

## DETECTING SARS-COV-2 THROUGH RT-PCR UTILIZING VARIOUS SAMPLE ORIGINS

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### **Abstract:**

Real-time reverse transcriptase-polymerase chain reaction (RT-PCR) is the predominant diagnostic method for detecting severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. This technique applies to various sample types, including nasopharyngeal swabs (NPS), oropharyngeal swabs (OPS), and self-collected saliva. However, the absence of positive results does not conclusively rule out infection. **Methods:** A comprehensive review was undertaken to analyse the strengths and limitations of existing diagnostic approaches for nonserologic detection of SARS-CoV-2 using RT-PCR. The article also suggests practical measures to enhance diagnostic reliability. **Results:** Among the initially identified 56 papers, 16 papers (encompassing 452 patients) were included in the review. Most papers present findings from diverse samples in limited case series, with a notable absence of comparative studies. **Conclusions:** The diagnostic accuracy of NPS and OPS is less than optimal, and the risk of aerosol dispersal contamination is noteworthy. SARS-CoV-2 RNA can be detected in self-collected saliva specimens from many infected individuals within 7 to 10 days after symptom onset. There is an urgent need for comparative trials to establish the preferred diagnostic modality. Adequate education and training of healthcare personnel are imperative

**Keywords:** COVID-19, Swab, Nasopharynx, Emergency, Infection, RtPcR

**Introduction:** Since its emergence in China in December 2019, the coronavirus disease 2019 (COVID-19), resulting from the primary infection by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has become a global concern. It has led to over 7,145,500 confirmed cases and more than 408,000 deaths worldwide (data as of June 10, 2020). The epidemiological profile has rapidly evolved.

Currently, the diagnosis of SARS-CoV-2 infection relies on real-time reverse transcriptase-polymerase chain reaction (RT-PCR) conducted on either nasopharyngeal swabs (NPS) or oropharyngeal swabs (OPS). Despite suboptimal detection rates, the collection of secretions from the upper airway through NPS/OPS remains the primary diagnostic approach for testing both symptomatic patients and asymptomatic individuals for COVID-19. This is effective when performed promptly and appropriately after the onset of symptoms. Considering the analytical sensitivity of the RT-PCR test and the epidemiological characteristics of COVID-19, it's crucial to acknowledge the potential for obtaining false-negative results. This could occur both in the early

phase of the disease (a few days before symptom onset) and towards the end of SARS-CoV-2 infection (around 20 days after symptom onset) due to a low viral load and shedding below the analytical sensitivity threshold of RT-PCR.

The US Centre for Disease Control and Prevention (US-CDC) recommends the collection of solely upper respiratory nasopharyngeal swabs (NPS) based on reported detection rates. However, the US Food and Drug Administration cautions that a negative RT-PCR result does not definitively rule out SARS-CoV-2 infection and should not be the sole basis for patient management decisions. Instances have been described where a negative NPS or OPS does not exclude COVID-19, as consistent diagnosis is achieved through bronchoalveolar lavage fluid after repeated negative testing with NPS and OPS.

Reduced detection rates may be attributed to inadequate sample collection in the nasopharynx, the risk of collecting secretions from the nasal cavity instead of the nasopharynx due to patient discomfort, or limited viral local tropism due to low expression of angiotensin-converting enzyme 2 receptors in the epithelial cells of the nasopharyngeal/oropharyngeal surface.

Table 1 provides an overview of currently available diagnostic techniques, but safety concerns arise as the diagnostic procedure may lead to the dispersal of infected aerosols, potentially causing nosocomial transmission. As of the time of writing, more than 28,600 cases among Italian healthcare workers, including 167 deaths among physicians, have been documented.

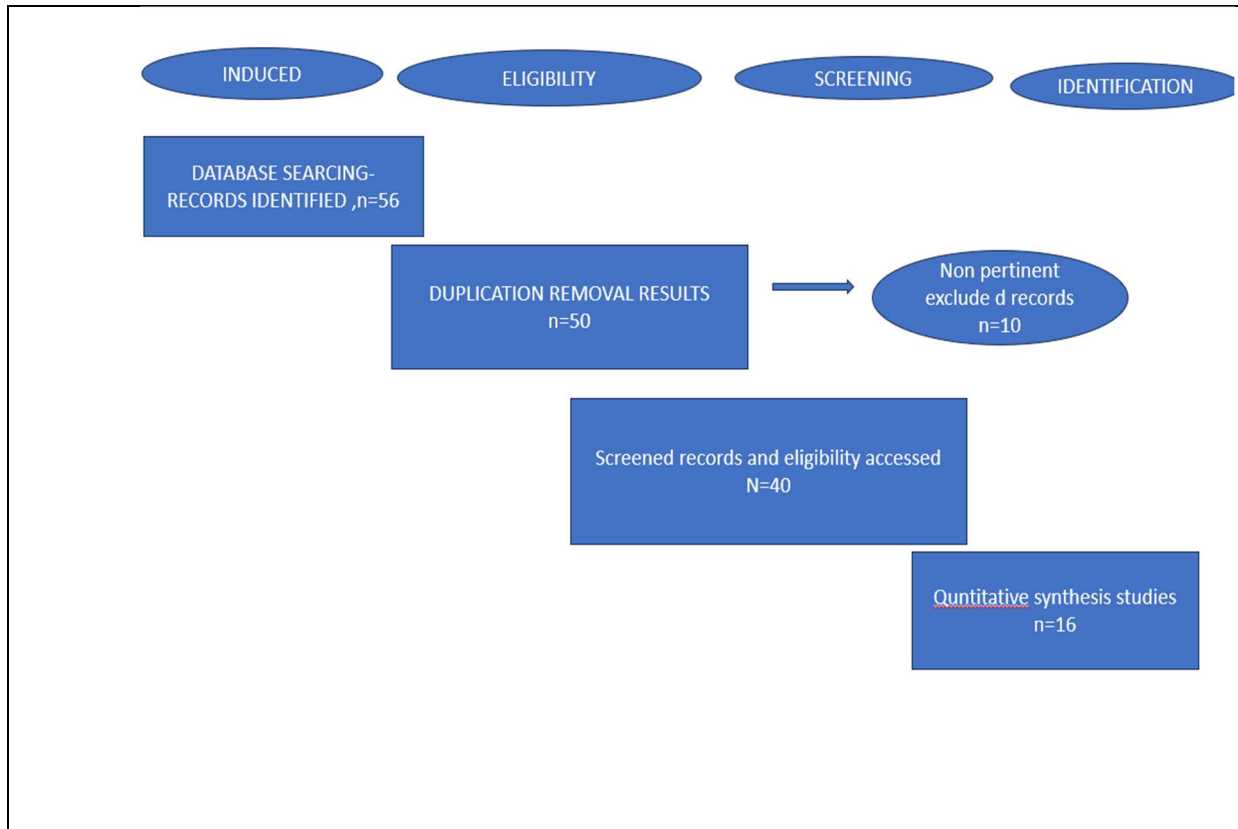
This article explores the advantages and limitations of various diagnostic sampling modalities for nucleic acid amplification-based diagnostics of SARS-CoV-2 infection, including NPS, OPS, and self-collected saliva specimens. It also puts forth practical suggestions to enhance diagnostic reliability.

