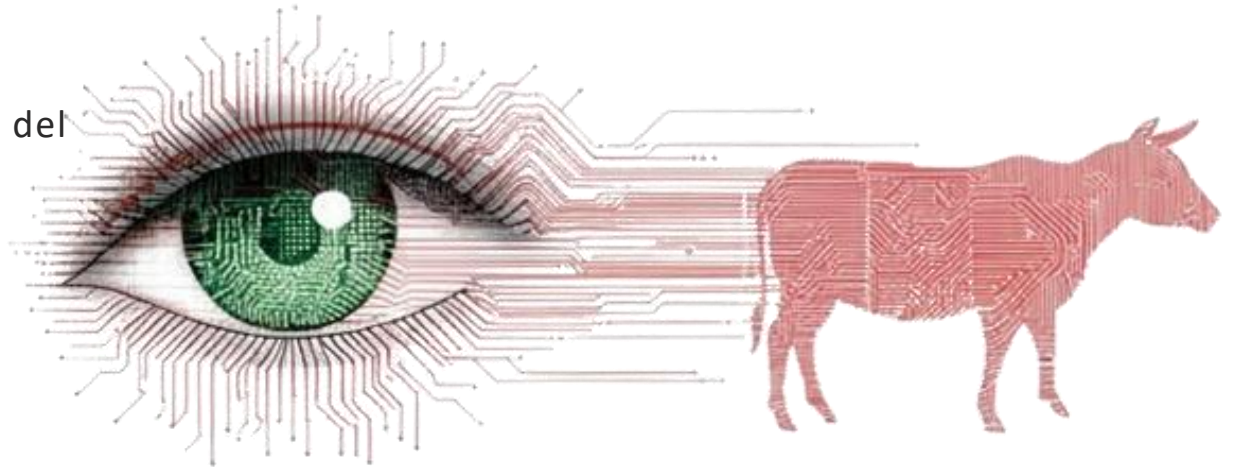


MÁS ALLÁ DEL OJO HUMANO:

INTELIGENCIA ARTIFICIAL EN MATADEROS

Fecha: 05 de junio de 2026

Lugar: Sala Ernest Lluch, Ministerio de Sanidad, Paseo del Prado, 18-20, 28014 - Madrid.





Desarrollando SNAPP-TB: un modelo basado en IA para apoyar la vigilancia de TB en matadero

Àlex Cobos^{1,2}, Majda Moussa^{3,4}, Solène Le Manac'h^{3,4}, Carlota Mendoza^{1,2}, Francisca Fonseca¹, Bernat Pérez¹, Natàlia Majó^{1,2}, Pablo Valdes^{3,4}, Enric Vidal¹

¹ **IRTA** ^R **CReSA**
Centre de Recerca
en Sanitat Animal

² **UAB**
Universitat Autònoma
de Barcelona

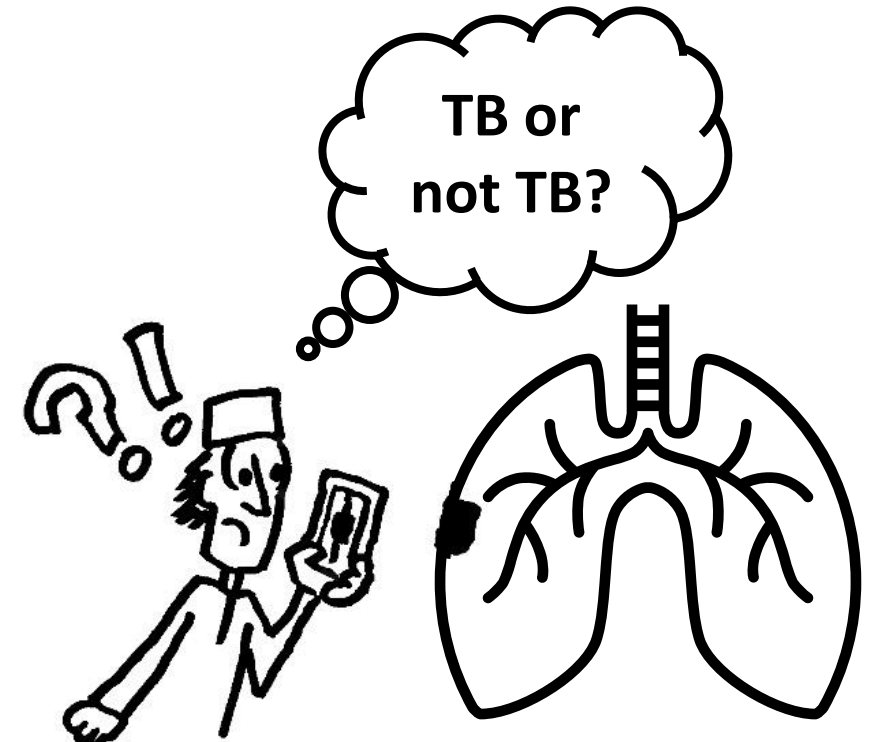
³ Centre de Recherche en
Infectiologie Porcine et Avicole
Swine and Poultry Infectious
Diseases Research Center

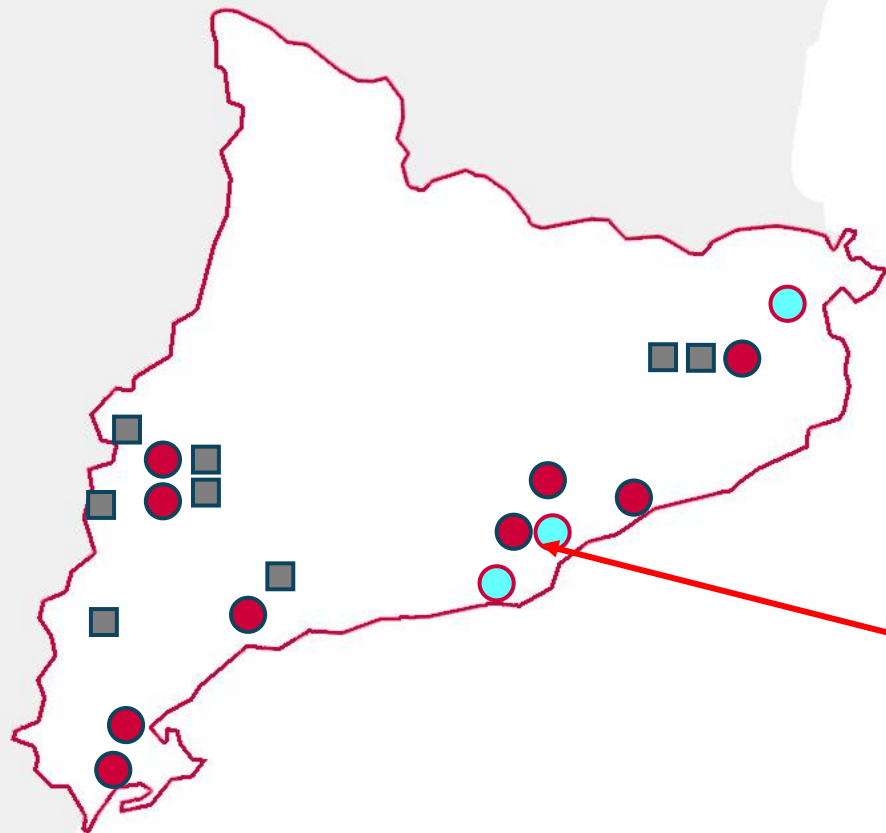

CRIPA
Université
de Montréal

⁴ **PIAAS**
Plateforme IA-Agrosanté 

ÍNDICE

- TB causada por el complejo *Mycobacterium tuberculosis*
- SESC: el programa de apoyo a matadero
- Identificando la necesidad: fortalecer la vigilancia pasiva frente a tuberculosis
- Solución propuesta
- Principales retos
- Resultados preliminares
- Conclusiones y perspectivas futuras





- IRTA centers
- Consortium centers

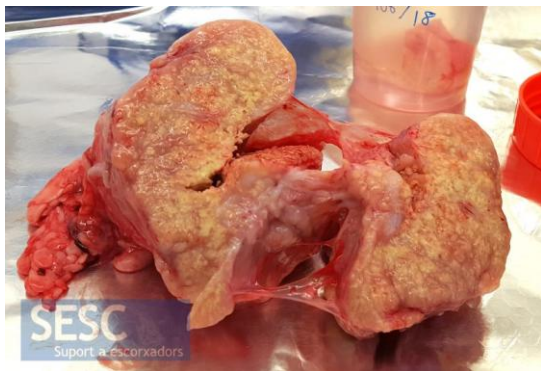
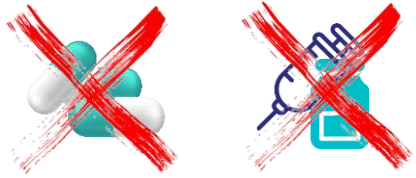
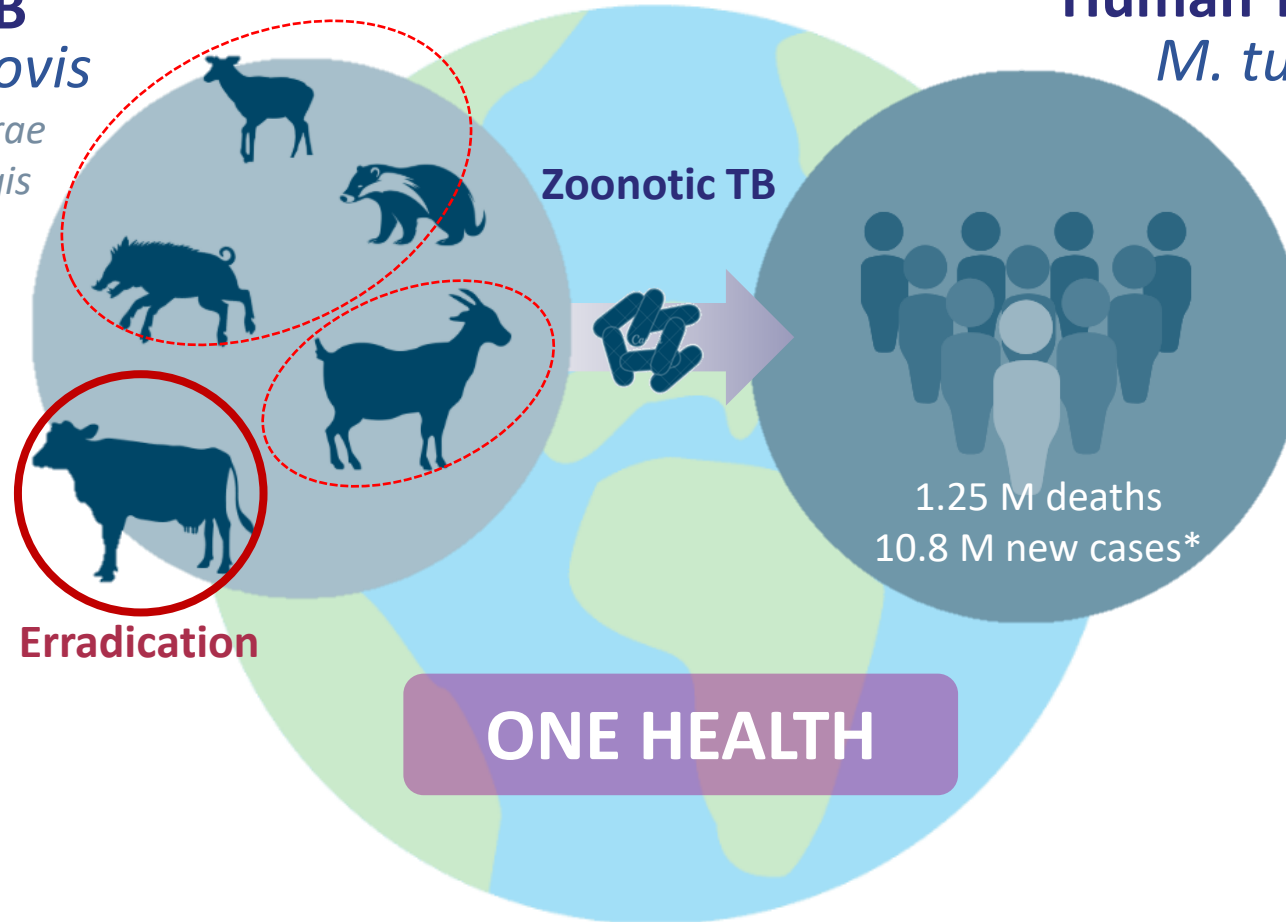
- Experimental farms and holdings



