VoxSanguinis
The International Journal of Transfusion Medicine
ISBT International Society of Blood Transfusion
Vox Sanguinis (2018)

ORIGINAL PAPER

DOI: 10.1111/vox.12741

Modelling the risk of transfusion-transmitted syphilis: a reconsideration of blood donation testing strategies

Thisuri Jayawardena,[1] Veronica Hoad,[2] Claire Styles,[2] Clive Seed,[2] Peter Bentley,[1,2] Vanessa Clifford,[3] Sarina Lacey[4] & Tessa Gastrell[4]

[1]*Faculty of Health and Medical Sciences, University of Western Australia, Perth, WA, Australia*
[2]*Australian Red Cross Blood Service, Perth, WA, Australia*
[3]*Australian Red Cross Blood Service, Melbourne, VIC, Australia*
[4]*Centre for International Economics, Sydney, NSW, Australia*

Vox Sanguinis

Background and Objectives Donor syphilis testing began in the 1940s amidst widespread transfusion-transmitted syphilis (TTS). Since then, the introduction of penicillin, pre-donation screening questionnaires and improved storage conditions have contributed to reducing transmission risk. Consequently, universal testing may no longer be cost-effective. This study analysed alternative options for donor syphilis testing to determine the optimal strategy.

Materials and Methods A model was developed using conservative parameter estimates for factors affecting TTS and 2009-2015 Australian donations to calculate risk outcomes (TTS infections, tertiary syphilis in recipients and transfusion-associated congenital syphilis) and cost-effectiveness of alternative testing strategies. The strategies modelled were as follows: universal testing, targeted-testing of high-risk groups (males ≤50 years old and first-time donors) and no testing.

Results The estimated risk of TTS is one in 49·5 million transfusions for universal testing, one in 6 million for targeted-testing of males ≤50 years old, one in 4 million for targeted-testing of first-time donors and one in 2·8 million for no testing. For all strategies, the risk of tertiary and congenital syphilis is <1 in 100 million. Universal testing is the least cost-effective strategy with an incremental cost-effectiveness ratio (ICER) estimated at $538·5 million per disability-adjusted life year averted.

Conclusion Universal testing is not required to maintain the risk of TTS within tolerable limits and is estimated to greatly exceed acceptable ICERs for blood safety interventions. However, despite a strong economic and risk-based rationale, given the epidemiology of syphilis in Australia is changing, feedback from critical stakeholders is not currently supportive of reducing testing.

Received: 16 May 2018, revised 8 October 2018, accepted 20 November 2018

Key words: blood donation testing, blood safety, residual risk estimation, syphilis, transfusion-transmissible infections.

Introduction

Historically, interventions in the blood-banking sector have sought to reduce all possible harm from transfusion, but the economic unsustainability of this approach is increasingly recognised [1]. One practice that continues in most developed countries is donor serological testing for syphilis (STS). In Australia, universal blood donor testing using the *Treponema pallidum* Haemagglutination Assay (TPHA) is current practice, but its contribution to risk reduction is unknown [2].

No cases of transfusion-transmitted syphilis (TTS) have been reported in developed countries for almost 40 years [3]. In contrast, 138 documented cases between 1915 and

Correspondence: Veronica Hoad, Australian Red Cross Blood Service, 290 Wellington St, Perth WA 6000, Australia
E-mail: vhoad@redcrossblood.org.au

1941 worldwide formed the background on which donor testing was introduced in the 1940s [4]. Since then, the risk of collecting an infectious donation has been reduced by deferral of high-risk donors through pre-donation questionnaires, lower syphilis incidence in the general population and education programs encouraging self-deferral of unwell individuals [2, 3]. Storage of blood products has further decreased transmission risk; red cell storage at <20°C for >120 h inactivates spirochaetes [5–7], plasma stored at −20°C for 48 h was shown to be non-infectious in an animal model [8], and oxygen flow levels in platelet storage bags are believed to be toxic to *Treponema pallidum* [2]. Hence, the infectivity of transfused products is expected to be low even without STS.