**Patients and methodology:** Section criteria the inclusion criteria comprised papers published in the English language within peer-reviewed journals, specifically addressing diagnostic accuracy, procedural advantages and limitations, and any potential standard procedures to enhance effectiveness and safety concerning the issue. The focus was on studies involving human subjects, encompassing both adults and children. Excluded were animal studies, while case reports, reviews, letters, opinions, and perspective papers were considered. Unpublished materials were not taken into account. The primary outcome measures assessed were the detection rates of SARS-CoV-2 nucleic acid using RT-PCR on various samples obtained from the upper airways. Papers lacking clarity on these criteria were not included. Excluded from consideration were papers that did not specifically report this particular outcome. Secondary outcomes aimed to identify the advantages and limitations of each procedure, along with any potential standard procedures that could be implemented to enhance effectiveness and safety.

**Information Sources and Search Strategy:** English language papers addressing sampling procedures from the upper airways for the nonserologic diagnosis of COVID-19 were selected through a MEDLINE search (accessed via PubMed on April 7, 2020). The search utilized the following terms: "COVID-19 AND nasopharyngeal swab," "COVID-19 AND oropharyngeal

swab," "COVID-19 AND saliva," and "COVID-19 AND swab." Separate literature searches were conducted for nasopharyngeal swabs (NPS), oropharyngeal swabs (OPS), and saliva specimen collection.

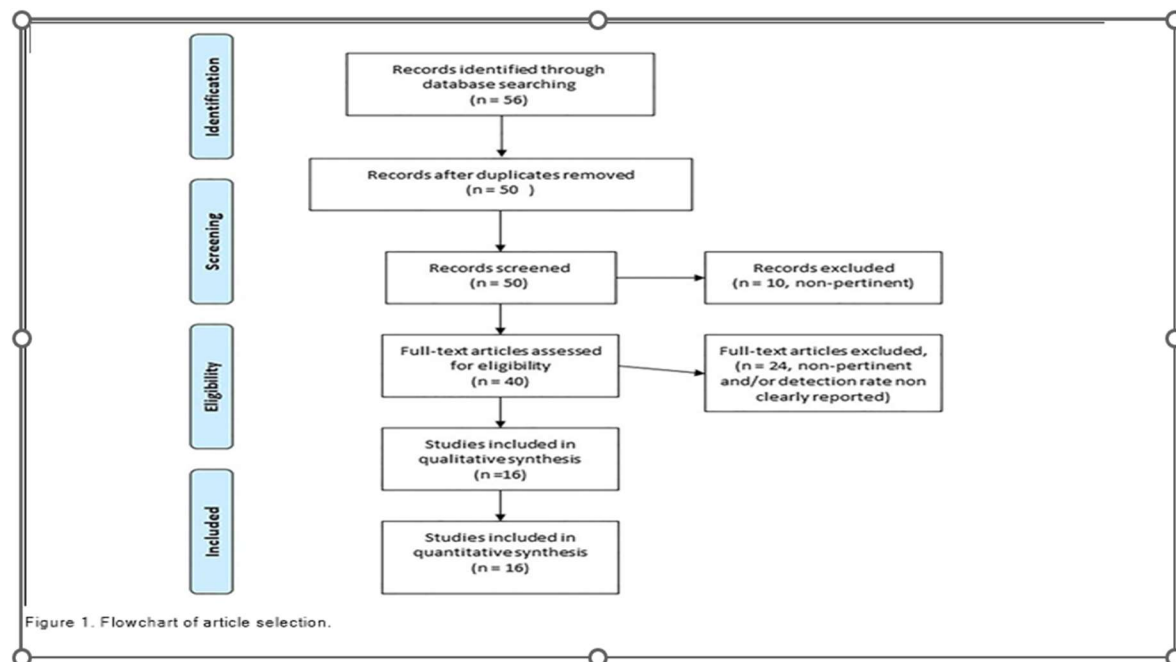
**Study Selection:** To ensure the relevance of all selected papers and identify any potentially overlooked ones, the reference lists were thoroughly reviewed. Eligibility assessment and the data collection process were independently conducted in an unblinded, standardized manner by two review authors. The data extraction sheet was organized as follows: Review author #1 extracted information, and Review author #2 verified it. In cases of disagreement between reviewers, consensus was sought, or consultation with a third author was pursued if no agreement was reached



**Results Study Selection and Characteristics:** Out of the initially identified 56 papers, a total of 16 were included in this minireview. These comprised 9 case series, 3 letters, 2 opinion/perspective papers, 1 state-of-the-art paper, and 1 case report, collectively involving 452 patients (refer to Figure 1). The majority of the papers detailed findings from various samples obtained in limited case series, with a notable absence of original studies specifically designed for comparative purposes on sampling techniques for collection from the upper airways.