TB causada por el complejo *Mycobacterium tuberculosis*

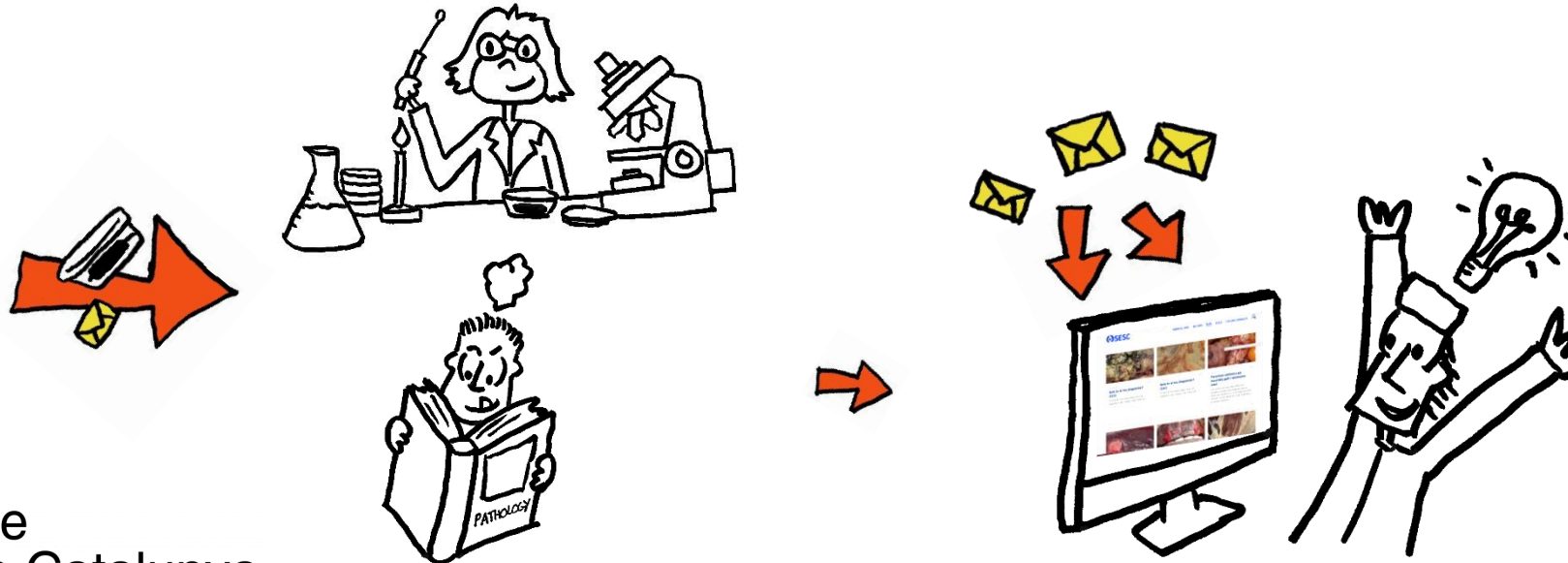
Animal TB
M. bovis
M. caprae
M. orygis

Human TB
M. tuberculosis
M. africanum



*WHO. Global Tuberculosis Report 2024

SESC : la red de apoyo a mataderos

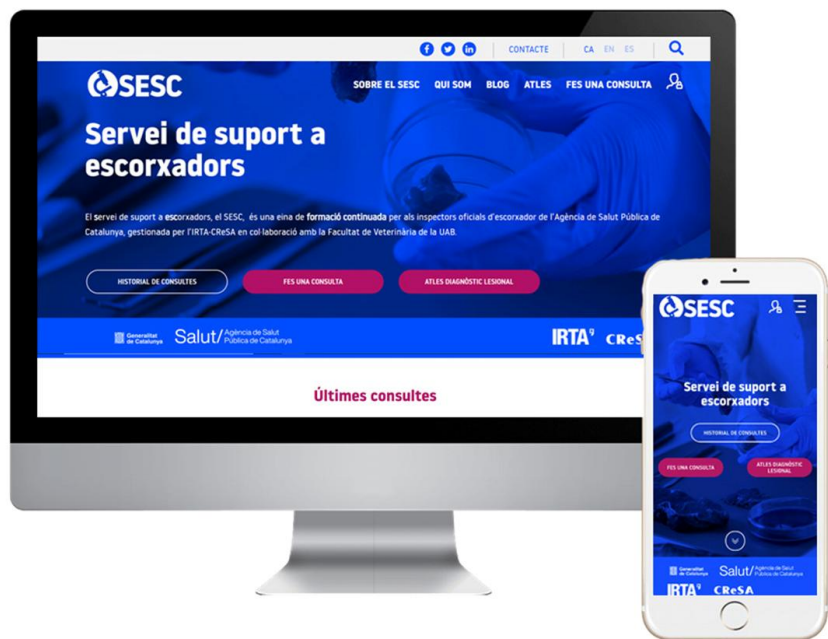


Salut/Agència de
Salut Pública de Catalunya

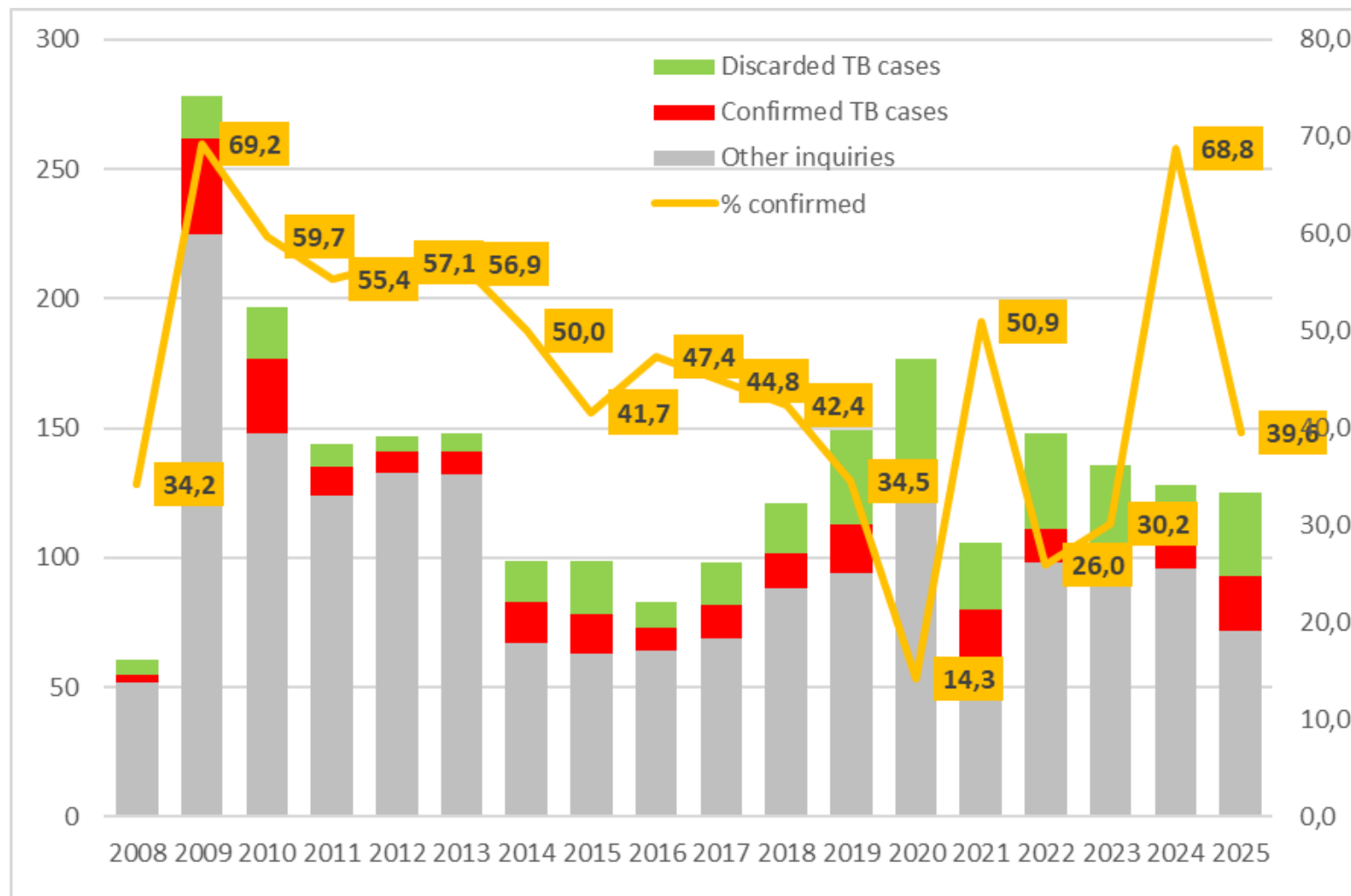


De media:

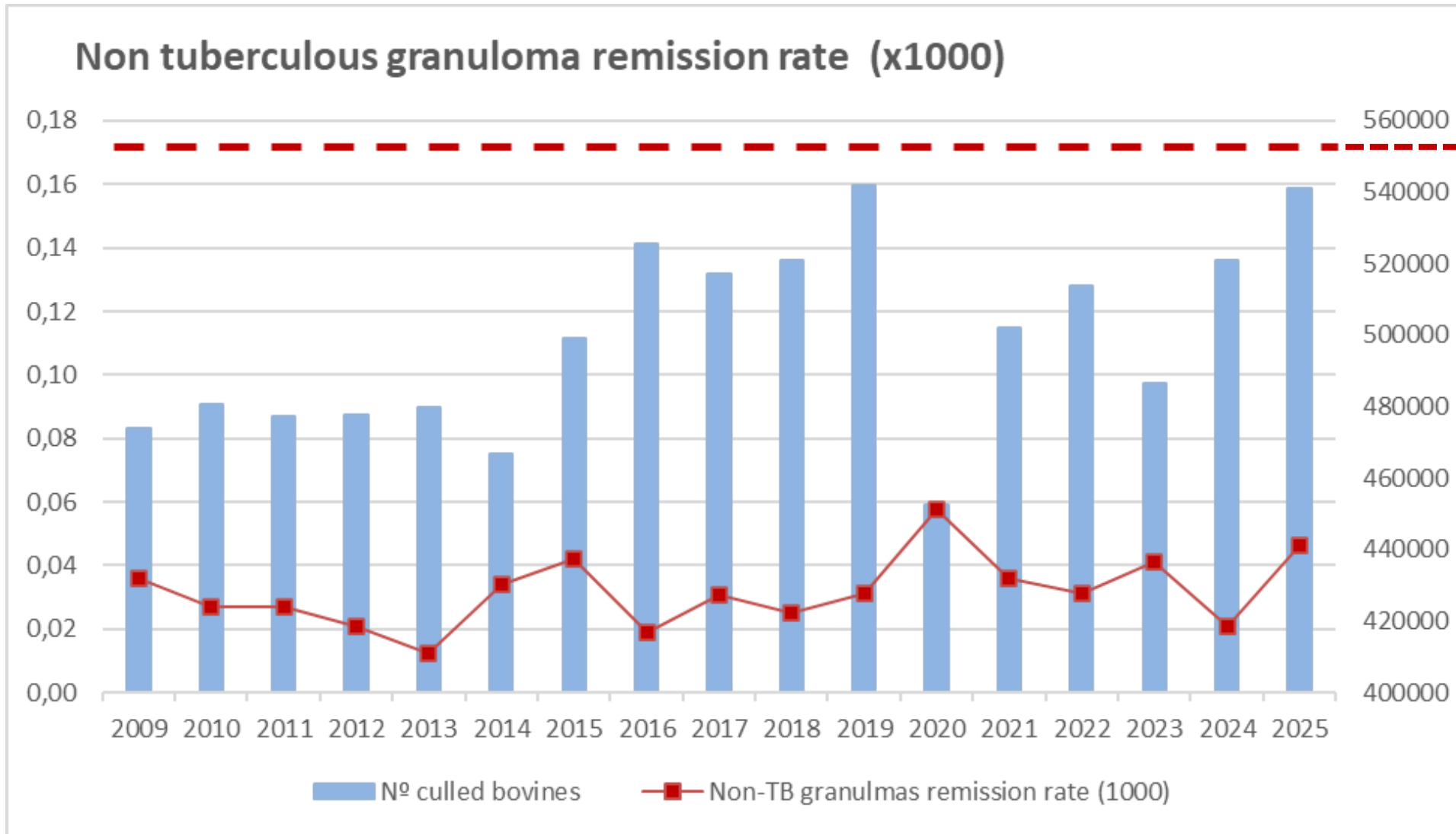
- 27,1% de las consultas del SESC están relacionadas con tuberculosis
- 45,7% de los casos sospechosos a TB se confirman



