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**Case Report**

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# Integration of artificial intelligence in the diagnosis of cervical tuberculous lymphadenitis: A case study

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**ABSTRACT**

**Introduction:** Cervical tuberculous lymphadenitis (CTL) or scrofula is the most common extrapulmonary presentation of tuberculosis (TB), accounting for nearly 50% of the cases. This case report illustrates the role of artificial intelligence (AI)-based image analysis tool in aiding CTL diagnosis.

**Main symptoms and clinical findings:** A 3-year-old male patient presented with a persistent, non-resolving cervical mass. The patient showed no systemic symptoms such as fever or night sweats. Clinical examination revealed firm, non-tender, lateral cervical adenopathy.

**Diagnosis and intervention:** The patient underwent multiple diagnostic tests including Mantoux, polymerase chain reaction, and fine-needle aspiration biopsy. AI-assisted imaging analysis suggested TB-related lymphadenopathy, prompting further microbiological confirmation. The patient was prescribed a two-months regimen of first-line anti-TB medication.

**Conclusion:** This case highlights the potential of AI in assisting in the early identification of CTL through image analysis. AI can complement conventional diagnostics, especially in resource-limited settings, by streamlining clinical decision making and reducing diagnostic delays.

**Keywords:** artificial intelligence, cervical tuberculous lymphadenitis, case report, diagnostic imaging, machine learning, pediatric tuberculosis

## INTRODUCTION

Tuberculosis (TB) remains a major global health burden and its incidence has shown a resurgence in the post-pandemic period [1]. Cervical tuberculous lymphadenitis (CTL), also known as scrofula, is the most frequent extrapulmonary form of TB, accounting for nearly half of all extrapulmonary cases [2, 3].

CTL primarily affects the cervical lymph nodes and is often misdiagnosed as other infectious or neoplastic conditions owing to its varied clinical presentation [4]. In children and young adults, the lack of systemic symptoms such as fever or night sweats frequently complicates early recognition [5, 6].

In addition, disruptions in TB control programs in recent years have contributed to delayed diagnosis and an increased incidence of extrapulmonary forms [7]. Traditional diagnostic methods, including microbiological and histopathological assessments, remain the gold standard but usually require prolonged processing times, which can delay treatment initiation [8].

Recent evidence further reinforces this perspective, and it was demonstrated in a systematic review and meta-analysis that ultrasound-based artificial intelligence (AI) models achieved a pooled sensitivity of 0.84 and a specificity of 0.85 for lymph node evaluation [9]. Similarly, it was reported the development of a 2.5D deep learning model that successfully differentiated lymphoma and tuberculous lymphadenitis in

**Figure 1.** Initial clinical presentation of the patient with a persistent cervical mass. The lesion appeared as a firm, non-tender swelling with progressive enlargement despite empirical antibiotic therapy (Reprinted with permission of legal guardians of patient)

**Figure 2.** Second clinical assessment showing persistence of the cervical swelling with no response to antibiotics, prompting further diagnostic evaluation (Reprinted with permission of legal guardians of patient)

HIV/AIDS patients [10]. In addition, it was described as a 2025 case of CTL in an otherwise healthy individual following latent TB infection treatment [11], while the study in [12] highlighted the diagnostic complexity of granulomatous lymphadenopathy and its relationship with TB. The study in [13] provided a scoping review of AI and machine learning in TB management, emphasizing the growing role of digital tools in diagnosis and treatment pathways. Collectively, these recent contributions support the integration of AI into TB diagnostics, particularly in extrapulmonary forms, such as CTL.

AI in medicine has shown promises for improving diagnostic accuracy by analyzing clinical images and assisting healthcare professionals in decision-making [14-18]. This case report discusses the role of an AI-powered image analysis tool in supporting the diagnosis of CTL in pediatric patients.

The patient signed the consent form, and the study was approved by the Comité de Ética de la Investigación con Medicamentos (CEIm) Hospital Universitario de Getafe on June 26, 2025, with approval code CEIm25/83. This study follows the CARE 2012 checklist [19].

## CASE PRESENTATION

### Patient Information

A three-year-old male was brought to a healthcare facility because of a cervical lump that had persisted for several weeks, as shown in **Figure 1**. He was born at term, with normal developmental milestones and no relevant medical history. Vaccination status was updated according to the national immunization schedule, including Bacillus Calmette-Guérin. The parents reported no associated systemic symptoms such as fever or night sweats, and there was no known history of TB exposure in the family. The initial management with antibiotic therapy was unsuccessful, prompting further clinical evaluation.

### Clinical Course

The patient was initially examined on October 21, 2024, when he was prescribed antibiotics for suspected bacterial infection. However, at follow-up on October 30, 2024, no improvement was observed, as shown in **Figure 2**. Given the lack of a response, the patient was referred to a hospital for further assessment. Despite the recommendations, the parents did not seek immediate hospital evaluation and returned on November 12, 2024, requesting additional medication.

