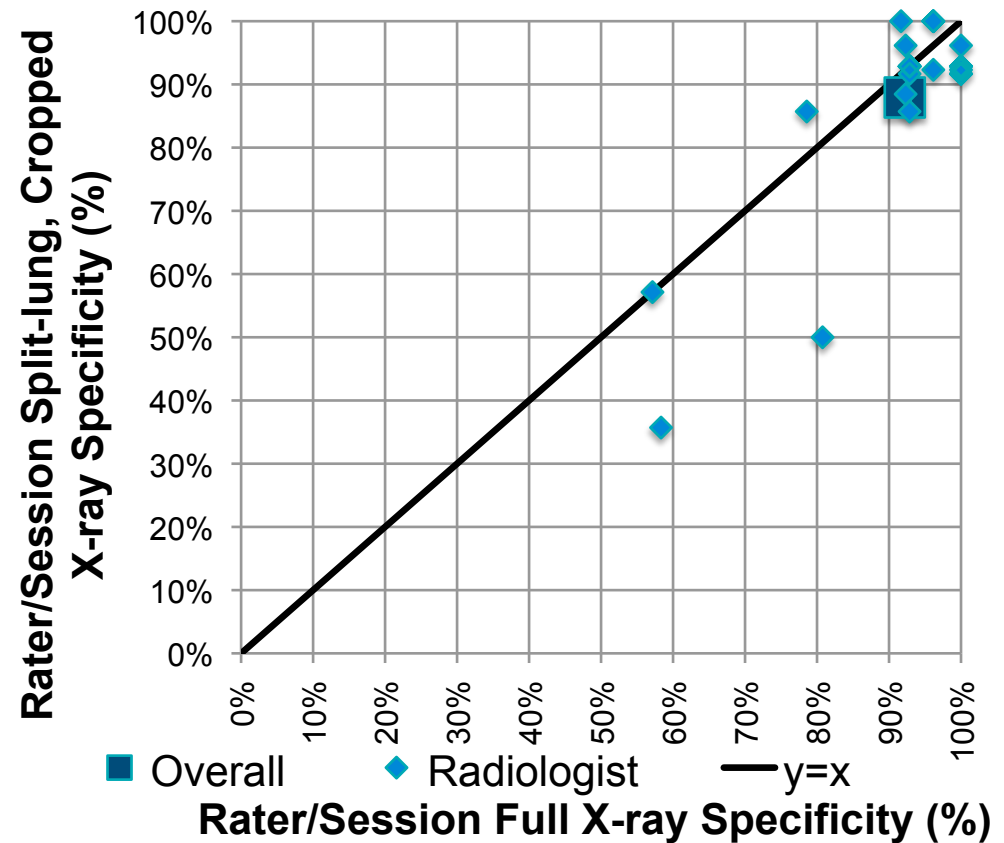
# Results: sensitivity

- For each radiologist/session, full chest x-ray sensitivity is compared with split-lung, cropped x-ray sensitivity.
- The black line represents equal sensitivity in either type of image.
- Spread out, but overall centred around the “equal accuracy” line.



