



Original Research

Economic burden estimation to inform prevention policies against emerging zoonotic diseases: The case of tick-borne encephalitis in France

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ABSTRACT

Objectives: Economic evidence on health losses can guide prioritisation of prevention policies for emerging zoonotic risks. Tick-borne encephalitis (TBE) is gaining attention in Western Europe, and notifications are rising in France. Our goal is to scope existing European burden estimates and to generate the first national figures for France using a standardized framework that can inform health policies.

Study design: This study was designed as a nationwide model-based cost-of-illness analysis combining a systematic literature review with a decision-tree simulation to estimate the costs of TBE in France.

Methods: The systematic scoping review (2000–2025) identified studies reporting TBE costs. Our original estimate for France relied on the BCoDE (Burden of Communicable Disease in Europe) model (European Centre for Disease Prevention and Control, ECDC) to simulate health states and lost DALYs (disability-adjusted life years) due to infections in France (2024). Direct medical costs, indirect productivity losses, and intangible welfare losses were included. Sensitivity analyses explored ranges for uncertain parameters.

Results: In France, total direct costs amounted to €2,021,701 and indirect costs to €289,550, averaging €11,112 per case. TBE caused about 43 lost DALYs, which translated into €33,229 per case. The annual burden was €9.22 million, with 75% intangible, 22% direct, and 3% indirect. Although aggregate burden remains low, per-case welfare losses are high.

Conclusions: Our findings provide the first quantitative TBE burden estimation for prevention planning in France. They support targeted vaccination and strengthened surveillance in emerging areas.

1. Introduction

Tick-borne encephalitis (TBE) has recently gained attention in Western Europe as an emerging arboviral infection transmitted by hard ticks of the *Ixodes ricinus* complex.¹ France reported sporadic cases for decades, but notifications have increased since 2019, including a cluster of foodborne infections in Ain.² Epidemiological surveillance has improved since the 2021 mandatory notification and reached an annual

peak of 62 cases in 2024. Despite the increase in diagnoses, the disease's impact remains highly uncertain. The literature on the economic impact of the disease across Europe reports highly variable outcomes, with, for example, DALYs (disability-adjusted life years) lost per TBE case varying by a factor of 13^{3,4} and the cost per case varying by a factor of 3.^{5,6} Early burden estimates can inform prioritisation, surveillance, and prevention planning for emerging zoonotic risks. The economic burden of TBE has never been assessed in France. We conducted a systematic review of

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studies evaluating the burden of TBE and estimated its cost in France based on a decision-tree model. This paper updates and deepens the analysis presented in the Anses (*Agence nationale de sécurité sanitaire, French Agency for Food, Environmental and Occupational Health & Safety*.) expert appraisal on TBE.⁷ This calculation will help identify the primary sources of economic losses associated with TBE and serve as a baseline for future analyses should the disease evolve in France.

2. Methods

2.1. Literature review

Sources and search strategy: We searched PubMed and Scopus databases with no study-design or geographic filters, restricting to studies reporting any burden (monetary or not) of TBE up to May 2025. Search strings combined burden and economic terms with TBE terms, as detailed in the supplementary material.

Eligibility criteria: We included studies that estimated TBE burden (e.g., DALYs per case or per population; YLL (years of life lost); YLD (years of life with disability), cost of disease) and/or used burden metrics in economic evaluations (e.g., QALYs (quality-adjusted life years), cost-utility). We excluded records without a burden outcome, editorials/commentaries, duplicate full texts, full texts not accessible, and non-English full texts without translation.

Screening, extraction, and synthesis: Titles/abstracts and then full texts were screened independently by two reviewers, and disagreements were resolved by consensus using the CADIMA online tool.⁸ For each included study we extracted: country, period, population/cases, outcome(s), perspective and cost categories, time horizon, and data sources. Given heterogeneity in designs and outcomes, we performed a narrative synthesis (no meta-analysis).