www.sesc.cat



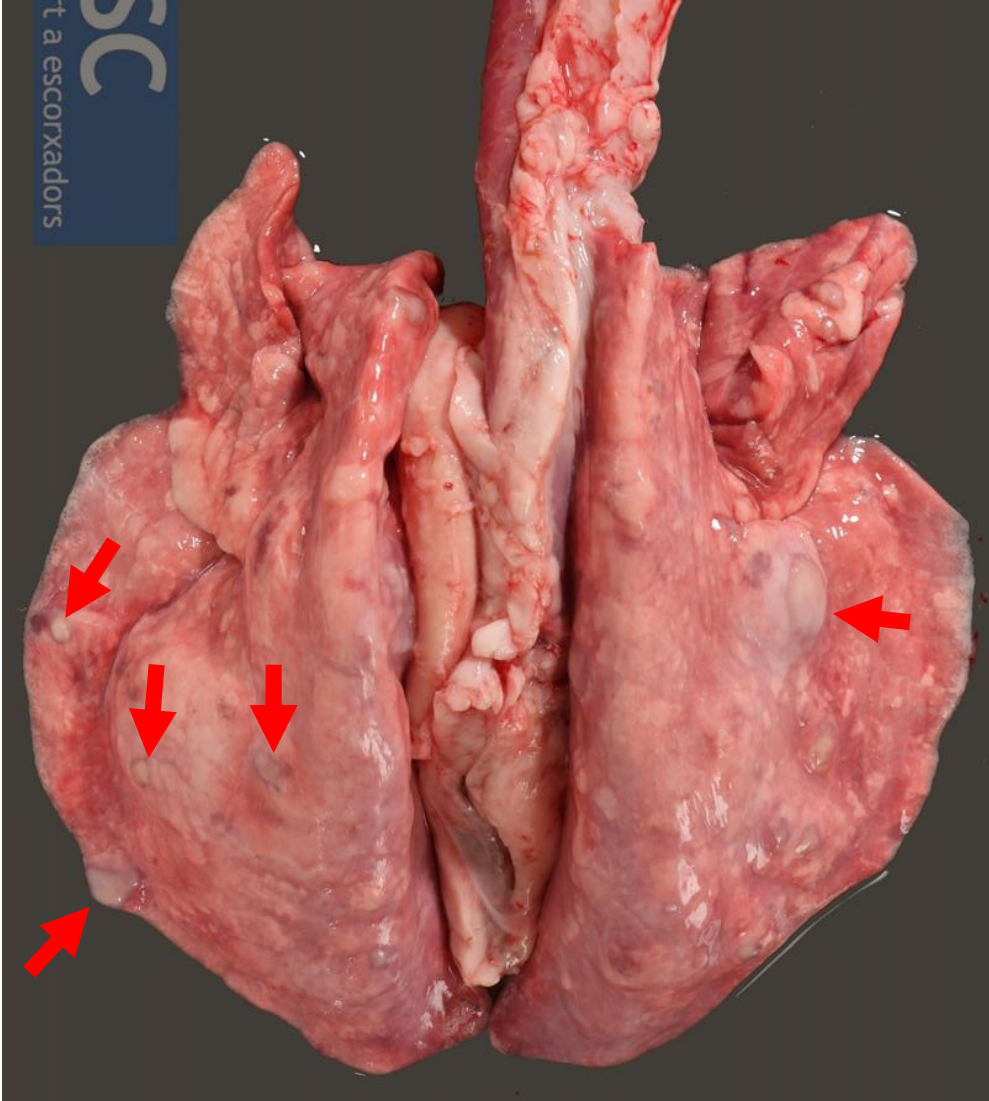
• Identificando la necesidad: fortalecer la vigilancia pasiva frente a tuberculosis



El ministerio de agricultura establece un objetivo mínimo de 0,17 granulomas no tuberculosos analizados por cada 1000 bovinos sacrificados.

Es necesario fomentar la remisión de granulomas!

- **Identificando la necesidad: fortalecer la vigilancia pasiva frente a tuberculosis**



Example of a lamb's lung with TB lesions that was condemned without sample submission.

- **Una fracción de los granulomas tuberculosos se descartan por los técnicos/veterinarios (y se registran como abscesos o otras lesiones), especialmente en pequeños rumiantes. No se remiten muestras.**
- **Declarar una sospecha de TB tiene implicaciones relevantes. Cataluña es oficialmente libre en tuberculosis bovina desde 2023, nuevos brotes pueden implicar vacío sanitario**

- **Identificando la necesidad: fortalecer la vigilancia pasiva frente a tuberculosis**



Linfadenitis granulomatosa fúngica



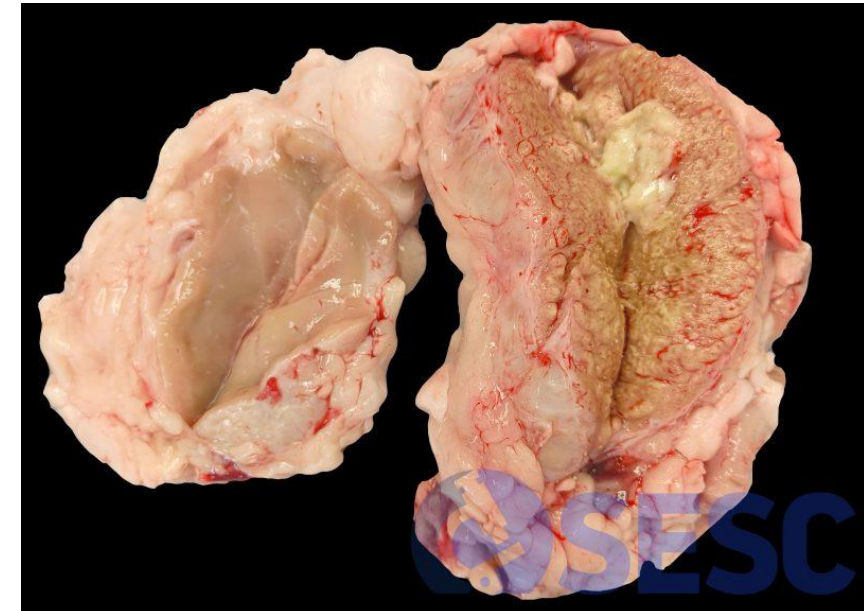
Neumonía granulomatosa focal parasitaria



Mesotelioma

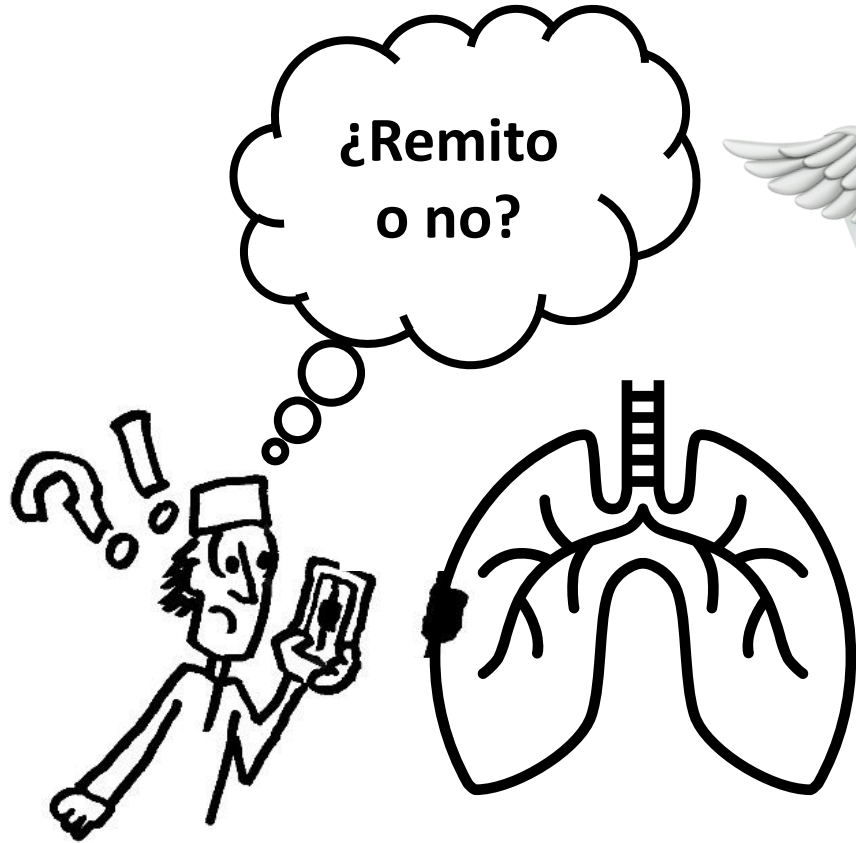


Linfadenitis granulomatosa por *M. avium*



Linfadenitis granulomatosa (TB)

Solución propuesta



IRTA^R **CReSA**
Centre de Recerca
en Sanitat Animal

SESC

Archivo de imágenes
Metadata de diagnóstico



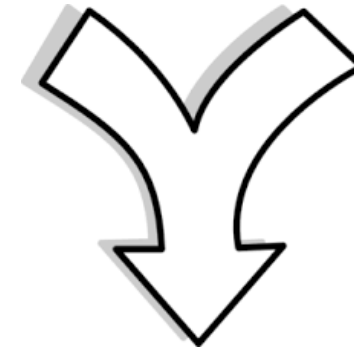
IRTA^R
Financiación POC

Centre de Recherche en
Infectiologie Porcine et Avicole
Swine and Poultry Infectious
Diseases Research Center



