



Review

Tuberculosis Control Protocols in the European Region: A Brief Overview

Aimilios Pliatsikas ¹, Costas Tsiamis ², Joseph Papaparaskevas ¹ , Georgia Vrioni ¹ and Athanasios Tsakris ^{1,*}

¹ Department of Microbiology, Medical School, National and Kapodistrian University of Athens, 11527 Athens, Greece; aimil_pl@hotmail.com (A.P.); ipapapar@med.uoa.gr (J.P.); gyvioni@med.uoa.gr (G.V.)

² Laboratory of Public and One Health Crises Management, Department of Public and One Health, School of Health Sciences, University of Thessaly, 43100 Karditsa, Greece; ktsiamis@uth.gr

* Correspondence: atsakris@med.uoa.gr

Abstract

Tuberculosis (TB) continues to be a significant public health challenge in Europe, despite a sustained decline in disease incidence over recent decades. This narrative review briefly traces the historical development of TB diagnosis and focuses on the evolution of TB control protocols from the early twentieth century to the present across Europe, through a longitudinal comparative analysis of its geographical regions. A literature search was conducted using publications, guidelines, and surveillance reports from the World Health Organization (WHO), the European Centre for Disease Prevention and Control (ECDC), and national public health authorities. The analysis follows a geographical framework encompassing Eastern, Western, Northern, and Southern Europe, reflecting historical, socioeconomic, and healthcare system differences. This study presents the transition from traditional diagnostic approaches based on clinical assessment, chest radiography, and smear microscopy to modern molecular and immunological techniques, including Xpert MTB/RIF assays and interferon-gamma release assays (IGRAs). Similarly, treatment strategies have evolved from sanatorium-based supportive care to standardized, evidence-based short-course regimens employing first- and second-line anti-TB drugs. However, marked regional differences remain in the implementation of contemporary protocols. Western and Northern European countries have largely adopted advanced diagnostic technologies and comprehensive surveillance systems and are approaching TB elimination targets. In contrast, Eastern Europe continues to bear a disproportionate disease burden, driven by multidrug-resistant TB, HIV co-infection, and socioeconomic disparities. TB control protocols in Southern Europe are progressively converging with those of Western Europe through the adoption of modern diagnostic approaches, standardized treatment regimens, and WHO-endorsed guidelines. The findings of this study underscore the need for greater harmonization of TB control protocols across Europe through an initiative coordinated by the ECDC/WHO. Accelerating progress toward TB elimination in the European Region will depend on expanding access to modern diagnostic technologies, implementing targeted interventions in high-burden settings, and strengthening cross-border collaboration through coordinated public health policies.



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1. Introduction

Tuberculosis (TB), caused by *Mycobacterium tuberculosis*, remains one of the most significant infectious diseases worldwide. Despite substantial advances in diagnosis,

treatment, and prevention, TB continues to be a major public health challenge, causing an estimated 10.7 million new cases and 1.23 million deaths annually according to the latest World Health Organization (WHO) Global Tuberculosis Report [1,2]. TB remains the leading cause of death from a single infectious agent and is among the ten leading causes of mortality globally [2]. Although recovery efforts have accelerated following disruptions associated with the COVID-19 pandemic, progress toward global TB elimination targets remains threatened by persistent healthcare inequalities and recent international funding challenges [2].

The global burden of TB is unevenly distributed. Southeast Asia accounts for approximately one-third of all cases worldwide, followed by the Western Pacific and African regions [2]. India alone contributes roughly one-quarter of the global TB burden, while Indonesia and China remain among the highest-burden countries [2]. It is of note that in the last 20 years, China ramped up a DOTS (directly observed treatment, short-course)-based TB control program with 80% population coverage, achieving the 2015 Millennium Development Goal of a 50% reduction in TB prevalence and mortality [3]. In Africa, although the absolute number of cases is lower than in Asia, several countries continue to experience some of the highest incidence rates globally, often exceeding 300 cases per 100,000 population [4–6]. The WHO Eastern Mediterranean Region also reports a substantial disease burden, with an estimated incidence of 112 cases per 100,000 population in 2021, ranking third among WHO regions [7].

In contrast, much of Europe has achieved relatively low TB incidence rates through sustained public health interventions, improved living conditions, and widespread access to healthcare. However, the epidemiological situation across the European region remains heterogeneous. While many Western and Northern European countries report fewer than 10 cases per 100,000 population annually, several Eastern European countries continue to experience considerably higher incidence rates and a disproportionate burden of drug-resistant TB [8]. Romania, for example, accounts for approximately one-quarter of all TB cases reported within the European Union, highlighting persistent disparities in disease burden across the continent [8].

These epidemiological differences are reflected in variations in TB control strategies, diagnostic practices, screening policies, and treatment protocols among European countries. Historical developments, socioeconomic conditions, migration patterns, healthcare system structures, and national public health priorities have all influenced the evolution of TB control measures across the region. Understanding these differences is important for evaluating current practices and identifying approaches that may contribute to further reductions in TB incidence and mortality.

2. Aim of the Study and Literature Search

The current narrative review briefly traces the historical development of TB diagnosis and focuses on the evolution of TB control protocols across Europe through a longitudinal comparative analysis of its geographical regions. It provides an overview of the development of TB control strategies from the early twentieth century to the present, highlighting regional differences and similarities. Particular attention is given to the evolution of public health policies and screening programs as well as their adaptation to changing epidemiological conditions. The analysis followed a geographical framework encompassing Eastern, Western, Northern, and Southern Europe, reflecting historical, socioeconomic, and healthcare system variations that have shaped TB control practices. The literature search of the study was conducted using publications, guidelines, and surveillance reports from the WHO, the European Centre for Disease Prevention and Control (ECDC), and national public health authorities. Additional peer-reviewed articles were consulted to provide

historical context and support the comparative analysis of TB control developments across European regions. Sources were selected based on their relevance to the evolution of TB prevention and surveillance within the European context.