The consequences of TTS are also now expected to be less severe. Widespread antibiotic use in hospitalised patients may inadvertently prevent syphilitic infection post-transfusion. If recognised, an incidental case of TTS could be treated cheaply and effectively with antibiotics [3], but failure to accurately diagnose syphilitic symptoms or asymptomatic seroconversion puts recipients at risk of developing tertiary disease [2]. Transfusion recipients are, however, disproportionally skewed towards older age groups [9] who may not survive the 10–20 years typically required to develop tertiary syphilis [10]. Even without treatment, two-thirds of patients will not progress to tertiary disease [10].

Serological assays have several limitations which complicate their use in donor screening. For treponemal STS assays, such as TPHA, positive results occur even after successful treatment and in the latent stages of disease, when syphilis is not considered transfusion-transmissible [2]. Biological false reactive results also occur in individuals with autoimmune diseases, viral infections and several other conditions [2]. Failure to identify donors in the window-period is another limitation, as antibodies are typically not detectable in the first 2–6 weeks of infection, when donor infectivity is believed to be highest [11].

Given these issues, universal donor syphilis testing is unlikely to be cost-effective or necessary to ensure safety of the blood supply in developed countries. In addition, it has very little, if any value as a surrogate for incident human immunodeficiency virus infections [12]. Therefore, alternative syphilis testing strategies warrant consideration. Denmark and Iceland do not test donations for syphilis [13] and do not have pathogen inactivation to reduce TTS risk [14]; however, their risk of TTS may be reduced due to lower disease incidence compared to other developed countries [15]. Targeted-testing of first-time donors is the current syphilis screening strategy in Norway [16]. Targeted-testing, whereby screening is limited to high-risk donors, is a cost-saving alternative with potentially minimal increase in risks to recipients. For syphilis, most international regulatory agencies have repeatedly cited insufficient scientific data and contemporary changes in syphilis epidemiology as the reason for retaining universal donor testing [2, 3].

This study models the residual risk and cost-effectiveness of donor syphilis testing in Australia, comparing universal donor testing, no testing and targeted-testing for syphilis to determine the optimal strategy. These two assessments are part of the core decision-making process for blood safety as outlined in the Alliance of Blood Operators' Risk-Based Decision-Making Framework [17]. To the best of our knowledge, this is the first study to generate a model for TTS risk in a developed country. A sensitivity analysis is included to reflect rising syphilis incidence since the mid-2000s in developed countries including Australia [18].

Materials and methods

Data collection

Syphilis screening test results for blood donations made in the period 1 January 2009–31 December 2015 were extracted from the Australian Red Cross Blood Service (Blood Service) National Blood Management System and analysed retrospectively. A 7-year period was selected for analysis due to low disease incidence in donors and significant inter-year variation. All donations were screened for antibodies to *T. pallidum* using the Beckman-Coulter PK®TP system (Brea, CA), a microhaemagglutination test run on the automated Beckman-Coulter PK 7300 analyser.

Donations testing positive on an initial plasma sample and at least one duplicate serum sample underwent confirmatory testing at an external reference laboratory. Additional confirmatory testing varied by state reference laboratory, but always included an alternative additional treponemal test and a non-treponemal test (Figure 1). Donations that were not confirmed as positive by an alternative assay (i.e. biological false reactive) were excluded from the analysis. This was to ensure the study was applicable in future following the Blood Service's imminent introduction of a second-line screening test (an EIA) that will decrease the number of false positive results. To identify cases of potentially infectious syphilis (PIS), which excluded past treated and probable late latent infections that are assumed to be non-infectious, confirmatory test results were reviewed along with donor risk information. Repeat donors were considered to have PIS if they had seroconverted within the last 2 years (TPHA negative to positive) with a positive confirmatory result, or had a history of syphilis treatment since their last TPHA non-reactive donation and infectious syphilis at the time of that donation cannot be conclusively ruled out, or were previously known to have past treated

syphilis and subsequently had possible reinfection (four-fold RPR titre rise). First-time donors were considered to have PIS if screening and confirmatory tests for treponemal antibodies were positive, in addition to RPR titre >8 or clinical evidence (signs of syphilis) or recent contact with a confirmed case.