PIAAS
Plateforme IA-Agrosanté

Expertise en IA



SNAPP-TB

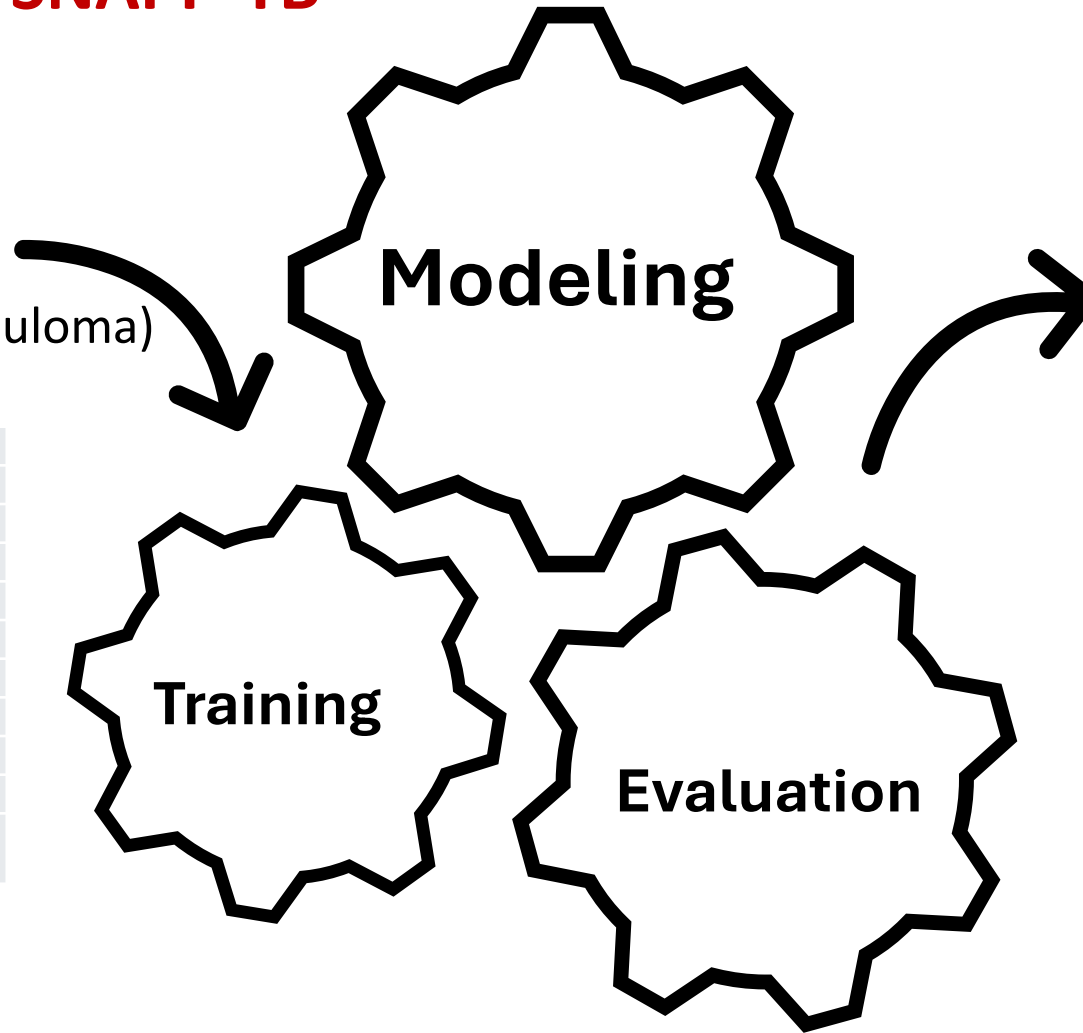
*Slaughterhouse Nodular
Assessment Picture-
based Predictor – TB*

Solución propuesta: SNAPP-TB

Preparación de datos:

- Mínimo 1000 imágenes
- Segmentación (tejido/granuloma)
- Metadata Diagnóstico

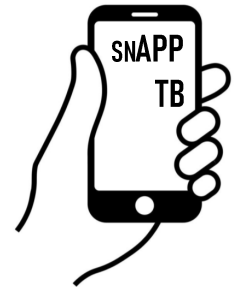
| |
|--|
| Tuberculosis |
| Non tuberculous mycobacterial granuloma |
| Fungal granuloma |
| Bacterial pyogranuloma |
| Parasitic granuloma |
| Neoplasia |
| Abscess |
| Lymphoid hyperplasia |
| No significant lesions |
| Other nodular lesions |
| Suppurative bronchopneumonia with bronchiectasis |



Resultado.

Predicción

- TB vs NC vs NonTB
- 11 tipos diagnósticos



Preparación

Dataset → 1000 imágenes

| Image | Reference | Tissue | Species | Age (Month) | Municipality | Count | Sampling date | Mineralization | Macro TB Dx | Final Diagnosis | Agent | Origin |
|--------|-------------|-----------|-----------|-------------|------------------------------|-------|---------------|----------------|---------------|------------------------------|------------------|------------------------|
| CR0001 | SESC-051/25 | RF LN | Bovine | | 13 Menarguens | Spain | 28/5/2025 | Unknown | Inconclusive | Bacterial pyogranuloma | Rhodococcus equi | Slaughterhouse finding |
| CR0002 | SESC-037/25 | MD LN | Bovine | | 16 Lleida | Spain | 7/4/2025 | Yes | TB compatible | Tuberculosis | CMT | Slaughterhouse finding |
| CR0003 | SESC-037/25 | PS LN | Bovine | | 16 Lleida | Spain | 7/4/2025 | No | Negative | No significant lesions | None | Slaughterhouse finding |
| CR0004 | SESC-045/25 | MS LN | Bovine | | 10 Alcarrás | Spain | 2/5/2025 | Yes | Inconclusive | Fungal granuloma | Unknown | Slaughterhouse finding |
| CR0005 | SESC-045/25 | MD LN | Bovine | | 10 Alcarrás | Spain | 2/5/2025 | Yes | Inconclusive | Fungal granuloma | Unknown | Slaughterhouse finding |
| CR0006 | SESC-045/25 | PO LN | Bovine | | 10 Alcarrás | Spain | 2/5/2025 | Yes | Inconclusive | Fungal granuloma | Unknown | Slaughterhouse finding |
| CR0007 | SESC-042/25 | Lung | Bovine | | 17 Les Franqueses del Vallès | Spain | 22/4/2025 | Yes | Negative | Suppurative bronchopneumonia | Mycoplasma bovis | Slaughterhouse finding |
| CR0008 | SESC-031/25 | MS LN | Bovine | | 18 Jeréz de los Caballeros | Spain | 27/3/2025 | Yes | TB compatible | Tuberculosis | CMT | Slaughterhouse finding |
| CR0009 | SESC-031/25 | MD LN | Bovine | | 18 Jeréz de los Caballeros | Spain | 27/3/2025 | Yes | TB compatible | Tuberculosis | CMT | Slaughterhouse finding |
| CR0010 | SESC-031/25 | RF LN | Bovine | | 18 Jeréz de los Caballeros | Spain | 27/3/2025 | Yes | TB compatible | Tuberculosis | CMT | Slaughterhouse finding |
| CR0011 | SESC-030/25 | PE LN | Bovine | | 69 Castelló d'Empúries | Spain | 26/3/2025 | Unknown | Negative | Neoplasia | None | Slaughterhouse finding |
| CR0012 | SESC-030/25 | PE LN | Bovine | | 69 Castelló d'Empúries | Spain | 26/3/2025 | Unknown | Negative | Neoplasia | None | Slaughterhouse finding |
| CR0013 | SESC-030/25 | PE LN | Bovine | | 69 Castelló d'Empúries | Spain | 26/3/2025 | Unknown | Negative | Neoplasia | None | Slaughterhouse finding |
| CR0014 | SESC-030/25 | Other tis | Bovine | | 69 Castelló d'Empúries | Spain | 26/3/2025 | Unknown | Negative | Neoplasia | None | Slaughterhouse finding |
| CR0015 | SESC-030/25 | Other LN | Bovine | | 69 Castelló d'Empúries | Spain | 26/3/2025 | Unknown | Negative | Neoplasia | None | Slaughterhouse finding |
| CR0016 | SESC-028/25 | SM LN | Wild boar | Unknown | Mas de Barberans | Spain | 24/3/2025 | Unknown | Negative | Other nodular lesions | Unknown | Slaughterhouse finding |
| CR0017 | SESC-023/25 | SM LN | Wild boar | Unknown | Roquetes | Spain | 10/3/2025 | Yes | TB compatible | Tuberculosis | CMT | Slaughterhouse finding |
| CR0018 | SESC-022/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | 10/3/2025 | Yes | TB compatible | Tuberculosis | CMT | Slaughterhouse finding |
| CR0019 | SESC-020/25 | SM LN | Wild boar | Unknown | La Fatarella | Spain | 4/3/2025 | Unknown | Negative | Other nodular lesions | Unknown | Slaughterhouse finding |
| CR0020 | SESC-019/25 | MS LN | Bovine | | 10 Santpedor | Spain | 3/3/2025 | Yes | Inconclusive | Fungal granuloma | Unknown | Slaughterhouse finding |
| CR0021 | SESC-017/25 | MS LN | Bovine | | 13 Lagata | Spain | 26/2/2025 | Unknown | Inconclusive | Fungal granuloma | Unknown | Slaughterhouse finding |
| CR0022 | SESC-016/25 | Lung | Bovine | | 8 Santa Pau | Spain | 25/2/2025 | Unknown | Negative | Suppurative bronchopneumonia | Unknown | Slaughterhouse finding |
| CR0023 | SESC-016/25 | Other LN | Bovine | | 8 Santa Pau | Spain | 25/2/2025 | Unknown | Negative | Suppurative bronchopneumonia | Unknown | Slaughterhouse finding |
| CR0024 | SESC-015/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0025 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0026 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0027 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0028 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0029 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0030 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0031 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0032 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0033 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0034 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0035 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0036 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0037 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0038 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0039 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0040 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0041 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0042 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0043 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |
| CR0044 | SESC-014/25 | SM LN | Wild boar | Unknown | Alfara de Carles | Spain | | | | | | Slaughterhouse finding |

Segmentación manual (500 imágenes)