3. Historical Development of Diagnostic Protocols

The diagnosis of TB has posed a major challenge to the medical community since antiquity, long before the development of laboratory-based diagnostic methods. Early diagnosis relied primarily on clinical examination and observation of symptoms. In the 2nd century AD, Galen described several characteristic manifestations of TB, including hemoptysis, night sweats, and fever, while acknowledging that these findings alone were insufficient for a definitive diagnosis [9]. Various empirical approaches were therefore attempted in antiquity. For example, Soranus of Ephesus proposed a rudimentary sputum test in which sputum was burned on hot coals and the resulting odor was used to infer the presence of disease [10]. Although such methods may appear unconventional by modern standards, they reflect the urgent need for diagnostic approaches during a period when medical knowledge and technology were still limited [9].

Until the 19th century, the infectious cause of TB had not been proven, although its contagious nature had been hypothesized by Aristotle in the 4th century BC and later by Fracastoro in the 16th century AD. Early diagnosis relied primarily on clinical symptoms, but the transition to modern evidence-based medicine began in the 17th and 18th centuries with the introduction of physical examination. As symptom-based diagnosis could not reliably distinguish TB from other respiratory diseases or malignancies, rudimentary diagnostic methods emerged, including burning sputum on hot coals to detect the odor of necrotic tissue, a crude precursor to modern volatile organic compound testing [9].

In 1882, Robert Koch announced the discovery of the TB bacillus at a conference in Berlin [10]. He subsequently succeeded in cultivating *M. tuberculosis* in vitro, enabling laboratory confirmation of the disease. By the 1930s, Löwenstein and Jensen had developed the malachite green-containing culture medium that remains the basis for mycobacterial cultivation today [10]. Microscopic detection also advanced with the introduction of the Ziehl–Neelsen acid-fast stain by Franz Ziehl and Friedrich Neelsen, which was later modified by Kinyoun to eliminate the need for heating [10]. This technique became the standard method for detecting acid-fast bacilli in sputum. The use of heat and strong acid was necessary because the waxy, mycolic acid-rich cell wall of mycobacteria retains the fuchsin stain despite acid decolorization [9,10].

In parallel, immunological diagnostic methods emerged. A skin test revealed for the first time that there were patients with a positive reaction. Following Koch's development of tuberculin, initially intended as a therapeutic agent but ultimately unsuccessful, its diagnostic potential was recognized. In 1907 and 1908, Clemens von Pirquet and Charles Mantoux introduced the tuberculin skin test, which involves intradermal injection of purified tuberculin and assessment of the resulting skin induration [11]. The test also demonstrated that individuals could have a positive immune response without clinical disease, leading to the concept of latent TB infection (LTBI). The Mantoux test remains widely used and is recommended by both the Centers for Disease Control and Prevention (CDC) and the WHO for the diagnosis of TB infection [11].

Medical imaging marked another major advance in TB diagnosis. Following Wilhelm Conrad Röntgen's discovery of X-rays in 1895, chest radiography became increasingly used during the early 20th century to detect pulmonary TB [12]. Radiographic visualization of characteristic lesions, particularly pulmonary cavities, established chest X-ray as a key screening and diagnostic tool, especially after World War II, facilitating earlier detection of both symptomatic and asymptomatic disease [12].

By the early 20th century, TB diagnosis combined detailed clinical history with basic laboratory tests, although definitive confirmation often depended on postmortem examination [13]. Following millennia of symptom-based diagnosis, the late 19th and early 20th centuries marked the transition to scientific, pathogen-specific diagnostic protocols, transforming TB into a clinically and microbiologically defined disease [14,15]. Individuals with severe respiratory symptoms, progressive wasting, or those living in crowded, impoverished urban settings (where TB was widely known as the “White Plague”) were routinely examined [16].

Throughout the 20th century, TB diagnosis evolved from clinical observation and gross pathology to standardized protocols incorporating tuberculin skin testing, chest radiography, sputum smear microscopy, and microbiological culture [17]. Public health screening programs expanded to include schoolchildren, military recruits, and household contacts of patients with TB, enabling the detection of latent infection and helping to prevent subsequent active disease [18].

It should be also noted that medical views until the Interwar period were largely aligned with the prevailing medical concepts of the time. Public understanding of disease and treatment was strongly influenced by contemporary medical theories and limited scientific knowledge. During the Interwar period, Hygiene Exhibitions emerged as an important means of disseminating medical information to the general population. International medical perceptions during this era were reflected across many countries, including the belief that the disease disproportionately affected specific social groups and that contemporary therapeutic approaches, such as surgical interventions and sanatorium treatment, were beneficial for patients [19].

Tuberculosis was a major public health crisis during World War II, fueled by widespread malnutrition, overcrowding, population displacement, and the collapse of healthcare services. The disease spread rapidly in military barracks, prisoner-of-war camps, and concentration camps, with mortality increasing by 160–240% in some war-affected regions [20–23]. Before the introduction of effective chemotherapy, treatment was largely limited to prolonged bed rest and nutritional support. The discovery of streptomycin at Rutgers University in 1943 marked the first effective antibiotic treatment for TB, accelerating the decline of the sanatorium era [24,25]. In the post-war period, TB morbidity and mortality remained elevated due to damaged healthcare systems, overcrowding, and the reactivation of latent infections [26]. In 1974, the WHO recommended replacing indiscriminate mass radiography with symptom-based sputum testing because of the high costs and radiation risks associated with population-wide screening [17].