**Synthesis of Results:** During the evaluation of the selected papers, a decision was made to conduct separate literature analyses for nasopharyngeal swabs (NPS)/oropharyngeal swabs (OPS) and saliva specimens. This decision was based on the observation that, in many case series, the diagnosis of SARS-CoV-2 infection involved the use of both NPS and OPS in a combined modality. In this context, 12 papers were considered relevant for assessing the diagnostic role of NPS/OPS in patients with COVID-19. These included 1 state-of-the-art article, 1 opinion paper, 1

case report, 2 letters (one with a single-case description and one presenting results from 28 patients), and 7 original papers conducted on limited case series of adult patients ranging between 5 and 292 individuals. Among these, the only comparative study was conducted by Xie et al., who compared SARS-CoV-2 RNA detection rates from Analysis of different samples, including oropharyngeal swabs (OPS), blood, urine, and stool samples, was conducted using various fluorescent RT-PCR kits. The additional original papers incidentally reported virologic results from specimens collected through OPS or NPS. Detection rates were reported in the range of 40% to 100% for NPS and 32% to 100% for OPS. These rates peaked in the early stage of the disease, reaching up to 100% when tested by day 5. However, after day 5, the rates dropped to 40% for NPS and 25% to 40% for OPS (refer to Table 2).



For assessing the potential diagnostic role of saliva sampling in COVID-19, only four papers were found to be relevant. These included one perspective paper without a case description, one letter with a single-case description involving gargle lavage, and two additional studies conducted on small case series (23 and 12 adult patients, respectively) from the same Chinese group. Reported detection rates ranged between 33% and 92%, with positive findings in 87% to 92% of affected patients when performed within 7 days (see Table 2).

Discussion Nasopharyngeal and oropharyngeal swabs play a crucial role in the consistent diagnosis of COVID-19 by detecting SARS-CoV-2 RNA in upper airway secretions. This is supported by evidence of the virus's extensive tropism and its high replication rate in the pharyngeal district. However, recent evidence suggests that the detection rate of SARS-CoV-2 RNA using RT-PCR on both nasopharyngeal swabs (NPS) and oropharyngeal swabs (OPS) may be lower than anticipated. In fact, it has been reported that 3% to 34.7% of patients with chest CT findings suggestive of COVID-19 initially tested negative on swab tests. Moreover, many patients

with an early negative RT-PCR result but consistent CT findings later tested positive in serial examinations after approximately 5 days on average. The analytical sensitivity of RT-PCR is constrained by two grey zones where false-negative results may occur: during the initial days of infection in mainly asymptomatic or mildly, During the collection of upper airway secretions, inadvertent collection into the nasal cavity instead of the nasopharynx can occur, leading to the failure to retrieve infected secretions in the intended location. In the case of oropharyngeal swabs (OPS), unintended contamination from the oral cavity is also possible. Moreover, suboptimal swab performance methods, such as collecting from the nasal cavity during nasopharyngeal swab (NPS) or from the tonsillar complex, have been suggested as standard collecting procedures. For instance, a national guideline presented unclear graphical representations (depicting collection from the middle nasal meatus and the tonsillar complex) despite providing adequate explanations.

Test and description	Specimen	WAY TO PERFORM
RT-PCR: two separate oligonucleotide primers/probes selected from regions of the virus nucleocapsid N gene; an additional set targeting the human RNase P gene. All 3 assays must match in order to report presumptive positivity for SARS-CoV-2.	NPS <sub>s</sub>	<ul style="list-style-type: none"> <li>• Sterilely open the outer case of the swab, Insert the swab into nasal cavity by slightly elevating the tip of the nose, Let the swab flow the floor of the nasal cavity (in parallel with the hard palate).</li> </ul>
	OPS <sub>s</sub>	<ul style="list-style-type: none"> <li>• Keep the tip of the swab in the nasopharynx for a few seconds, then rotate and extract.</li> </ul>
	SELF COLLECTED SALIVA	<ul style="list-style-type: none"> <li>• Sterilely open the outer case of the swab, Gently lane the tongue depressor anteriorly over the tongue, Reach with the tip of the swab the posterior wall of the oropharynx.</li> <li>• Instruct the patient to how correctly perform a throat-clearing maneuver, Invite the patient to sterilely open the container, Invite the patient to perform a throat-clearing maneuver and cough out saliva into the container,.</li> </ul>
	BAL (Wang, Pascarella)	<ul style="list-style-type: none"> <li>• Collect BAL or <u>fibrobronchoscope</u> brush biopsy through bronchoscopy (only for intubated patients with severe illness and upper respiratory samples negative)</li> </ul>

Table 1. Diagnostic Test for SARS-CoV-2 Detection

The collection of upper airway secretions for SARS-CoV-2 diagnostic purposes has been standardized by the US-CDC, recommending the use of swabs with a synthetic tip and shaft made of aluminum or plastic materials. Based on our experience, NPS should be conducted as follows: after sterilely opening the outer case of the swab, it is inserted into the nasal cavity by slightly elevating the tip of the nose, enlarging the nostril, and reducing the risk of contamination of the nasal vestibule. The swab then moves over the floor of the nasal cavity parallel to the line of the hard palate. After reaching the nasopharynx, the swab remains there for a few seconds, is rotated, and then extracted to enhance the absorption of secretions for diagnosis. Oropharyngeal swabbing involves gently pressing the tongue depressor anteriorly over the tongue, avoiding contact with the tongue. The swab should be positioned near the posterior wall of the oropharynx to collect secretions descending from the upper nasopharynx. Figures 2 and 3 depict the proper collection of nasopharyngeal and oropharyngeal secretions during NPS and OPS execution, respectively, performed by a trained ear, nose, and throat examiner and confirmed through transnasal videoendoscopic control. To minimize nosocomial transmission, certain procedural details can be adopted. Won et al. proposed... A laboratory-safe and cost-effective protocol for COVID-19 detection has been proposed by Won et al. According to this protocol, the patient conducts the