2.2. Disease burden estimation framework

2.2.1. Decision-tree model

Our analysis relied on the BCoDE (Burden of Communicable Disease in Europe) toolkit,⁹ an open-access software developed by the European Center for Disease Prevention and Control (ECDC). Provided with the number and sex/age distribution of symptomatic cases for a given year, this toolkit simulates using Monte Carlo simulations ($n = 1000$) two relevant sets of data. First, it determines the different health states representative of the disease progression that will arise from an initial pool of infected patients through transition probabilities between health states, including recovery (see Fig. 2). Second, it calculates the corresponding DALYs lost, YLL, and YLD, for each health state and by age and sex group. The transition probabilities and data sources are detailed in the supplementary material.

2.2.2. Economic parameters

To estimate the burden from the perspective of the whole society, we

included direct, indirect, and intangible costs (all expressed in € for the year 2024, later written €2024).

Direct costs: Given the low number of cases in France and the absence of detailed data on individual case management, the estimation of direct healthcare costs in this report is based on a theoretical care pathway elaborated on the health states of the decision-tree model (see Fig. 2). This pathway was informed by data from patients diagnosed with TBE in Alsace between 2016 and 2022,¹⁰ typical hospital stays associated with the disease, and expert opinion.

Hospital stays associated with the diagnosis of “other viral encephalitis transmitted by ticks” (code A848) identified in the PMSI (“*Programme de médicalisation des systèmes d’information*”, French annual registry of hospital stays) were searched and valued using 2024 tariffs. We considered the level of severity through a weighted approach reflecting the distribution of severity in the Alsace patient cohort, i.e., 38% of cases in level 1 (less severe) and 62% in level 3 (more severe). In order to assess the uncertainty on the severity level, sensitivity analyses were conducted (Section 2.2.3). General Practitioner (GP) and specialist consultations, physiotherapy, and speech therapy were estimated based on expert opinion and valued using NGAP (“*Nomenclature générale des actes professionnels*”, paramedicals’ tariffs 2024-2025). Transport and informal care were excluded.

The direct cost of severe sequelae associated with the residual paresis state was estimated by applying the monthly disability compensation allowance (“*Prestation de compensation du handicap*”) for people in need of assistance for daily life (€1246/month) to the average duration of the Paresis phase (34 y). Hence, a total cost for the residual paresis health state of €507,984, a figure much higher than the base case value of¹¹ (€28,592). Potential care expenditures associated with less severe sequelae were not included.

Indirect costs: indirect costs are based on days of absence resulting in productivity loss. In the absence of detailed follow-up data, the analysis applies conservative assumptions (see Table 1).

Intangible costs: Intangible costs correspond to the impact of the disease on quality of life and years of life lost due to premature mortality. This is measured by DALYs, which capture a loss of well-being. For this analysis, DALYs lost due to TBE yielded by the BCoDE model were monetised to allow aggregation of the three categories of costs (direct, indirect, and intangible). We retained the DALY value used in France.¹⁴

2.2.3. Sensitivity analysis

Given that the heaviest uncertainty in the patient care pathway weighs on the type of hospitalisation ME cases actually go through, we centered our sensitivity analysis on this parameter that impacts both direct costs (hospitalisation) and indirect costs (post-hospitalisation absence). We thus tested two alternative scenarios:

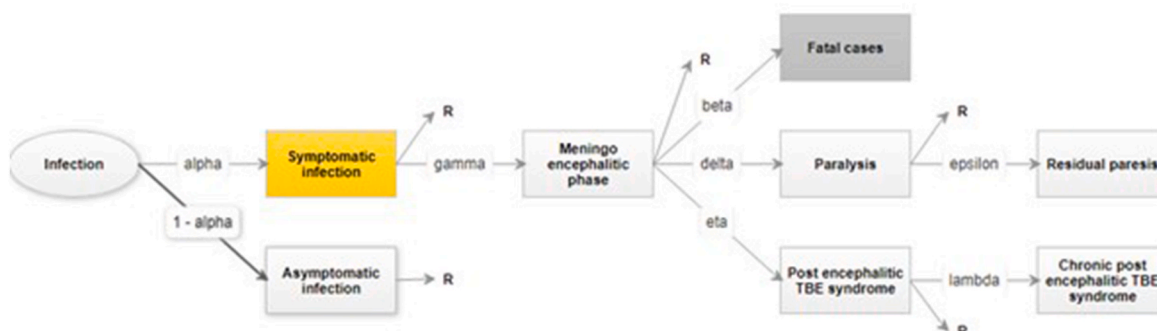


Fig. 1. PRISMA Flow Diagram for TBE Burden search.

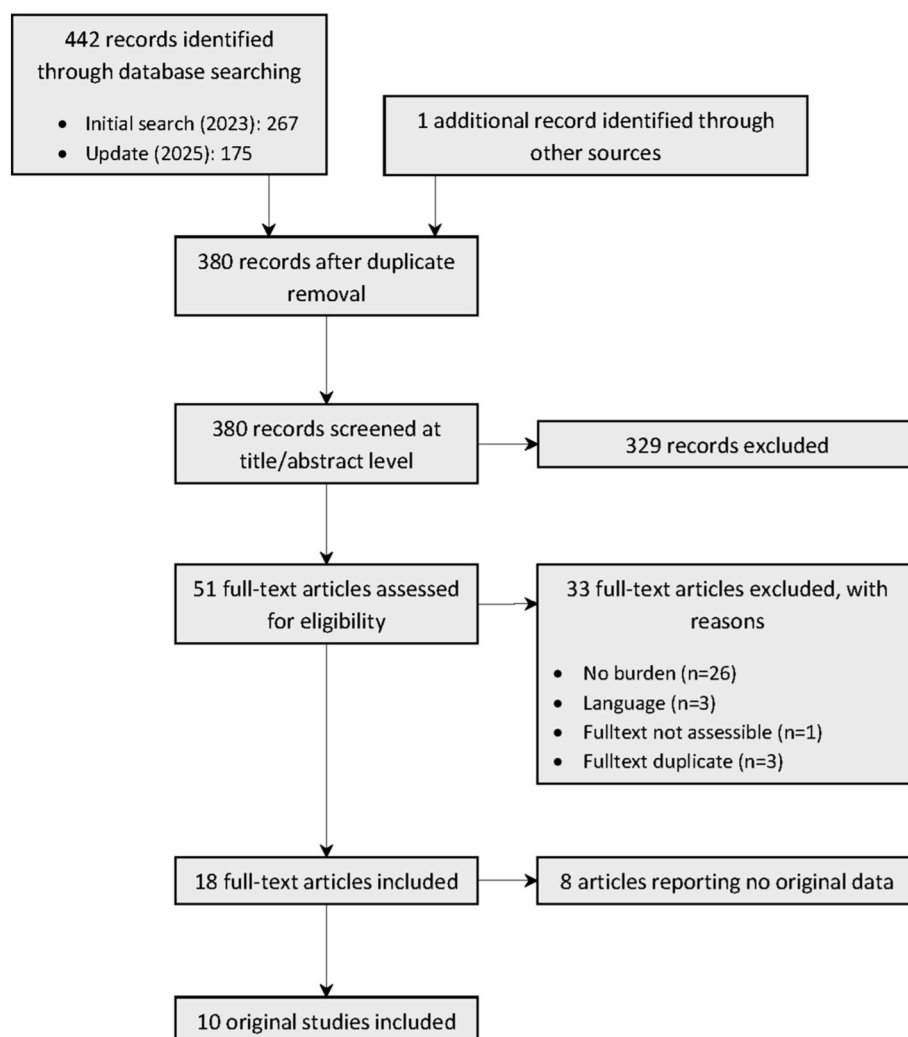


Fig. 2. Health-state progression of TBE in the BCoDE model (ECDC, 2024).