In modern times, TB diagnostic protocols combine established and newer technologies. For LTBI, interferon- γ release assays (IGRAs), which measure the immune response to *M. tuberculosis*-specific antigens, complement the tuberculin skin test and have become widely adopted over the past two decades [27]. For active TB, chest radiography or computed tomography (CT), together with sputum or other appropriate clinical specimens for laboratory analysis, remain the initial diagnostic approach. Ziehl–Neelsen and fluorescent staining continue to provide rapid detection of acid-fast bacilli, while culture on solid or liquid media remains the gold standard for diagnosis and drug susceptibility testing. In recent years, molecular assays based on polymerase chain reaction (PCR), such as the Xpert MTB/RIF system, have enabled rapid detection of *M. tuberculosis* and rifampicin resistance within hours rather than weeks. These molecular tests are now incorporated into WHO-recommended diagnostic protocols as the initial tests for suspected TB in many countries and are central to the early detection of drug-resistant disease [12].

LTBI testing (TST and IGRA) evaluates the host’s immune response to exposure, while active TB diagnostic pathways focus on confirming the presence of replicating bacteria

and active clinical disease. Crucially, a positive screening test for TB exposure cannot differentiate between the two states, making a clear diagnostic pathway essential to ensure correct medical management (Table 1) [28,29]. LTBI tests measure the host’s immune response to exposure, whereas active TB diagnostics isolate or detect the physical presence of *M. tuberculosis* (Table 2) [18,30–35].

Table 1. Overview of core differences between the LTBI testing pathway and the active TB diagnostic pathway.

Feature	LTBI Testing Pathway	Active TB Diagnostic Pathway
Primary Goal	Detect immunological memory of <i>M. tuberculosis</i> exposure.	Confirm active bacterial replication and disease localization.
Target Population	Asymptomatic individuals with risk factors (e.g., healthcare workers, contacts).	Symptomatic patients (cough, weight loss, and night sweats) or abnormal X-rays.
Key Diagnostics	Tuberculin skin test (TST), interferon-gamma release assays (IGRAs).	Sputum smears, cultures, nucleic acid amplification tests (NAAT/GeneXpert), and chest X-rays.
Bacterial Direct Evidence	None. Pathogens are dormant and cannot be isolated.	High. Microbes are isolated from sputum or tissue samples.

Table 2. Basic distinctions between the LTBI testing (TST/IGRA) pathway and active TB diagnostic pathway.

Feature	LTBI Testing (TST/IGRA)	Active TB Diagnostic Pathway
Clinical Objective	Identify asymptomatic individuals who might benefit from preventive therapy.	Confirm active disease to immediately initiate multidrug treatment regimens.
Target of Detection	The host’s cellular immune response (T-cell memory).	The physical presence of live bacteria or bacterial DNA.
Patient Presentation	Asymptomatic; patient feels well and is non-infectious.	Symptomatic (cough, weight loss, night sweats, and fever) or abnormal imaging.
Primary Modalities	In vivo skin induration (TST) or ex vivo blood testing (IGRA).	Sputum microscopy, molecular assays (Xpert), cultures, and chest imaging.

In summary, contemporary TB diagnosis integrates established and modern diagnostic approaches. Clinical assessment and imaging remain essential for the initial evaluation of suspected cases, while microscopy and culture continue to play key diagnostic roles alongside molecular and immunological assays that enhance diagnostic accuracy and speed. The historical evolution of diagnostic protocols from the old observations of the past to the complex laboratory tests of the present reflect the continuous progress in the understanding and treatment of TB.

4. Tuberculosis Protocols in Europe

For the purposes of this review, European countries are categorized into four geographical regions (Eastern, Western, Northern, and Southern Europe) based on traditional geographical, historical, and political classifications [36]. Both EU and non-EU countries are included in the analysis. Given their transcontinental position, Turkey and the Russian Federation are discussed in a separate subsection.

4.1. Eastern Europe

Eastern Europe includes countries of the former Soviet Union as well as several Central and Eastern European countries with a high endemicity of TB. Historically, Eastern

Europe has experienced one of the highest TB burdens in Europe, a situation shaped by socioeconomic transitions following the dissolution of the Soviet Union, healthcare system disruptions, and the emergence of MDR-TB. The region continues to carry one of the highest TB burdens in the WHO European Region, with several countries reporting annual incidence rates many times higher than those observed in Western Europe. For example, in 2021, Ukraine had an estimated 71 TB cases per 100,000 population [37,38], while, as mentioned above, Romania reported 42 cases per 100,000 population [8]. Although the overall incidence of TB has gradually declined over recent decades, the pace of progress remains uneven across the region because of persistent socioeconomic inequalities, health system limitations, and the ongoing impact of armed conflict and population displacement in some countries.

Eastern Europe also bears a disproportionate burden of multidrug-resistant tuberculosis (MDR-TB) and human immunodeficiency virus (HIV) co-infection. Among patients with a history of previous TB treatment, more than 50% harbor multidrug-resistant strains in several countries of the region [39,40]. Particularly high rates of MDR-TB among previously treated patients have been reported in Belarus (69%) and Moldova (62%) [41,42]. Intravenous drug use represents an additional major risk factor influencing TB epidemiology across many of the newly independent states [43]. Socioeconomic instability, together with the rapid spread of the HIV epidemic—largely driven by injecting drug use—has further intensified the TB burden. Between 2000 and 2012, mortality among patients co-infected with TB and HIV was estimated to be three to five times higher in Eastern Europe than in Western Europe. Ukraine, particularly during the early 21st century, became a representative example of the growing prevalence of TB-HIV co-infection among people who inject drugs [44,45]. These trends highlight the continuing challenges in early diagnosis, treatment adherence, infection control, and the provision of integrated care for socially vulnerable populations [43].