↓ QuPath software



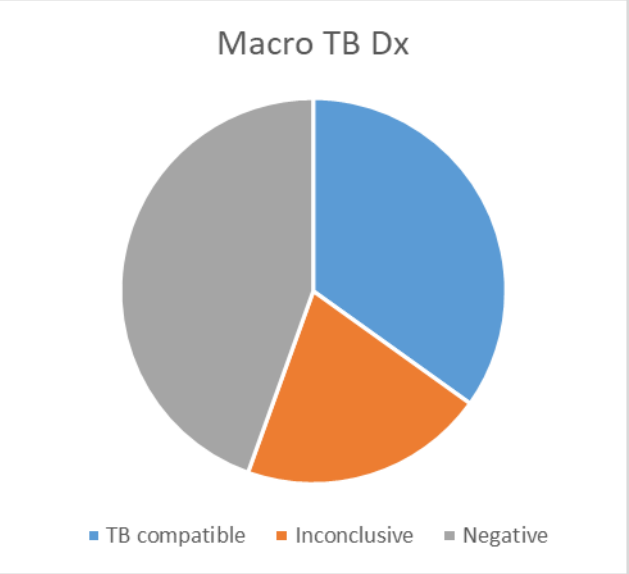
Tissue

Lesión

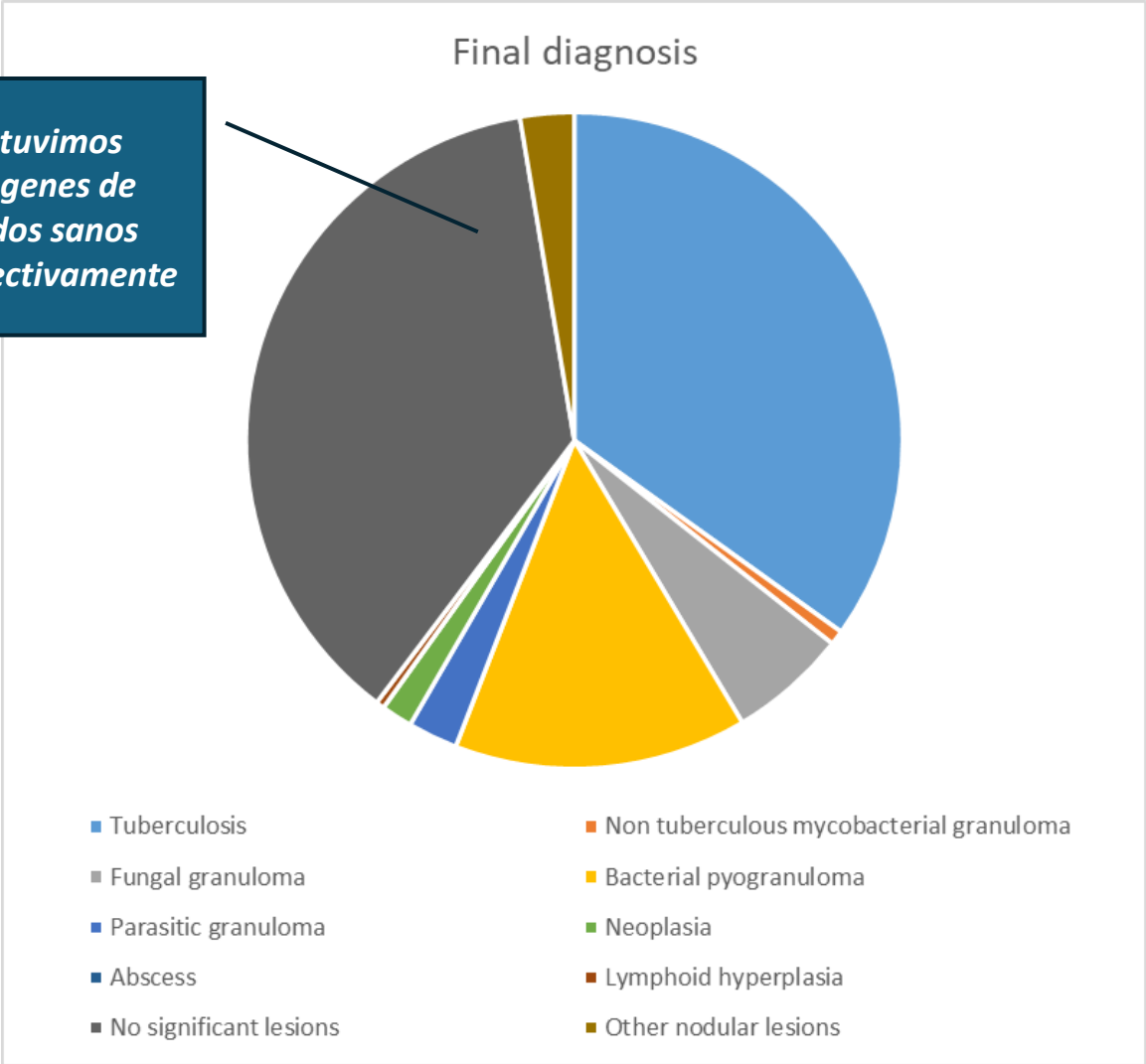


¡Solo tejidos seccionados!

Preparación datos



Obtuvimos imágenes de tejidos sanos prospectivamente



| Final Dx | Macro TB Dx | Decisión SVO |
|--|-------------------|--------------------------------------|
| Tuberculosis | Compatible con TB | Mandar a laboratorio para analizar |
| Non tuberculous mycobacterial granuloma | | |
| Fungal granuloma | | |
| Bacterial pyogranuloma | No concluyente | Mandar a laboratorio para analizar |
| Parasitic granuloma | | |
| Neoplasia | Negativo | No es necesario mandar para analizar |
| Abscess | | |
| Lymphoid hyperplasia | | |
| No significant lesions | | |
| Other nodular lesions | | |
| Suppurative bronchopneumonia with bronchiectasis | | |

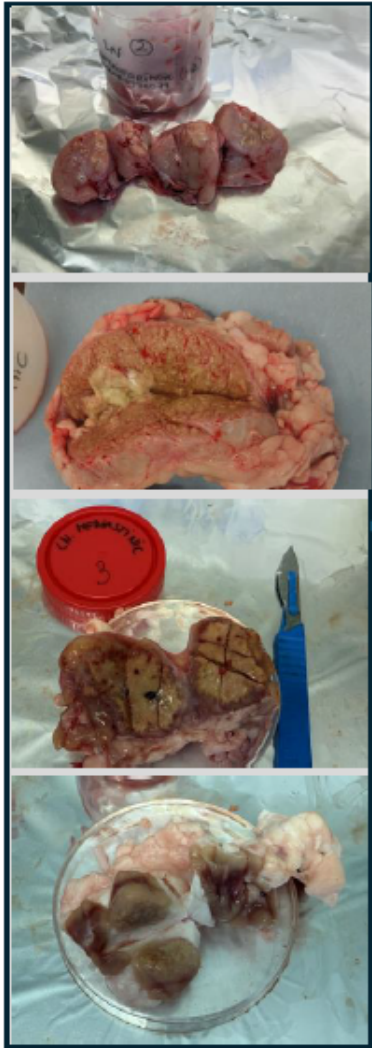
Principales retos

- **Procesado de las imágenes: diferenciar tejido del fondo**
- **Imágenes insuficientes → amplificación de datos**
- **Desbalance de categorías → encontrar una estrategia para balancear**



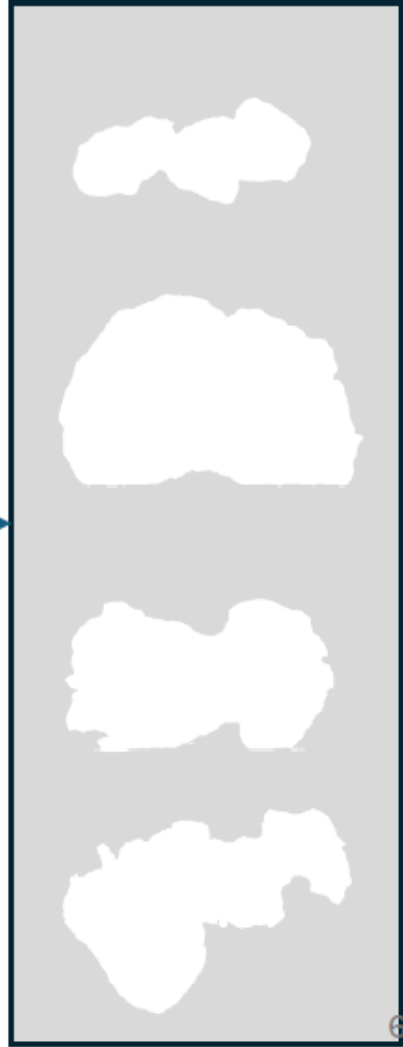
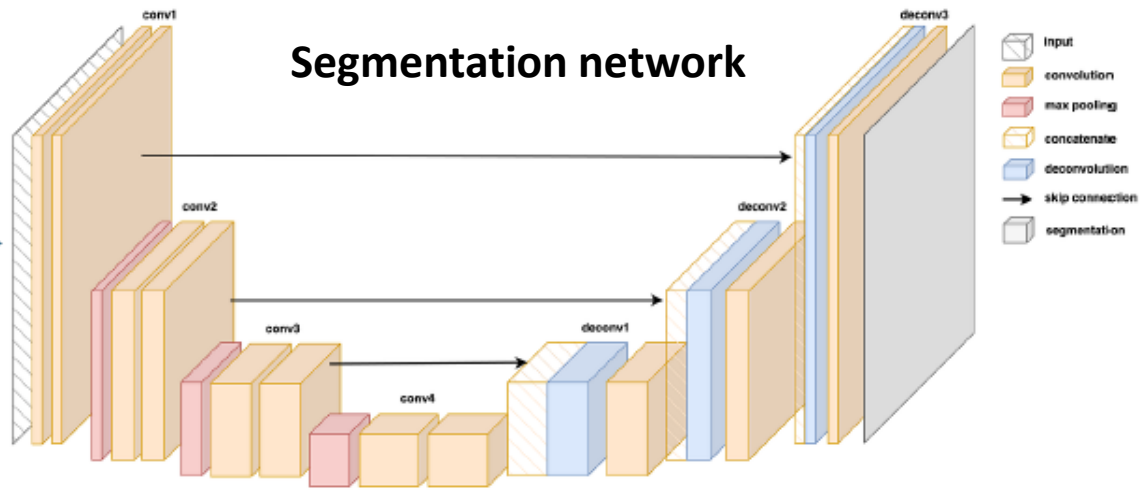
Data preprocessing: diferenciar tejido de fondo

500 annotated images



Model: U-Net with ResNet34 Encoder

- Architecture: U-Net (for image segmentation)
- Encoder (Backbone): ResNet34
- Pretrained on: ImageNet (Transfer Learning)
- Input: RGB images (3 channels)
- Output: Binary mask (Tissue vs Background)
- Hardware: GPU acceleration



Data preprocessing: diferenciar tejido de fondo

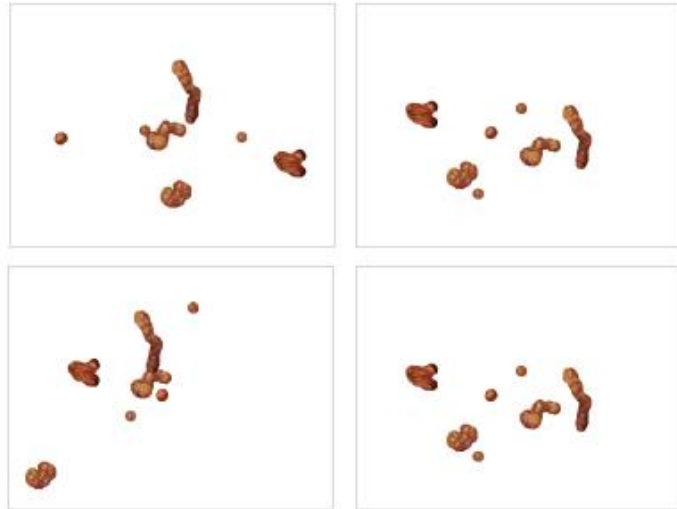
Resultados: ejemplos de segmentación de tejido basado en IA



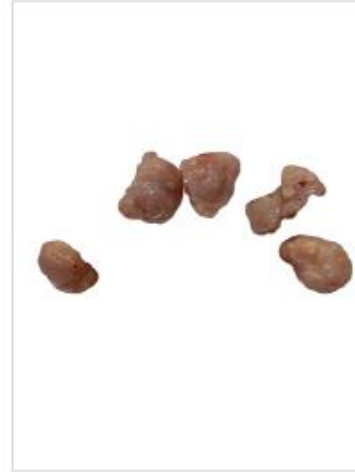
Imágenes insuficientes → creación de datos artificiales

Se extrajeron granulomas de las imágenes anotadas manualmente para generar variaciones

