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Cost-effectiveness of tuberculosis infection screening at first reception into English prisons: a model-based analysis

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Summary

Background The World Health Organization recommends systematic screening for tuberculosis in incarcerated populations, which are consistently at high risk of tuberculosis relative to the general population. In England, new receptions into prisons do not receive screening for tuberculosis infection, and evidence from economic evaluations is lacking.

Methods We performed a cost-effectiveness analysis of introducing systematic screening for tuberculosis infection at first reception into English prisons from a health systems perspective. We used a tuberculosis transmission model calibrated to public data on prison populations and flows. We developed decision tree models of prison-specific tuberculosis care pathways and their costs, informed by stakeholders and pilot studies. Sensitivity analyses included eliminating loss to follow-up (LTFU) in care cascades, zeroing extramural escort costs, and targeting screening to those born in countries with higher tuberculosis incidence (over 40 per 100,000 per year).

Findings In our base case analysis, the intervention had an incremental cost-effectiveness ratio (ICER) of £78,000 per quality-adjusted life-year (QALY) gained. Reducing LTFU and avoiding prison escort costs would substantially improve cost-effectiveness, to ICERs of £70,000 and £54,000 per QALY gained, respectively. Targeting those born in higher incidence countries was predicted to be cost-saving.

Interpretation Universal tuberculosis screening and preventive treatment for new receptions into English prisons is not cost-effective by the usual threshold of £30,000. However, targeting high-risk groups could be cost-saving. Tuberculosis interventions should explore ways to reduce LTFU and extramural healthcare in order to meet the needs of those incarcerated while minimizing costs.

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Keywords: TB; Tuberculosis preventive therapy; TPT; Persons deprived of liberty; Economic evaluation; Cost-utility analysis; Inclusion health; Mathematical model

Introduction

Incarcerated populations are consistently at high risk of developing tuberculosis compared to the general population, with incidence rate ratios over 10 in most World Health Organization (WHO) regions.[1] The global incidence of tuberculosis in incarcerated populations has been estimated at 125,000 per year,[2] representing around 1% of the global total. In central and South America, rising incarceration rates mean that over 10% of notified tuberculosis is now among incarcerated people,[3] and modelling suggests that changes in incarceration policy could contribute to renewed declines in

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Research in context

Evidence before this study

We searched Pubmed on 4/10/2024 using (prison*[tiab] OR incarcerate*[tiab]) AND (cost-effect*[tiab] OR economic [tiab] OR model [tiab]) AND (tuberculosis [tiab] OR TB [tiab]) AND ("2000/01/01" [dp]: "2024/10/4" [dp]) and selected reports of studies evaluating the cost-effectiveness of introducing tuberculosis interventions for incarcerated populations. In 2012, Winetsky et al. used a transmission model for a cost-utility analysis of active case finding strategies for tuberculosis in the prisons in the former Soviet Union. In 2013, Kowada used a static model of tuberculosis for a cost-utility analysis of tuberculosis screening approaches on incarceration for generic developed countries, but did not consider a comparison with no screening. Static models were used to compare diagnostic strategies for tuberculosis case finding in prisons in terms of incremental costs per case found were considered by Schmid et al. in 2014 for Brazil and Smit et al. in 2017 for Belgium. In 2020, Kim et al. used a static model to estimate an ICER of 22,000 USD per disability-adjusted life-year (DALY) averted for including digital chest X-ray in tuberculosis disease screening on entry to prison in South Africa. In their 2021 cost-utility analysis for a selection of US states, Jo et al. used a transmission model to evaluate tuberculosis preventive therapy for incarcerated populations, among other target groups, finding ICERs ranging from 43,000 USD to 110,000 USD per quality-adjusted life-year (QALY) gained (excluding New York).

Added value of this study

Our study is one of only very few cost-utility analyses of introducing tuberculosis interventions for incarcerated populations since 2000, and the only one for England. Our modelling approach represented transitions through incarceration to release, as well as tuberculosis transmission within and outside places of incarceration. We represented aspects of care specific to incarcerated populations in England, and based parameters quantifying the intervention on pilot and survey data. We were able to explore the performance of targeting screening to particularly high risk populations.