Consequently, Eastern Europe faces some of the greatest challenges in TB control, particularly because of the high prevalence of drug-resistant disease and HIV co-morbidity. Diagnostic and treatment protocols are undergoing a gradual transition to align with current WHO recommendations and strengthen national TB control programs. Traditional approaches, including prolonged hospitalization and mass radiographic screening, are increasingly being replaced by other practices, such as rapid molecular diagnosis, the shift toward all-oral shorter MDR-TB treatment, and integrated care in the community, despite existing difficulties, such as insufficient resources and the need for training of health personnel [46–49]. The adoption of digital technologies, improved laboratory networks, and enhanced surveillance systems has further contributed to earlier diagnosis and more effective monitoring of treatment outcomes. Despite these advances, implementation remains uneven because of limited financial resources, shortages of trained healthcare personnel, fragmented healthcare systems, and barriers to accessing care among vulnerable populations. Continued international collaboration and financial support from organizations such as the WHO and other regional partners remain essential to strengthening TB prevention, diagnosis, treatment, and surveillance, thereby helping to reduce the persistent gap in TB control between Eastern and Western Europe [50].

4.2. Western Europe

Western Europe, which includes countries such as the United Kingdom, France, Germany, and the Benelux states, has a low incidence of TB. The evolution of TB control in Western Europe reflects decades of investment in public health infrastructure, standardized treatment protocols, and continuous epidemiological surveillance, which transformed TB from a common infectious disease into one largely confined to specific high-risk pop-

ulations. In most of these countries, TB has declined to the point where it is largely confined to specific high-risk populations, with incidence rates generally below 10 cases per 100,000 population. Before the COVID-19 pandemic, TB incidence was approximately five cases per 100,000 population in Germany, seven in France, and eight in the United Kingdom, with many cases occurring among migrants, refugees, and individuals originating from high-endemic countries. In countries such as Sweden, the Netherlands, and the United Kingdom, more than 70% of TB cases occur in foreign-born individuals [51]. The disease also has high rates in vulnerable groups, such as the homeless, drug users, prisoners, and the elderly, because of past infections being triggered. This patient profile has fostered the perception that Western Europe is now in the phase of targeted prevention and elimination of the disease in line with the WHO Action Framework for low-incidence countries [52].

Diagnostic protocols in Western European countries are considered among the most advanced, with modern laboratory infrastructure with extensive use of rapid tests (IGRAs for latent TB infection, Xpert and line-probe assays for active TB). There is also a strong public health system for contact tracing, since each TB case triggers a contact tracing survey to identify and screen people from the patient's environment. Western European countries also emphasize screening of high-risk groups, implementing specific screening programs for newly arriving migrants and refugees from high-endemic countries (often with chest X-rays and/or IGRA tests) [52]. The practice helps to identify silent cases or the latent type of infection that needs preventive treatment.

Also, BCG (*Bacillus Calmette-Guérin*) vaccination in Western Europe has moved to a targeted phase, as countries such as the Netherlands, Belgium, and Italy have phased out decades-old mass vaccination, reserving it only for infants and children who belong to vulnerable groups or have lived in environments with a high risk of TB [53]. The United Kingdom, which once universally introduced BCG vaccination in adolescents, now selectively vaccinates high-risk infants. These vaccination policy changes were based on the low circulation of the bacillus in the community and the risk/benefit ratio of the vaccine in populations with minimal exposure [54]. In the first decades of the 21st century, international migration has increased across all United Nations and World Health Organization regions. The main growth has been observed in the European and Asian regions. Due to refugee flows in the European continent, TB screening has become a public health issue of great importance, especially for the major entry countries [55]. In 2018, the ECDC published Public Health Guidance on screening and vaccination for infectious diseases in newly arrived migrants and asylum seekers, recommending screening for TB amongst a cluster of major infectious diseases (HIV, HBV, HCV, schistosomiasis, strongyloidiasis, intestinal helminthic infections, etc.) [56]. Active TB screening using universal (indiscriminate) chest radiography (CXR) has been adopted in several European countries. TB risk may be influenced by geopolitical and temporal trends and the heterogeneity of TB risk amongst mobile populations indicates that CXR-led screening should be targeted at specific high-risk groups. TB screening algorithms vary across Europe, with some settings adopting universal chest radiography (CXR) [57]. The WHO-recommended practice of "indiscriminate" CXR screening was discontinued in 1974 due to declining global TB prevalence [58]. However, a recent resurgence in universal CXR screening is observed to be driven by the emphasis of The End TB Strategy on early case detection and improved access to digital radiography equipment (including tele-reporting) [56–60].

The findings reinforce the need for systematic TB screening and treatment in order to reduce the risk of disease reactivation and the flexibility of public health strategies based on the geographical origin of migrants and displaced populations [61]. When it comes to TB treatment, Western European countries strictly apply international standards. EE has adopted a set of 29 standards known as the Union Standards for TB Care (ESTC) [62], which

include best practices in diagnosis, treatment, comorbidities, and prevention. An evaluation conducted in several reference centers found that clinical practice in EE countries is in line with the ESTC [63]. In Western Europe, treatment of susceptible TB is mainly provided on an outpatient basis. Patients receive their medicines at home with regular monitoring, often through directly observed treatment by community nurses or even video monitoring, and are only admitted to hospitals if their condition is severe or cannot be adequately isolated in the family setting. TB treatment success rates in Western countries are usually high, although according to the ECDC, the average success rate in EU countries was 72% in 2021, which is below the 85% target [8], showing room for improvement. Although Western European countries have few cases, these cases are either very resistant or the patients are characterized by complex socio-medical problems. Nevertheless, countries that can afford to provide access to newer drugs (bedaquiline, delamanid, etc.) are implementing appropriate treatment regimens for TB treatment. In addition, emphasis is also placed on the treatment of latent infection in high-risk individuals, such as patients with recent infections, immunocompromised persons, and people who have been in contact with outbreaks. The “End TB Strategy” aims to reduce 80% of the incidence of TB by 2030, which for the EU translates into 2.4 cases per 100,000 people. At present, the achievement of the above-mentioned target is not certain according to the ECDC; however, Western Europe is investing in strengthening efforts with additional resources and interventions to accelerate the decline in cases [8]. Western Europe has protocols with high standards, supported by strong health systems. However, the challenge facing Western European countries is to eliminate the last reservoirs of TB in recent population groups. The policies pursued by states focus on targeted control, prevention, and integrated care, a model different from Eastern Europe, which reflects the low-incidence epidemiology and public health principles in appropriate Western democracies [59].