Selection of targeted-testing strategies

Age, sex and first-time vs. repeat status of the PIS donors were compared to that of the overall donor population using Fisher's exact test to identify risk factors for making a PIS donation. Potential donor criteria for targeted-testing strategies were selected from the identified risk factors. For each potential strategy, the proportion of PIS donations that would have been captured in 2009–2015 vs. total donations that would have been tested were calculated. From this analysis, two targeted-testing strategies that maximised the former proportion and minimised the latter were selected for further modelling: a less conservative but potentially cheaper option (targeted-testing of first-time donors) vs. a more conservative and expensive option (targeted-testing of males ≤50 years old).

In September 2016, the Blood Service ceased syphilis testing of plasmapheresis donations intended solely for fractionated plasma products, as syphilis is not a required test and bacterial infectivity is eliminated during the manufacturing process [19]. To account for this change and to provide accurate future estimates, the risks calculated from 2009 to 2015 were applied to donations intended for fresh component manufacture in 1 January–30 June 2017.

Risk model

A model was developed to simulate the risk of TTS under the four donor testing strategies: universal testing (current strategy in Australia), targeted-testing of males ≤50 years old, targeted-testing of first-time donors and no testing. The model begins with the annual risk of collecting a PIS donation expected to test positive (based on the 2009–2015 donation data). This risk was modified using parameter estimates for the various factors affecting TTS (including impact of storage, window-period infections and concomitant antibiotic use in hospitalised recipients). Parameter estimates were identified from the existing literature and are summarised in Table 1. Due to the range of reported values for most parameters and uncertainty in the underlying research studies, a 'low estimate', 'middle estimate' and 'high estimate' for each parameter was chosen from the available literature

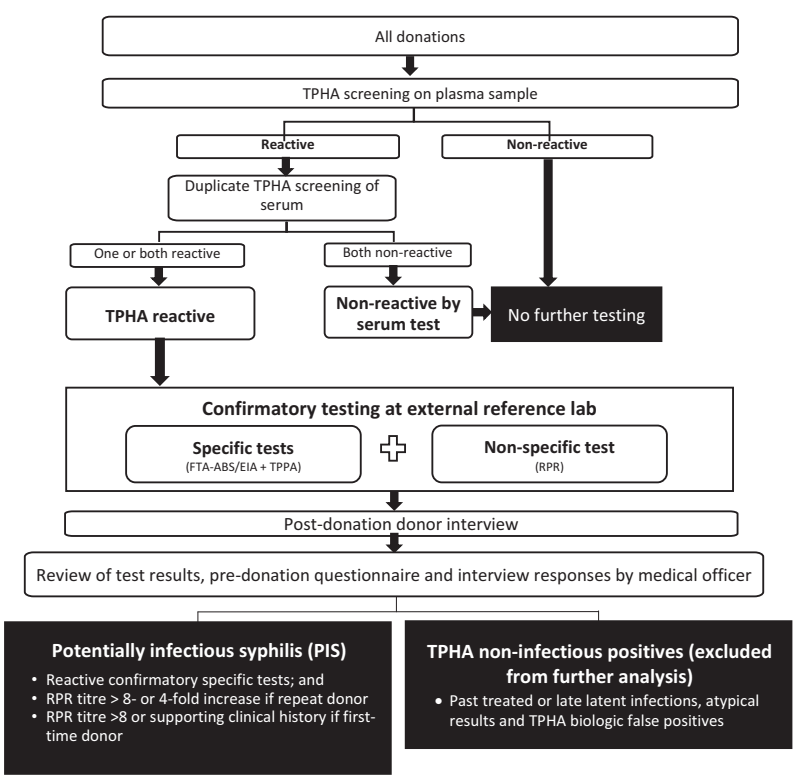

Fig. 1 Blood Service donor syphilis testing algorithm and interpretation 2009-2015. EIA, enzyme immunoassay; FTA-ABS, fluorescent treponemal antibody absorption test; RPR, rapid plasma reagin; TPHA, *Treponema pallidum* haemagglutination assay; TPPA: *T. pallidum* particle agglutination assay.

representing a 'best-case', 'most-likely' and 'worst-case' scenario, respectively (see Supporting Information for details). For each strategy, a corresponding range of risk outcomes was calculated: the primary outcome was the risk of TTS infection in recipients; secondary outcomes were the risk of subsequent tertiary syphilis in a recipient and risk of congenital syphilis from transfusion in pregnant women. See Supporting Information for a schematic overview of the model showing the impact of the parameter estimates on the calculation of risk outcomes.