Implications of all the available evidence

Our transmission modelling cost-utility analysis of introducing universal tuberculosis infection screening at first reception into English prisons was not cost-effective at typical English thresholds of 30,000 GBP per QALY gained. However, restricting screening to those born in countries with estimated tuberculosis incidence over 40 per 100,000 per year was cost-saving. Provision of population-equivalent tuberculosis care for incarcerated populations in high-income low-tuberculosis incidence countries may require investments outside usual thresholds, and consideration of targeted and optimized approaches.

tuberculosis for many countries in this region.[4] While in the European region, tuberculosis notifications in incarcerated populations are declining, tuberculosis treatment outcomes remain substantially worse than in the general population,[5] with the closed, crowded, communal nature of the setting highly conducive to the spread of respiratory disease.[6,7] The resident population is also at higher risk of experiencing health inequalities, including less access to community healthcare, higher rates of tuberculosis risk factors such as rough sleeping and injecting drug use, and poorer health outcomes.[8,9] Since 2021, the WHO has strongly recommended systematic screening for tuberculosis disease in incarcerated populations,[10] but challenges to implementation remain,[11] and recommendations and evidence on interventions for tuberculosis infection in incarcerated populations are lacking.

England is a WHO low tuberculosis incidence country, with a notification rate of 8.5 per 100,000 in 2023.[12] There is however large variation by region and risk group, with 80% of notifications in those not born in the United Kingdom (UK), and 17% in those with social risk factors. In England in 2023, 4.2% of notified tuberculosis in people aged 15 years or over reported current or previous imprisonment.[12] This estimate may well underestimate the contribution of prisons due to stigma in reporting imprisonment. Between 2017 and 2024, local Health Protection Teams in England and Wales have produced at least six tuberculosis prison outbreak reports, detailing high transmission rates and secondary cases, including to prison staff. Bio-behavioural survey data from 2022 to 2024 across a variety of English prison types, and a previous a small-scale survey in a remand prison found tuberculosis infection rates of around 7%.[13]

Currently in England all new receptions into prisons are offered verbal symptom screening for tuberculosis disease; there is no routine assessment for tuberculosis infection. If individuals screen positive on the verbal screen for tuberculosis disease they will be isolated and referred for further evaluation including chest X-ray and molecular diagnostic testing of sputum. Challenges exist to this screening process, including symptoms going unrecognised or being discounted, for example due to long term smoking or drug withdrawal. In addition, operational pressures may limit capacity for isolation and influence decisions. Those requiring chest X-ray will usually be escorted by prison officers offsite to a community X-ray facility, which has associated National Health Service (NHS) costs, can be operationally

challenging, and also offers a poor patient experience.[14,15] Those who are found to have tuberculosis disease will be treated, and contact tracing undertaken to identify any associated cases, which may include screening contacts for tuberculosis infection.

While prisons are an important focus of national elimination strategies for tuberculosis in England and UK National Institute for Health and Care Excellence (NICE) recommends tuberculosis infection screening,[16] there is no published evidence available on the cost effectiveness of screening and treating tuberculosis infection amongst people in English prisons. It is hypothesised screening in this population could identify those who would benefit from treatment, reducing the risk of developing tuberculosis disease and subsequent transmission and outbreaks, as well as reducing poor patient outcomes. This in turn would contribute more broadly to the national tuberculosis elimination agenda.

We therefore undertook a model-based cost-effectiveness analysis of tuberculosis infection screening for those entering pre-trial custody, compared to usual care where a low coverage of screening takes place.

Methods

We undertook an economic evaluation over a 70 year time horizon from a health systems perspective, which includes all actors or actions which have an objective of improving human health, as recommended by the WHO for economic evaluations.[17] Our health economics and modelling framework combined a model of the flow of incarcerated people through the English prison system, a model of tuberculosis transmission and illness, and models of patient care pathways to calculate changes in resource use, costs, and health outcomes under the intervention.

Model of flow through the English prison system

To represent the distribution of durations spent detained in the English prison system system, we developed an ordinary differential equation model of the incarcerated population and flows, and those released (Fig. 1A). We used an equilibrium assumption and Bayesian methods to fit this model to a number of targets identified from public data, namely: the total population; the fraction detained in open prisons; the total rates of release and sentencing; and the mean detention duration at release. We defined a pseudo-likelihood for each target as a normal distribution with standard deviation of 5% of the target value, which was used as the mean. Inference was performed using Markov chain Monte Carlo (MCMC) using Stan, and 4000 joint samples of the flow parameters were retained for use in analysis. For details of priors and parametrization, see Appendix 1.1.