4.3. Northern Europe

Northern Europe includes the Nordic countries, the Baltic, and sometimes the UK/Ireland, which have a low to very low incidence of TB compared to Western European countries. Historically, Northern European countries experienced a substantial burden of TB during the late nineteenth and early twentieth centuries. However, continuous improvements in living conditions, socioeconomic development, universal healthcare systems, and comprehensive public health measures led to a steady decline in TB incidence, making the region one of the first in Europe to approach the low-incidence threshold [7,9]. In fact, nowadays, several Northern European countries have the lowest TB rates in the world. Iceland recorded just two cases per 100,000 people in 2021, while Norway recorded three cases, and Sweden four cases [8]. Like the West, most cases are found in foreign migrants from states with a high TB rate, with the rate in Sweden exceeding 85% of cases. The Baltic countries, Estonia, Latvia, and Lithuania, are an exception within Northern Europe, as they have historically been characterized by a higher incidence, but in recent years there has been dramatic progress. For example, Latvia in the 1990s recorded 70 cases per 100,000 people, while in 2019 incidence dropped to 25. Currently, the above-mentioned countries are also in the moderate–low incidence category, although they still face a significant burden of the disease [12,28].

The protocols followed in Northern Europe are not substantially different from those in Western Europe, as all of these countries share a similar philosophy and level of healthcare. Scandinavia, characterized by a strong welfare state and public health, has comprehensive contact tracing and epidemiological surveillance programs. For example, in Finland and Denmark, every case of TB activates a public health team that maps contacts and offers testing/treatment if needed. Diagnostic capabilities are high level as centralized TB reference

laboratories perform rapid molecular testing and whole genome analyses to investigate transmission [64].

Regarding BCG vaccination, Northern Europe was one of the first regions to discontinue universal vaccination when the incidence dropped to very low levels. Sweden discontinued mass vaccination from 1975, maintaining it only for infants in risk groups, Finland discontinued vaccination in 2006, and Denmark in 1980 [65]. The decisions were based on the fact that new generations of individuals were no longer at significant risk of infection within borders and that the benefit of the vaccine did not outweigh the potential side effects when the disease is rare. Currently, all Nordic countries have a targeted vaccination policy, as only children of a particular origin or living conditions are vaccinated, for example, children with a parent from a country with high TB or who will travel long term to such a country [66].

As far as treatment is concerned, Northern Europe follows international standards with care being individualized. TB patients are usually treated by specialized multidisciplinary teams, and in many countries, such as Norway and Finland, social services such as housing and financial support are provided to patients during treatment to ensure adherence [67]. Hospitalization in Northern European countries is used sparingly, usually only until the patient becomes non-contagious and complications are eliminated. Countries such as Norway and Iceland have achieved high treatment success rates and very low domestic transmission, as each new case is almost always associated with an overseas origin rather than domestic spread, resulting in a focus on early diagnosis of imported cases and care of migrants in pursuit of disease elimination [64].

In the Baltic countries with higher MDR rates, special efforts have taken place through international initiatives, such as the Baltic TB Project under the WHO, resulting in strengthening laboratories with molecular resistance testing and equipping hospital units with better drugs. Lithuania, Estonia, and Latvia have full access to the new MDR- TB regimens, having greatly reduced cases, yet they are still ranked as high-priority countries for TB among European countries due to the legacy of MDR [67].

Northern Europe has a profile of successful disease control, with a low incidence, a satisfactory level of public health, and advanced protocols. The emphasis is on maintaining these gains in order to prevent the re-emergence of domestic transmission and to integrate refugees–migrants into the health system so that cases do not increase. The protocols therefore place emphasis on prevention, rapid diagnosis of each case, and full compliance with treatment through close monitoring and support of patients [68].

4.4. Southern Europe

Southern Europe includes the Mediterranean countries, Italy, Spain, Greece, Portugal, Malta, Cyprus, and sometimes the Western Balkans. Historically, Southern Europe experienced a substantial TB burden during the first half of the twentieth century, but sustained socioeconomic development, improved living conditions, and the gradual implementation of effective public health measures have led to a marked decline in disease incidence over recent decades [7]. Currently, the region shows an intermediate picture, as some Southern Europe countries now have a very low incidence, like Western Europe. For example, Greece and Cyprus in 2021 had 3–4 cases per 100,000 people [8], while Portugal managed in 2021 to have 15 cases per 100,000 people, whereas in 1990 its incidence in the same population was 50 [69]. More generally, Southern European countries have been strongly affected by migratory waves in recent decades, with Italy, Greece, and Spain being countries hosting large numbers of migrant refugees from regions such as Africa and Asia, where TB rates are particularly high [68]. Migratory flows have altered the epidemiological profile of the countries; for example, in Italy over 60% of TB cases are found in foreigners. Also, in

Greece, most cases have been among migrants in the last decade, and public health systems in these countries have been called upon to adapt to provide TB screening and treatments to populations characterized by a plethora of social and language barriers [66].

Diagnostic protocols in Southern Europe are similar to those in Western Europe, as all countries have basic technological tools such as microscopy, culture, and molecular tests. In practice, there may be variations in terms of overlap; for example, within Greece or Italy, some rural areas may not have direct access to Xpert and samples are sent to a central laboratory. However, in general, in recent years programs have been implemented to have at least one TB reference laboratory per region. In Southern countries, radiological screening is a key tool, particularly for migrants, with Italy and Greece performing chest X-rays as part of the health screening of asylum seekers [70]. Mantoux dermoscopy is still used extensively, particularly in children as part of school screening. However, progressively in countries such as Spain and Portugal, IGRAs are gaining ground, having been incorporated into protocols for diagnosis of latent infection in health professionals and migrants [71].