On December 12, 2024, the patient underwent reevaluation, during which AI-assisted image analysis was conducted, as shown in **Figure 3**. AI suggested TB-related lymphadenopathy for image matching, prompting additional laboratory tests. Mantoux test revealed significant induration (18 mm), fine-needle aspiration (FNA) showed absence of material without neoplastic proliferation, and polymerase chain reaction (PCR) confirmed the presence of mycobacterium TB. Based on these findings, a final diagnosis of CTL was established and anti-TB treatment was initiated.

### Diagnostic Process and Challenges

The patient underwent a thorough diagnostic assessment following the persistence of cervical lymphadenopathy despite the initial antibiotic treatment. Given the lack of improvement and the presence of firm, non-tender adenopathy, clinicians proceeded with additional testing to determine the etiology of the condition.

A Mantoux test yielded a positive result with an induration of 18 mm, suggesting prior exposure to mycobacterium TB. To conduct a more thorough investigation, an FNA biopsy was conducted, which revealed abscess material without neoplastic proliferation, ruling out malignancy as a primary cause of lymphadenopathy. Additionally, a PCR test confirmed the presence of mycobacterium TB, confirming the diagnosis of CTL.

In addition to these traditional diagnostic methods, an AI-assisted image matching tool was employed. The AI algorithm recognized features suggestive of TB-related lymphadenopathy, aligned with clinical suspicion, and guided the need for confirmatory microbiological tests. This application provides an additional layer of diagnostic support,


**Figure 3.** AI-assisted image analysis of the cervical lesion. The algorithm suggested tuberculous lymphadenopathy with high similarity scores when compared to its reference database, guiding confirmatory testing with microbiological methods (Source: Authors' own elaboration)

particularly for differentiating TB lymphadenopathy from other possible conditions.

The diagnostic journey was not without challenges. A delay in hospital referral contribute to prolonged uncertainty and disease progression. In addition, the initial misdiagnosis of bacterial lymphadenitis led to an ineffective antibiotic regimen, which delayed the initiation of appropriate TB treatment. However, AI-assisted analysis prompted further investigations, helping prioritize TB as a primary suspect and expediting confirmatory testing.

A range of differential diagnoses was considered before a conclusion was reached. These included:

- **Bacterial lymphadenitis**, given the initial presentation of cervical swelling without systemic TB symptoms.
- **Lymphoma**, due to the persistence and firm nature of the lymphadenopathy.
- **Sarcoidosis**, which can present with granulomatous lymph node involvement.
- **Reactive lymphadenopathy**, a common response to infectious processes.

Given the confirmed diagnosis of CTL, prognosis was determined based on disease severity, treatment adherence, and the patient's overall health.

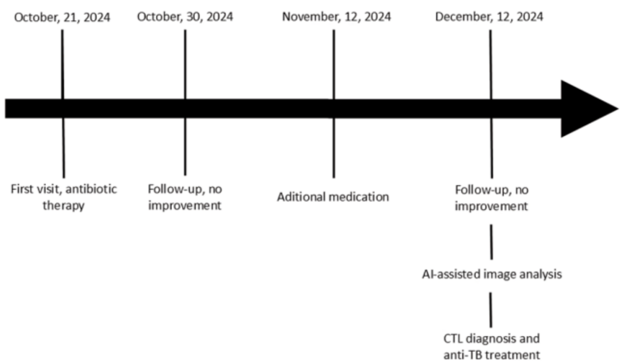


**Figure 4.** Timeline of the patient's clinical course, diagnostic process, and initiation of therapy (shows the sequence from the first evaluation to AI-assisted analysis, confirmation of CTL, and treatment onset) (Source: Authors' own elaboration)

## Treatment

Following diagnosis, an appropriate anti-TB regimen was initiated according to international guidelines. The patient was prescribed the following medications.

- Isoniazid 150 mg, administered as one tablet daily in the morning (≈10 mg/kg).
- Rifampin 300 mg (20 mg/ml syrup, 15 ml daily), corresponding to ≈20 mg/kg.
- Pyrazinamide 500 mg (two tablets daily), corresponding to ≈33 mg/kg.

Ethambutol was not included in this case because the disease was an isolated extrapulmonary form (cervical lymphadenitis) with a low bacillary burden. This approach is supported by pediatric TB management protocols, which allow the omission of ethambutol in non-severe extrapulmonary TB to minimize the pill burden and potential ocular toxicity.

The standard course of therapy followed the WHO recommendation of a six-month regimen (2HRZ/4HR), consisting of a two-month intensive phase with isoniazid, rifampin, and pyrazinamide, followed by a four-month continuation phase with isoniazid and rifampin [1].

## Timeline

The chronological sequence of the patient's clinical course is shown in **Figure 4**. The initial evaluation was conducted on October 21, 2024, when empirical antibiotic therapy was prescribed. A follow-up on October 30, 2024, revealed no improvement, and the parents sought additional medication on November 12, 2024. On December 12, 2024, the patient underwent AI-assisted image analysis, which suggested tuberculous lymphadenopathy and prompted confirmatory testing with Mantoux, FNA, and PCR, leading to the final diagnosis of CTL and initiation of anti-TB therapy. A subsequent follow-up visit in early 2025 confirmed adherence to treatment and clinical improvement, although the short observation period limited conclusions on long-term outcomes.

## Details on the Artificial Intelligence Model Used by the Platform

The AI tool employed in this case was Belle.ai (Belle.ai Inc., USA), a commercial image analysis platform designed to support clinical decision-making. The system uses the EfficientNet-B4 convolutional neural network (CNN) [13] trained on a dataset of more than 2,400 dermatological conditions, including both common and rare disorders. The training set was highly diverse, encompassing patients across different age groups, ethnicities, and all Fitzpatrick skin types, which reduced the risk of bias related to skin tone.

To enhance robustness, the dataset incorporates images of varying resolutions ranging from 300 × 300 pixels to 6,000 × 4,000 pixels, making it adaptable to photographs obtained with different devices. Pre-training was conducted on the ImageNet dataset [20] using transfer learning to improve performance. Validation with a four-fold cross-validation protocol demonstrated an average sensitivity of 0.848 and a specificity of 0.900.

Belle.ai is implemented as a mobile application that generates a ranked list of matches between the input image and its reference database, which are expressed as confidence scores. A higher score indicated a closer correspondence between the lesion pattern and the conditions in the training set. Importantly, the tool is not certified as a medical device and does not provide a definitive diagnosis. Instead, it functions as a decision-support system that can guide clinicians toward further investigations and support, but not replace, their final clinical judgment.

## DISCUSSION

CTL is one of the most common forms of extrapulmonary TB and frequently affects children and young adults. It accounts for 30-40% of extrapulmonary TB cases [2, 3]. The most common presentation is a unilateral lateral-cervical or supraclavicular mass with a rigid and painless consistency. Over time, the lesion can become necrotic, fluctuate, and produce inflammatory symptoms, with ulcer formation, fistulization, and caseous drainage [6, 8].

Diagnosis is usually established through FNA and microbiological or cytological studies with smear microscopy, culture, and PCR, which reach a sensitivity of approximately 77% and specificity of 80% [8]. In cases where FNA results are inconclusive, biopsy remains the next step. Visualization of caseating granulomas is highly suggestive of TB [11].

Recent advances in digital health have influenced medical diagnostics in several fields. The integration of machine-learning algorithms has transformed radiology, dermatology, and pathology by enabling faster and more accurate image interpretation [13-18]. In particular, CNNs have improved the detection and classification of imaging patterns, showing a performance comparable to expert clinicians in several domains [15-18].

This case highlights the application of AI in aiding in the early diagnosis of CTL, particularly when conventional clinical findings are inconclusive. The use of an AI-powered image analysis tool provides an additional layer of support, enabling clinicians to prioritize TB in the differential diagnosis. However, reliance on AI should always be complemented by microbiological and histopathological confirmation to ensure diagnostic accuracy [7, 8].

Recent studies have further reinforced the potential of AI in TB diagnosis. The study in [9] demonstrated through a systematic review and meta-analysis that ultrasound-based AI models achieved a high pooled accuracy for lymph node evaluation. The study in [10] developed a 2.5D deep learning model capable of differentiating lymphoma from tuberculous lymphadenitis in HIV/AIDS patients, underscoring the utility of AI in complex differential diagnoses. It was reported a case of CTL without systemic manifestations in a healthy individual, highlighting diagnostic challenges when typical symptoms are absent [6]. It was reviewed granulomatous lymphadenopathy, noting the importance of considering TB among its causes [11]. The study in [12] emphasized in a scoping review that AI and machine learning are emerging as valuable tools for TB management, although their application in extrapulmonary forms remains under development.

The main limitation of this case was the short follow-up period, which prevented the assessment of long-term outcomes. Nevertheless, the rapid improvement observed after anti-TB therapy supports the diagnostic accuracy of combining the AI-assisted analysis with conventional methods.

In addition, the limitations related to AI systems must be acknowledged. The diagnostic performance of AI-based tools strongly depends on the quality and diversity of the training dataset, and external validation in different populations remains limited. Image matching may be influenced by variations in resolution, lighting conditions, or device type, which can affect the reproducibility in real-world practice. Moreover, AI cannot establish a definitive diagnosis on its own and should always be interpreted along with microbiological and histopathological confirmation to ensure clinical accuracy [13, 18].

## CONCLUSION

This case underscores the potential of AI in the diagnosis of CTL, demonstrating that AI-assisted image analysis can facilitate early suspicion and appropriate diagnostic pathways. Although AI should not replace conventional diagnostic methods, it serves as a valuable tool for augmenting clinical decision making, particularly in regions with limited resources. Future research should focus on integrating AI with TB diagnostic protocols to enhance their accuracy and accessibility.

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**AI statement:** The authors stated that no generative AI tools were used in the writing or editing of this manuscript. The AI mentioned in this study refers exclusively to the diagnostic imaging tool employed for the case.

**Declaration of interest:** Susely Figueroa-Iglesias is an employee of Belle-Torus Corporation, Cambridge, MA, USA. The other authors declare that they have no conflicts of interest related to this work.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

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