There is a probability of δ for a patient in the ME phase to evolve to the Paralysis phase; R: recovery

- a *floor* scenario: all hospitalisations coded at level 1; hence a lower direct cost (€3138 vs €7068) and a shorter post-hospital absence length (7 d. vs. 21.26 d).
- a *ceiling* scenario: all hospitalisations coded at level 3; hence a higher direct cost (€9477 vs €7068) and a longer post-hospitalisation absence (30 d vs 21.26 d)

3. Results

3.1. Literature review

The literature search yielded 10 original studies (Fig. 1). Overall, the selected studies were published between 2012 and 2024 and cover Slovenia, Sweden, Germany, Italy, and a multi-country European analysis. They either directly estimated the burden of the disease^{3–6,15,16} or used burden measures in economic evaluations.^{11,17–19} A detailed presentation is available in the [Supplementary Material 3 \(Appendixes 3a, 3b, 3c\)](#). Across burden studies, DALYs per case ranged from 0.23 (population-based estimates^{3,4}) to 3.1 (when long-term sequelae and deaths are more fully accounted for⁴). At the population level, estimates range from 0.69 DALYs per 100,000 (EU level) to ~168 DALYs per 100,000 (Slovenia), reflecting differences in incidence, age structure, and adjustments for underdiagnosis.

Economic burden estimates report average costs per case ranging from €6866 (hospitalised cases only; Italy) to €21,834 after five years

(Sweden) including indirect costs. In the latter study, costs are largely driven by hospitalisation and work absenteeism.

Common methodological limitations of the studies include: under-diagnosis and incomplete capture of the first clinical stage, limited age stratification, and partial accounting for indirect and intangible components. These gaps motivate a country-specific application for France that integrates direct, indirect, and intangible costs, presented next.

3.2. Estimations for France

3.2.1. Epidemiological data

In 2024, 62 TBE cases were notified in France,¹² of which 52 experienced a hospital stay. We retained these 52 cases that can be ascertained as passing through the meningo-encephalitic (ME) phase. Because the BCoDE model requires symptomatic cases as the number of cases input, and the French surveillance system reports only ME cases, we had to calibrate the input data according to the observed number of ME cases (52). The latter was therefore multiplied by 4 to approximate the total number of symptomatic infections (as done by and explained by³ in note k, p. 10), yielding approximately 208 symptomatic cases. Cases were distributed by sex according to the actual 2024 French cases in the surveillance data (sex ratio 2.4). Age distribution was approximated using regional cohort data (Alsace, 2012–2022).¹⁰ In the absence of data, no correction for under-reporting or attribution bias was applied.

Table 1
Key epidemiological and economic input parameters.^a

Variable/ Assumption	Value (type)	Detailed assumption/ Comment	Source
Symptomatic cases	≈208 (cases)	Derived from 52 ME cases × 4 (ratio symptomatic/ hospitalised)	BCoDE inference; ³
Meningo- encephalitic (ME) phase, nb of cases	≈52.1 (cases)	Hospitalised cases, 2024	12
Residual paresis, nb of cases	≈3.2 (cases)	Long-term neurological sequelae	BCoDE simulation
Deaths, nb of cases	≈0.4 (cases)	Annual probability of fatal outcome	BCoDE simulation
DALYs lost (total)	≈43 (DALYs)	YLL + YLD for all health states	BCoDE simulation
Absence duration— symptomatic phase	1 (day)	Short GP consultation; mild febrile form	Expert elicitation ⁸
Hospitalisation stay duration (ME phase)	14.1 (days)	Average stay for ICD-10 A848 cases 2024	PMSI 2024
Post-acute absence duration (ME phase)	22.6 (days)	Weighted mean: 38% level 1 (7 d) + 62% level 3 (30 d)	Authors' calc. based on ⁸
Long-term sequelae, absence duration	Not included	Insufficient quantitative data for paresis or cognitive impairment. <16 years: parental absence considered; >65 years: retired, absence excluded	8
Population considered	16–65 years old	<16 years: parental absence considered; >65 years: retired, absence excluded	Demographic assumption
Daily productivity loss	€152.2/ day	Gross wage + employer charges, weighted by sector (private: 4/5th vs. public: 1/5th) & employment rate.	INSEE 2024; authors' calc.
Hospitalisation cost	€9476.91	38% L1 + 62% L3 severity weighting	ATIH ⁹ 2024
GP consultation cost	€30	Standard NGAP tariff	Tariff 2024
Specialist consultation cost	€50	Average across neurology/infectious disease	Tariff 2024
Physiotherapy session cost	€22.10	Average session cost	NGAP 2024
Paracetamol (box) cost	€1.16	Over-the-counter price 2024	BdM_IT 2024
Residual paresis (severe sequelae) cost	€507,984	Monthly disability allowance (€1246) × 12 months × average duration 34 y.	13
Monetary value per DALY (VSLY)	€161,000	Value used in French cost- benefit appraisals	14 (updated)