Tuberculosis transmission model

To represent the natural history and transmission of tuberculosis, we extended our model of the incarcerated

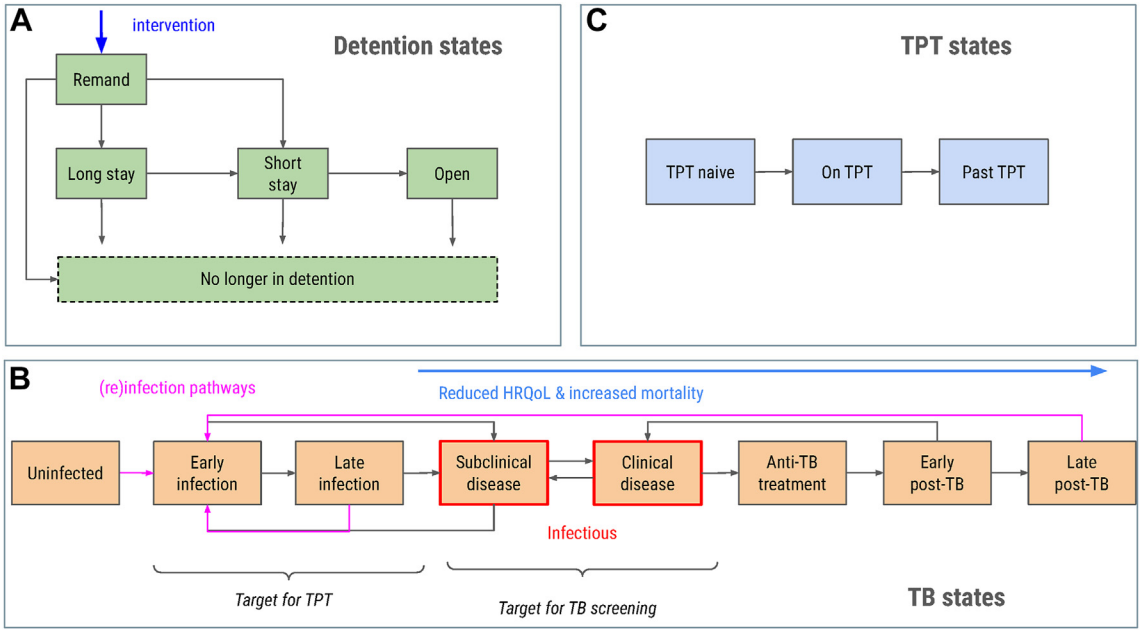

Fig. 1: Transmission model structure. A: Detention states and flows between them. The intervention is situated at the flow into remand (blue). B: The tuberculosis (TB) states and transitions, with infectious states in red. States under the blue arrow experience worse health-related quality of life (HRQoL) and increased risk of tuberculosis or death. C: States representing tuberculosis preventive therapy (TPT). The full compartmental model is the product of these three domains, comprising 5 × 8 × 3 = 120 ordinary differential equations.

population to include standard tuberculosis states, including subclinical and clinical tuberculosis disease, but also tracking those with previous tuberculosis disease as experiencing worse health-related quality of life (HRQoL) and higher risks of tuberculosis disease or death (Fig. 1B). We further stratified the states by tuberculosis preventive therapy (TPT) status (naive, current, previous; Fig. 1C), for a system of $5 \times 8 \times 3 = 120$ states. Tuberculosis transmission within the prison system is assumed to be driven by untreated tuberculosis disease among those imprisoned, with random mixing. Community transmission once released is represented as a single generation of transmission and disease. Sensitivity analyses consider a fixed (static) force-of-infection in incarcerated populations and neglecting community transmission. For full details, see Appendix 1.2. Evidence supporting tuberculosis model parameters (Appendix Table A8) was identified based on knowledge of the literature and additional ad hoc searches.

Decision tree models of care pathways and intervention

To estimate the economic costs and outcomes of care, we developed decision tree models based on UK clinical and public health guidelines and discussions with practitioners. Three separate but linked pathways were represented: 1) screening for tuberculosis on first reception at prison; 2) tuberculosis infection screening and management pathway; and, 3) management of imprisoned people who develop tuberculosis symptoms.

The initial tuberculosis risk assessment should be done within 48 h of arrival by verbal symptom screening and can include a chest X-ray where facilities exist, although X-ray rarely happens in practice. People who screen positive are evaluated for tuberculosis disease by physicians, typically involving clinical assessment, laboratory investigations and possibility for referral to the local NHS tuberculosis service. Individuals diagnosed with tuberculosis disease should start anti-tuberculosis therapy (ATT); those for whom tuberculosis disease has been excluded enter the second pathway, which may result in their initiating tuberculosis preventive therapy (TPT) if diagnosed with tuberculosis infection. The final pathway applies to those who develop tuberculosis symptoms while imprisoned, and may involve referral to local NHS tuberculosis services and may trigger contact tracing if tuberculosis disease is diagnosed. See Appendix 1.3 for details.

Usual care is assumed to involve low screening on imprisonment and is compared with higher coverage of screening (Fig. 1A). Decision trees were operationalized in R, and for each input parameter set the fraction and cost of a cohort entering the pathway that ended in ATT, TPT, or no treatment were outputted, stratified by tuberculosis status (disease, infection but not disease, neither). These outputs were used to represent care pathway outcomes in the transmission model.