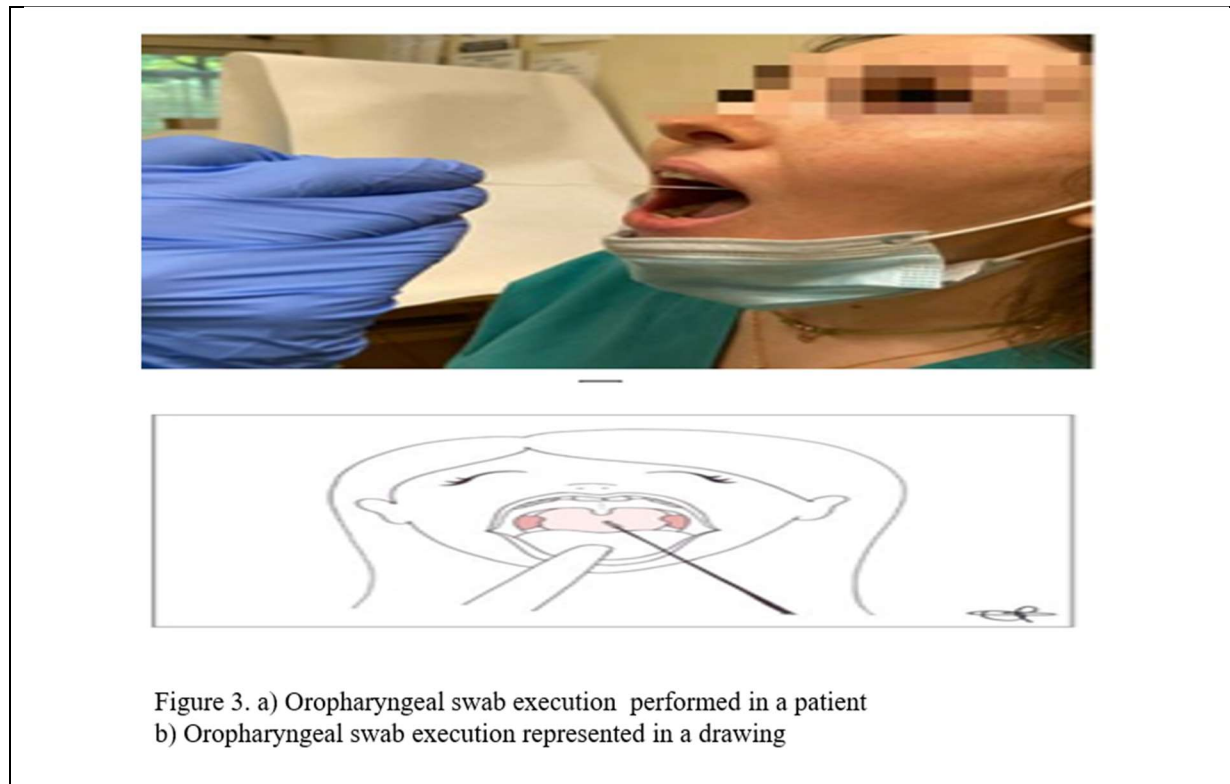
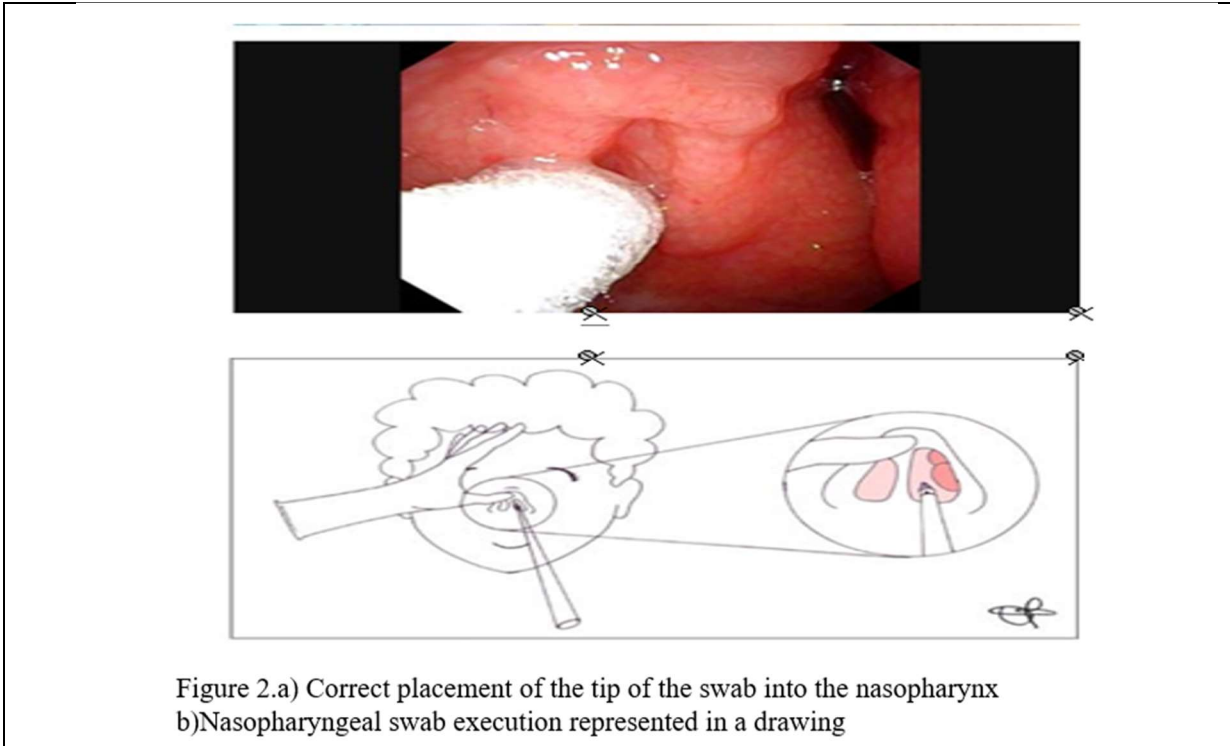
collection procedure under a well-ventilated fume hood with constant air inflow. This setup includes spatial separation between the OPS station and the laboratory

Conclusion: the consistent diagnosis of SARS-CoV-2 infection using traditional nasopharyngeal swabs (NPS) and oropharyngeal swabs (OPS) faces limitations due to suboptimal diagnostic accuracy resulting from inadequate sampling techniques and the significant risk of nosocomial transmission. Urgent attention is required for conducting comparative trials dedicated to defining the preferred diagnostic modality.

