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ASSESSING THE EFFECTIVENESS OF SEROLOGICAL TESTS FOR EARLY DETECTION OF COVID-19

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Abstract. *This study investigated the effectiveness of serological tests for COVID-19 detection. Specifically, it analyzed the results of two different serological tests and a nasopharyngeal swab test for a sample of 879 people. The area under the ROC curve was measured for both serological tests to determine their overall diagnostic accuracy, while the sensitivity and specificity of the tests were analyzed at different thresholds to identify the optimal cutoff points.*

The findings suggest that serological tests have the potential to be a valuable tool in early detection of COVID-19, which can help reduce the spread of the infection. These tests can also provide additional information on the presence of antibodies, which can help identify individuals who have already been infected with the virus and may have developed some level of immunity.

This research contributes to the growing body of knowledge on COVID-19 testing and detection, and it has important implications for public health and clinical practice. By identifying the most effective ways to use serological tests, healthcare providers can improve their ability to detect and respond to COVID-19 cases, ultimately helping to mitigate the impact of the pandemic.

Keywords*: serological tests, nasopharyngeal swab test, COVID-19 detection, sensitivity and specificity, ROC curve.*

1. Introduction

Spreading of COVID-19 (COrona VIrus Disease 19) infection can be reduced with early detection of infected people, so that they can start quarantine as soon as possible. The nasopharyngeal swab test is highly reliable but it requires time and is expensive, serological tests are faster and cheaper, but less reliable. Serological tests find the presence of IgG (Immunoglobulin G) and a high level of this antibody in blood means that the person is or has been affected by COVID-19. This research shows the results of the analysis of two serological tests, discussing the setting of the thresholds to declare a positive result.

2. Method

A group of 879 people was subjected to 3 tests: one nasopharyngeal swab test and two serological tests (Test 1 and Test 2 in the following), recording the amount of IgG; 17 cases were removed from the dataset due to an uncertain swab test result. The positive swab tests were 71, whereas the negative ones were 791.

Test 1 contained 6 outliers, which were identified using DBSCAN [1] with parameters = 4 and M = 3, and then removed (only from Test 1). In these cases the swab test was negative.

Swab test result was considered correct, and ROC curve (sensitivity versus false alarm, see *Figure 1*) was measured for the two serological tests. The area under ROC was measured equal to 0.94 for Test 1 and 0.93 for Test 2.

For convenience, sensitivity and specificity versus threshold are also plotted in *Figure 2*.

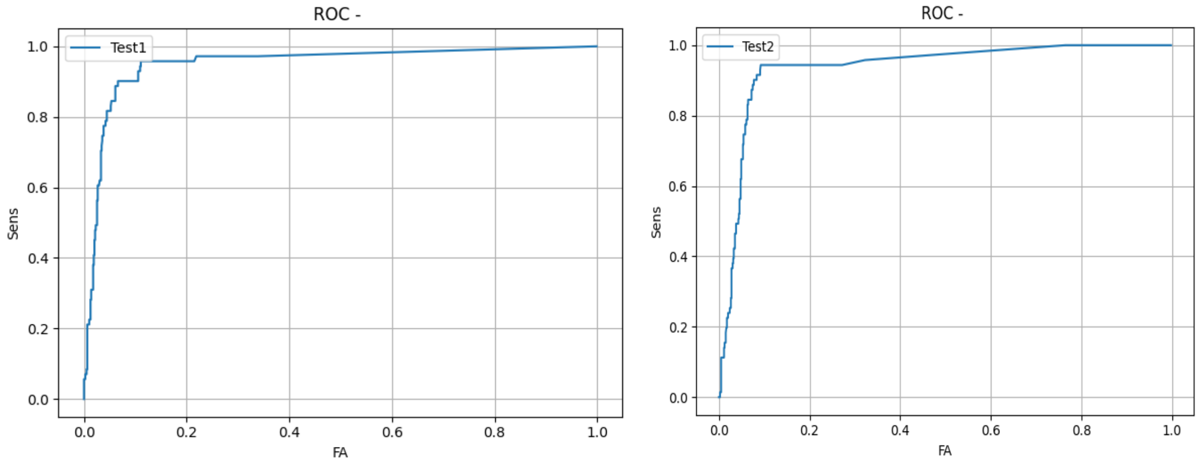

Figure 1. ROC curve for Test 1 (left) and Test 2 (right).

