

Embedded Computational Methods for Syphilis Testing or Diagnosis

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Summary

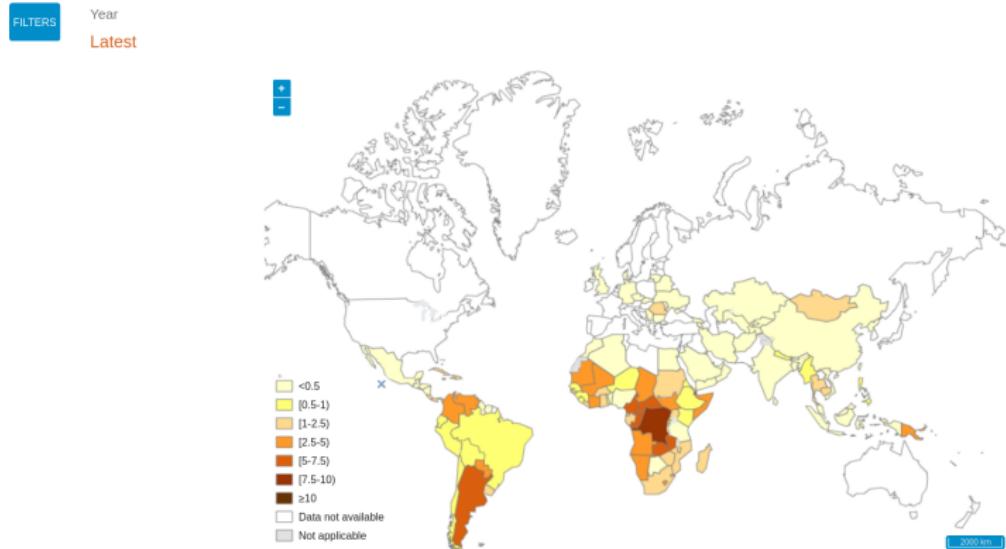
- 1 Syphilis
- 2 Diagnostic
- 3 Computational methods
- 4 Embedded Systems
- 5 Embedded Computational Method for Syphilis Testing
- 6 Conclusions
- 7 References

Stats

- World Health Organization (WHO) estimated that in 2016 there were more than 1 million new cases of syphilis in pregnant women [1];
- Brazil registered an increase of 4157% new cases the disease between 2010 and 2018 [1].

Stats [2]

Antenatal care attendees who were positive for syphilis (%), reported



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Brazil's was 0.83% in 2011.

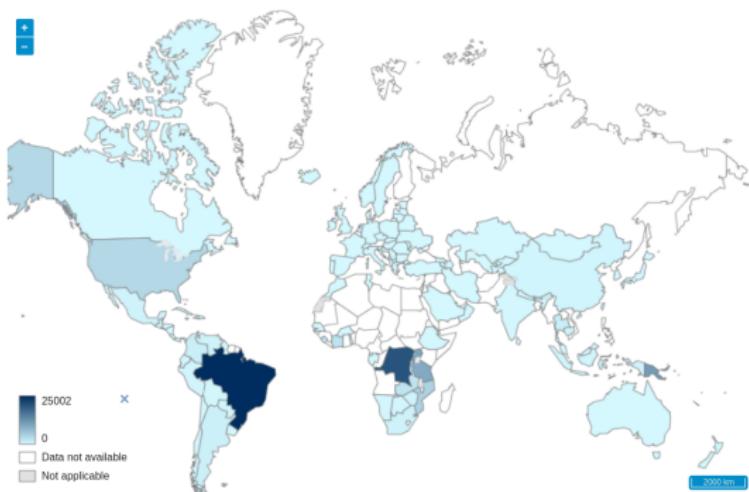
Stats [2]

Congenital syphilis number of cases, reported

FILTERS

Year

Latest



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World Health Organization

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Brazil's was 25002 in 2023

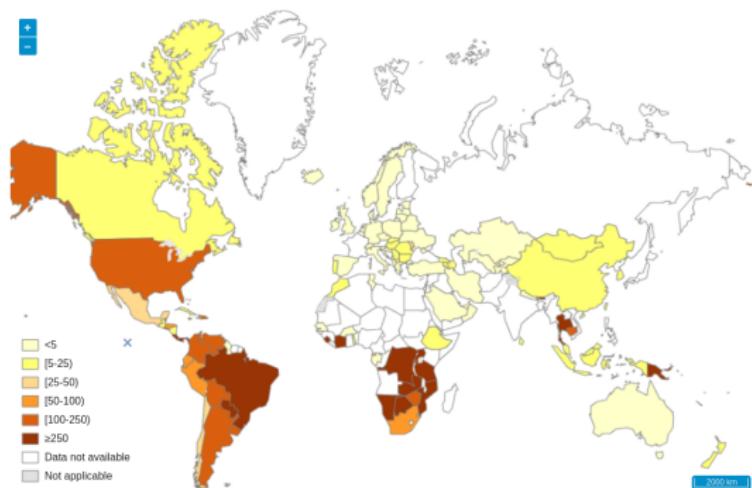
Stats [2]

Congenital syphilis rate per 100 000 live births, reported

FILTERS

Year

Latest



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World Health Organization

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Brazil's was 1033.78 in 2023