	NPS	OPS	SALIVA
ADVANTAGES	It rapidly peaks during early stage	It rapidly peaks during early stage	Simple; Very inexpensive; It does not cause patient discomfort; It can be performed by the patients themselves also outside the hospital; Low risk of nosocomial transmission; Can be used to monitor viral load; It allows collection of both descending nasopharyngeal secretions and lower fluids ascending from the tracheobronchial tree (throat-clearing maneuver)
LIMITATIONS	Risk of contamination; Risk of nosocomial transmission; Possible side effects such as bleeding; Unpleasant and possibly painful; It is already on the decline at the time of first presentation; Precocious negativity despite active viremia persistence; Not adequate for serial monitoring viral load Not so easy to perform in children	It requires examiner training; Risk of contamination; Risk of nosocomial transmission; It is already on the decline at the time of first presentation; Precocious negativity despite active viremia persistence; Not adequate for serial monitoring viral	load It depends on the patient's ability to understand the instructions for use and its compliance
DETECTION RATE	40%-100% (100% within day 5; 40% after day 5)	32%-100% (32%-100% within day 5; 25%-40% after day 5)	33%-92% (87%-92% within day 7; 33% after day 20)
COST	9 to 10 k	8 to 10k	1 to 2k

Table 2. Advantages and Limitations of Sampling Procedures From the Upper Respiratory Tract for Diagnosis of SARS-CoV-2 Infection.

The diagnostic reliability of RT-PCR analysis performed on saliva samples collected through various methods warrants further investigation. The collection of deep saliva, obtained through a throat-clearing maneuver, is particularly intriguing as it encompasses fluids from the posterior oropharynx, composed not only of saliva but also of secretions descending from the nasopharynx and ascending from the tracheobronchial district. To enhance the effectiveness and safety of diagnostic procedures, there is a crucial need for clear and unambiguous definition and dissemination of standardized procedures. Additionally, the education and training of healthcare personnel should be prioritized to ensure the proper execution of diagnostic protocols.



## References

1. World Health Organization. Coronavirus Disease 2019 (COVID19). Situation Report-120. Updated June 10, 2020. Accessed June 11, 2020. [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200610-covid-19-sitrep-142.pdf?sfvrsn=4180898cd\\_2](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200610-covid-19-sitrep-142.pdf?sfvrsn=4180898cd_2)
2. Centers for Disease Control and Prevention. Interim Guidelines for Collecting, Handling, and Testing Clinical Specimens from Persons for Coronavirus Disease 2019 (COVID-19). Updated July 8, 2020. Accessed April 16, 2020. <https://www.cdc.gov/coronavirus/2019-nCoV/lab/guidelines-clinical-specimens.html>
3. Lippi G, Simundic AM, Plebani M. Potential preanalytical and analytical vulnerabilities in the laboratory diagnosis of coronavirus disease 2019 (COVID-19). *Clin Chem Lab Med*. 2020; 58(7):1070-1076
4. Wang W, Xu Y, Gao R, et al. Detection of SARS-CoV-2 in different types of clinical specimens. *JAMA*. 2020;323(18): 1843-1844.
5. Food and Drug Administration. New-York SARS-CoV-2. Real-Time RT-PCR Diagnostic Panel-February 29. Updated March 15, 2020. Accessed March 9, 2020. <https://www.fda.gov/media/135662/download>
6. Winichakoon P, Chaiwarith R, Liwsrisakun C, et al. Negative nasopharyngeal and oropharyngeal swab do not rule out COVID-19. *J Clin Microbiol*. 2020;58(5):00297-00280.
7. Hamming I, Timens W, Bulthuis ML, et al. Tissue distribution of ACE2 protein, the functional receptor for SARS coronavirus. a first step in understanding SARS pathogenesis. *J Pathol*. 2004; 203(2):631-637
8. Centers for Disease Control and Prevention. CDC 2019-Novel Coronavirus (2019-nCoV) Real-Time RT-PCR Diagnostic Panel. Updated July 13, 2020. Accessed July 13, 2020 <https://www.fda.gov/media/134922/download>.
9. Torretta S, Zuccotti G, Cristofaro V, et al. Nonserologic test for COVID-19: how to manage? *Head Neck*. 2020;42(7):1552-1554
10. Pascarella G, Strumia A, Piliago C, et al. COVID-19 diagnosis and management: a comprehensive review. *J Intern Med*. 2020; 288(2):192-206.
11. Centers for Disease Control and Prevention. Interim Guidelines for COVID-19 Antibody Testing. Updated August 1, 2020. Accessed July 15, 2020 [https://www.cdc.gov/coronavirus/2019-ncov/lab/resources/antibody-tests-guidelines.html#anchor\\_1590280017822](https://www.cdc.gov/coronavirus/2019-ncov/lab/resources/antibody-tests-guidelines.html#anchor_1590280017822).
12. Torretta S, Gaini LM, Pignataro L. Why Italian ENT physicians should be aware of SARS-CoV-2. *Acta Otorhinolaryngol Ital*. 2020;40(2):152-153
13. Istituto Superiore di Sanit`a (Roma). Epidemia COVID-19. Sorveglianza Integrata COVID-19 in Italia. Aggiornamento del 10 Giugno; 2020. Updated June 10, 2020. Accessed June 11, 2020 [https://www.epicentro.iss.it/coronavirus/bollettino/Infografica\\_10giugno%20ITA.pdf](https://www.epicentro.iss.it/coronavirus/bollettino/Infografica_10giugno%20ITA.pdf)
14. Federazione Nazionale degli Ordini dei medici Chirurghi e degli odontoiatri. Elenco dei medici caduti nel corso dell'epidemia COVID-19; Updated August 18, 2020. Accessed June 11, 2020. <https://portale.fnomceo.it/elenco-dei-medici-caduti-nel-corso-del-lepidemia-di-covid-19>

15. Loeffelholz MJ, Tang YW. Laboratory diagnosis of emerging human coronavirus infections - the state of the art. *Emerg Microbes Infect.* 2020;9(1):747-756
16. Hase R, Kurita T, Muranaka E, Sasazawa H, Mito H, Yano Y. A case of imported COVID-19 diagnosed by PCR-positive lower respiratory specimen but with PCR-negative throat swabs. *Infect Dis (Lond).* 2020;52(6):423-426.
17. Chen W, Lan Y, Yuan X, et al. Detectable 2019-nCoV viral RNA in blood is a strong indicator for further clinical severity. *Emerg Microbes Infect.* 2020;9(1):469-473.
18. Xie X, Zhong Z, Zhao W, Zheng C, Wang F, Liu J. Chest Ct for typical 2019-ncov pneumonia: relationship to negative rt-pcr testing. *Radiology.* 2020;296(2): E41-E45
19. Woölfel R, Corman VM, Guggemos W, et al. Virological assessment of hospitalized patients with COVID-2019. *Nature* 2020; 581(7809):465-469.
20. Ling Y, Xu SB, Lin YX, et al. Persistence and clearance of viral RNA in 2019 novel coronavirus disease rehabilitation patients. *Chin Med J (Engl).* 2020;133(9):1039-1043.
21. Zhang W, Du RH, Li B, et al. Molecular and serological investigation of 2019-nCoV infected patients: implication of multiple shedding routes. *Emerg Microbes Infect.* 2020;9(1):386-389.
22. Xie C, Jiang L, Huang G, et al. Comparison of different samples for 2019 novel coronavirus detection by nucleic acid amplification tests. *Int J Infect Dis.* 2020; 93:264-267
23. Won J, Lee S, Park M, et al. Development of a Laboratory-safe and Low-cost Detection Protocol for SARS-CoV-2 of the Coronavirus Disease 2019 (COVID-19). *Exp Neurobiol.* 2020; 29(2):107-119
24. Lo IL, Lio CF, Cheong HH, et al. Evaluation of SARS-CoV-2 RNA shedding in clinical specimens and clinical characteristics of 10 patients with COVID-19 in Macau. *Int J Biol Sci.* 2020;16(10): 1698-1707
25. Khurshid Z, Asiri FYI, Al Wadaani H. Human saliva: noninvasive Fluid for Detecting Novel Coronavirus (2019-nCoV). *Int J Environ Res Public Health.* 2020;17(7): E2225
26. To KK, Tsang OT, Yip CCY, et al. Consistent detection of 2019 novel coronavirus in saliva. *Clin Infect Dis.* 2020;71(15):841-843
27. To KK, Tsang OT, Leung WS, et al. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. *Lancet Infect Dis.* 2020;20(5):565-574
28. Saito M, Adachi E, Yamayoshi S, et al. Gargle lavage as a safe and sensitive alternative to swab samples to diagnose COVID-19: a case report in Japan. *Clin Infect Dis.* 2020;71(15):893-894.
29. Torretta S, Capaccio P, Gaffuri M, et al. ENT management of children with adenotonsillar disease during COVID-19 pandemic. Ready to start again? *Int J Pediatr Otorhinolaryngol.* 2020;28: 110145.
30. To KK, Lu L, Yip CC, et al. Additional molecular testing of saliva specimens improves the detection of respiratory viruses. *Emerg Microbes Infect.* 2017;6(6):e49.

31. To KKW, Yip CCY, Lai CYW, et al. Saliva as a diagnostic specimen for testing respiratory virus by a point-of-care molecular assay: a diagnostic validity study. *Clin Microbiol Infect.* 2019; 25(3):372-378.
32. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (covid-19) in china: a report of 1014 cases. *Radiology.* 2020; 296(2): E32-E40
33. Istituto Superiore di Sanit`a (Roma). Rapporto ISS COVID-19. N 11\2020. Raccomandazioni per il corretto prelievo, conservazione e analisi sul tampone oro/nasofaringeo per la diagnosi di COVID-19. Gruppo di lavoro ISS Diagnostica e sorveglianza microbiologica COVID-19: aspetti di analisi molecolare e sierologica. Updated May 29, 2020. Accessed April 16, 2020. [https://www.iss.it/rapporti-covid-19/-/asset\\_publisher/btw1J82wtYzH/content/id/5329985](https://www.iss.it/rapporti-covid-19/-/asset_publisher/btw1J82wtYzH/content/id/5329985)
34. Capaccio P, Pignataro L, Corbellino M, et al. Acute Parotitis: a possible precocious clinical manifestation of SARS-COV-2 infection. *Otolaryngol Head Neck Surg.* 2020;163(1):182-183
  