^a ATIH: *Agence technique de l'information sur l'hospitalisation*; BCoDE: Burden of Communicable Disease in Europe; BdM_IT: *Base des Médicaments et Informations Tarifaires*; DALY: Disability Adjusted Life Year; GP: General Practitioner; ICD: International Classification of Diseases; INSEE: *Institut national de la statistique et des études économiques*; ME: Meningo-encephalitic; NGAP: *Nomenclature Générale des Actes Professionnels*; PMSI: *Programme de médicalisation des systèmes d'information*; VSLY: Value of a Statistical Life Year; YLD: Years of Life with Disability; YLL: Years of Life Lost.

3.2.2. BCoDE model estimation for France

The BCoDE model estimated 52 cases progressing to the meningo-encephalitic phase, of which about 30 developed persistent neurological symptoms and 8 evolved to the paralytic phase. Approximately 0.4 deaths were predicted annually (0.75% fatal cases, see [Supplementary Material 2.a](#)).

Direct medical costs accounted for €2,021,701 (see [Supplementary Material 4](#) for calculation details), dominated by the residual paresis state (80.9% of the total direct costs) followed by hospitalisations during the meningo-encephalitic phase (18.2%). Indirect productivity losses amounted to €289,550 (see [Supplementary Material 4](#)), mainly due to work absences averaging 14 days among working-age patients. The

combined direct and indirect costs reached €2,311,251, corresponding to €11,112 per symptomatic case. The distribution of the costs depending on the health state is presented in [Fig. 3 a](#).

Total DALYs lost (including deaths) were estimated at 43, monetised at €6,911,730, corresponding to €33,229 per symptomatic case and representing 75% of total costs. Deaths and chronic sequelae (paresis and persistent symptoms) accounted for the vast majority of these intangible losses ([Fig. 3 b](#)).

3.2.3. Total burden

The integrated annual burden of TBE in France (2024) amounts to €9,222,981 (see [Supplementary Material 4](#)), corresponding to €44,341 per symptomatic case (direct + indirect + intangible costs). Among cost categories, intangible costs represent 75% of total costs, direct costs 22%, and indirect costs 3%. The health state contributing the most to direct and indirect costs was residual paresis (70.8%), followed by the ME state (27.2%). The chronic sequelae account for 37.7% of the intangible costs (slightly above the deaths (32.9%)).

3.2.4. Sensitivity analysis

Under the *floor* scenario, total direct costs decreased by 10% and indirect costs by 36%, leading to an overall reduction of 13% in combined direct and indirect costs (see [Appendix 3](#)). Conversely, under a *ceiling* scenario, direct and indirect costs increased by 6% and 22%, respectively, leading to a +8% increase in combined direct and indirect costs. Since intangible costs represent the largest component of total costs and are not affected by this hospitalisation level parameter, the total societal burden varied only marginally, from €8.91 million (*floor*) to €9.41 million (*ceiling*), corresponding to a −3% to +2% change relative to baseline. These results confirm that while economic assumptions affect the magnitude of direct and indirect costs, they do not alter the qualitative ranking of cost components: intangible losses remain the dominant contributor to the total burden.