Stats [2]

Prevalent cases of active syphilis (in thousands)



Last updated: 2024-06-12

Indicator Location	Prevalent cases of active syphilis (in thousands)	
	Male	Female
Global		
2022	12371 [11056-13687]	12087 [10795-13379]
2021	11772 [10584-12960]	11499 [10337-12662]
2020	11200 [10097-12302]	10928 [9853-12003]
2019	10756 [9811-11702]	10465 [9540-11391]
2018	10284 [9446-11122]	9990 [9168-10813]
2017	9908 [9129-10687]	9616 [8853-10379]
2016	9574 [8850-10299]	9294 [8585-10003]

Brazil's was 25002 in 2023

Stats [2]

Incident cases of active syphilis in 15-49 year olds (in thousands)

FILTERS

Last updated: 2024-06-12

Indicator	Incident cases of active syphilis in 15-49 year olds (in thousands)	
Location	Male	Female
Global		
2022	4062 [2851-5273]	3938 [2753-5124]
2021	3819 [2709-4928]	3700 [2615-4785]
2020	3608 [2586-4631]	3491 [2493-4489]
2019	3462 [2513-4411]	3339 [2419-4259]
2018	3316 [2419-4212]	3191 [2325-4057]
2017	3190 [2338-4041]	3066 [2245-3886]
2016	3062 [2255-3869]	2943 [2165-3721]

15-49 year olds

Transmission

- Sexually Transmitted Infection [3];
 - Sexual contact;
 - From mother to child during pregnancy, childbirth, or breastfeeding;
 - Viruses, bacteria, or other microorganisms
- Bacterium *Treponema pallidum* [4] [5];



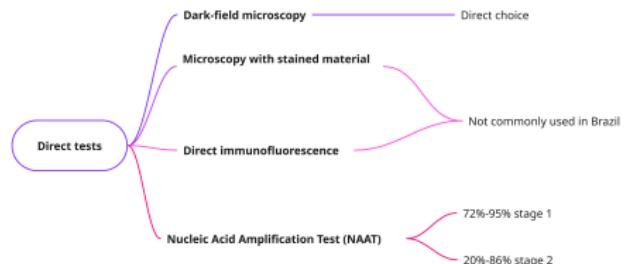
Fonte: CDC/Bill Schwartz, Courtesy: Public Health Image Library.

Disease

- Stages [4] [6]
 - **Primary Syphilis:** A sore (chancre) appears, usually on the genitals, which disappears on its own.
 - **Secondary Syphilis:** The bacteria spread throughout the body, causing skin rashes and affecting other organs. Risk of congenital syphilis.
 - **Tertiary Syphilis:** If untreated, it can cause severe and fatal damage to the heart and nervous system.
- No vaccine [7]
- Treated cheaply [8]

Methods [7]