# Results: specificity

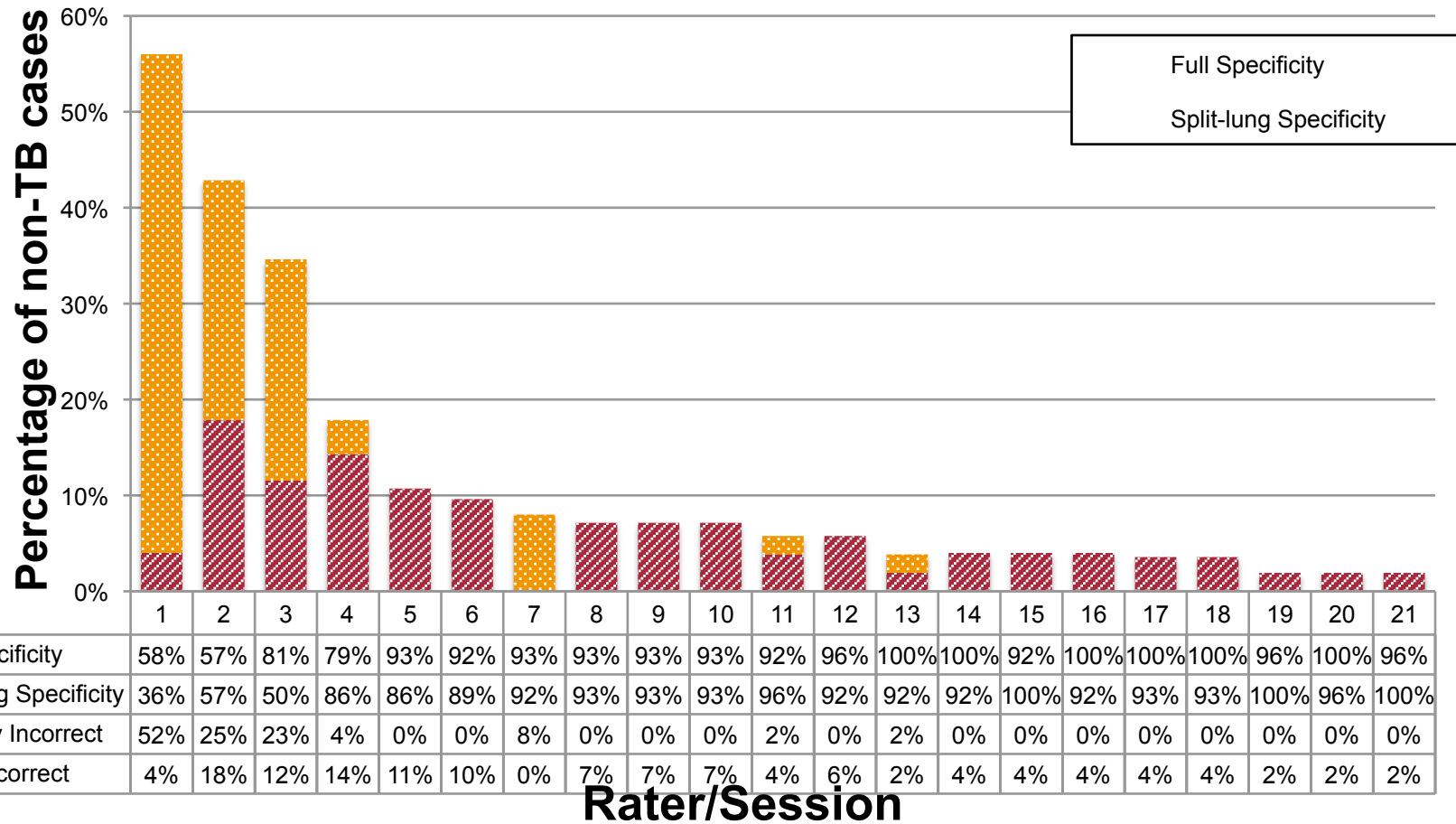
- For each radiologist/session, full chest x-ray specificity is compared with split-lung, cropped x-ray specificity.
- The black line represents equal specificity in either type of image.
- Three major outliers out of 21 raters skew the results.



# Results: specificity outliers

- Three radiologists performed significantly worse at correctly diagnosing TB-free x-rays compared to the others.
- They incorrectly diagnosed many non-TB cases that no other radiologist incorrectly diagnosed.
- One of the three performed poorly, but since their specificity results were equal for both split-lung and full x-ray cases, hypothesis was not affected

# Results: specificity outliers



# Statistical results

- The data were fit to a generalized linear model
- A standard Wald test was performed to determine if there was any difference in diagnostic accuracy depending on image type
- For sensitivity, the p-value was 0.58
- For specificity, the p-value was 0.037, or 0.41 when the two outliers were removed
- This shows that there is no difference in diagnostic accuracy between the image types.

# Results: rater experience

- Radiologists were asked for their estimation of the task's relative difficulty
- Scale from 1 (“not difficult”) to 5 (“very difficult”)
- Radiologists agreed the task was easier than they first imagined before completing the survey

	Pre-survey	Post-survey	Change from pre- to post-survey
Average Difficulty	2.923	1.462	-1.462
Standard Deviation	1.037	0.660	1.050

# Conclusion

- There is **no noticeable difference in sensitivity** between a full chest x-ray (58.7%) and a split-lung, cropped x-ray (61.0%) for screening for tuberculosis.
- There is some evidence (2 very atypical points) that suggests that specificity is worse for split-lung, cropped x-rays (87.9%) than for full chest x-rays (92.2%), but the **majority of radiologists performed well in both cases.**



# Summary and Future

- Examine the possibility of using pulmonary sized (two-lung) digital X-ray detectors in place of traditional chest sized devices
  - Less user acceptance issues
  - Can still achieve significant cost reductions to make digital technology accessible to lower volume underserved populations
- Variation in radiologist diagnostic capabilities suggests examining the use of teleradiology and/or CAD
  - Teleradiology can send cases to a TB expert populated radiology call center to improve sensitivity and specificity
  - CAD, as a decision support system, could aid a physician or radiologist make a better diagnosis

# Thank you

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