Risk tolerability assessment

The Blood Service has an internal risk tolerability framework that classifies syphilis as a high severity agent with a tolerable risk level of <1 in 1 million transfusions. This level was considered when assessing the acceptability of modelled risks.

Cost-effectiveness analysis

Estimates and data sources for the parameters used in cost-effectiveness modelling are summarised in Table 2. For each testing strategy, the combined costs of Blood Service syphilis screening tests and treatment for potential cases of symptomatic acute TTS (secondary syphilis), tertiary syphilis and congenital syphilis were considered. The costs of discarded components due to false positives, medical time and other indirect costs were not included in the model.

Results from the risk analysis were utilised to calculate the potential health impact on recipients. The health impact of TTS infection was morbidity associated with symptomatic secondary syphilis occurring in a proportion of cases. The health impacts of transfusion-associated tertiary and congenital syphilis were disease-related morbidity and mortality. Morbidity was quantified into years of life lost due to disability (YLD) and death was quantified into years of life lost due to premature death (YLL); these were combined to give the overall health impact for each strategy, measured in disability-adjusted life years (DALYs).

For estimating cost-effectiveness, total costs and DALYs associated with each strategy were calculated over a 50-year period (to sufficiently capture delays between infection and tertiary syphilis manifestations). The overall outcome was the incremental cost-effectiveness ratio (ICER; measured as $/DALY averted) calculated for universal and targeted-testing strategies compared to the no testing strategy. To reflect the rising trend of syphilis incidence in Australia, ICERs were also calculated under a twofold and tenfold increase in TTS cases (see Supporting Information for further explanation and equations).

Results

Screening data

Of 9 221 194 donations made during the 7-year period, a total of 584 (0·0063%) donors met the confirmed case definition of syphilis with only 35 (5·99% of confirmed positives) donors with PIS identified. First-time and repeat donors represented 8·4% and 91·6% of overall donations and 43% (15 cases) and 57% (20 cases) of PIS donations, respectively. Identified risk factors associated with testing positive for PIS were first-time donation (relative risk [RR] 8·15, $P < 0·05$), male (RR: 2·38, $P < 0·05$) and age ≤50 years old (RR: 2·84, $P < 0·05$). See Supporting Information for further details.

Risk outcomes

Modelled risks under each testing strategy are given in Table 3. The middle estimates of TTS per component transfused ranged from 1 in 49·5 million (0·0189 cases per year) under universal testing to 1 in 2·8 million (0·333 cases per year) under no testing. Based on middle estimates for all testing strategies, the modelled risk of transfusion-associated tertiary syphilis in recipients was <1 in 100 million transfusions and the risk of transfusion-associated congenital syphilis was <1 in 500 million births. All strategies returned tolerable risk levels, except for the high TTS estimates of no testing and targeted-testing of first-time donors. The performance of each strategy is outlined in Table 4.

Cost-effectiveness analysis

In testing costs alone, the most expensive strategy is universal testing (AUD $4·40 million per year), followed by targeted-testing of males ≤50 years old ($1·39 million) and first-time donors ($530,000). Under the current level of syphilis incidence, universal testing relative to no testing has an ICER of $538·5 million/DALY averted. Targeted-testing of first-time donors is the most cost-effective strategy in the low risk ($3·62 billion/DALY averted) and middle risk ($206·5 million/DALY averted) estimate scenarios. Targeted-testing of males ≤50 years old is the most cost-effective strategy under the high-risk estimate scenario ($62·2 million/DALY averted).

Sensitivity analysis showed that with a twofold or tenfold increase in TTS infections the ICERs remain very high with universal testing, estimated at $53·9 million/DALY averted with a tenfold increase (see Supporting Information).