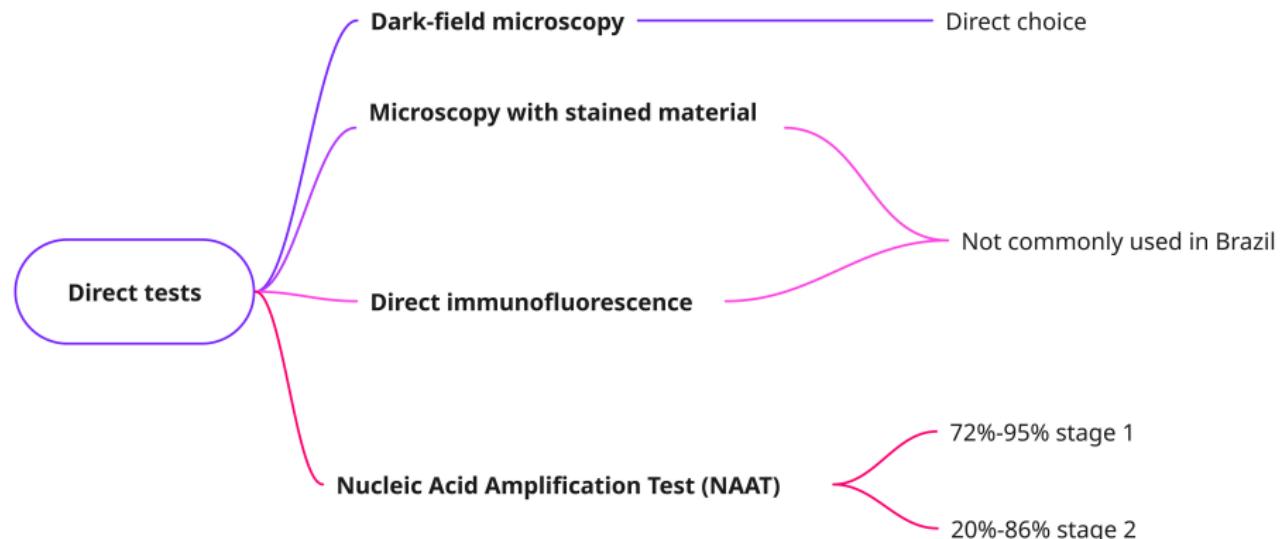
Direct tests



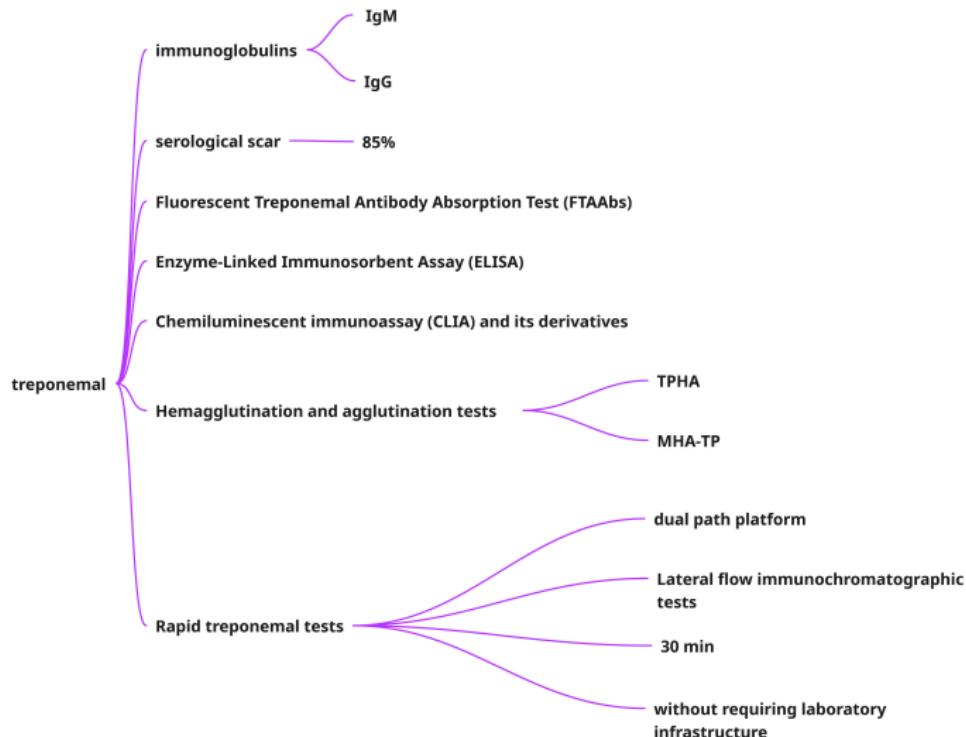
Immunologic tests



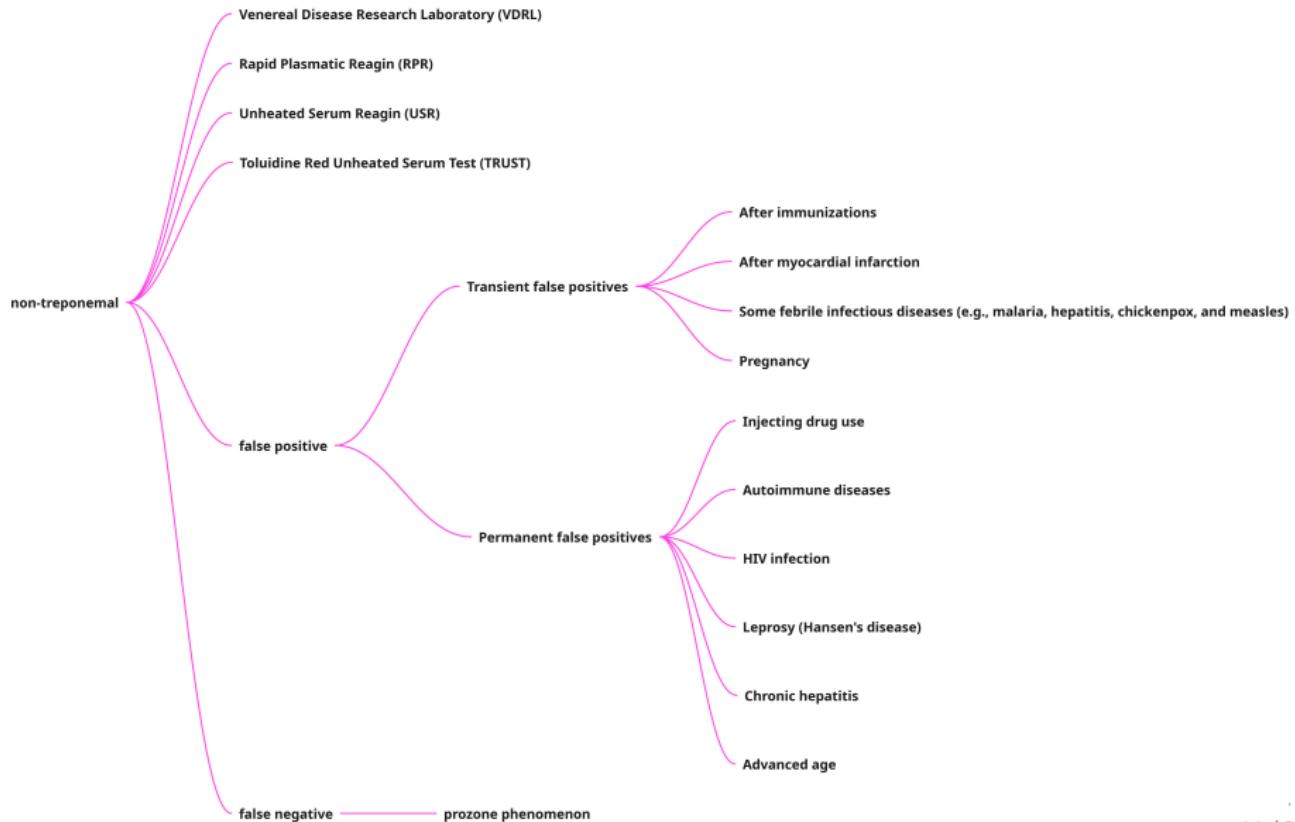
Direct tests



Immunologic treponemal