Economic and analytical approach

In England, people in prison access healthcare through the NHS, similar to the general population, with some services commissioned within prisons and others provided outside the prison estate. While the NHS covers the cost of all healthcare services, the prison service is responsible for escort and security expenses during off-site appointments. The cost analysis primarily used a health system perspective following World Health Organisation guidelines,[17] but identified and included prison service costs relevant to prison-based healthcare interventions. Resources required for activities along the care pathways were identified and the quantities of the resources estimated based on guidelines or literature. Resource use was valued by multiplying the resource use and relevant unit costs in 2021 Great British Pounds (£). Unit costs were obtained from relevant sources such as NHS reference costs, Personal Social Services Research Unit costs, prison-based pilot projects and literature. See Appendix 1.4 for details.

We quantified health benefits as quality-adjusted life-years (QALYs) that summed life-years lost due to deaths caused by tuberculosis and reductions in HRQoL, during tuberculosis disease and among tuberculosis survivors. We assumed a life-expectancy without tuberculosis of 40 years. This was chosen as representative of the life expectancy in England at ages typical of people in prison or developing tuberculosis, and applied to both community contacts and people who have entered prison.

Because tuberculosis disease can result many years after an exposure, both costs and benefits were accrued over a 70 year time horizon after introducing the intervention, with 3.5% discounting applied to both in base case in line with the NICE reference case. A cost-effectiveness threshold of £30,000 per QALY gained was used to demark cost-effectiveness and in calculating net monetary benefit. Net monetary benefit aggregates economic costs and health benefits using a common unit of utility to compare interventions. Net monetary benefit for introducing an intervention is positive if and only if the intervention is cost-effective.

All model parameters were treated as uncertain within a probabilistic sensitivity analysis (PSA) framework. A sample with replacement of 10,000 parameters from the MCMC analysis of detention flows was merged with samples of the same size from decision tree outputs, and a sample of tuberculosis natural history and epidemiological parameters. These distributions are specified in the Appendix Tables A8, 11–13. For each parameter set, the transmission model was run towards equilibrium for 50 years to avoid transients, and then costs and benefits captured under the continuously-

maintained intervention and usual care. As analysis variants, we restricted our PSA samples to inputs that resulted in per capita tuberculosis notification rates among imprisoned people of between 30 and 100 per 100,000 person years. This range was intended to represent a plausible range of notification rates for the UK, motivated by considering the interval estimates of tuberculosis incidence per 100,000 incarcerated people in UK in Martinez et al.,[2] (34–342) and the global incidence rate ratio estimate in Cords et al.[1] applied to the notification rate in England (65–111).

We present results on the intervention TPT and ATT treatment cascades, and the proportion and average cost of TPT, ATT, or no treatment under intervention and usual care for those with tuberculosis disease, infection, or neither. We also present total and incremental ATT and TPT courses, associated costs, and tuberculosis incidence, mortality and quality of life loss. Finally we computed net monetary benefit and incremental cost-effectiveness ratios (ICERs).

Targeted screening and sensitivity analyses

To consider the effect of targeting tuberculosis screening we modelled strategies targeting only higher risk groups among new receptions to prison. We parameterized the performance of two specific exemplar strategies highlighted based on biobehavioral survey data among imprisoned people, namely screening only those: 1) born in countries with estimated tuberculosis incidence ≥40/100,000 person-years; or 2) additionally, those with a history of homelessness, injecting drug-use, or problematic alcohol use. We modelled targeting as a zero-cost pre-screen step and present net monetary benefits across a range of sensitivities and specificities using a threshold of £30,000/QALY gained. Target group size and relative tuberculosis infection prevalence define an equivalent sensitivity and specificity for the pre-screening step of the strategy considered (see Appendix 1.6 and 7).

To understand the impact of particular assumptions, we ran sensitivity analyses in which we set to zero: cascade loss to follow-up for prison GP assessments, NHS attendance, treatment initiation, and treatment completion; cascade costs associated with escorts out of prison; community transmission; all transmission (fully static analysis); all transmission and all post-tuberculosis effects.

Role of the funding source

This work was funded by the UK Health Security Agency (UKHSA) Health Equity and Inclusion Health Division, using a model prototype funded under MRC (MR/W029227/1). UKHSA members acted as co-authors advising on design, data, interpretation and writing the report. Ethical approval was not required for this modelling study using aggregate data.

Results

Using data from pilot studies on enrollment and retention through the ATT and TPT cascades in our model, suggested that even with full coverage of screening, 31% of those eligible for ATT and 24% of those eligible for TPT would make it through to treatment completion (Fig. 2). Under our sensitivity analysis assuming no loss to follow-up, we found corresponding treatment completion rates of 69% and 44%, respectively.