In terms of BCG policy, Spain and Italy discontinued generalized vaccination for TB in the 1980s (Italy typically in 2001), with Portugal discontinuing vaccination in 2017, while Greece stopped mass vaccination after 2016, when the vaccine started to be administered to high-risk groups. In the South, the current trend is to carry out targeted BCG where needed, for example, in Roma children or migrants from countries with high TB rates. This transition has been aided by falling incidence, but also by the logic of integration with the rest of the EU, which considers BCG optional in low-incidence settings [66].

The treatment protocols follow WHO and EU guidelines. Southern Europe is indeed also mostly within the EU, covered by the ESTC standards. Practically every state has issued guidelines for TB, which are harmonized with the corresponding international guidelines. In the case of susceptible TB, the 6-month directly observed regimens are applicable. Similarly, for MDR, the southern countries, in particular Portugal and Greece, which have a significant number of such cases, have access to shortened regimens. For example, in Portugal, since 2020 the short 9-month regimen has been used in selected MDR patients, and where appropriate, the BPAL regimen is also used, which has a duration of 6 months [1,39]. An issue in these countries may be adherence to treatment by patients with social difficulties. For example, in Greece, there has been a problem of foreign patients leaving the hospital before completing treatment due to fear or desire to continue their journey. In this context, an attempt is being made to address the problem by better information and cooperation with migrant communities, as well as by activating shelters for homeless TB patients. Portugal has also developed support programs to ensure that patients, especially those in the urban areas of Lisbon and Porto, complete their treatment [68].

Overall, Southern Europe lies between the low load of the West/North and the highest load of the East. Most Southern countries have low levels of TB, thanks to improving conditions and strong health systems, but their geographical position as a bridge to endemic areas requires constant vigilance. Their protocols focus on early detection, especially among mobile populations, an integrated patient care with an emphasis on the social dimension of treatment and alignment with European practices to meet the targets of the disease outbreak. Countries such as Spain and Portugal have set a target of falling to less than 10 cases per 100,000 people by 2030, while Greece and Italy have set a target of keeping it low despite the migratory pressures they are under.

4.5. Transcontinental European Countries: The Cases of Turkey and the Russian Federation

Although Turkey and the Russian Federation are transcontinental states extending into Asia, both are included within the WHO European Region and have played important roles in shaping the epidemiology and control of TB across Europe [72]. Their experiences

provide important examples of contrasting approaches to TB control and are therefore discussed separately before the regional analysis.

Turkey historically experienced a substantial TB burden during the early and mid-twentieth century. However, major improvements in socioeconomic conditions, public health infrastructure, and TB control strategies have contributed to a marked decline in disease incidence over recent decades [73,74]. Overall, TB incidence decreased by approximately 86.6% during the study period of 2000–2010 reported in [73–76].

TB control activities in Turkey are coordinated through the National Tuberculosis Control Program under the supervision of the Ministry of Health and are implemented in accordance with WHO recommendations. National surveillance is based on case-based reporting systems that comply with WHO reporting requirements and the recording standards established by the EuroTB surveillance network [73]. The integration of standardized surveillance, systematic case detection, and supervised treatment has been instrumental in reducing the national TB burden.

The Russian Federation represents one of the most important settings for TB control within the WHO European Region because of its historically high disease burden and the significant prevalence of multidrug-resistant tuberculosis (MDR-TB). Following the dissolution of the Soviet Union, TB incidence increased markedly, with reported cases approximately doubling between 1991 and 2000 and incidence rates reaching nearly 90 cases per 100,000 population [77,78].

The socioeconomic challenges associated with the post-Soviet transition adversely affected TB control efforts. Disruptions in population-based screening programs, reduced healthcare resources, and interruptions in drug supply contributed to increased transmission and facilitated the emergence of MDR-TB [37,79,80]. Consequently, Russia became one of the countries with the highest MDR-TB burdens globally.

Drug-resistant TB remains a major public health challenge. The persistence of MDR-TB strains has reduced treatment effectiveness and necessitated adaptations in clinical management, laboratory capacity, and epidemiological surveillance systems [80,81]. Considerable regional variation has been reported, with MDR-TB prevalence reaching approximately 40% in some areas, including Arkhangelsk Oblast [82,83].

In addition, HIV-associated TB has increased substantially over the past two decades. According to national data, approximately one-fifth of newly diagnosed TB cases are associated with HIV co-infection, while nearly half involve MDR-TB [84]. Despite these challenges, Russia has achieved significant reductions in TB morbidity through strengthened national control measures, expanded diagnostic capacity, and improved treatment programs. Nevertheless, regional disparities in healthcare accessibility and quality continue to influence TB outcomes [84].

Several studies have reported further declines in TB incidence during the 2000–2010 period, coinciding with intensified governmental TB control initiatives and broader international collaboration among BRICS countries (Brazil, Russian Federation, India, China, and South Africa) [85].

The contrasting experiences of Turkey and the Russian Federation highlight the considerable heterogeneity of TB epidemiology and control strategies within the WHO European Region. To further illustrate these differences, key epidemiological indicators from selected European countries are summarized in Table 3 [72].

Table 3. TB epidemiological indicators for selected individual European countries, annual data 2023 (Source: Tuberculosis Surveillance and monitoring in Europe, European Centre for Disease and Prevention Control (ECDC)/World Health Organization (WHO) Regional Office for Europe, 2025).