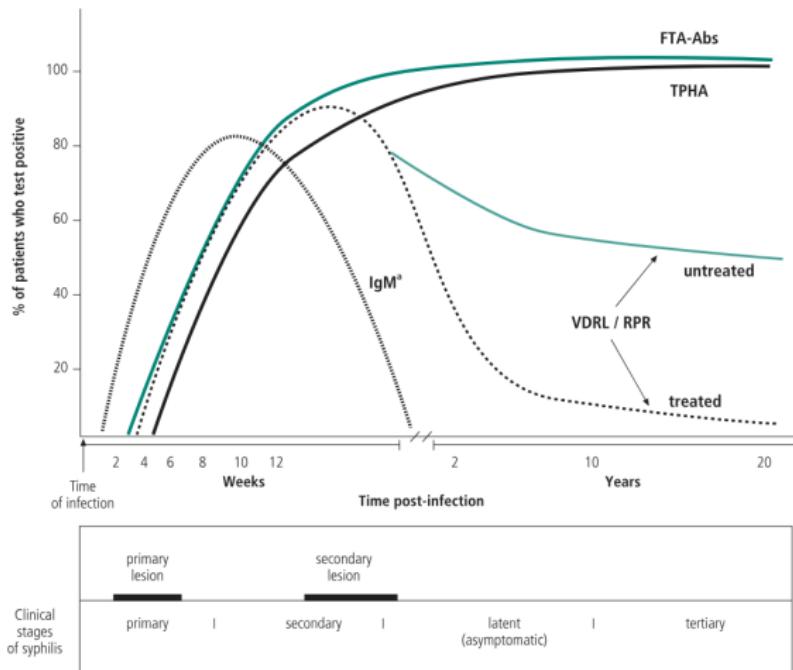


Immunologic non-treponemal



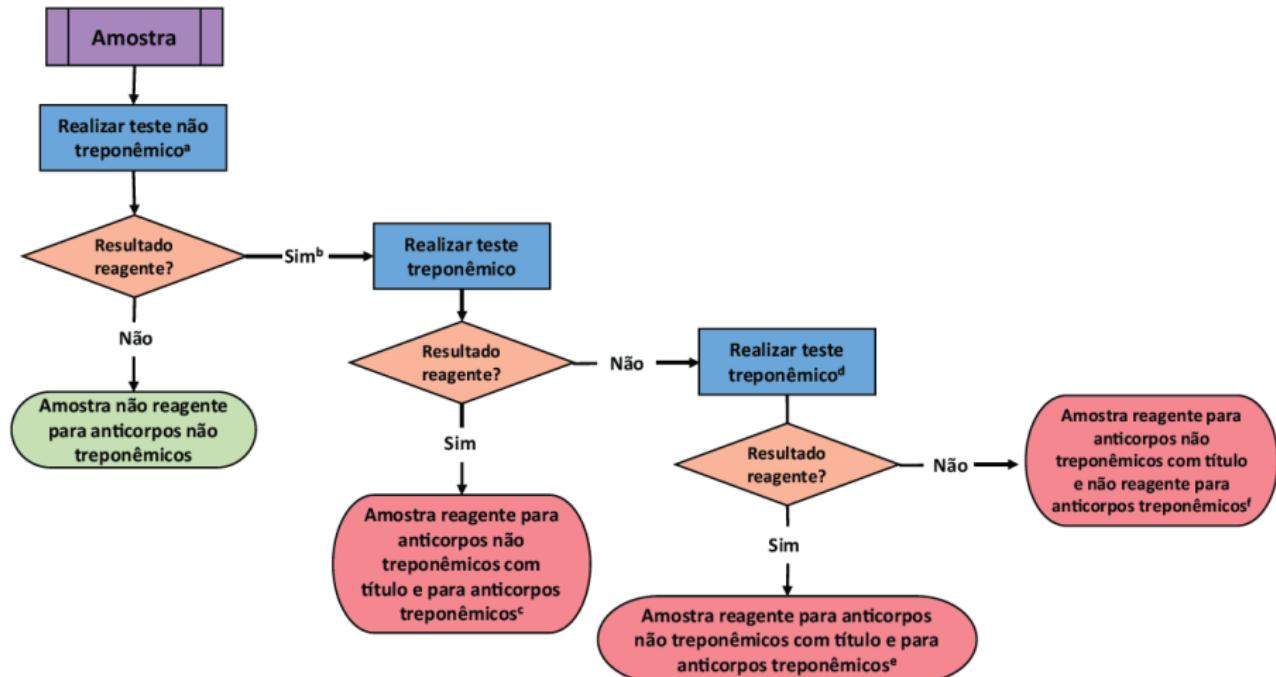
Common patterns of serological reactivity in syphilis patients [9]