The outcomes of these cascades are reflected in Table 1, which was used to represent the interventions in the transmission model. Table 1 also includes the probabilities of inappropriate treatments, as well as the unit costs for each tuberculosis state/treatment pair. Inappropriate treatment is rare, but often results in substantially larger unit costs due to typically longer routes through diagnosis to treatment.

We projected the intervention to result in substantial increases in TPT use: an increase of 460 (95% uncertainty interval [UI]: 220–765) courses per 10,000 people eligible for screening (Table 2). The net effect on ATT courses was a smaller increase of 80 (95% UI: 10–152) courses per 10,000 people eligible for screening, despite a reduction in tuberculosis incidence of 43 (95% UI: 11–113) per population. These increases in treatment, together with the increased resources for screening and diagnosis resulted in a net increase in economic costs of £96,744 (95% UI: £69,130–£127,305) per 10,000 people screened.

These efforts were projected to result in reduced mortality of 7 (95% UI: 2–18) per 10,000 people screened, and gains in HRQoL of 8 (95% UI: 2–25) per 10,000 people screened, which together implied gains of 47 (95% UI: 12–124) QALYs. Comparing the increased resources and health gains produced a base case ICER of £78,000 per QALY gained, in excess of the usual UK cost-effectiveness thresholds (Table 2). The sensitivity analysis assuming no loss to follow-up yielded an ICER of £70,000/QALY gained; the sensitivity analysis assuming no escort costs in care cascades yielded an ICER of £54,000/QALY gained. The sensitivity analyses neglecting transmission and post-tuberculosis effects resulted in higher ICERs (see Appendix Table A14). The analysis variants restricting to tuberculosis notification rates in the range 30–100 per 100,000 resulted in higher ICERs: £168,000/QALY gained for the base case; £153,000/QALY gained for no loss to follow-up; £118,000/QALY gained for no escort costs.

Exploring a range of target group size and tuberculosis infection prevalence for a zero-cost pre-screen, showed that higher target group tuberculosis infection prevalence and smaller target group size resulted in larger net benefit (Fig. 3) Biobehavioral survey data suggested that tuberculosis infection prevalence was 20% in target group 1) and 8% in target group 2),

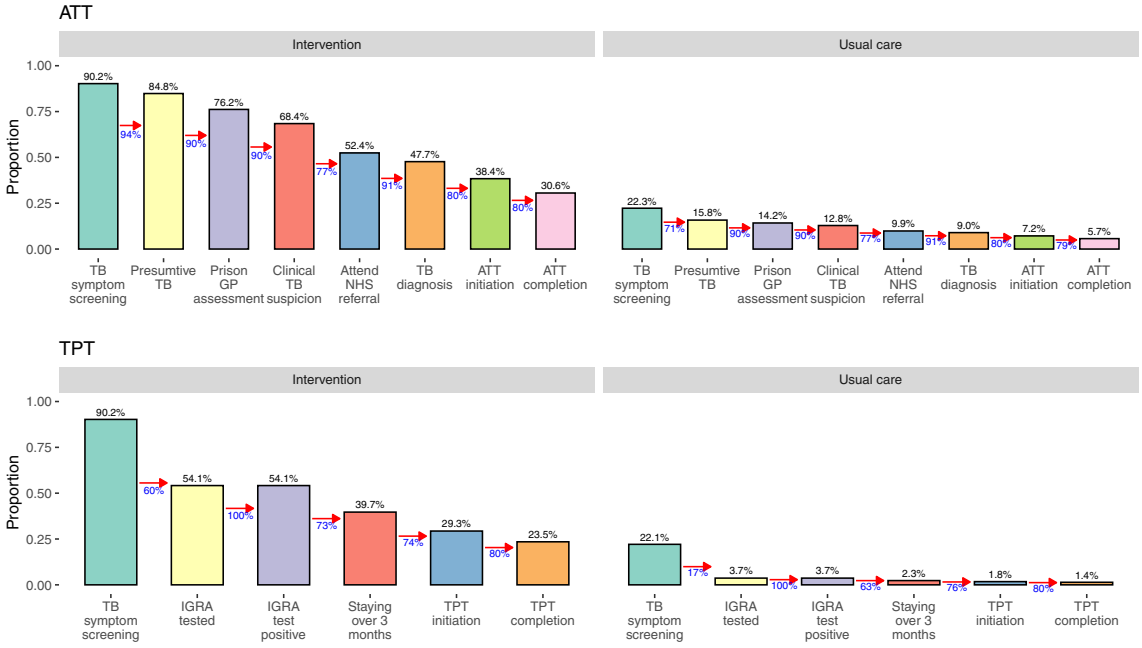

Fig. 2: Intervention cascades. ATT, anti-tuberculosis treatment (for disease); TPT, tuberculosis preventive treatment; TB, tuberculosis; GP, general practitioner; NHS, National Health Service; IGRA, interferon gamma release assay (for tuberculosis infection).