	Population	TB Incidence (Per 100,000 Population)		Estimated TB Mortality (Per 100,000 Population)		Number of Notified TB Cases Per 100,000 Population	RR/MDR-TB Notification Among All Bacteriologically Confirmed Tb Cases		Treatment Success Rates		TB/HIV Co-Infection Cases (with Known HIV Status)	
		N	%	N	%		N	%	N	%	N	%
Western/Northern European Countries												
France	66,438,822	5500	8.3	450	0.7	5183	66	100.0	1449	36.5	-	-
Denmark	5,948,138	220	3.6	10	0.2	284	2	1.7	38	18.4	137	71
Germany	84,548,229	4100	4.8	290	0.3	4817	173	6.7	2304	61.7	-	-
Southern European Countries												
Greece	10,242,906	540	5.2	42	0.4	459	9	3.9	-	-	347	70.4
Spain	47,911,585	2800	5.9	170	0.4	4532	51	2.8	2684	73.7	3220	76.5
Italy	59,499,452	2600	4.4	300	0.5	3346	49	3.5	-	-	-	-
Eastern European Countries												
Poland	38,762,846	3900	10.0	480	1.2	5321	101	3.2	-	-	-	-
Czechia	10,809,715	520	4.8	36	0.3	461	25	7.5	225	62.5	308	67.1
Lithuania	2,854,095	810	28.0	110	3.9	1058	116	19.2	538	87.2	702	97.2

5. Conclusions and Public Policy Proposals

Despite a common framework of guidelines at the European level, there are considerable variations in the treatment of TB by region (Table 4). The countries in Western and Northern Europe are close to the goal of eradicating the disease, have modern health systems, extensive use of modern diagnostic and treatment tools, and focus on prevention through treatment of latent infection. In contrast, in Eastern Europe, countries still face a high burden of disease, particularly in MDR/XDR forms due to a combination of factors, as resources are inadequate and there are aggravating socioeconomic conditions. In Southern Europe, states are in a transitional stage with incidence being low or moderate and practices are characterized by increasing homogeneity with the West, although states face additional challenges of migratory pressures and any internal inequalities.

Despite regional differences, all European countries face several common challenges in TB control. First, sustained political commitment and adequate funding are essential to maintain progress, particularly following the setbacks caused by the COVID-19 pandemic. Second, the growing burden of drug-resistant TB requires a coordinated pan-European response, as multidrug-resistant (MDR) strains can spread across borders through population mobility, with Eastern Europe remaining disproportionately affected. Countries must also strengthen strategies to improve access to diagnosis, treatment, and continuity of care for vulnerable populations, including people who are homeless, people who inject drugs, prisoners, undocumented migrants, and asylum seekers. Innovative public health approaches are therefore needed to ensure equitable access to healthcare services and improve treatment adherence. In this context, the development of digital tools for integrated, person-centered, multi-disease screening should be further promoted to enhance medico-demographic data collection, support primary healthcare services, identify migrants at increased risk of TB, and facilitate individualized care [85].

Refugees, asylum seekers, and migrants arriving in Europe from countries with high prevalence of TB, or from transit countries, are at greater risk of infection. There is a greater incidence of TB among migrants and asylum seekers, with reception centers reporting higher proportions of foreign-origin cases. The living conditions of mobile populations and their socioeconomic status often make them vulnerable to TB transmission. Also, European national health systems may not record their health status or the diagnosis of comorbidities, due to differing philosophies on migration policy in every country, e.g., quick rejections of asylum applications, massive deportations, etc. According to the data, foreign-born patients with TB represented 8.7% of all TB cases in the WHO European Region in 2019, although the data varied widely between EU and European Economic Area (EEA) countries (34.5%) and non-EU/EEA countries and areas (2.2%) (Table 5).

According to data from the WHO Regional Office for Europe, migrants and refugees in the EU/EEA bear a disproportionate burden of MDR-TB compared with the native-born population of the host countries. Overall, foreign-born individuals account for approximately 73.4% of MDR-TB cases reported in the EU/EEA. In France, Germany, Italy, and the United Kingdom, more than 80% of MDR-TB diagnoses occur among foreign-born individuals, whereas in Romania and Lithuania fewer than 5% of MDR-TB cases are reported in this population. Despite the higher burden of MDR-TB among certain migrant and refugee groups, available evidence indicates that the risk of transmission to the general population in host countries remains low [86,87]. Finally, reducing the stigma associated with TB remains an important public health priority. Fear of discrimination and social exclusion may discourage individuals with symptoms from seeking timely medical evaluation, leading to delayed diagnosis, ongoing transmission, and poorer treatment outcomes. Public education campaigns and culturally appropriate community engagement are therefore essential components of effective TB control.

Table 4. Geographic profile and key points of tuberculosis in the European continent.

European Geographic Regions	Epidemiology	Diagnostic Protocols	Vaccination Policy/Treatment	MDR
<i>Eastern Europe</i> 	-Vast majority of Europe's cases -Greatest burden of TB due to multidrug resistance and HIV co-morbidity	-Diagnostic protocols are in the transition phase	-Treatment protocols in a transition phase -Replacement of old patterns (prolonged hospitalization and mass radiological screening) by rapid molecular diagnosis and oral treatment	-Increased rates of multidrug-resistant TB among treated patients
<i>Western Europe</i> 	-Low incidence of TB -It is now considered as a disease of special populations (below 10 cases per 100 000 people) -High rates in vulnerable groups	-Diagnostic protocols with high standards -Extensive use of rapid tests (IGRAs for latent TB, Xpert, and line-probe assays for active TB) -Epidemiologic surveillance of people from the patient's environment -Screening of high-risk groups -Specific screening programs for newly arriving migrants and refugees	-BCG vaccination in Western Europe has moved to a targeted phase (infants and children who belong to vulnerable groups or have lived in environments with a high risk of TB) -TB treatment success rates are usually high -Can afford to provide access to newer drugs (bedaquiline, delamanid, etc.) -Emphasis on the treatment of latent infection in high-risk individuals	-Western European countries have few cases, however, these are either very resistant or the patients are characterized by complex socio-medical problems
<i>Northern Europe</i> 	-Low to very low incidence of TB -In states with high progress in TB rate reduction, most cases are found in foreign migrants -Regional profile of successful disease control, with low incidence of TB	-The protocols are not different from those in Western Europe -Comprehensive contact tracing and epidemiological surveillance programs -Centralized TB reference laboratories, rapid molecular testing, and genome analyses	-One of the first regions to discontinue universal vaccination when the incidence dropped to very low levels -Treatment follows international standards with care being individualized -High treatment success rates	-High MDR rates in the Baltic countries -International initiatives (Baltic TB Project under the WHO) -Strengthening of laboratories with molecular resistance testing and equipping hospital units with better drugs

Table 4. Cont.