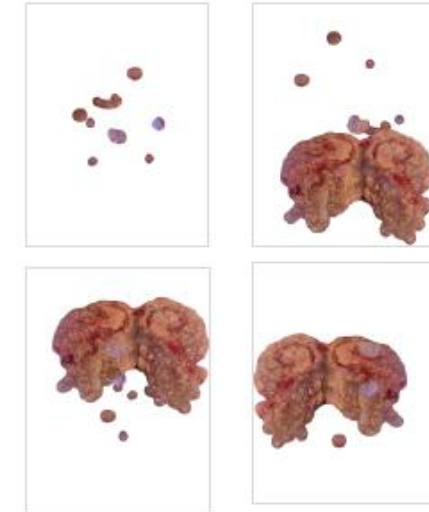
Bacterial pyogranuloma



Fungal granuloma

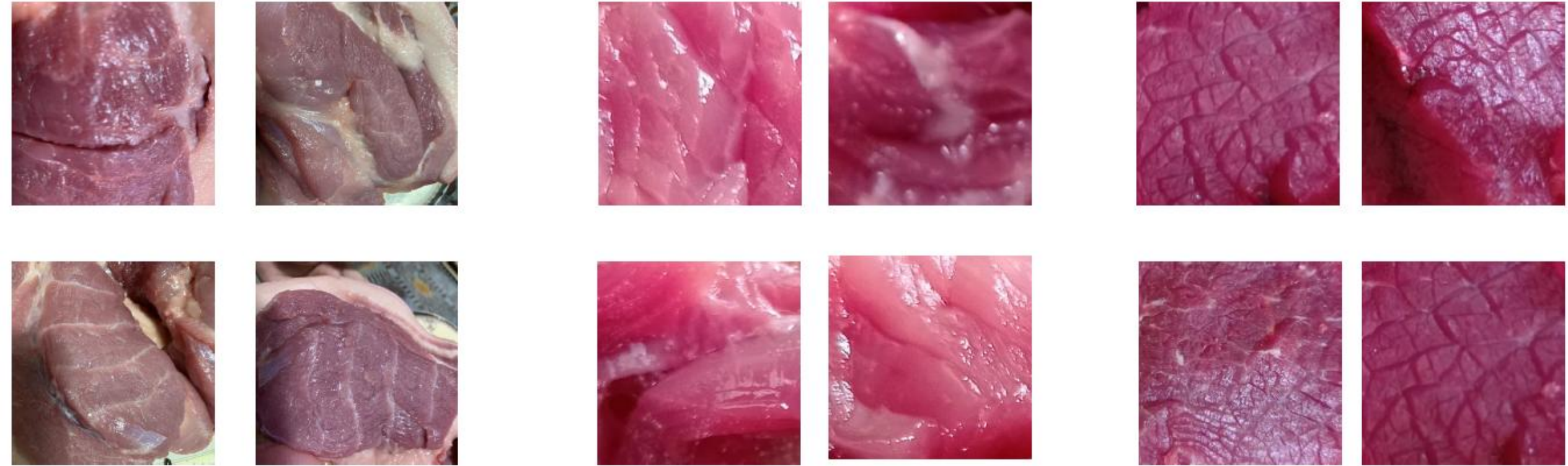


Tuberculous granuloma



Imágenes insuficientes → encontrar una estrategia para balancear

Se obtuvieron >10k imágenes de tejido sano en la plataforma Kaggle



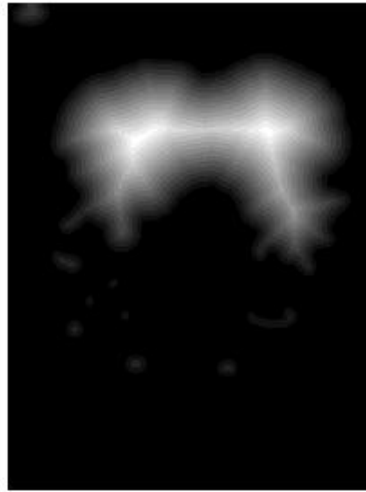
Imágenes insuficientes → encontrar una estrategia para balancear

Las variaciones se acoplaron a los tejidos sanos

Original Image



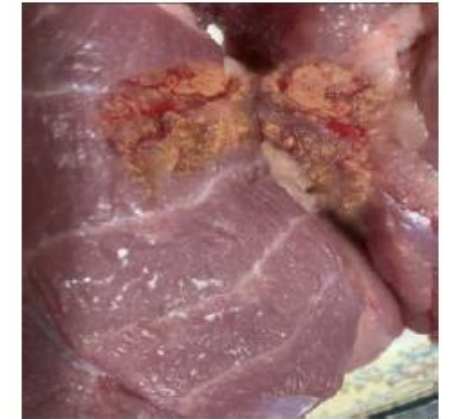
Height Map



Meat Cut



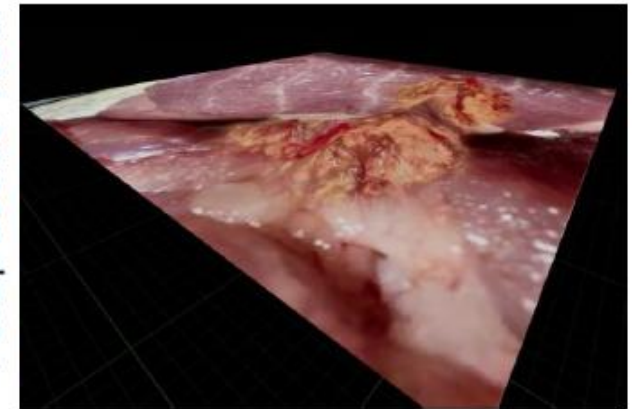
Top View



Se generaron 30k imágenes anotadas en 3h, balanceadas entre categorías

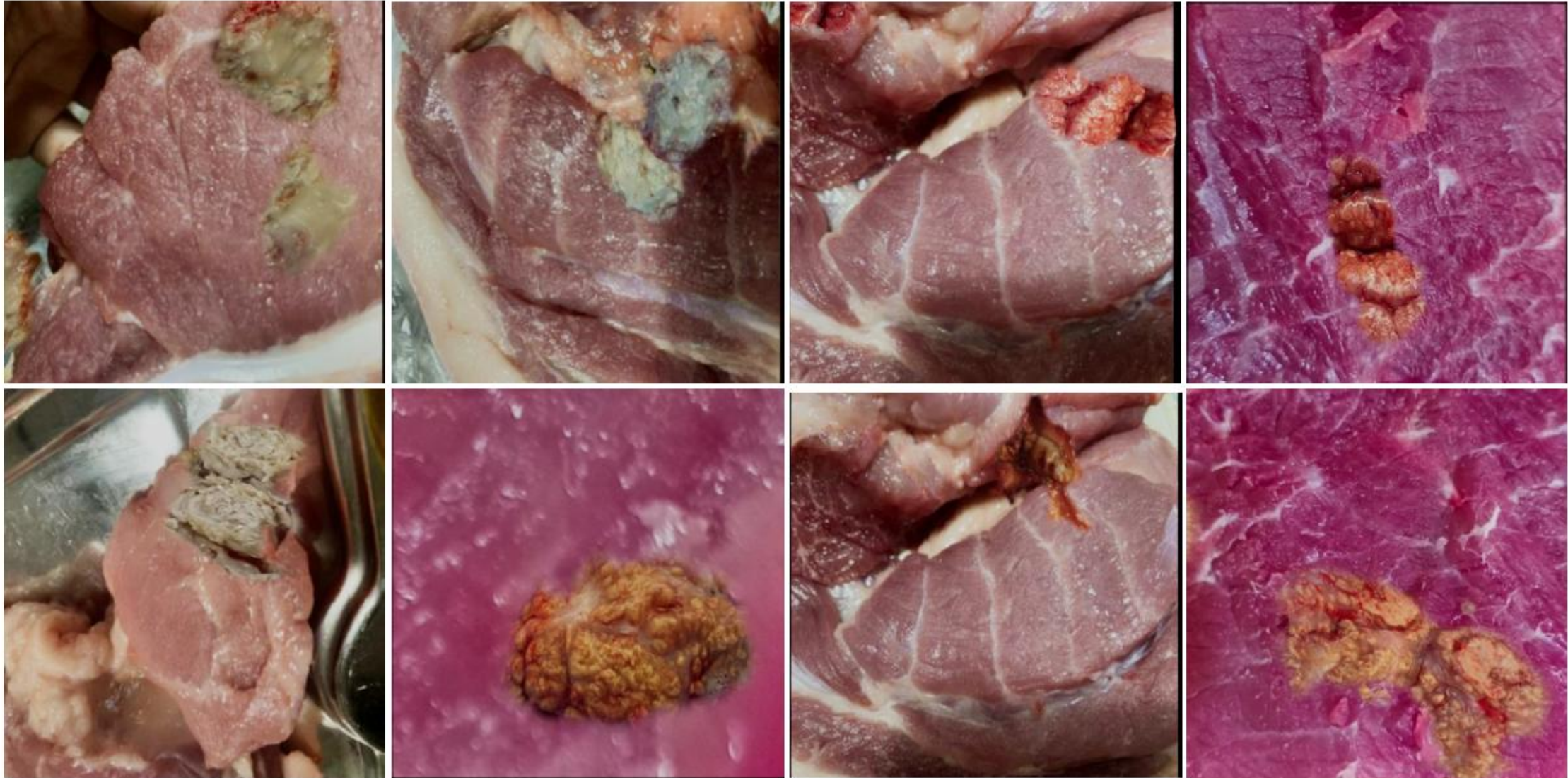


Perspective View



Imágenes insuficientes → encontrar una estrategia para balancear

Ejemplos imágenes generadas

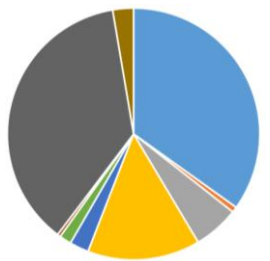


Imágenes insuficientes → encontrar una estrategia para balancear

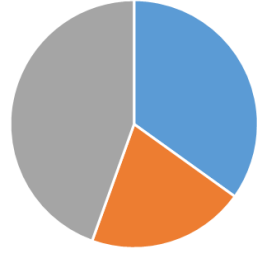
Estrategia 1: entrenar el modelo para distinguir

- Negativo (**NTB**)
- TB compatible + Inconcluyente (**TB-risk**)

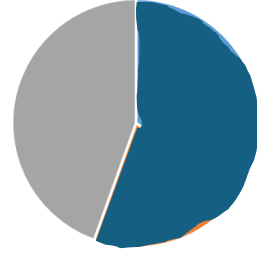
| Final Dx | Macro TB Dx | Meat inspector decision |
|--|---------------|---|
| Tuberculosis | TB compatible | Submit to Laboratory analysis |
| Non tuberculous mycobacterial granuloma | | |
| Fungal granuloma | Inconclusive | |
| Bacterial pyogranuloma | | |
| Parasitic granuloma | Negative | No need to submit samples for TB confirmation |
| Neoplasia | | |
| Abscess | | |
| Lymphoid hyperplasia | | |
| No significant lesions | | |
| Other nodular lesions | | |
| Suppurative bronchopneumonia with bronchiectasis | | |



Imbalanced



Imbalanced



Balanced

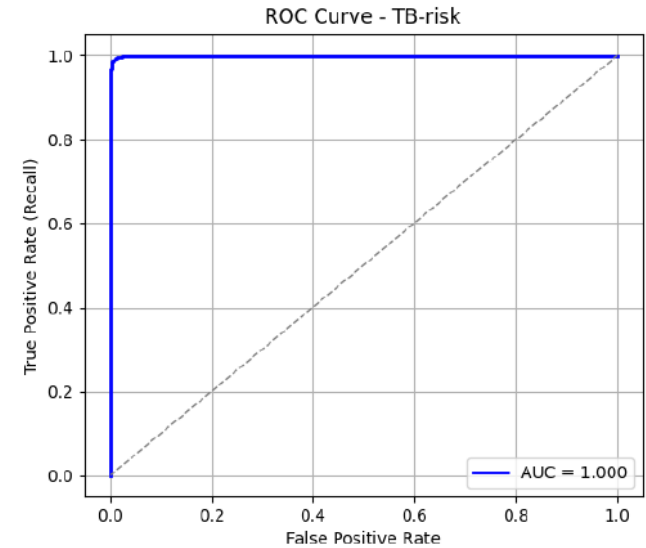
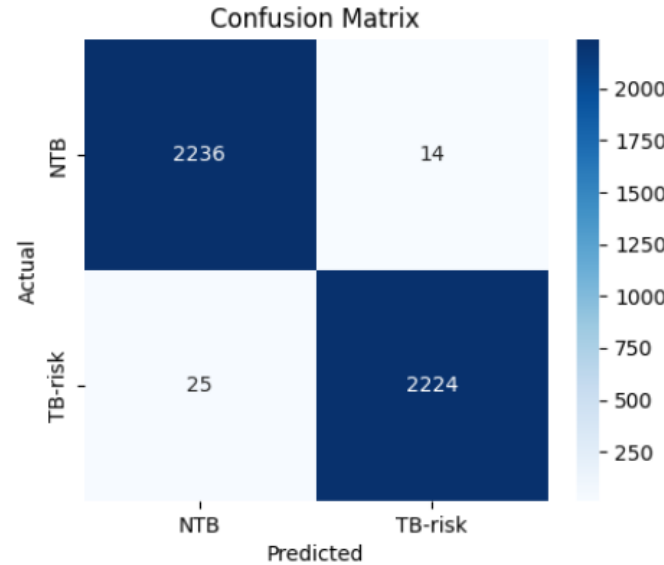
Resultados preliminares

Stage 1: Entrenar el modelo con 30k imágenes.