4. Discussion

Published studies assessing the health burden of TBE rely on different calculation methods and populations, and the data considered are heterogeneous, limiting comparability across studies. Nevertheless, several elements can be drawn from the literature: the incidence of TBE varies greatly within Europe, with levels of prevalence often much higher compared to France, resulting in a highly variable population-level burden across countries; there is also considerable uncertainty regarding the number of cases, due to the under-identification of mildly symptomatic or nonspecific cases. The two studies conducted in Slovenia illustrate how different adjustments for under-identification and under-reporting can substantially affect the results.^{15,20} It is therefore recommended to estimate the levels of under-identification and under-reporting in France in order to adjust the case numbers used to calculate the burden. The European-level study comparing the DALYs lost due to various infectious diseases, found that TBE accounted for 0.25% while influenza for 29.8%.³ Studies assessing the burden in DALYs focused on the individual impact of the disease, but do not include its economic impact on society (healthcare costs, direct costs, or productivity losses, i.e., indirect costs), except for⁶ in Sweden. These authors estimated tangible costs (direct and indirect), but did not value the impact of the disease on quality of life. In this cost-of-illness study, tangible costs averaged €20,504 per case in the first year after diagnosis and €24,126 after three years. Hospitalisation and work absence represented 52% and 42% of the total cost, respectively. In our French estimation, the corresponding burden for tangible costs reaches €11,112 per symptomatic case, with direct medical costs accounting for 87.5% and productivity losses for 12.5%. The much lower per-case cost in France reflects the small number of severe cases observed, on a much smaller sample, and the conservative assumptions regarding hospitalisation length and post-acute absence, as well as a methodological

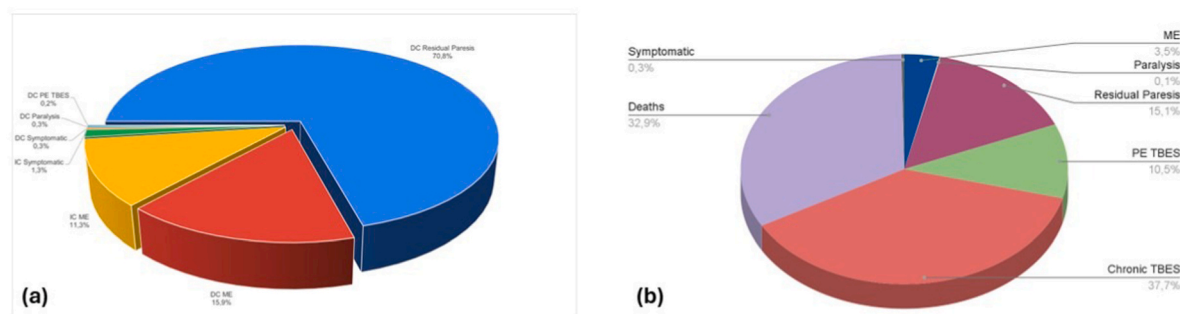


Fig. 3. Composition of the combined direct (DC) and indirect costs (IC) by health state (3.a.) and intangible costs (monetised lost DALYs by health state) (3.b).

discrepancy (empirical matching in Sweden vs. theoretical care pathway monetisation).

When intangible costs are included, the overall burden in France rises to €44,341 per case, underscoring the predominance of welfare losses in the total cost of TBE. This average cost is theoretical and model-based, since it includes the BCoDE estimated probability of death even though no fatal case has been reported in France in 2024. Excluding deaths from the model would lower the mean cost per case to around €33,412. For intangible costs, the average loss of 43 DALYs for the total population is far below estimates reported for more affected countries. For example,¹⁵ estimated, using the same tool, a TBE burden of 224.55 DALYs lost per year over 2009–2013 in Slovenia, for a population 30 times smaller than France. The large epidemiological gap between an endemic country like Slovenia and a low-incidence country like France explains these striking differences despite differences in population size. In the French model, intangible losses (valued at €6.9 million, or 75% of total costs) are driven by deaths and long-term sequelae, with the meningo-encephalitic phase alone accounting for more than 9.4% of total costs and residual paresis for 29%.