compared with 7% among all new receptions.[13] These groups were estimated to comprise 6% and 20% of the screening group, respectively (Appendix 1.7). These values correspond to a positive net benefit for target group 1), which was cost saving (Fig. 3) because the screening costs were smaller than the reduction in costs associated with managing subsequent tuberculosis in prison and the community. Targeting group 2), the net benefit was negative, and therefore not cost-effective at a threshold of £30,000/QALY gained (Fig. 3). Net monetary benefit does not indicate whether an intervention is cost-saving.

Discussion

Our model-based cost-effectiveness analysis of tuberculosis infection screening and TPT on first reception into prisons in England found that non-targeted screening would not be cost-effective at the upper end of typical recommended UK cost-effectiveness thresholds. However, we found that targeting interventions using a zero-cost pre-screening step to select who is screened further has the potential to yield a cost-effective intervention. One specific example we considered, parametrized with survey data—namely applying the intervention to those born in medium or high

Arm	Quantity	Outcome/State[a]	TB disease	TB infection[b]	TB uninfected
Usual care	Probability	ATT	7.2% (1.8%–16%)	0.4% (0.1%–0.9%)	0.3% (0.1%–0.7%)
		TPT	0% (0%–0%)	1.7% (0.1%–6.2%)	0% (0%–0%)
		neither	92.8% (84%–98.2%)	97.9% (93.1%–99.9%)	99.7% (99.3%–99.9%)
	Unit cost	ATT	£28,305 (£23,558–£34,009)	£45,092 (£35,291–£60,447)	£44,775 (£34,830–£61,738)
		TPT	–	£9199 (£4691–£21,773)	–
		neither	£487 (£113–£1157)	£96 (£16–£249)	£70 (£16–£158)
Intervention	Probability	ATT	38.4% (19.7%–55.7%)	1.2% (0.5%–2%)	0.8% (0.3%–1.4%)
		TPT	0% (0%–0%)	29% (13.9%–44.4%)	0% (0%–0%)
		neither	61.6% (44.3%–80.3%)	69.8% (53.9%–85.3%)	99.2% (98.6%–99.7%)
	Unit cost	ATT	£28,257 (£23,585–£33,834)	£59,905 (£43,647–£92,133)	£53,402 (£38,037–£84,837)
		TPT	–	£3855 (£3049–£5083)	–
		neither	£3953 (£1755–£7649)	£794 (£485–£1191)	£240 (£188–£296)

The cohort proportion and average cost by outcome and tuberculosis state at entry. Parentheses denote 95% quantiles around mean. TPT, tuberculosis preventive therapy; ATT, antituberculosis therapy; TB, tuberculosis. [a]Excluding those on ATT or TPT. [b]Excluding TB disease.

Table 1: **Screening pathway results.**

tuberculosis incidence countries—resulted in an intervention that was not only cost-effective, but cost-saving due to tuberculosis management costs averted in prisons and the community.

The low cost-effectiveness of the intervention when applied without targeting stems from the relatively low prevalence of tuberculosis infection in English prisoners, the difficulty of achieving high completion of TPT in this population, and the high cost of prison-specific elements of the cascade of care. Recent survey data suggest that prisoners in England have IGRA positivity rates of 7%.[13] While this prevalence is substantially higher than the general population, it remains below the estimated global average, and much below estimates for incarcerated individuals in high tuberculosis incidence settings. Using drop-offs in our modelled care cascade based on pilot data (Fig. 2), we found that only 38% of those offered TPT ultimately received and completed a course. Finally, any care components that require prisoners to be securely escorted out of detention for treatment or assessment in hospitals are extremely costly due to costs associated with required prison staff escorts and bedwatch duties, and contribute to unit costs for assessment and treatment being higher than seen in the community.

Our analysis had limitations concerning the data available to parametrize flows through the prison system, the epidemiology of tuberculosis, and for parameterizing exploration of targeted screening. We did not have data on durations and flows between categories of UK prison, but instead made use of publicly available data and a Bayesian approach that dealt with the underdetermined nature of the problem. Doing this allowed a prison model that captured overall durations of detention, but would be less reliable for interventions targeted by sentence or prison type. We were not able to model the fraction of the inflow who had previously been incarcerated, nor were we able to consider targeted interventions focussing on those entering prison with a history of homelessness or substance misuse separately.