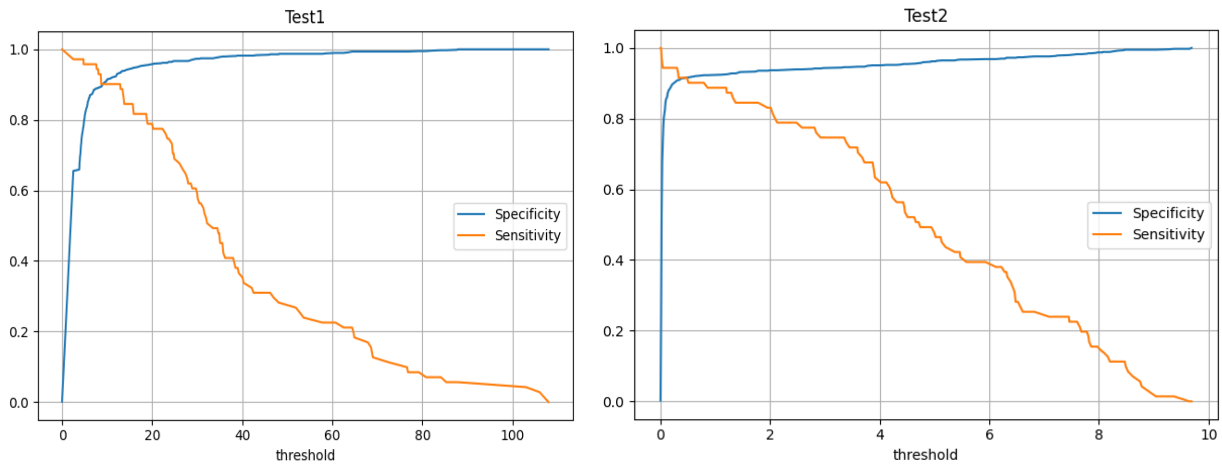

Figure 2. Sensitivity and specificity versus threshold for Test 1 (left) and Test 2 (right).

The following notation will be used: D means that the patient is really infected, H means that the patient is healthy, T_p means that the test is positive, T_n mean that te test is negative.

The general approach in case of a positive serological test is to check again the person using the nasopharyngeal swab. This makes acceptable a relatively large false positive probability $P(T_p|H)$, with the only drawback that healthy people stay for a couple of days at home, maybe in an anxious state.

What cannot be accepted is instead a large false negative probability: in this case nasopharygeal swab is not tested, and the person can spread the virus to many others. Thus, it is important to have a large sensitivity $P(T_p|D)$ (probability that the test is positive given that the person has the disease), but even more important is the probability $P(D|T_n)$ that the person has the disease given the test is negative. This last probability should be kept as small as possible.

Having assumed COVID-19 prevalence equal to 2 %, Figs. 3 and 4 respectively show versus the threshold:

1. The probability $P(D|T_p)$ that the patient is truly infected given that the test is positive and the probability $P(D|T_n)$ that the patient is infected given that the test is negative.

2. The probability $P(H|T_p)$ that the patient is healthy given that the test is positive and the probability $P(H|T_n)$ that the patient is healthy given that the test is negative.

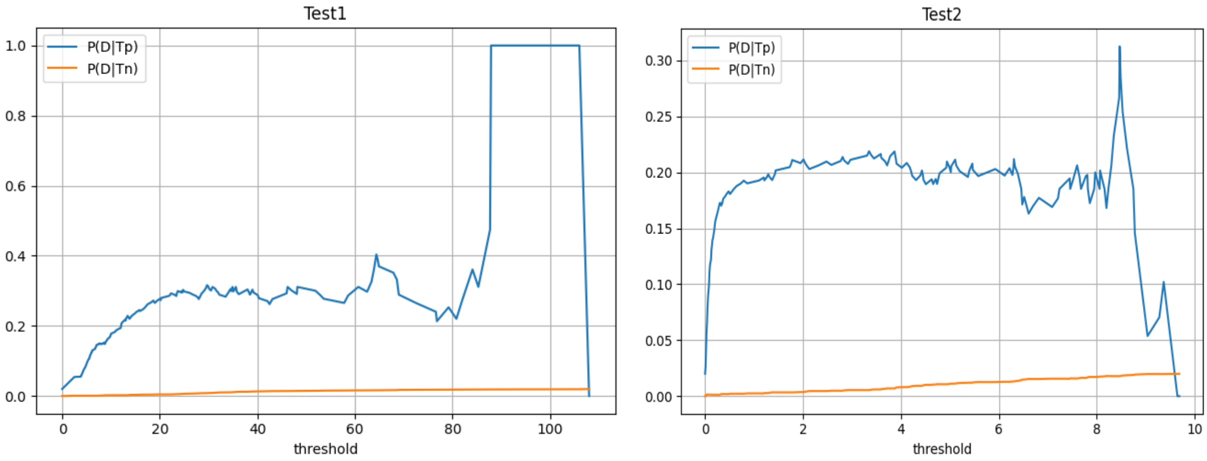

Figure 3. $P(D|T_p)$ and $P(D|T_n)$ versus threshold for Test 1 (left) and Test 2 (right).

