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Automated Tuberculosis Screening & Real-Time Chest X-Ray Triage Using Deep Learning

An Interpretable MobileNetV2 & Grad-CAM Decision-Support Framework for High-Burden Clinics

Presenter & Educational Background	Co-Author & Institutional Affiliation
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Presentation Outline: Background → Aim & Purpose → Methods → Experimental Results → Discussion & Summary

01 · BACKGROUND & CLINICAL BOTTLENECK

Radiologist Shortages Delay TB Diagnosis and Fuel Transmission

Pakistan ranks among the **top five high-burden Tuberculosis (TB) nations** globally (WHO 2026). While chest radiography (CXR) is the primary screening tool, specialist bottlenecks in public hospitals leave contagious patients unisolated.

Workflow Stage	Current Public Hospital Reality	Clinical & Public Health Impact
1. National Burden	Over **140 daily TB deaths** and hundreds of thousands of new cases annually in Pakistan.	High patient volume overwhelms outpatient diagnostic departments.
2. X-Ray Acquisition	Digital chest X-rays capture radiopaque lung consolidations and upper-lobe cavities rapidly.	Images accumulate in unprioritized queues awaiting specialist review.
3. Reporting Delay	Severe shortage of trained radiologists in rural and overcrowded public clinics.	**Multi-day reporting lag** between scan acquisition and diagnosis.
4. Transmission Risk	Patients return home or remain in crowded wards before positive scans are read.	Active airborne contagion continues prior to clinical isolation.

Core Clinical Need: Clinics require an automated point-of-capture triage filter that flags high-risk radiographs immediately rather than waiting days in a chronological queue.

02 · AIM & PURPOSE

Real-Time Point-of-Capture AI Triage with Visual Transparency

Our objective is to deploy an interpretable deep learning screening assistant directly at X-ray acquisition to prioritize contagious TB cases while keeping physicians in full diagnostic control.

Pipeline Stage	Operational Mechanism	Clinical Action Triggered
1. Point-of-Capture Input	Posteroanterior chest radiograph is ingested immediately upon acquisition (< 1 second runtime).	Zero disruption to existing radiology technician workflow.
2. Risk Probability Scoring	Fine-tuned MobileNetV2 outputs a continuous TB probability evaluated at a **0.40 triage threshold**.	Scans ≥ 0.40 are flagged **High-Risk**; scans < 0.40 enter routine review.
3. Grad-CAM Saliency Overlay	Gradient-weighted Class Activation Mapping highlights exact lung regions driving the alert.	Clinicians verify anatomical pathology and rule out border artifacts.
4. Priority Isolation & Review	Flagged patients are isolated immediately and moved to the top of the physician's reading queue.	Reduces community transmission and accelerates confirmatory testing.

> **Human-in-the-Loop Role:** The system operates strictly as a *real-time triage assistant*—it accelerates queue prioritization and visual verification while doctors retain final diagnostic authority.

Class-Weighted Transfer Learning & Grad-CAM Explainability

Component	Implementation Details & Design Rationale
Dataset & Stratified Split	**TB Chest X-Ray Database** (Rahman et al., Qatar University/Kaggle): **4,200 labeled CXRs** (3,500 Normal, 700 TB-positive). Stratified 80/20 split yields **3,360 training** and **840 held-out validation** images.
Preprocessing & Augmentation	Standardized to **224 × 224 × 3 pixels** with MobileNetV2 intensity scaling. Applied on-the-fly geometric augmentation (horizontal flip, ±8% rotation, ±10% zoom) to prevent overfitting on the minority class.
Handling 5:1 Imbalance	Applied **5:1 class-weighted binary cross-entropy loss** (`Normal: 1.0, TB: 5.0`), penalizing missed TB cases five times more heavily during backpropagation to counter the accuracy paradox.
Two-Stage Transfer Learning	**MobileNetV2** (ImageNet pre-trained): *Stage 1* froze base feature layers for 8 epochs (Adam, lr = 10^{-3}); *Stage 2* unfroze the top 30 layers for 5 fine-tuning epochs (lr = 10^{-5}) to adapt to pulmonary textures.
Grad-CAM Verification	Computed positive gradients flowing into the final convolutional layer (`out_relu`) to project spatial heatmaps onto the lung parenchyma, exposing spurious shortcut cues.

Why MobileNetV2? Lightweight depthwise-separable convolutions enable fast offline inference (< 1 sec/scan) on standard clinic PCs without requiring dedicated hospital GPUs.

04 · EXPERIMENTAL RESULTS (HELD-OUT VALIDATION SET, N = 840)

Strong Discrimination (AUC 0.993) & Verified Lung Localization

ROC-AUC	Sensitivity (Recall)	Specificity
0.993	**82.9%**	**100.0%**
Near-perfect separation	116 / 140 TB caught	700 / 700 Normal cleared