Table 1 Input variables contributing to clinical consequences of donations with potentially infectious syphilis

	Low estimate	Middle estimate	High estimate	Data source
Donation risks				
Mean TPHA window period	14 days	30 days	45 days	Clinical practice guidelines [32, 33], [11]
Length of donor infectivity	1 year	1 year	2 years	Clinical practice guidelines [32, 33]
Percentage of repeat donations used for fresh component manufacture	56·3%	56·3%	56·3%	Blood Service internal manufacturing data
Percentage of PIS donors who are bacteraemic at time of donation	1·02%	11·62%	22·22%	[34, 35]
Storage and transfusion risks				
Percentage of *Treponema pallidum* survival in stored red cells	4·31%	5·42%	6·79%	[5–7]
Percentage of *T. pallidum* survival in stored clinical plasma	0%	0·37%	1·34%	[8]
Percentage of *T. pallidum* survival in stored platelets	85·9%	85·9%	100%	[36, 37]
Percentage of manufactured red cells transfused	97·3%	97·3%	97·3%	National Blood Authority Fate Database
Percentage of manufactured clinical plasma components transfused	89·7%	89·7%	89·7%	National Blood Authority Fate Database
Percentage of manufactured platelets transfused	87·2%	87·2%	87·2%	National Blood Authority Fate Database
Recipient risks				
Percentage of recipients not receiving sufficient antibiotic cover while in hospital	97·1%	97·1%	97·1%	2014 National Antimicrobial Usage Report (Australia) [38]
Percentage of recipients surviving long enough to develop tertiary syphilis	22·6%	32·55%	42·5%	[39]
Percentage of recipients progressing to tertiary syphilis	6·52%	6·52%	6·52%	Calculated using data from the National Notifiable Diseases Surveillance System [26] and National Hospital Morbidity Database [40]
Congenital syphilis risks				
Percentage of women receiving transfusions during pregnancy	0·124%	0·124%	0·124%	[41]
Average number of components given to a transfused pregnant woman	7·75	7·75	7·75	[41]
Annual births in Australia	305377	305377	305377	Australian Bureau of Statistics [42]
Risk of congenital syphilis in child of an infected mother	23%	51·5%	80%	[43]

Discussion

Our conservative modelling shows universal testing is not required to maintain the TTS risk at a tolerable level and is markedly less cost-effective than the other strategies analysed. For all modelled strategies, the risk of TTS is negligible based on middle estimates (representing the most likely risk scenario) and the risk of transfusion-associated tertiary syphilis or congenital syphilis is miniscule regardless. Targeted-testing of males ≤50 years old appears to provide the best combination of capturing PIS donations while significantly improving cost-effectiveness. Compared to universal testing, this strategy would intercept 70% of PIS donations at approximately 30% of the cost. A further advantage is maintaining the risk at a tolerable level across all estimates, including the conservative high-risk scenario.

One limitation of our study is the uncertainty in parameter estimates underlying the model owing to limitations in the quantity and quality of existing research. In particular, effective antibiotic coverage of recipients may be much higher than estimated. On average, 40% of hospitalised patients in Australia receive antibiotics on any given day [20], and recommended first- or second-line

Table 2 Input variables contributing to cost-effectiveness analysis

Parameter	Low estimate	Middle estimate	High estimate	Data source
Costs				
TPHA test: including consumables, labour (10%)[a] and overheads	$ 5·64 per test	$ 5·64 per test	$ 5·64 per test	Internal Blood Service data
Treatment cost: Benzathine benzylpenicillin pack 10 × 1016·6 mg pre-filled syringes with needle	$309·22 per treatment	$309·22 per treatment	$309·22 per treatment	Australian Pharmaceutical Benefits Scheme [44]
Disability weights				
Mild early syphilis infection	0·002	0·006	0·012	WHO Global burden of disease study 2015 [45]
Adult tertiary syphilis	0·134	0·203	0·29	WHO Global burden of disease study 2015 [45]
Congenital syphilis	0·315	0·315	0·315	WHO Global burden of disease study 2004 [46]
Secondary syphilis health outcomes				
Proportion of recipients with TTS that are symptomatic	38%	38%	38%	[47, 48]
Duration of symptomatic disease	0·07 years	0·07 years	0·07 years	[49]
Time to onset of symptoms	0 years	0 years	0 years	[50]
Proportion of cases that lead to death	0%	0%	0%	[49]
Tertiary syphilis health outcomes				
Duration of symptomatic disease	10 years	10 years	10 years	[49]
Time to onset of symptoms	15 years	15 years	15 years	[50]
Proportion of cases that lead to death	15%	15%	15%	[49]
Congenital syphilis health outcomes				
Duration of symptomatic disease	3 years	3 years	3 years	[49]
Time to onset of symptoms	0 years	0 years	0 years	[50]
Proportion of cases that lead to death	1%	1%	1%	[49]