European Geographic Regions	Epidemiology	Diagnostic Protocols	Vaccination Policy/Treatment	MDR
<i>Southern Europe</i> 	- Southern Europe lies between the low load of the West/North and the highest load of the East - Strongly affected by migratory waves in recent decades	- Diagnostic protocols similar to those in Western Europe - Basic technological tools such as microscopy, culture, molecular tests - Some rural areas may not have direct access to Xpert and samples are sent to a central laboratory - Programs have been implemented to have at least one TB reference laboratory per region - Mantoux dermoscopy is still used extensively - IGRAs are gaining ground into protocols for diagnosis of latent infection	- In BCG policy, some countries have discontinued generalized vaccination for TB - The trend is to carry out targeted BCG - The treatment protocols follow WHO and EU guidelines and comply with the ESTC standards - The protocols focus on early detection, especially among mobile populations - In the case of susceptible tuberculosis, the 6-month directly observed regimens are applicable - Social difficulties in treatment	- Significant number of MDR cases - Short 9-month regimen in selected MDR patients - BPpL regimen is also used (duration of 6 months)

Table 5. Proportions of TB cases in people of foreign origin in the total populations of selected countries (Source: Report on the Health of Refugees and migrants in the WHO European Region: No Public Health without Refugee and Migrant Health. Geneva, WHO 2018 [87]).

Countries	People of Foreign Origin Among TB Case Notifications (%)
Malta	96.0
Cyprus	93.3
Sweden	89.8
Slovenia	36.4
Czechia	29.3
Spain	28.5
Estonia	21.9

Based on the above findings, there is a need to strengthen and harmonize diagnostic infrastructures. A pan-European initiative coordinated by the ECDC/WHO is proposed to ensure that all EU countries, especially high burden countries such as those in Eastern Europe, have adequate access to modern diagnostic techniques. Investment in biosafety level laboratories and training of staff, as well as the supply and maintenance of molecular diagnostic equipment, is required. The use of portable molecular testers at remote sites and networking laboratories for rapid transfer of samples and results should be promoted. At the same time, standardization of evidence-based diagnostic protocols based on uniform criteria should be promoted in order to reduce internal variation.

Eastern European countries also need to be supported technically and financially in order to fully adopt the newer treatment regimes. An expansion of oral short-term regimens for MDR-TB is needed. The above-mentioned Europe-wide regimen tailored to the individual resistance profile will help to drastically reduce the duration of treatment and improve patient outcomes. There is also a need to ensure access to newer medicines (such as bedaquiline- and delamanid-containing regimens) in all countries, through joint procurement or sharing mechanisms, so that no TB patient in Europe is receiving outdated and less effective regimens. Individualized care is also needed to ensure effective management of difficult cases. The above-mentioned practices will help transfer expertise from experienced centers in the West to Eastern countries and ensure that each patient receives the best possible treatment.

Additionally, it is necessary to establish protocols requiring the initiation of antiretroviral therapy in all TB/HIV cases within a few weeks of TB diagnosis, regardless of region, and monitoring of patient compliance. Lower-performing states could benefit from additional funding to strengthen so-called TB and HIV programs.

Health policies should also encourage the de-institutionalization of TB management, particularly in Eastern European countries. There is a need to review funding incentives by adapting health systems so that funding does not depend on a patient's bed stay but rather on indicators of successful treatment in the community. The WHO can provide technical assistance for this reform, so that countries are not penalized financially when they reduce hospitalizations. Strengthening of primary and public health structures is also recommended. Healthcare providers should recruit and train stakeholders, digital health specialists, health visitors, nurses, and social workers to supervise home treatment, support patients, and conduct follow up contact. Such interventions have proven particularly effective in the West and the North, and it is recommended that this be extended to Eastern countries. The development of mobile units and cooperation with NGOs to provide treatment for hard-to-reach populations, such as people who are homeless or drug users, is

also considered necessary. Programs implemented in various European countries, such as London and Copenhagen, can be used as guides to best practices.

It is proposed that there should be governmental European (EU and non-EU states) cooperation and funding, as the disease is a regional health issue, so European countries need to work more closely together. A European TB Solidarity Fund with contributions from most states is required, which would finance the critical gaps in the Eastern states. The above-mentioned treaty is an investment move that will benefit the whole continent by reducing the reservoirs of resistant TB. It is also recommended to strengthen the role of platforms (ECDC, TBnet, and the WHO Collaborative Center), observational centers, and national registries in order to have real-time exchange in epidemiological surveillance data and jointly undertake cross-border TB outbreak actions and facilitate multi-state research. It is also proposed to negotiate, at the EU level, lower prices for TB drugs and tests, especially for new drugs that can be expensive, as well as harmonization of the regulatory framework so that a new diagnostic or drug approved in one state is quickly and continuously recognized by other states.

Finally, investing in research for new anti-TB tools is recommended as a long-term policy proposal. Europe, with its pharmaceutical and scientific capabilities, can take the lead in developing new vaccines and diagnostic tools that will facilitate the further fight against the disease.

In summary, eliminating TB in Europe requires a two-pronged approach: on the one hand, continuing and strengthening past practices in countries close to the target, and on the other hand, practical solidarity and support for countries that are lagging, to bridge the gap. The implementation of the above proposals is fully in line with scientific evidence and tailored to the specificities of each country, seeking to be an important step towards a TB-free future on the European continent.

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