Model Architecture – EfficientNet-B0

- **Backbone:** EfficientNet-B0 pretrained on ImageNet
- **Trained on:** Synthetic data
- **Custom Classifier Head Added:**
 - Fully connected layer (512 neurons)
 - Batch Normalization
 - ReLU activation
 - Dropout (0.4) for regularization
- **Output Layer:** Final linear layer adapted to task-specific classes (0/1)
- **Advantage:** High accuracy with efficient computation and fewer parameters
- **Purpose:** Learn domain-specific feature representations

Evaluación del modelo: Test run con 4499 imágenes sintéticas



TB-risk Recall (Sensitivity): 0.989

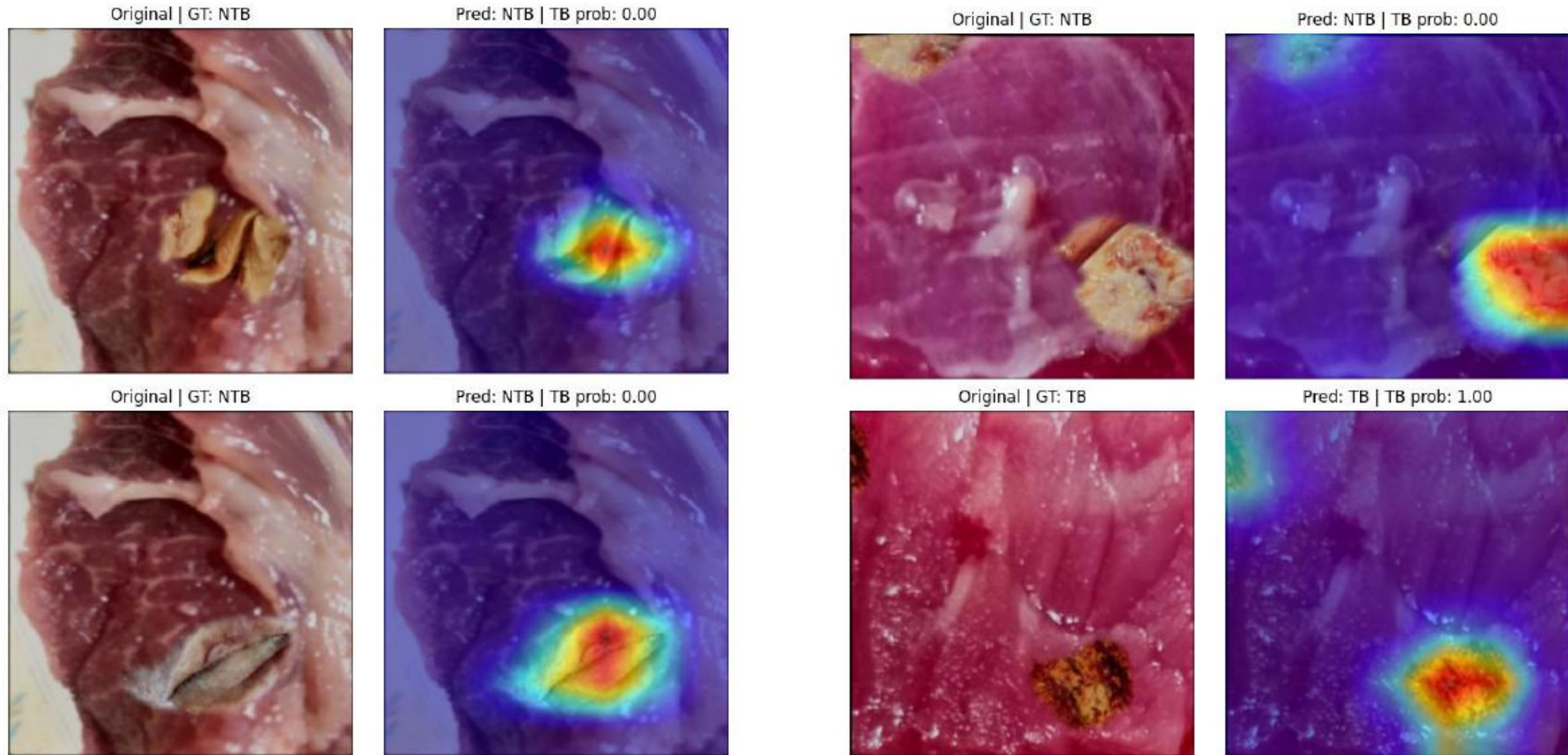
NTB Specificity: 0.994

Accuracy = 99% on 4499 samples (2250 NTB, 2249 TB)

Clinically safe threshold: 1.00 | Recall: 0.960 | FPR: 0.000

Resultados preliminares

Stage 1: Predicción del modelo en imágenes sintéticas:

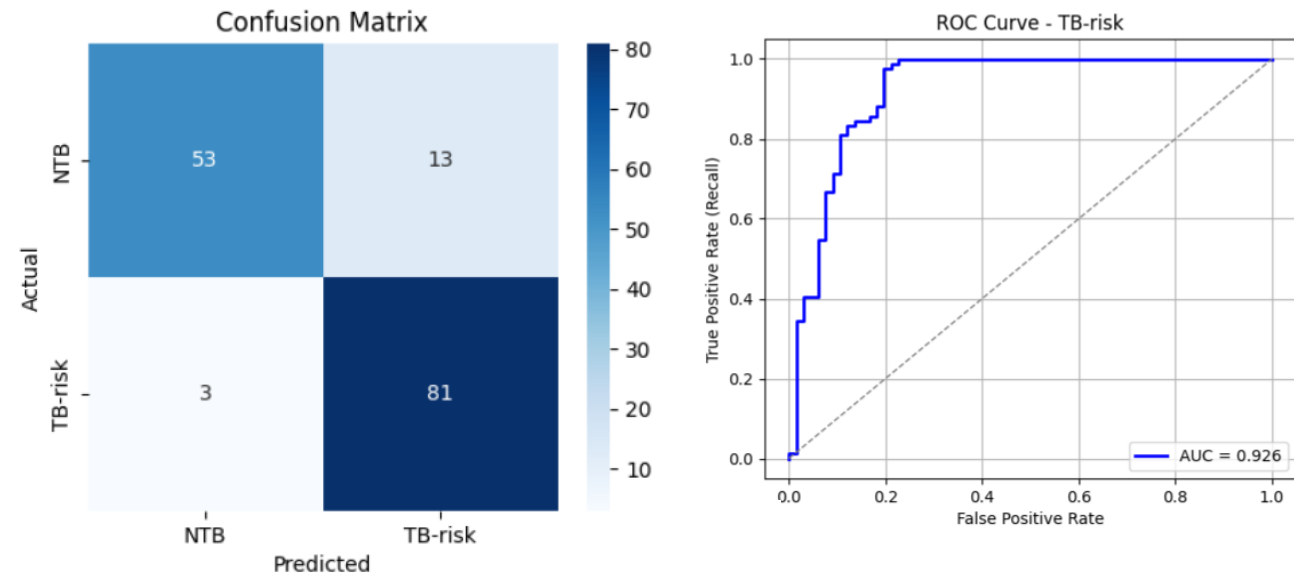


Resultados preliminares

Stage 2: Se ajustó el modelo con datos reales (1000 imágenes)

- **FrozenBackbone** : Previous pretrained model (EfficientNet-B0)
- Enabled **transfer learning**.
- **Custom Classifier Head Added**
- **Gradual Unfreezing:**
 - Start with classifier layers only
 - Slowly unfreeze backbone layers for stable adaptation
 - Purpose: Adapt pretrained features to real data, improve accuracy, and reduce overfitting

Evaluación del modelo I: Test run con 150 imágenes



TB-risk Recall (Sensitivity): 0.964

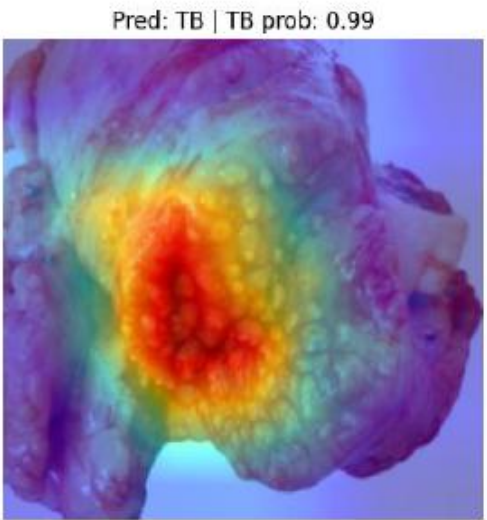
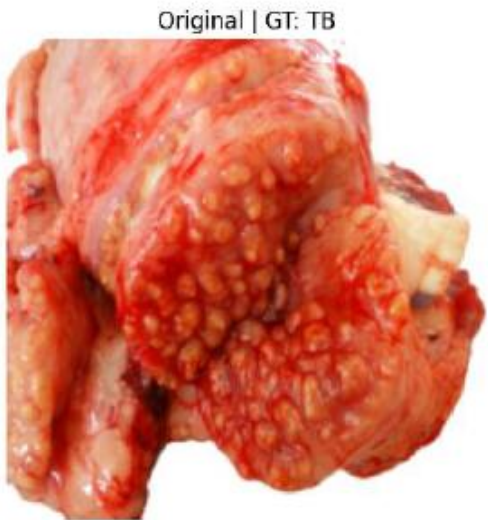
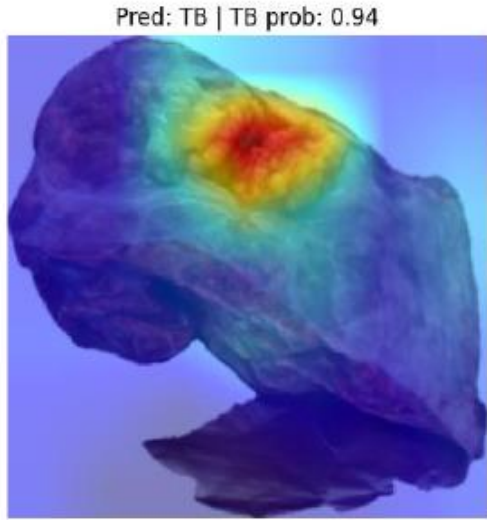
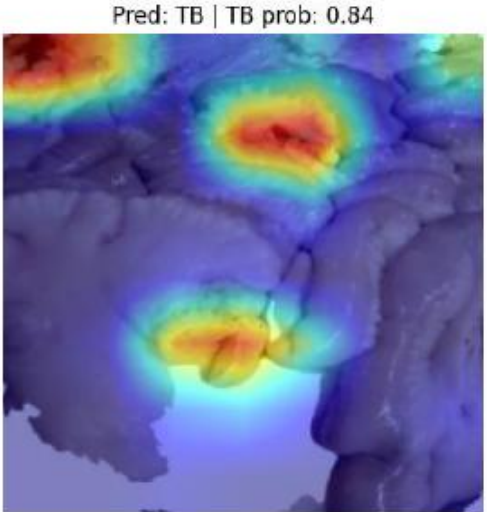
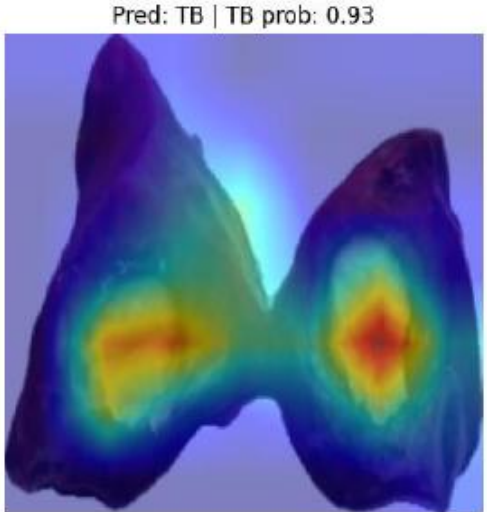
NTB Specificity: 0.803

Clinically safe threshold: 0.43 | Recall: 1.000 | FPR: 0.227

Accuracy ~90% on 150 samples (66 NTB, 84 TB)

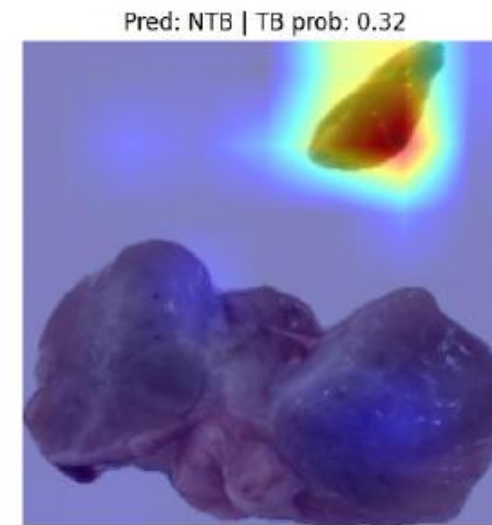
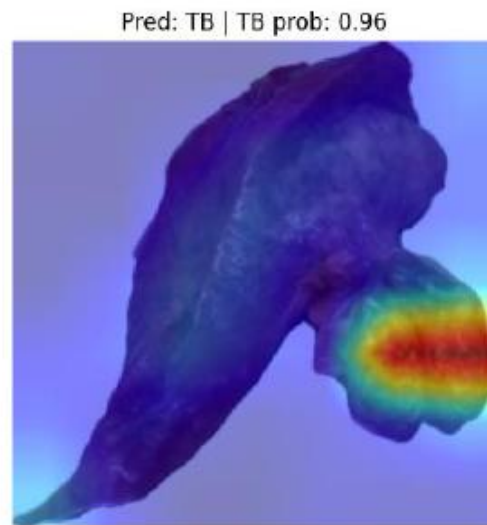
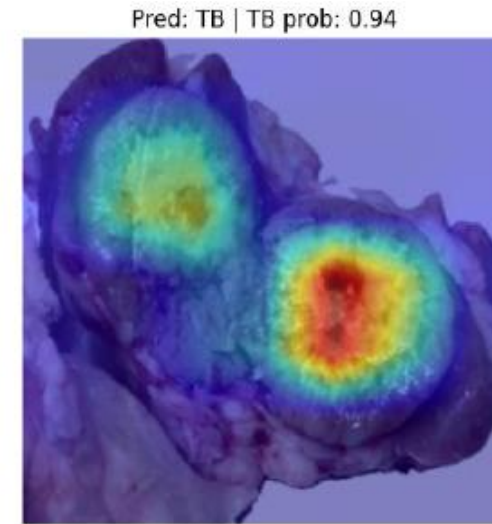
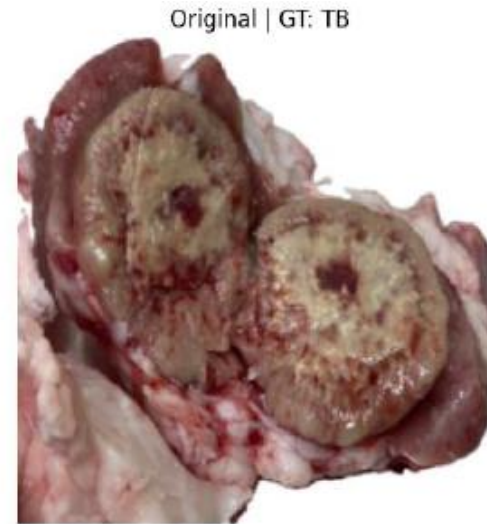
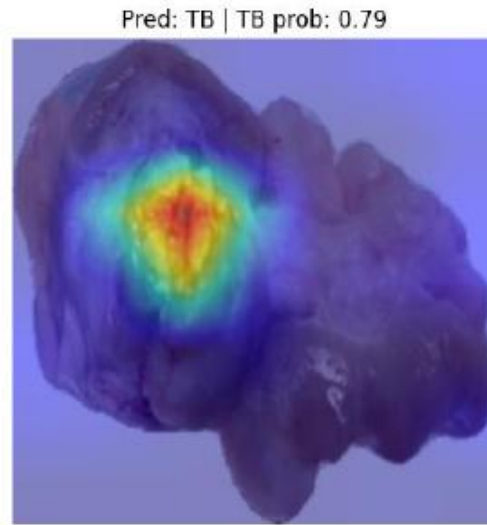
Resultados preliminares

Stage 2: Predicción del modelo en imágenes reales:



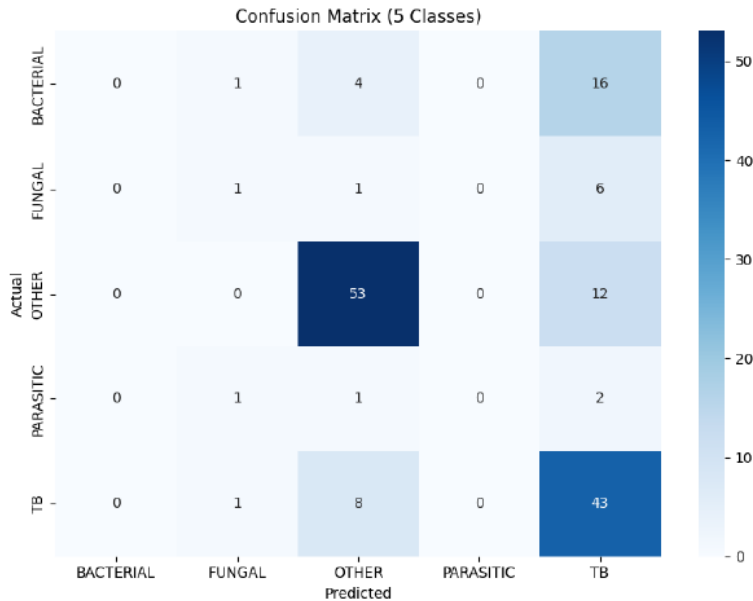
Resultados preliminares

Stage 2: Predicción del modelo en imágenes reales:



Resultados preliminares

Clasificación multi clase (5 categories).



Multiclass Classification Report:

| | precision | recall | f1-score | support |
|--------------|-----------|--------|----------|---------|
| BACTERIAL | 0.00 | 0.00 | 0.00 | 21 |
| FUNGAL | 0.25 | 0.12 | 0.17 | 8 |
| OTHER | 0.79 | 0.82 | 0.80 | 65 |
| PARASITIC | 0.00 | 0.00 | 0.00 | 4 |
| TB | 0.54 | 0.83 | 0.66 | 52 |
| accuracy | | | 0.65 | 150 |
| macro avg | 0.32 | 0.35 | 0.33 | 150 |
| weighted avg | 0.54 | 0.65 | 0.58 | 150 |

TB Recall (Sensitivity): 0.827

- El modelo clasifica los casos no concluyentes (bacterias, hongos, parásitos) como TB.
- No es un objetivo realista con la colección actual de imágenes

| Final Dx | Macro TB Dx | Meat inspector decision |
|--|---------------|---|
| Tuberculosis | TB compatible | Submit to Laboratory analysis |
| Non tuberculous mycobacterial granuloma | | |
| Fungal granuloma | Inconclusive | |
| Bacterial pyogranuloma | | |
| Parasitic granuloma | | |
| Neoplasia | Negative | No need to submit samples for TB confirmation |
| Abscess | | |
| Lymphoid hyperplasia | | |
| No significant lesions | | |
| Other nodular lesions | | |
| Suppurative bronchopneumonia with bronchiectasis | | |

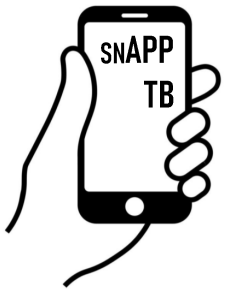
Conclusiones y perspectivas futuras

- **El modelo puede eliminar background y identificar tejido y lesiones**
 - No es necesario anotar imágenes manualmente para mejorar el modelo.
- **El modelo puede clasificar imágenes de lesiones a nivel macroscópico entre:**
 - Granulomas TB y no concluyentes (**sensibilidad del 90,7%**)
 - Lesiones no tuberculosas y tejidos sin lesiones (**especificidad del 60,6%**)
- **El modelo tiene mal rendimiento al intentar clasificar las lesiones entre las diferentes 11 categorías.**
- **Es necesario aportar más imágenes en categorías poco representadas para mejorar el funcionamiento del modelo.**

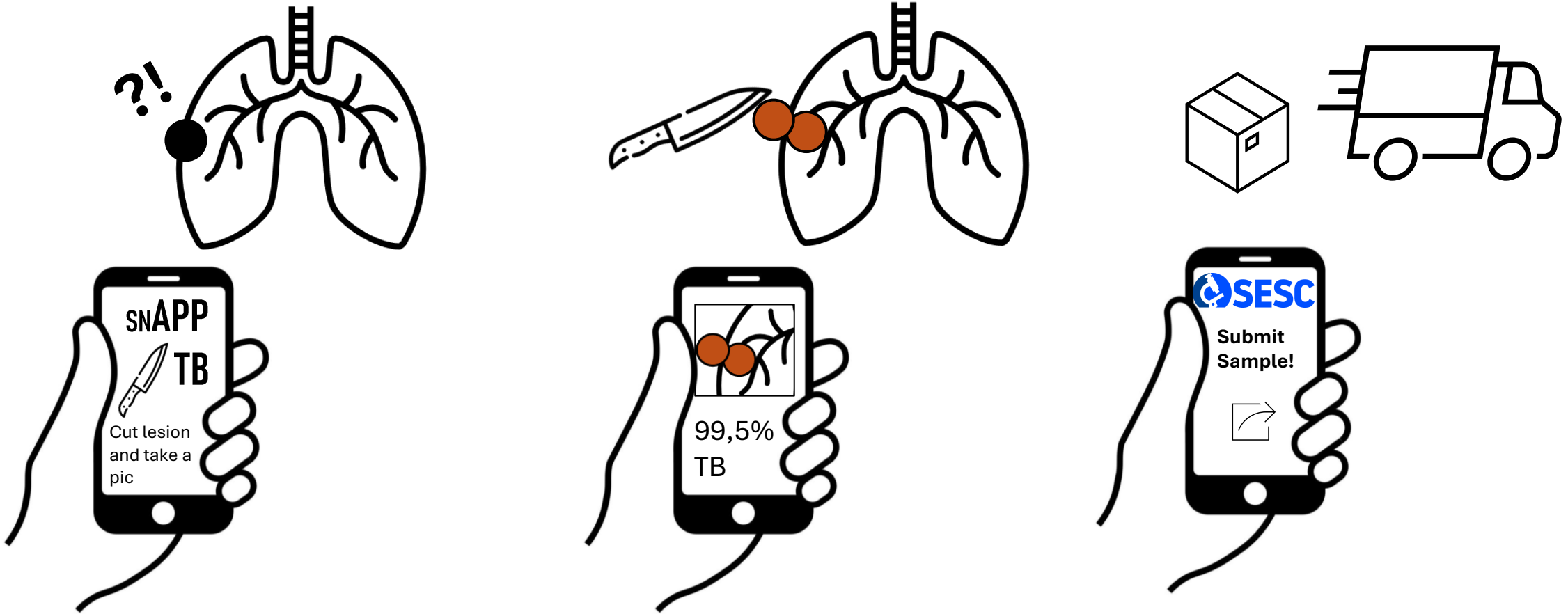
Próximos pasos



- **Encontrar financiamiento para desarrollar una versión inicial de una APP que los usuarios de matadero (SESC) puedan usar para remitir imágenes y muestras al laboratorio**



- **Paralelamente, las imágenes adquiridas prospectivamente se podrían usar para mejorar el modelo, e incluso –a largo plazo- desarrollar la clasificación de múltiples categorías.**



Gracias por vuestra atención!