35. Ansarullah, S. I., Saif, S. M., Andrabi, S. A. B., Kumhar, S. H., Kirmani, M. M., & Kumar, D. P. (2022). An intelligent and reliable hyperparameter optimization machine learning model for early heart disease assessment using imperative risk attributes. *Journal of Healthcare Engineering*, 2022. <https://doi.org/10.1155/2022/9882288>.
36. Kumhar, S. H., Ansarullah, S. I., Gardezi, A. A., Ahmad, H., Abd Elgawad, A. E. E., & Shafiq, M. (2023). Translation of English Language into Urdu Language Using LSTM Model. *Computers, Materials & Continua*, 74(2), 3899-3912. <https://doi.org/10.32604/cmc.2023.032290>.
37. G. S. P. Ghantasala et al., "Tech-Enabled Banking Revolt:The Transformational Era of IT in the Financial Sector," 2023 Seventh International Conference on Image Information Processing (ICIIP), Solan, India, 2023, pp. 133-136, doi: 10.1109/ICIIP61524.2023.10537647.
38. Shaik, R. B., Banu, S. B., Siddiqui, S. A., Jyothi, M. K., Bhaumik, A., Chandini, S., & Aarif, M. (2023). Organizational Commitment Of Employee A Rising Risk In The Educational Sector. *Boletin de Literatura Oral-The Literary Journal*, 10(1), 2496-2505.
39. Banu, S. R., Banu, S. B., Shaik Chandini, D. V., Jyothi, M. K., & Nusari, M. S. (2022). Assessment of research skills in undergraduates students. *Journal of Positive School Psychology*, 6938-6948.
40. S. B. Banu, S. W. Akhtar, S. Arshad, S. R. Banu, S. Chandini and G. P. Ghantasala, "High Heels Are No More an Accessory of Fashion for Women- A Study Unrevealing the Health Effects of Wearing High Heels," 2024 10th International Conference on Communication and Signal Processing (ICCSP), Melmaruvathur, India, 2024, pp. 406-410, doi: 10.1109/ICCSP60870.2024.10543799.
41. Sahu, G., Anant, M., & Tiwari, S. The Impact of Social Media on the Positive Development of Teenagers in the Contemporary age

42. Sahu, G., Anant, M., Tiwari, S., & Gupta, T. C. (2024). SEZ-Led Economic Growth: Evaluating The Impact Of Export Promotion Policies On Developing Countries, With A Focus On India—An Analytical Study. *Educational Administration: Theory and Practice*, 30(4), 1215-1220.
43. Sahu, G., Anant, M., & Tiwari, S. (2023). Information and Communication Technology (ICT) in the context of Rural Women Empowerment. *The journal of contemporary issues in business and government*, 29(3), 323-329.
44. Sahu, G., Anant, M., & Tiwari, S. The Impact of Social Media on the Positive Development of Teenagers in the Contemporary age.
45. Malik, A., Gautam, S., Abidin, S., & Bhushan, B. (2019, July). Blockchain technology-future of IoT: including structure, limitations and various possible attacks. In 2019 2nd international conference on intelligent computing, instrumentation and control technologies (ICICICT) (Vol. 1, pp. 1100-1104). IEEE.
46. Abidin, S., Swami, A., Ramirez-Asís, E., Alvarado-Tolentino, J., Maurya, R. K., & Hussain, N. (2022). Quantum cryptography technique: A way to improve security challenges in mobile cloud computing (MCC). *Materials Today: Proceedings*, 51, 508-514.
47. Abidin, S., Vadi, V. R., & Rana, A. (2021). On confidentiality, integrity, authenticity, and Freshness (CIAF) in WSN. In *Advances in Computer, Communication and Computational Sciences: Proceedings of IC4S 2019* (pp. 87-97). Springer Singapore.
48. Sucharitha, Y., Vinothkumar, S., Rao Vadi, V., Abidin, S., & Kumar, N. (2021). Wireless communication without the need for pre-shared secrets is consummate via the use of spread spectrum technology. *J Nucl Ene Sci Power Generat Techno*, 10(9), 2.
49. Abidin, S. (2019). Enhancing security in WSN by artificial intelligence. In *International Conference on Intelligent Data Communication Technologies and Internet of Things (ICICI) 2018* (pp. 814-821). Springer International Publishing.
50. Bhoopathy, V., Behura, A., Reddy, V. L., Abidin, S., Babu, D. V., & Albert, A. J. (2021). WITHDRAWN: IOT-HARPSECA: A SECURE DESIGN AND DEVELOPMENT SYSTEM OF ROADMAP FOR DEVICES AND TECHNOLOGIES IN IOT SPACE.
51. Abidin, S. (2017). Greedy Approach for Optimizing 0-1 Knapsack Problem. *Communications on Applied Electronics*, 7(6), 1-3.