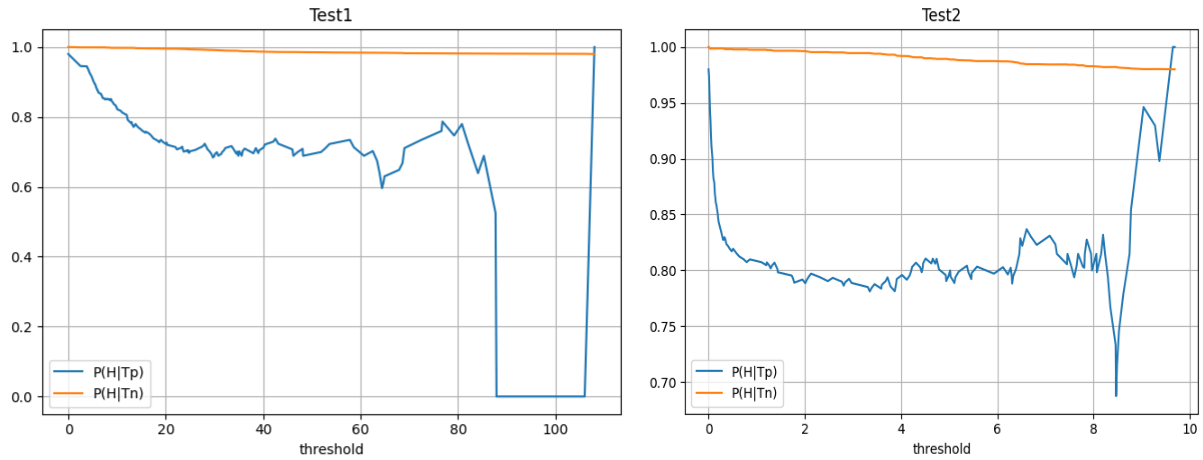

Figure 4. $P(H|T_p)$ and $P(H|T_n)$ versus threshold for Test 1 (left) and Test 2 (right).

3. Choice of the threshold

3.1. Test 1

- Sensitivity and specificity are both equal to 0.9 when the threshold is equal to 9, in which case $P(D|T_n) = 2.23 \cdot 10^{-3}$ and $P(D|T_p) = 0.156$.
- Being this sensitivity not large enough, it is convenient to decrease the threshold; we suggest a threshold equal to 7.59 for which:
  - Sensitivity $P(T_p|D) = 0.958$, false negative probability $P(T_n|D) = 0.042$.
  - Specificity $P(T_n|H) = 0.889$, false positive probability $P(T_p|H) = 0.111$.
  - $P(D|T_n) = 0.001$, $P(H|T_n) = 0.999$.
  - $P(D|T_p) = 0.15$, $P(H|T_p) = 0.85$.

3.2. Test 2

- Sensitivity and specificity are both equal to 0.915 when the threshold is equal to 0.445, in which case $P(D|T_n) = 1.18 \cdot 10^{-3}$ and $P(D|T_p) = 0.181$.
- Since this sensitivity can not be considered sufficient, the lower threshold 0.3 is recommended, for which:
  - Sensitivity $P(T_p|D) = 0.944$, false negative probability $P(T_n|D) = 0.056$.
  - Specificity $P(T_n|H) = 0.908$, false positive probability $P(T_p|H) = 0.092$.

- $P(D|T_n) = 0.001$, $P(H|T_n) = 0.999$.
- $P(D|T_p) = 0.173$, $P(H|T_p) = 0.827$.

4. Conclusion

In this study, we analyzed two serological tests for the detection of COVID-19, and assessed the setting of the thresholds for declaring a positive result. The tests showed good performance, with area under ROC curves of 0.94 and 0.93, and acceptable false positive rates. We recommend a threshold of 7.59 for Test 1 and 0.3 for Test 2, based on sensitivity, specificity, and probabilities of false positive and false negative results, as well as the prevalence of COVID-19 in the population. These thresholds can help improve the early detection of infected individuals, reduce the spread of the disease, and optimize the use of resources for testing and quarantine. Further studies and validations of these tests and thresholds are necessary to confirm their effectiveness and reliability in different populations and conditions.

REFERENCES

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