Given the lack of disaggregated data on French patients at this stage, several conservative assumptions had to be made for this assessment, relying on small sample observations and expert elicitations, but it is the first essential step toward a better understanding and monitoring of this still poorly understood emerging disease. However, the literature review helped to benchmark and validate the magnitude of these assumptions. In the future, longitudinal follow-up of patients reported through mandatory notification would allow for a more robust assessment of intangible costs. More precise qualitative information on patient trajectories and the potential impacts on their families would also improve understanding of the overall burden of TBE.

At the national level, this estimate of DALYs lost enables an initial positioning of TBE relative to other diseases. Scaled to the total population in 2024, the non-fatal DALY loss corresponds to 0.063 DALY per 100,000, representing a very small fraction (0.0006%) of the total disease- and injury-related 10,499 DALYs per 100,000 inhabitants in France estimated for 2019.²¹ The share of TBE in these overall intangible costs incurred by diseases in France is therefore extremely small at present. Even if the aggregate burden is modest compared to major diseases, the high cost per case and rising incidence (with 98 TBE notifications recorded in France in 2025, representing a further increase from 2024²²) may justify preventive action for individuals and the alimentary dairy sector. Geographic targeting appears particularly feasible in the French context: the mandatory notification system introduced in 2021 now allows precise identification of areas with active viral circulation at the departmental level, with the Grand Est, Auvergne-Rhône-Alpes, and Bourgogne-Franche-Comté regions consistently concentrating the majority of cases.²² A vaccination strategy targeting residents and outdoor workers in these geographic hotspots is therefore well-supported by surveillance data, and the Haute Autorité de Santé has initiated a formal evaluation of such a targeted vaccination strategy.²³ While more evidence is needed to characterize risk by

occupation and recreational profile precisely, recent expert elicitation work conducted in the French context provides useful initial guidance:²⁴ forestry workers, wood industry workers, and professionals conducting scientific or analytical field activities were identified as the most exposed to tick bites.

The annual burden of TBE in France is currently low in aggregate but substantial on a per-case basis. Given the scarcity of detailed epidemiological and clinical data, this assessment deliberately relies on conservative assumptions to present a lower bound of the potential societal impact. A more thorough monitoring of patients' health status and evolution over time is needed to assess the burden of TBE accurately. Future work should refine these estimates through longitudinal follow-up of patients and better quantification of chronic sequelae, productivity losses, and caregiver impacts.

These results illustrate how the burden of disease and cost of illness exercises can inform upstream stages of the policy process, by clarifying the scale and structure of the problem before specific preventive or curative options are appraised. The French case, characterized by low aggregate incidence but high per-case welfare losses, shows why emerging zoonoses require context-specific economic assessments to avoid both overreaction and neglect in public decision-making. More broadly, the proposed framework can be replicated for other vector-borne and zoonotic infections in Europe, to build a coherent evidence base for anticipatory and cost-effective infectious disease prevention policies.

Ethical statement

Ethical approval was not required for this study, as it relied exclusively on aggregated surveillance data and previously published sources without use of identifiable individual-level information.

Author contributions

Conception and data: ML, VR, YH, CS, AV; Formal Analysis: ML, VR; Scoping Review: ML, VR; Writing (original draft and revisions): ML, VR, YH, CS, AV.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors used ChatGPT to translate from the French and draft parts of the initial analysis in English. After using this tool, the authors reviewed, corrected, and edited all generated content and take full responsibility for the final version of the article.

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Declaration of competing interest

The authors do not have any competing interests.

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The views expressed in this paper are those of the authors alone and do not necessarily reflect the position of ANSES.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.puhe.2026.106365>.

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