52. Sajid, M., Jawed, M. S., Abidin, S., Shahid, M., Ahamad, S., & Singh, J. Capacitated Vehicle Routing Problem Using Algebraic Harris Hawks Optimization Algorithm. In *Intelligent Techniques for Cyber-Physical Systems* (pp. 183-210). CRC Press.
53. Abidin, S., Raghunath, M. P., Rajasekar, P., Kumar, A., Ghosal, D., & Ishrat, M. (2022, July). Identification of disease based on symptoms by employing ML. In *2022 International Conference on Inventive Computation Technologies (ICICT)* (pp. 1357-1362). IEEE.
54. Malik, A., Parihar, V., Srivastava, J., Kaur, H., & Abidin, S. (2023, March). Prognosis of diabetes mellitus based on machine learning algorithms. In *2023 10th International Conference on Computing for Sustainable Global Development (INDIACom)* (pp. 1466-1472). IEEE.
55. Vadi, V. R., Abidin, S., Khan, A., & Izhar, M. (2022). Enhanced Elman spike neural network fostered blockchain framework espoused intrusion detection for securing Internet of Things network. *Transactions on Emerging Telecommunications Technologies*, 33(12), e4634.
56. Abidin, S., Dhariwal, M. K., Rane, K. P., Sivakumar, G., Babu, D. V., & Kumar, I. R. (2021). Development and Organize of Wireless Sensor Network in Home Management using IoT. *International Journal of Aquatic Science*, 12.
57. Chadha, S., Mittal, S., & Singhal, V. (2020). Ancient text character recognition using deep learning. *International Journal of Engineering Research and Technology*, 3(9), 2177-2184.
58. Chadha, S., Mittal, S., & Singhal, V. (2019). An insight of script text extraction performance using machine learning techniques. *International Journal of Innovative Technology and Exploring Engineering*, 9(1), 2581-2588.
59. Gupta, N., Chauhan, R., & Chadha, S. (2020). Unmanned Aerial Vehicle (UAV) for Parcel Delivery. *Int. J. Eng. Res. Technol*, 13(10), 2824-2830.
60. Chadha, S., Chauhan, R., & Gupta, N. (2022). Flood Prediction And Rainfall Analysis Using LightGradient Boosted Machine. *NeuroQuantology*, 20(9), 1690.
61. Makkar, I. S., & Chadha, S. (2024, March). Unsupervised Emotion Matching for Image and Text Input. In *2024 IEEE International Conference on Interdisciplinary Approaches in Technology and Management for Social Innovation (IATMSI)* (Vol. 2, pp. 1-6). IEEE.
62. Gupta, N., Chadha, S., Chauhan, R., & Singhal, P. (2023, December). Damage Evaluation Following Natural Disasters Using Deep Learning. In *International Advanced Computing Conference* (pp. 90-103). Cham: Springer Nature Switzerland.
63. Gupta, N., Chadha, S., Srivastava, G., & Chauhan, R. (2021, October). Mortality Rate Extrapolation Based on Symptomatic Symptoms of Novel Corona Virus. In *2021 5th International Conference on Information Systems and Computer Networks (ISCON)* (pp. 1-5). IEEE.
64. ShikhaChadha, D. S., & Singhal, V. Ancient Text Character Recognition Using Deep Learning.

65. Verma, S., Gupta, N., Anil, B. C., & Chauhan, R. (2022). A Novel Framework for Ancient Text Translation Using Artificial Intelligence. *ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal*, 11(4), 411-425.
66. Mandala, V. (2018). From Reactive to Proactive: Employing AI and ML in Automotive Brakes and Parking Systems to Enhance Road Safety. *International Journal of Science and Research (IJSR)*, 7(11), 1992–1996. <https://doi.org/10.21275/es24516090203>
67. Mandala, V. (2019). Optimizing Fleet Performance: A Deep Learning Approach on AWS IoT and Kafka Streams for Predictive Maintenance of Heavy - Duty Engines. *International Journal of Science and Research (IJSR)*, 8(10), 1860–1864. <https://doi.org/10.21275/es24516094655>
68. Mandala, V. (2019). Integrating AWS IoT and Kafka for Real-Time Engine Failure Prediction in Commercial Vehicles Using Machine Learning Techniques. *International Journal of Science and Research (IJSR)*, 8(12), 2046–2050. <https://doi.org/10.21275/es24516094823>
69. Mandala, V., & Surabhi, S. N. R. D. (2024). Integration of AI-Driven Predictive Analytics into Connected Car Platforms. *IARJSET*, 7(12). <https://doi.org/10.17148/iarjset.2020.71216>
70. Mandala, V. Towards a Resilient Automotive Industry: AI-Driven Strategies for Predictive Maintenance and Supply Chain Optimization.
71. Mandala, V., & Surabhi, S. N. R. D. (2021). Leveraging AI and ML for Enhanced Efficiency and Innovation in Manufacturing: A Comparative Analysis.
72. Mandala, V. (2021). The Role of Artificial Intelligence in Predicting and Preventing Automotive Failures in High-Stakes Environments. *Indian Journal of Artificial Intelligence Research (INDJAIR)*, 1(1).
73. Mandala, V., & Surabhi, S. N. R. D. Intelligent Systems for Vehicle Reliability and Safety: Exploring AI in Predictive Failure Analysis.
74. Mandala, V., & Kommisetty, P. D. N. K. (2022). Advancing Predictive Failure Analytics in Automotive Safety: AI-Driven Approaches for School Buses and Commercial Trucks.
75. Mandala, V., & Mandala, M. S. (2022). ANATOMY OF BIG DATA LAKE HOUSES. *NeuroQuantology*, 20(9), 6413.
76. Mandala, V., Premkumar, C. D., Nivitha, K., & Kumar, R. S. (2022). Machine Learning Techniques and Big Data Tools in Design and Manufacturing. In *Big Data Analytics in Smart Manufacturing* (pp. 149-169). Chapman and Hall/CRC.
77. Mandala, V. (2022). Revolutionizing Asynchronous Shipments: Integrating AI Predictive Analytics in Automotive Supply Chains. *Journal ID*, 9339, 1263.
78. Mandala, V., & Surabhi, S. N. R. D. (2024). Machine Learning Algorithms for Engine Telemetry Data: Transforming Predictive Maintenance in Passenger Vehicles. *IJARCCCE*, 11(9). <https://doi.org/10.17148/ijarccce.2022.11926>
79. Surabhi, S. N. R. D., Mandala, V., & Shah, C. V. AI-Enabled Statistical Quality Control Techniques for Achieving Uniformity in Automobile Gap Control.
80. Shah, C. V., Surabhi, S. N. R. D., & Mandala, V. ENHANCING DRIVER ALERTNESS USING COMPUTER VISION DETECTION IN AUTONOMOUS VEHICLE.

81. Mandala, V., Jeyarani, M. R., Kousalya, A., Pavithra, M., & Arumugam, M. (2023, April). An Innovative Development with Multidisciplinary Perspective in Metaverse Integrating with Blockchain Technology with Cloud Computing Techniques. In 2023 International Conference on Inventive Computation Technologies (ICICT) (pp. 1182-1187). IEEE.
82. Mandala, V., Rajavarman, R., Jamunadevi, C., Janani, R., & Avudaiappan, T. (2023, June). Recognition of E-Commerce through Big Data Classification and Data Mining Techniques Involving Artificial Intelligence. In 2023 8th International Conference on Communication and Electronics Systems (ICCES) (pp. 720-727). IEEE.