Quantity	Usual care	Intervention	Incremental
TPT courses	25 (1–94)	485 (238–807)	460 (220–765)
ATT courses	412 (69–1279)	492 (150–1324)	80 (10–152)
Undiscounted costs	105,852 (24,495–301,280)	202,596 (112,044–393,005)	96,744 (69,130–127,305)
Incident TB	703 (98–2285)	659 (83–2185)	−43 (−113 to −11)
TB deaths	126 (20–408)	120 (18–390)	−7 (−18 to −2)
Life-years lost to TB (discounted)	904 (150–2951)	866 (139–2873)	−39 (−104 to −10)
QoL lost to TB (discounted)	294 (47–1010)	286 (45–985)	−8 (−25 to −2)
QALYs lost to TB	1199 (227–3821)	1152 (212–3707)	−47 (−124 to −12)

TPT, tuberculosis preventive therapy; ATT, antituberculosis therapy; TB, tuberculosis; QoL, quality of life (due to tuberculosis morbidity but not mortality); QALYs, quality-adjusted life-years (including both life-years lost and morbidity). Parentheses denote 95% quantiles around mean.

Table 2: **Resource use and health benefits per 10,000 people.**

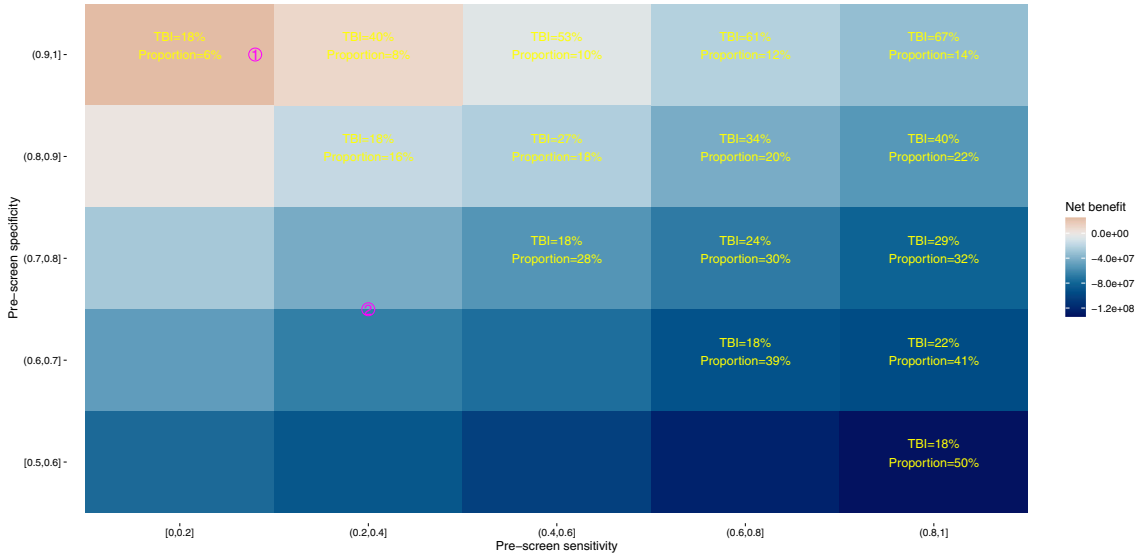

Fig. 3: Monetary net benefit for targeted screening approaches. For each pre-screen sensitivity and specificity midpoint, yellow text shows the corresponding tuberculosis infection (TBI) prevalence and proportional size of the group screened-in for further assessment. Fill colour shows the mean expected net monetary benefit for each tile, with red colours corresponding to positive net benefit (i.e. cost-effective at a threshold of £30,000 per quality-adjusted life-year gained); blue colours correspond to negative net monetary benefit. Net monetary benefit does not indicate whether an intervention is cost-saving. Magenta numbers ①, ② locate the likely location of exemplar target groups defined in the text.

There was limited data to inform tuberculosis transmission within prisons, and community incidence and transmission of tuberculosis associated with previously incarcerated individuals. However, our transmission model did take into account reductions of transmission within prison and subsequent community transmission was represented over a single generation. While a single generation of community transmission may miss some benefits, it is likely to capture most indirect effects due to declining tuberculosis rates and the use of discounting for costs and benefits. We did not undertake systematic reviews to inform all model parameters. Furthermore, we explored many of these features with sensitivity analyses and found our conclusions qualitatively unchanged. The sensitivity analysis restricting to results with plausible but lower tuberculosis notification rates resulted in higher ICERs due to the more limited potential for health benefits from the intervention. Our analysis is very specific to English prisons, but some of our results will have relevance to other low tuberculosis incidence settings.

Additional survey data on social risk factors and comorbidities could help identify other high risk groups. A more complete understanding of individuals' overlapping social risk factors and patterns of engagement with health and social care over time would allow a better assessment of the interaction between public health policies aiming to engage at different entry points. This understanding would allow assessment of broader strategies for improving health and reducing inequalities for these high risk groups in a coordinated fashion.

Although there have been no previously published economic evaluations considering incarcerated individuals in the UK, cost-effectiveness analyses have been undertaken in other settings. In 2012, Winetsky et al.[18] applied a transmission model to consider active case finding (ACF) strategies in the prisons in the former Soviet Union, with very high tuberculosis prevalence and extremely high rates of drug-resistance, and found that annual ACF rounds for tuberculosis disease were optimal. Since then, Kim et al.[19] considered digital X-ray for tuberculosis disease screening among people entering detention in South Africa, finding an ICER of 22,000 USD using a decision tree model. Smit et al.[20] considered screening for tuberculosis disease in Belgium finding ICERs of around 12,000 EUR per person identified with tuberculosis disease. The most comparable existing study to ours is Jo et al.,[21] which undertook a cost-utility analysis of TPT in various target groups including prisoners for several US states using a transmission model. Jo et al. found ICERs ranging between 43,000 and 110,000 USD/QALY excluding New York, but did not consider prison-specific costs of care. Liu et al.[4] have recently modelled the contribution of mass incarceration to tuberculosis transmission in Latin America, but did not consider interventions. Others have considered screening and TPT for formerly incarcerated people.[22] A major strength of our work is a costing based on detailed prison-specific pathways of care, which account for the specific details of healthcare delivery in prisons.

Key challenges remain in designing effective and cost-efficient interventions in prison populations. Although pilot data exist, the proportion of people who will accept screening, and how this varies with risk is poorly known. Designing approaches which are acceptable and maximize participation is a priority. High rates of churn and short durations of detainment in remand mean investigations need to be rapid or have good referral linkages so as not to compromise completion rates. Costs associated with escorted trips out of prisons, which are also inefficient due to high cancellation rates, may be reduced by use of mobile X-ray kit and teams that can visit prisons and follow-up by telemedicine appointments. Investment to support staff and build capacity may be needed for successful adoption.[23] Finally, combining screening interventions across other conditions such as hepatitis C virus etc. may allow for economies of scope that bring down costs. Additional data, modelling, and piloting could help design such strategies, and should consider impacts on equity. If appropriate data were available, distributional cost-effectiveness analysis could allow assessments between efficiency and equity. It is possible that there are additional costs beyond health care and prison estate that we have not been able to capture. Adoption of a societal perspective could capture benefits such as increased productivity, which we did not include. We were not able to stratify by sex or ethnicity in this analysis.

People in contact with the criminal justice system are an inclusion group identified for prioritization as part of NHS England's Core20PLUS approach to reducing health inequalities. Moreover, people incarcerated in the UK have the right to an equivalent level of healthcare under the Mandela rules, the Council of Europe European Prison Rules, and the WHO framework on Health in Prisons.[24] In order to achieve equivalence of care, the additional costs of surmounting the particular barriers and meeting the additional needs of those under the care of the state within the prisons system may require different willingness to pay than interventions for the general population. The intervention we have modelled includes an increase in detection and treatment of tuberculosis disease around reception from very low projected rates under the current usual care. Irrespective of the cost-effectiveness of the intervention package, this shortfall in identifying people who need treatment represents a missed opportunity and a potential failure to meet their rights to equitable care.

Tuberculosis screening for those born in medium and high tuberculosis incidence countries entering prison is expected to be cost-saving as well as benefiting

health. Consideration would need to be given to acceptability, equity, and avoiding stigmatization in decisions around adoption and design of targeted screening. Further work should seek to design other targeted screening approaches that are also cost-effective. Cost-effectiveness could also be improved by approaches to screening and provision which increase acceptability and completion, and through delivery models that reduce prison-specific costs.

Contributors

Designed and implemented analysis: NM, PJD, with input from all authors. First draft of article: NM, PJD. Data analysis NM, PJD, SW, CFF. Review of methods and results: RH, CFF, TF, AR, CE. Edited article and consented to submit: all authors. NM and PJD had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Data sharing statement

All code and data to reproduce this analysis are publicly available on GitHub at https://github.com/nmafirakureva/PPDpathways. The transmission model used in this analysis is available as an R package on GitHub at https://github.com/petedodd/ecrins.

Declaration of interests

PJD: funding to institution from UKHSA, MRC. RH: consulting fees from UK MoJ, University of Nottingham, University of Sheffield; payments in project review roles from EU H2020; membership of NIHR Dementia Policy Research Unit & NIHR Evidence Synthesis hub. TF: employed by UKHSA, chair of school governors. CE: employed by UKHSA.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2025.103245.

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