[a]Only 10% of the total labour costs were included because the PK7300 platform is also used for blood group analysis.

treatments for syphilis (benzylpenicillin, azithromycin, doxycycline, amoxicillin, amoxicillin-clavulanate and ceftriaxone [21]) represent over 40% of all prescribed antibiotics [20]. Therefore, the proportion of recipients that may be protected against syphilis may be as high as 16%. Other uncertain parameters include the length of the TPHA window period, duration of donor infectivity, risk of bacteraemia in donors (estimated by PCR testing which may be relatively insensitive for blood samples) and *T. pallidum* survival in platelet storage. The Supporting Information provides the justification for the infectivity parameters used and documents the associated uncertainty, particularly in platelets. The assumption that syphilis is infectious with modern blood storage techniques remains unproven, but clearly the conservative assumption is necessary to have a model with an above zero risk. Conservative values were selected for uncertain parameters, resulting in an overestimation of risk; establishing more accurate values would most likely reduce the calculated risk further (possibly into the tolerable range for all high estimates). The lack of TTS cases in developed countries since 1977 [3, 22] supports the likelihood that some or all of the uncertain parameters are closest to or perhaps more favourable than the 'best-case scenario' values. It is also consistent with our risk estimates.

Given that the most likely risk of TTS is negligible for all testing strategies, cost-effectiveness should be considered. In Australia, interventions that cost more than $50 000/DALY averted are considered not cost-effective [23]. A threshold of $1 million/quality-adjusted life year (QALY) has been quoted as an implicit threshold in blood safety [24], given that historical focus has been on the prevention of transfusion-transmitted infection regardless of monetary impact. We acknowledge uncertainties in our cost-effectiveness model. DALYs were used instead of QALYs because this information was readily available, but this did not take into account the potential increased morbidity or account for the significant co-morbidities in the recipient population. We did not adjust for any possible volume-based price increases that may occur if syphilis testing was reduced. However, the middle-estimate ICERs for all testing strategies at the current level of TTS risk are above $200 million/DALY averted and are also many times higher than other implemented blood safety interventions [25]. Even if TTS risk were to increase tenfold, universal testing would cost $53·9 million/DALY

Table 3 Modelled syphilis risks for recipients under different donor testing strategies

	Middle risk estimate (low to high estimate)–1 in:			Years to observe one case[a]		
Testing strategy	**TTS infection**	**Tertiary syphilis**	**Congenital syphilis**	**TTS infection**	**Tertiary syphilis**	**Congenital syphilis**
Universal testing	49·5 million (1·2 billion to 15 million)	2·3 billion (8·4 billion to 530 million)	9·1 billion (510 to 1·7 billion)	53·1	2498	29 725
Targeted-testing: males aged ≤50 years old	6·0 million (76 to 1·4 million)	280 million (5·2 billion to 50 million)	1·1 billion (31 billion to 170 million)	6·5	304	3619
Targeted-testing: first-time donors	4·0 million (50 million to 860 000)	190 million (3·4 billion to 31 million)	730 million (20 billion to 100 million)	4·3	201	2392
No testing	2·8 million (34 million to 710 000)	130 million (2·3 billion to 26 million)	510 million (14 billion to 84 million)	3·0	142	1685

[a]based on middle estimates.

Table 4 Comparison of syphilis detection and testing rates for universal and targeted-testing strategies

Testing strategy	**Number of potentially infectious syphilis donations expected to be captured per year (%[a])**	**Number of donations expected to be tested per year (%[a])**
Universal testing	3·43 (100%)	779 492 (59·4%)
Targeted-testing: males aged ≤50 years old	2·42 (70·8%)	246 233 (18·8%)
Targeted-testing: first-time donors	1·81 (52·6%)	93,594 (7·1%)

Donations intended solely for fractionated plasma products have been removed as testing on these donations was ceased in September 2016.
[a]Compared to universal testing strategy.

averted, over 1000 times the considered Australian threshold. Although no testing can be considered the most cost-effective strategy, it is contraindicated by stakeholder, ethical and regulatory perspectives in Australia, including social concern and reputational risk given the uncertainty in the estimates. Likewise, first-time donor testing, which has the next most favourable cost-effectiveness profile, is unlikely to be acceptable as it would capture only 50% of PIS donations. Conversely, targeted-testing of males ≤50 years old could potentially address these concerns while significantly reducing cost and the ICER to prevent TTS infections.