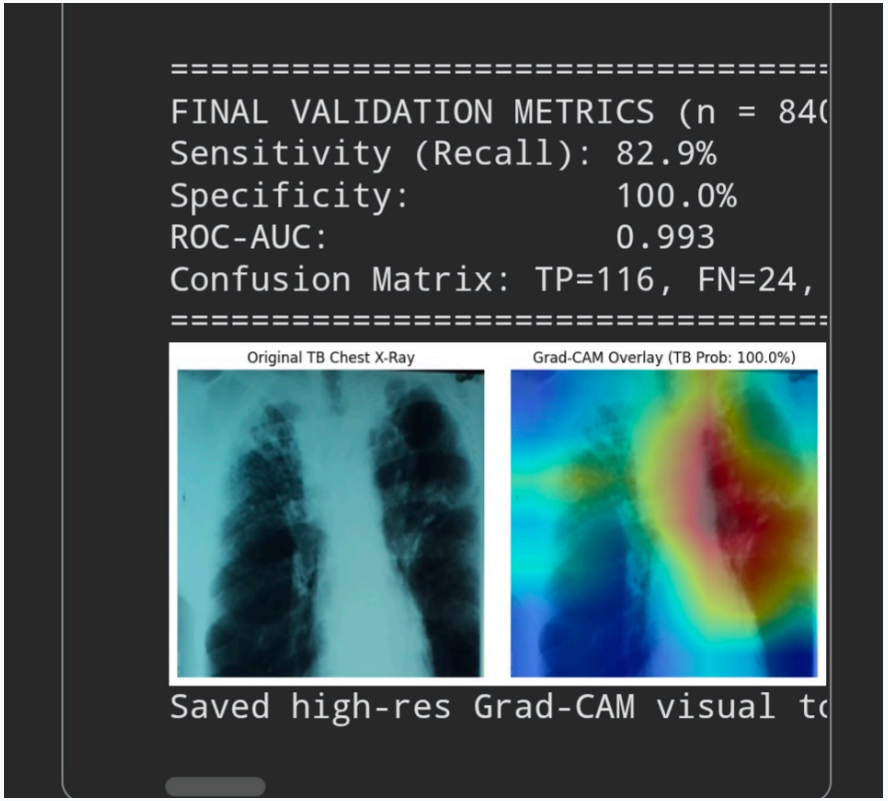
Validation Performance Breakdown (Threshold = 0.40)

ROC-AUC Discrimination Power — **99.3% (0.993)**

Specificity (Zero False Alarms: FP = 0) — **100.0% (700/700)**

TB Sensitivity (TP = 116, FN = 24) — **82.9% (116/140)**

Key Observation: Across 840 unseen scans, the model eliminated false positives completely (FP = 0) while achieving 0.993 AUC; lowering the operating threshold below 0.40 can further trade specificity for higher recall where desired.



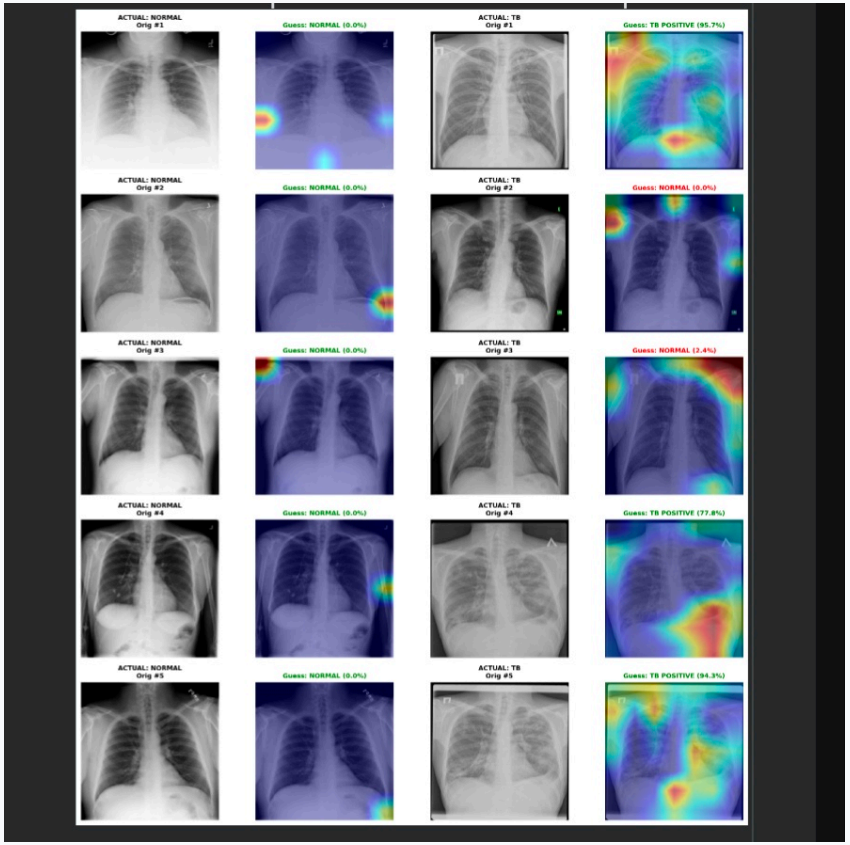
Held-out TB validation scan: Grad-CAM localizes left pulmonary infiltrate (TB Prob: 100.0%) while ignoring outer bony borders.

05 · DISCUSSION & KEY FINDINGS SUMMARY

Interpretable, Clinic-Ready AI Triage for Resource-Limited Settings

Key Finding	Clinical & Technical Takeaway
1. High Diagnostic Separation	Fine-tuned MobileNetV2 achieved **0.993 ROC-AUC**, **100.0% specificity**, and **82.9% sensitivity** on 840 unseen scans without false-alarm fatigue.
2. Verified Anatomical Focus	Grad-CAM heatmaps confirm predictions rely on true pulmonary opacities, while exposing subtle early-stage false negatives for clinician review.
3. Practical Deployment	Compact architecture runs locally on standard clinic computers without internet dependency, enabling immediate isolation of high-risk patients.
4. Future Clinical Validation	Next phase: multi-center prospective validation on local Pakistani hospital X-ray equipment and threshold calibration for triage sensitivity.

Conclusion: Combining lightweight transfer learning with Grad-CAM delivers fast, trustworthy TB screening tailored to Pakistan's public health needs. **Thank you.**



10-case audit (5 Normal, 5 TB): 5/5 Normal cleared (0.0%); clear TB infiltrates caught (95.7%, 77.8%, 94.3%), while subtle cases illustrate human-in-the-loop necessity.