Fig. 1. Common patterns of serological reactivity in syphilis patients

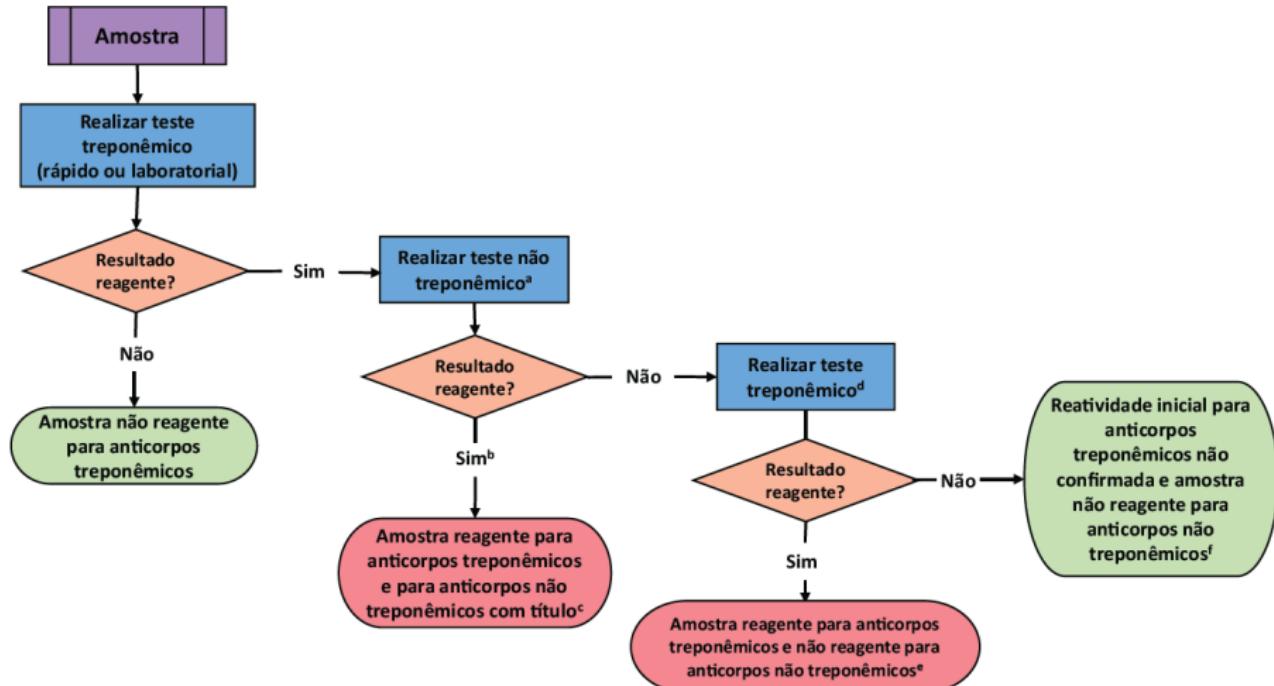


^a IgM by ELISA or FTA-ABS 195 or immunoblot

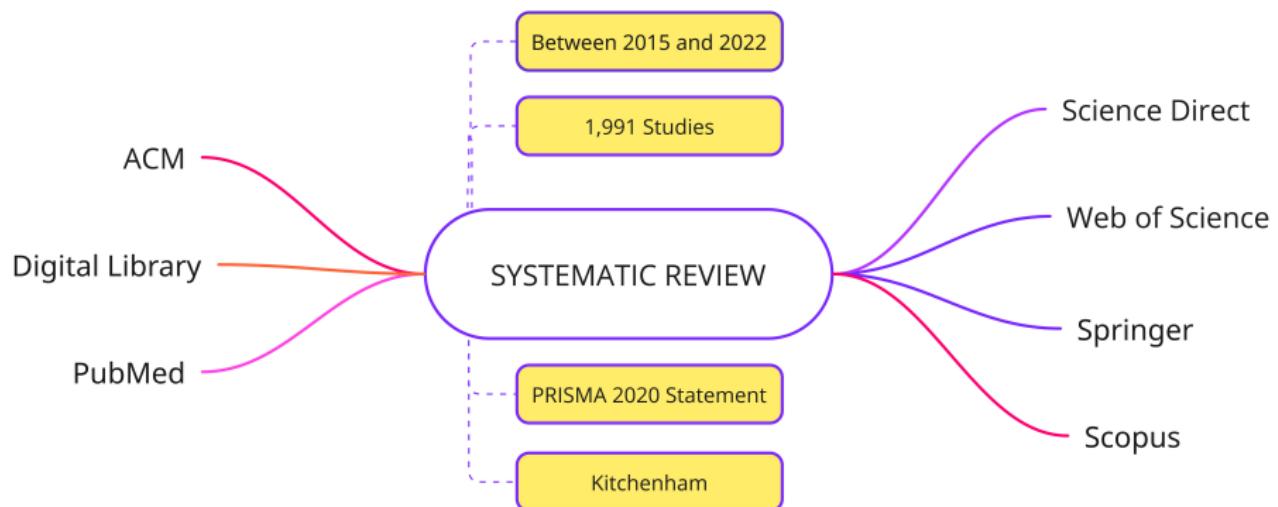
Classic approach[7]



Reverse approach[7]



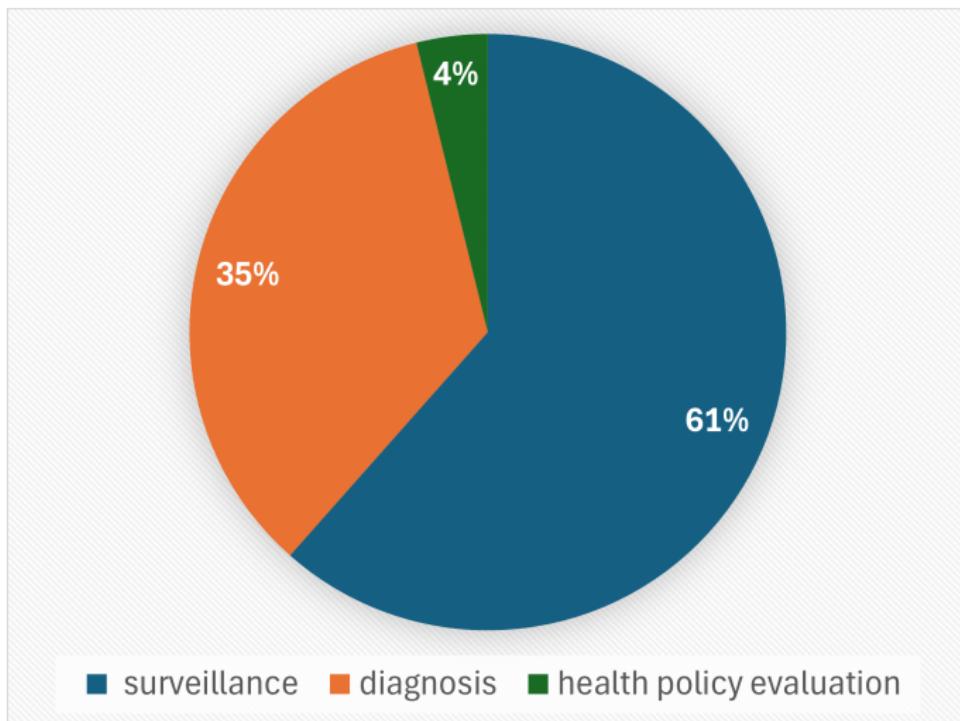
Computational methods applied to syphilis [8] [10] [11]



Search String

Syphilis AND ("machine learning"
OR "artificial intelligence"
OR "computational intelligence"
OR "deep learning"
OR fuzzy
OR "artificial neural network"
OR "specialist systems"
OR "smart system")

Subareas



Methods [8]

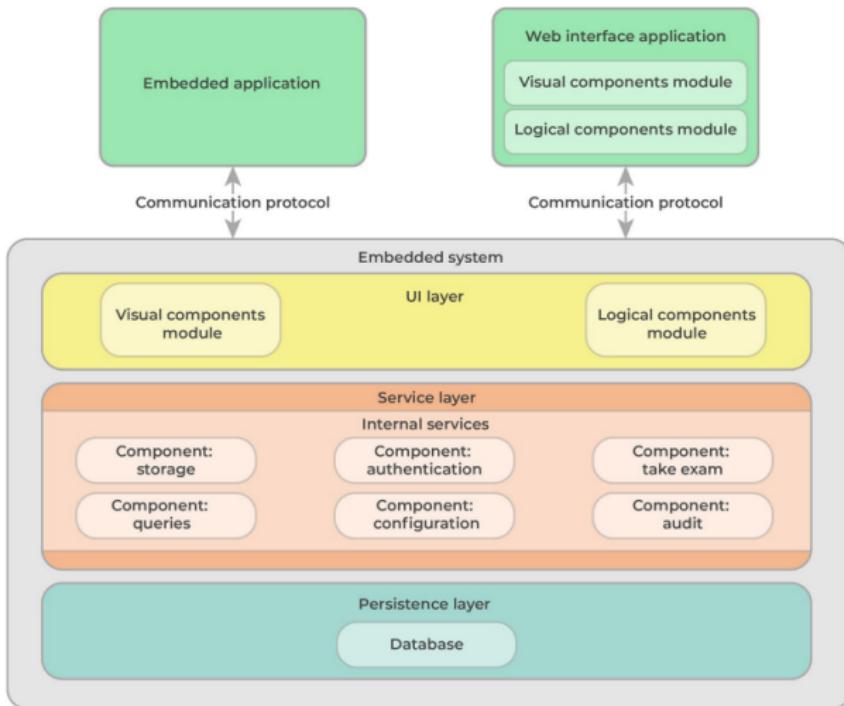
References	Year	Score	Health target	Objective	Techniques (best model)	Performance (best model)			
						Acc	Recall	Precision	AUC
Wang et al. (47)	2022	1.0	Diagnosis	Classifying infectious diseases	MIDDM	72.60%	72.60%	89.45%	-
Elder et al. (48)	2021	1.0	Diagnosis	Classifying STIs	Super Learning (ensemble model)	-	-	-	76%
Bao et al. (49)	2021	1.0	Diagnosis	Predicting STIs diagnosis	GBM	77%	81%	-	85.8%
Dexter et al. (50)	2020	1.0	Diagnosis	Classifying STIs	RF	-	91%	89%	99.22%
Mathur et al. (51)	2021	0.83	Diagnosis	Classifying 20 diseases	CNN ensemble	-	-	-	98%
Lu et al. (52)	2019	0.83	Diagnosis	Identifying indicators	Multivariable Logistic Regression	-	-	-	94.1%
King et al. (53)	2018	0.83	Diagnosis	Classifying STIs	Multivariable Logistic Regression	c-statistic: 0.703 and 0.676			
SUN WG (54)	2021	0.66	Diagnosis	Classifying syphilitic uveitis	Multinomial Logistic Regression	100%	-	-	-
Pinoliad et al. (55)	2020	0.66	Diagnosis	Classifying syphilis and other STIs	Deep Learning	90%	100%	58%	-

Study Case 1 [1]

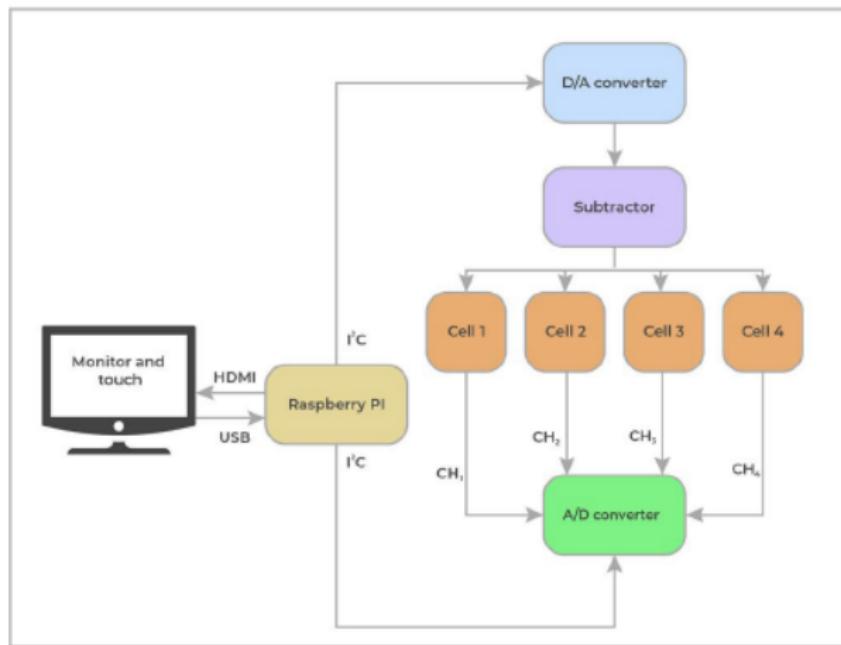
Fig. 6 **A** miRNA device. **B** Syphilis device



Study Case 1 - Components



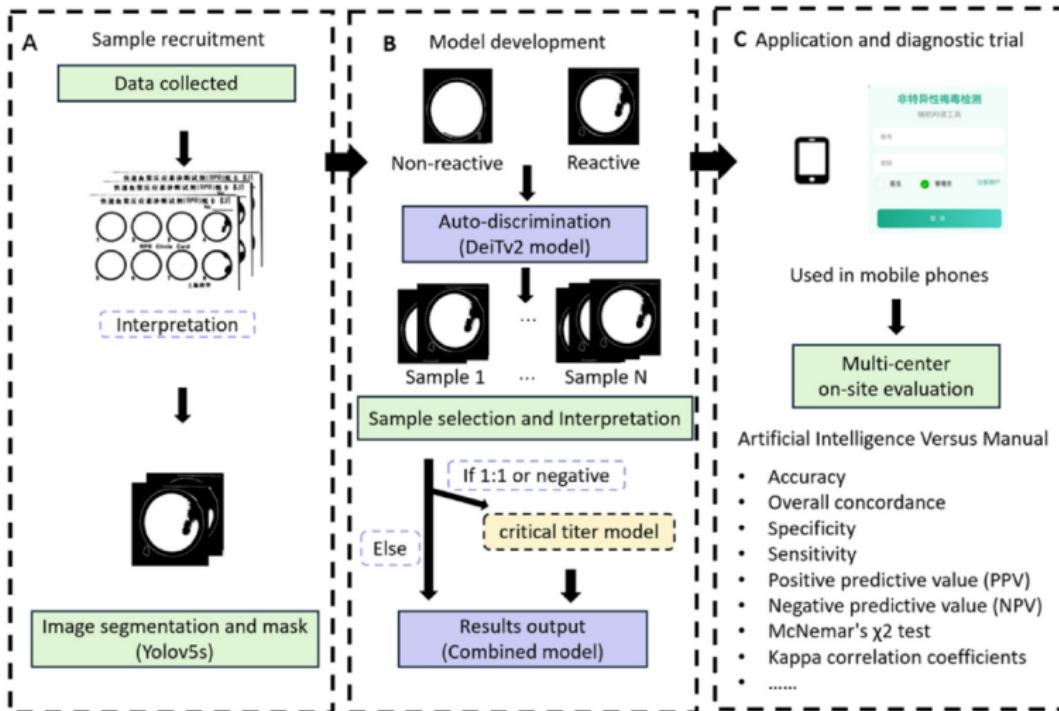
Study Case 1 - Hardware



Study Case 1 - Key Information

- 30 cm wide, 24 cm high, 14 cm deep;
- costs USD 299.00;
- Based on 8,733,194 requests were made to the application server:
 - 1 h;
 - 2426 requests per second;
 - 10.41 gigabytes sent;
 - 366.73 megabytes received;
 - response time of 13 ms.

Study Case 2 [12]



Artificial Intelligence Versus Manual

- Accuracy
- Overall concordance
- Specificity
- Sensitivity
- Positive predictive value (PPV)
- Negative predictive value (NPV)
- McNemar's χ^2 test
- Kappa correlation coefficients
-

Study Case 2 - Model Evaluation

- Reactive accuracy of 76.00% (95% CI 64.50%–84.79%);
- Non-Reactive accuracy of 75.60% (95% CI 60.14%–86.62%);
- Two models combined accuracy for reactive circles 82.67% (95% CI 71.82%–90.09%);
- Two models combined accuracy for non-reactive circles 84.44% (95% CI 69.94%–93 · 01%);
- ROC-AUC value for the individual model was 0.76;
- ROC-AUC value for the combined model achieved a ROC-AUC value of 0.83.

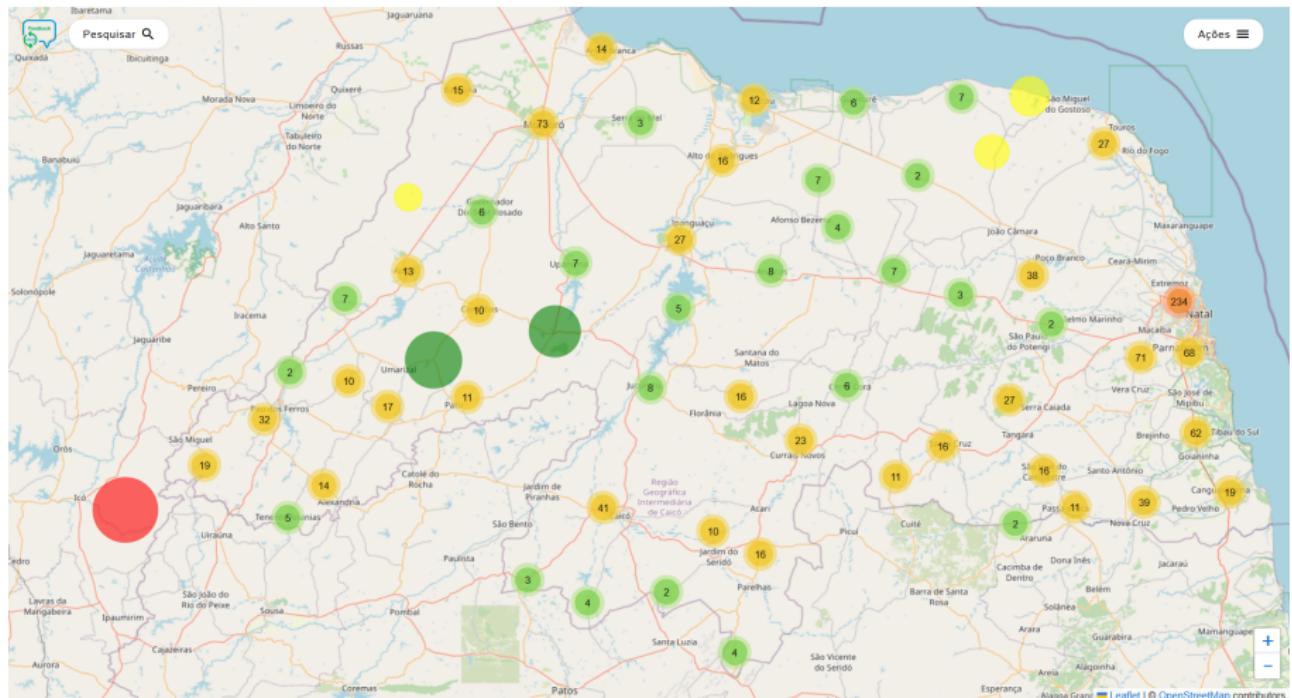
Study Case 2 - Field Evaluation

The sensitivity of the tool was 94.85% (95% CI 89.29%–97.73%)

Specificity was 91.56% (95% CI 88.78%–93.71%)

Overall concordance for positive and negative results was 92.23

Mapa UBS [13]



Telehealth [14]

"Teleconsultations resolved 85% (5219/6140) of cases, with 15% (921/6140) requiring in-person referrals or emergency care. The average absenteeism rate was 15% (1083/7223), and consultation durations were between 15 and 20 minutes."

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