Our modelling provides a compelling argument to alter our syphilis testing strategy. However, the epidemiology of syphilis in Australia is changing. There was a peak of 4366 cases of infectious syphilis in 2017 compared to 3465 and 2757, respectively in 2016 and 2015 [26]. This increase should be interpreted with caution due to case definition changes and has been contributed to by a multijurisdictional outbreak of syphilis in the Aboriginal and Torres Strait Islander population. In 2016, 16% of all notifications were from the Indigenous population with the rate in Indigenous people in remote communities 50 times higher than the non-Indigenous remote rate [27]. However, the isolated nature of these communities, combined with extreme social disadvantage and poorer health outcomes [28], results in Indigenous Australians from remote communities being extremely unlikely to donate blood. In contrast to 54% of Indigenous infectious syphilis notifications being in males, 94% of infections in the non-Indigenous population were in males, demonstrating the known association with men who have sex with men, including a large proportion who are HIV positive [29]. Preliminary Blood Service data suggest the increased community rate has resulted in an increase in blood donors with syphilis, increasing in 2016 from an average of 0·3 to 1 per 100 000 donations [30]. Feedback from key stakeholders including our regulators, funders and senior government health experts indicates a precautionary approach with a strong preference for maintaining current testing regimes, in part because the Blood Service is reviewing the deferral periods for higher risk sexual behaviours, including the deferral for men who have sex with men. It should be noted the cost-effectiveness sensitivity analysis results account for a tenfold increase in syphilis incidence.

Robust blood infectivity studies would contribute to the ongoing unanswered debate about syphilis infectivity in blood components. Our cost-effectiveness analysis

demonstrates the considerable resources spent on syphilis screening in Australia and likely worldwide. Syphilis infectivity research would therefore have significant international implications for blood services, especially in the context of rising syphilis infection rates. We recommend that further research on syphilis infectivity in blood components is done as a priority.

Processes for donor screening and manufacturing are similar in other developed countries allowing our model to be adjusted for use internationally once pathogen inactivation (PI) is incorporated where applicable. Future risk estimates from multiple countries would narrow the evidence gap identified by international regulators and provide guidance for altering syphilis donor testing recommendations for developed countries. Platelet components account for 89% of the total risk in our model despite totalling 13% of components issued. PI of platelets has demonstrated effectiveness against syphilis [31]. For international blood services that have implemented PI for platelets, the risk of TTS is anticipated to be miniscule and based on an approximate 90% reduction on our calculated risks, a strong argument for ceasing already exists.

In conclusion, from a cost-effectiveness and risk perspective there is a compelling argument to alter Australia's blood donor syphilis testing strategy, with targeted-testing of males ≤50 years old considered to be optimal. The potential opportunity costs gained by altering syphilis testing for blood donors are significant. This strategy is associated with tolerable TTS risks for all estimates including the conservative high-risk scenario and trend for increasing syphilis cases occurring in Australia and elsewhere [19]. However, recent changes in the epidemiology of syphilis in Australia and potential changes in the deferral periods for donors with higher risk sexual behaviours have resulted in key stakeholders concluding that it is not appropriate to consider reducing donor syphilis testing at this point in time. The Blood Service will continue to monitor changes in syphilis disease epidemiology and will revisit this decision once the impact of potential changes in donor deferrals are known and epidemiology changes are clearer, based on the strong argument presented in this study.

Acknowledgements

The authors thank analyst Mark Rashleigh and testing laboratory staff for providing Blood Service data reports. Australian governments fund the Australian Red Cross Blood Service for the provision of blood, blood products and services to the Australian community.

Author contributions

All authors contributed to research design, or the acquisition, analysis or interpretation of data, and critically reviewed and approved the manuscript.

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Supporting Information

Additional Supporting Information may be found in the online version of this article: