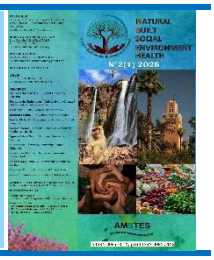
Natural Built Social Environment Health

ISSN 3085-461X

www.nbseh.org



Impact of storage temperature and duration on rRT-PCR Cycle Threshold (Ct) values in SARS-CoV-2-positive nasopharyngeal Samples: A study at a provincial hospital in Morocco

Oumaima Mallouk [1,a], Aicha Qasmaoui [2,b], Rachid Amgoun [3,c], Said Hilali [1,d], Samira Natoubi [4,e *]

[1] Department of Applied Biology, Faculty of Science and Technology, University Hassan I, Settat, Morocco.

[2] Department of Medical Bacteriology, Laboratory of Epidemic Diseases, National Institute of Hygiene, Rabat, Morocco.

[3] Microbiology Laboratory, Provincial Hassan II Hospital, Delegation of the Health Ministry, Settat, Morocco.

[4] Laboratory of Care, Health and Sustainable Development 2S2D, Higher Institute of Nursing Professions and Techniques of Health (ISPITS) Casablanca, Annexe Settat Morocco.

[a] ***ORCID:*** *****-****-****-*****; ***Email***: *oumaimamallouk22@gmail.com*

[b] ***ORCID:*** *0009-0003-3788-7573*; ***Email***: *aichabacterio@gmail.com*

[c] ***ORCID:*** *****-****-****-*****; ***Email***: *r.amgoun@hotmail.fr*

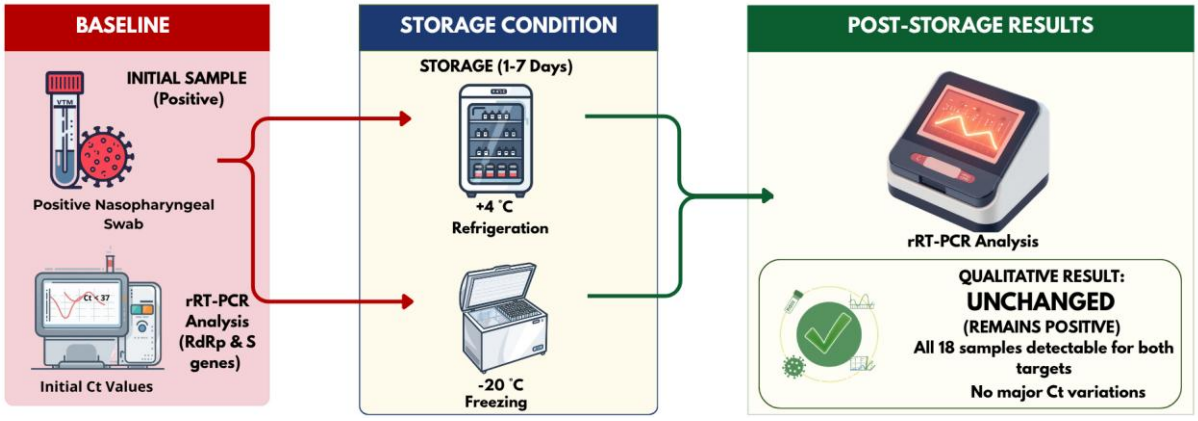
[d] ***ORCID:*** *0000-0001-9296-3557*; ***Email***: *said.hilali@uhp.ac.ma*

[e] ***ORCID:*** *0000-0001-5536-8265*; ***Email***: *samiranatoubi@yahoo.fr*

* Corresponding author: **Samira Natoubi** ; *Email*: samiranatoubi@yahoo.fr

Graphical Abstract

Accurate SARS-CoV-2 detection by RT-PCR depends not only on analytical performance but also on pre-analytical conditions. Sample collection, handling, and storage directly impact RNA integrity and cycle threshold (Ct) values, influencing diagnostic reliability.



DOI: 10.63095/NBSEH.26.338615

Received: *07 March 2026*
Revised: *18 May 2026*
Accepted: *05 June 2026*
Published online: *07 June 2026*

Citation: Brett-Crowther, M., 2026, Water and the Future of the Middle East & North Africa (MENA). *Natural Built Social Environment Health* **2**(3), 168-180. https://doi.org/10.63095/NBSEH.26.338615

Abstract: Reverse transcription polymerase chain reaction (RT-PCR) is the gold standard for SARS-CoV-2 diagnosis of infection. Pre-analytical factors such as storage temperature and duration may affect RNA stability and, consequently, RT-PCR performance. This study aimed to assess the impact of these factors on cycle threshold (Ct) values to ensure reliable diagnostic results. Eighteen SARS-CoV-2–positive nasopharyngeal swab samples were stored at +4 °C and −20 °C and analyzed by RT-PCR over a period of 1 to 7 days. Detection of the S (Spike) and RdRp (RNA-dependent RNA polymerase) genes was performed, and Ct values were compared before and after storage. All analyses were conducted using the same standardized protocol for RNA extraction, amplification, and result interpretation. All initially positive samples remained positive after storage. Ct values showed only minor variations, with mean decreases of −1.02 cycles for RdRp and −1.05 cycles for the S gene after storage. Variations of up to 2–3 Ct cycles were observed in some samples. These findings suggest that short-term storage under standard conditions is unlikely to affect SARS-CoV-2 detection by RT-PCR. Because of the limited sample size, the analysis was mainly descriptive. Therefore, short-term storage of SARS-CoV-2 samples under routine laboratory conditions did not alter RT-PCR qualitative results.

Keywords: *SARS-CoV-2, RT-PCR, CT value, Storage temperature, Storage duration.*

Introduction

Since its emergence in Wuhan, China, in late 2019, SARS-CoV-2 rapidly evolved into a global pandemic that placed unprecedented demands on public health systems and diagnostic laboratories worldwide [1]. As the virus spread globally, timely and accurate detection became the hallmark of pandemic management, guiding clinical decision-making, contact tracing, and containment strategies [1]. Among the available diagnostic tools, real-time reverse transcription polymerase chain reaction (RT-PCR) has remained the gold standard for identifying active infections because of its high sensitivity in detecting viral nucleic acids [2].

The enormous number of clinical specimens, often reaching thousands per day in some regions, posed logistical challenges beyond laboratory testing capacity. Samples from areas without molecular testing capabilities are often transported to reference laboratories, where processing delays require controlled storage [3]. In routine diagnostic settings, laboratories frequently rely on temporary storage of samples prior to analysis, raising concerns about the reliability of RT-qPCR results under such conditions. These pre-analytical variables, including storage temperature and duration, are critical determinants of sample integrity and may influence the stability of viral RNA, potentially contributing to variability in RT-PCR results [4]. Despite the recognized importance of pre-analytical factors in molecular diagnostics, the specific impact of storage conditions on SARS-CoV-2 RNA stability remains insufficiently characterized. Most existing studies have focused on analytical performance or assay comparison. Only a limited number of studies have experimentally evaluated how storage temperature and duration influence viral RNA detectability under routine laboratory conditions.

In contrast, studies specifically addressing pre-analytical storage conditions have reported inconsistent findings. Some have suggested minimal RNA degradation under short-term storage. Others have indicated potential alterations in Ct values depending on temperature and duration. These discrepancies highlight the need for further investigation under real-world laboratory conditions, particularly in resource-constrained settings where immediate processing is not always feasible. Moreover, it is not clear whether short-term storage under commonly used conditions (such as refrigeration or freezing) significantly alters RT-PCR cycle threshold (Ct) values, which are often used as indirect indicators of viral load. In this context, describing Ct variations under different storage conditions may provide useful preliminary insights, even in the absence of inferential statistical testing. Addressing this uncertainty is essential to ensure the reliability and interpretability of molecular diagnostic results.

Based on these considerations, this study aimed to explore whether storage temperature and duration may influence SARS-CoV-2 RNA stability and result in variations in RT-PCR Ct values. This exploratory approach focuses on descriptive analysis of Ct value variations and qualitative RT-PCR outcomes under different storage conditions and durations.

This study investigates the influence of storage temperature and duration on the reliability of SARS-CoV-2 detection by RT-qPCR. Specifically, we evaluated whether these parameters affect viral RNA degradation and subsequent changes in Ct values, by analysing previously confirmed positive samples subjected to different storage conditions. This study provides descriptive observations intended to inform laboratory practices. By providing empirical data under real-world laboratory constraints, this study seeks to contribute to the optimization of sample handling protocols and to strengthen the robustness of molecular diagnostic practices. Understanding these effects is essential to ensure diagnostic reliability, maintain workflow efficiency, and support laboratory performance.

Materials and methods

This laboratory-based experimental study was conducted in the Microbiology laboratory of Hassan II Hospital, Settat, Morocco. Nasopharyngeal swabs were collected from COVID-19 contact cases in Settat between May 10 and June 10, 2021. During this period, 579 nasopharyngeal samples were collected, excluding duplicates, of which 72 tested positive for SARS-CoV-2 by RT-qPCR (Fig. 1).

All nasopharyngeal specimens included in this study were collected using standardized sampling kits consisting of a sterile nasopharyngeal swab placed in a tube containing viral transport medium (VTM). Contact cases were sampled at the Attanmya Center in Settat, a facility dedicated exclusively to COVID-19 screening, whereas hospitalized patients and individuals requiring emergency care were sampled directly at the hospital. Specimen collection was performed by personnel trained in nasopharyngeal sampling techniques and in accordance with recommended hygiene and biosafety measures. In all cases, sample packaging, transport, and storage procedures were strictly followed, including transportation to the laboratory in insulated containers to maintain appropriate conditions.

Samples were collected under routine diagnostic conditions, and initial Ct values showed variability between samples, reflecting differences in viral load among patients. After collection, nasopharyngeal swabs were transported to the laboratory in viral transport medium under refrigerated conditions (approximately +4 °C) and processed within a short time frame, in accordance with routine diagnostic procedures.

From each sample, 300 µL of the transport medium was aliquoted into Eppendorf tubes and stored at +4 °C and −20 °C for variable durations. This approach was adopted to evaluate the effect of storage temperature and duration on SARS-CoV-2 RNA stability and RT-qPCR reliability under conditions where immediate processing is not feasible [5]**.**

Aliquots were prepared to avoid repeated freeze–thaw cycles, and each aliquot was thawed only once prior to RT-qPCR analysis. Ct values were measured at baseline and after storage within the same specimen to assess the impact of storage conditions.

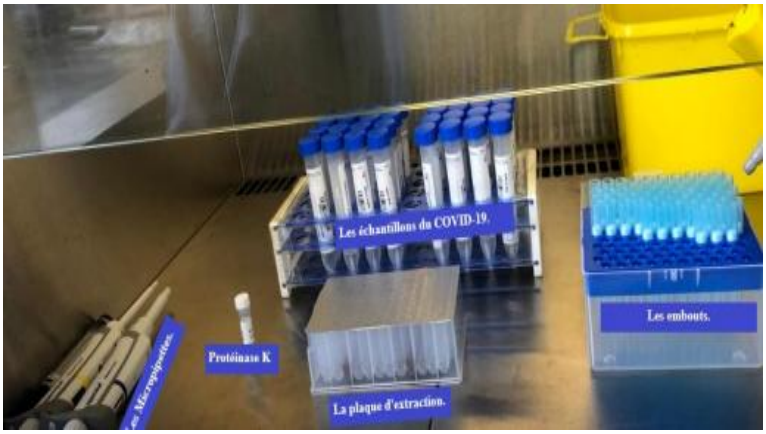


Figure 1. Pre-analytical setup for SARS-CoV-2 RNA extraction. Nasopharyngeal specimens, Proteinase K, extraction plate and pipette tips arranged for automated nucleic acid extraction prior to RT-PCR analysis.

Nucleic acids were extracted using the automated Big Fish® extraction system, based on magnetic bead technology. A volume of 200 µL of each sample was processed according to the manufacturer's instructions. Proteinase K was used to enhance viral lysis. All procedures were performed under appropriate biosafety conditions to prevent contamination. The reaction mixture was prepared prior to amplification in a designated reagent preparation room. Master mix preparation was performed using the MAScIR SARS-CoV-2 M 2.0 kit. SARS-CoV-2 specific probes were labelled with the Cy5 fluorophore for the S gene, and the FAM fluorophore for RdRp gene.

RT-qPCR was performed using a qTower real-time thermal cycler system (Analytik Jena AG, Germany) (Fig. 2). A one-step real-time reverse transcription PCR assay was used to amplify simultaneously two SARS-CoV-2 target genes: the RNA-dependent RNA polymerase (RdRp) gene and the S (spike protein) gene, following the manufacturer's protocol (MAScIR SARS-CoV-2 Kit; OSANG Healthcare Co., Ltd., Korea). Results were interpreted according to the manufacturer's recommendations. SARS-CoV-2 positivity was confirmed by Ct values obtained for both target genes, with Ct values < 37 considered positive according to the kit guidelines.



Figure 2. Real-time RT-PCR workstation used for quantitative detection of SARS-CoV-2 RNA and monitoring of cycle threshold (Ct) values for the RdRp and S gene targets under different storage conditions.

Positive and negative controls were included in each run to ensure assay validity. An Internal Control (IC) was employed to monitor the efficiency of RNA extraction and the amplification process (Fig. 3). The IC is expected to yield a positive result in all valid patient samples, confirming proper extraction, absence of significant PCR inhibition, and correct execution of the analytical procedure.

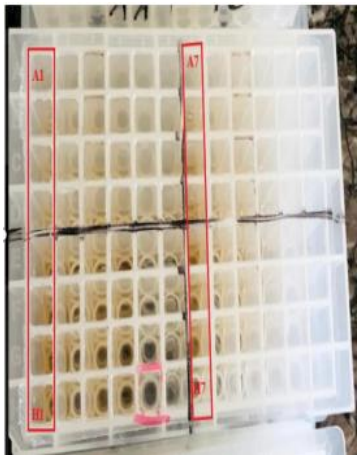
A)  **B)** 

Figure 3. RNA extraction workflow for SARS-CoV-2 detection using the Big Fish® automated extraction system. **(A)** Extraction plate containing nasopharyngeal specimens and reagents arranged for automated magnetic bead-based RNA extraction. **(B)** Big Fish® automated nucleic acid extraction system used for the purification of SARS-CoV-2 RNA prior to RT-qPCR analysis.

Statistical analysis

Data were analysed using IBM SPSS software (version 27). Given the small sample size (n = 18) and the repeated-measures nature of the data, a mainly descriptive approach was adopted.

Ct values before and after storage were summarized using mean ± standard deviation (SD) and range. Variations in Ct values were assessed descriptively across storage temperatures (+4 °C and −20 °C) and durations (1 to 7 days).

The analysis focused on evaluating the stability of RT-qPCR results, particularly the preservation of Ct values below the positivity threshold (Ct < 37). No inferential statistical tests were performed because of the limited sample size, in order to avoid overinterpretation of the results.

Results

In the present study, 18 nasopharyngeal swab samples were analysed to evaluate the effect of storage temperature and duration under real-world pre-analytical conditions, which represent a major source of variability in molecular diagnostics.

RT-PCR analysis demonstrated that all initially positive samples remained positive despite variations in storage conditions. Table 1 presents the cycle threshold (Ct) values according to storage duration (1 to 7 days) and temperature conditions (+4 °C and −20 °C). All SARS-CoV-2–positive samples remained positive (Ct < 37), with Ct values remaining within a comparable range across storage conditions, indicating overall stability of viral RNA. But, variations of up to 2–3 Ct cycles were observed in some samples, depending on storage conditions and duration. These variations, although not affecting qualitative interpretation, may be relevant in molecular diagnostics, as Ct shifts of this magnitude can reflect potential changes in viral RNA quantity or sample integrity. This variability highlights the importance of considering pre-analytical conditions when interpreting Ct values, particularly in clinical or borderline cases. Both target genes remained detectable when initially present. In some cases, only one target gene was detected. For example, in sample no. 8040, the S gene was not amplified; and this result remained unchanged after 24 hours of storage.

Ct values showed minimal variation after storage. Mean Ct values slightly decreased from 26.85 to 25.83 ($\Delta Ct = -1.02$) for RdRp and from 25.20 to 24.15 ($\Delta Ct = -1.05$) for the S gene. All Ct values remained below the positivity threshold (Ct < 37), with no qualitative change, observed

after storage. The results are summarized in Table 1, which includes laboratory identification codes assigned to each sample to ensure data traceability.

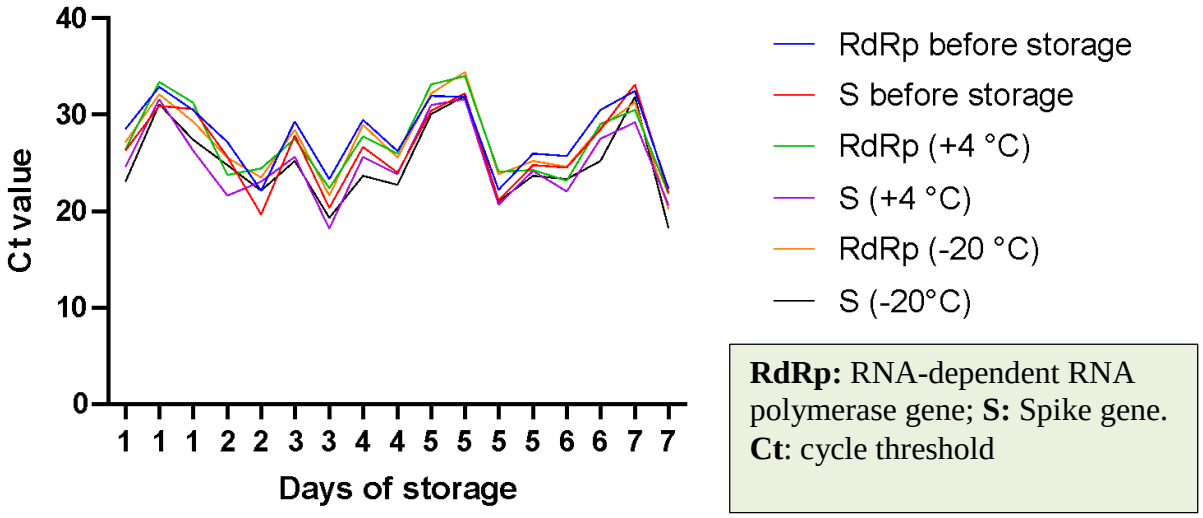


Figure 4. Comparison of RdRp and S gene Ct values before storage and after storage at +4 °C or −20 °C for 1–7 days in SARS-CoV-2-positive nasopharyngeal samples.

The graph illustrates the Ct values of the RdRp and S genes measured in SARS-CoV-2–positive nasopharyngeal samples before storage and after storage under two temperature conditions (+4°C and −20°C) over a period ranging from 1 to 7 days. Overall, the Ct values for both genes remained relatively stable across all samples and storage conditions, with no marked shifts observed between pre-storage and post-storage measurements.

Similarly, no consistent differences were detected between samples stored at +4°C and those stored at −20°C, suggesting that both storage conditions preserved the integrity of viral RNA within the studied time frame. The patterns observed for RdRp and S genes were comparable, indicating that gene detection was not differentially affected by storage temperature or duration.

These findings suggest that, under the conditions tested, short-term storage of nasopharyngeal samples at either +4°C or −20°C does not substantially impact Ct values for RdRp and S targets in SARS-CoV-2–positive specimens.

Discussion

Reverse transcription polymerase chain reaction (RT-PCR) remains the gold standard for the diagnosis of SARS-CoV-2 infection due to its high analytical sensitivity and specificity [6]. During amplification, the cycle threshold (Ct) value, which is inversely proportional to viral load,

is commonly used as a surrogate marker of viral RNA quantity. But, Ct values may be influenced by both analytical and pre-analytical factors. Among these**,** pre-analytical variability including sample collection, handling, storage temperature, and storage duration, represents one of the most important sources of variability in currently used molecular diagnostic procedures [7, 8].

In this study, we evaluated the effect of storage temperature and duration on the stability of SARS-CoV-2 RNA in nasopharyngeal swab samples collected at the medical analysis laboratory of Hassan II Hospital, Settat. Our data clearly indicate that SARS-CoV-2 positive samples remained positive after up to seven days of storage**,** regardless of the storage temperature (+4 °C and −20 °C). Importantly, no major changes in Ct values were observed for either the RdRp or S target genes.

These observations are consistent with previously published studies demonstrating that SARS-CoV-2 RNA remains stable under various storage conditions. In particular, minimal variations in Ct values have been reported for nasopharyngeal swab samples stored at +4°C for a few days, particularly if such samples were conserved using suitable transport or extraction buffers [9, 10]. In line with our results, previous studies have reported that SARS-CoV-2 RNA remains stable under both refrigerated and frozen storage conditions, supporting the robustness of RT-PCR detection across different laboratory contexts [5,11]. Despite the overall stability observed, variations in Ct values of up to 2–3 cycles were reported under certain pre-analytical conditions. These changes are consistent with a reduction in detectable viral RNA, probably related to sample handling and storage conditions affecting RNA integrity [12]. Although these variations did not affect the qualitative interpretation of results in our study, they may be clinically relevant in specific situations, particularly for samples with low viral loads near the detection threshold. This finding underscores the importance of cautious interpretation of Ct values in clinical practice. In the context of patient follow-up, adjustment of the therapeutic regimen and other medical decisions should not be based solely on Ct values, as these may be influenced by multiple pre-analytical and analytical factors.

The pre-analytical phase, particularly sample collection, is highly important in the accuracy of RT-PCR assays. Proper nasopharyngeal sampling is essential to ensure sufficient human cellular material, which is indirectly verified through internal control amplification. Insufficient amplification of the human target gene is considered an invalid result and is more likely attributable to poor sample collection rather than a low viral load.

Previous studies have highlighted that pre-analytical factors can influence the reliability of SARS-CoV-2 RT-PCR testing and should therefore be carefully controlled throughout the

diagnostic process [13]. In addition to sample collection, RNA transport and storage conditions play a crucial role in preserving RNA integrity. Delays in sample processing, temperature fluctuations, and repeated freeze–thaw cycles may potentially lead to RNA degradation. However, the results of the present study indicate that when samples are transported under standard conditions and stored appropriately, viral RNA integrity is well preserved, as reflected by minimal variations in Ct values. These findings are consistent with previous studies, which reported no apparent loss of detection sensitivity after short-term storage at 4 °C and −20 °C [14].

Interestingly, samples showing detection of a single viral gene prior to storage maintained the same detection pattern after storage. This observation suggests that storage conditions do not selectively affect specific genetic targets, but rather preserve the molecular profile of the sample. This is particularly relevant for samples with low viral loads, where even minor degradation could potentially affect detectability. Although storage conditions did not significantly influence Ct values in this study, other factors may contribute to variability. These include the presence of PCR inhibitors such as mucus, blood, or certain medications, which may interfere with amplification efficiency and lead to increased Ct values or amplification failure [15]. Nevertheless, this study has several limitations that should be acknowledged. First, the sample size was relatively small (n = 18), which may limit the generalizability of the findings. This is mainly caused by the fact that limited residual volumes were available following routine diagnostic procedures. Additionally, a number of samples were referred to the National Institute of Hygiene (INH), Morocco, for sequencing, which further reduced the pool of specimens accessible for this study. Furthermore, some samples exhibited high viscosity, complicating accurate aliquoting and consistent handling, and they were therefore excluded from analysis.

Second, no inferential statistical analyses were performed because of the limited sample size, which restricts the ability to assess statistical differences. Third, the observed Ct variability, although not affecting qualitative results, may still be relevant in borderline cases. Finally, this study did not assess the impact of repeated freeze–thaw cycles or long-term storage beyond seven days, which could further influence RNA stability.

Therefore, the conclusions of this study should be interpreted with caution. Although our findings suggest that short-term storage under standard conditions does not compromise SARS-CoV-2 detection, we cannot exclude the possibility of quantitative variability under different or more extreme conditions.

Overall, the results of this study confirm that, when pre-analytical parameters are adequately controlled, variations in storage duration and temperature do not appear to have any substantial

effect on the qualitative outcome of SARS-CoV-2 RT-PCR testing. These findings suggest a degree of operational flexibility in sample storage under routine diagnostic conditions, particularly in high-throughput or resource-limited settings. They also highlight the importance of careful interpretation of Ct values and strict control of pre-analytical parameters, including sample quality and the presence of potential PCR inhibitors, to ensure optimal test sensitivity and reliability.

These constraints may have reduced the statistical power of the study and may limit the generalizability of the findings. As such, the results should be interpreted with caution, and further investigations of larger samples are recommended to validate these findings.

Conclusion

All initially positive samples remained positive throughout the study period, with only minor variations in Ct values for the RdRp and S target genes under both storage conditions. These findings suggest that short-term storage temperature and duration are unlikely to affect SARS-CoV-2 RT-PCR detection under routine laboratory conditions. Further studies with larger sample quantities (to allow for high, low and borderline Ct values) are warranted to confirm these findings.

Acknowledgments: We thank all the staff of the Microbiology laboratory of Hassan II Provincial Hospital, Settat, for their valuable support and assistance.

Ethical Approvals: This study did not include patient data or identifiable personal information. Only anonymized SARS-CoV-2-positive nasopharyngeal samples were used for technical analysis. Administrative authorization was obtained from Hassan II Provincial Hospital, Settat, prior to conducting the study.

Code availability: Not applicable

Conflict of interest: The authors declare that they have no conflict of interest

References

[1] Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., Zhan, F., Ma, X., Wang, D., Xu, W., Wu, G., Gao, G.F., & Tan, W., 2020,

A novel coronavirus from patients with pneumonia in China, 2019. *New England Journal of Medicine* **382**(8), 727–733. https://doi.org/10.1056/NEJMoa2001017

[2] Li, J., Lai, S., Gao, G.F., & Shi, W., 2021, The emergence, genomic diversity and global spread of SARS-CoV-2. *Nature* **600**, 408–418. https://doi.org/10.1038/s41586-021-04188-6

[3] Anagoni, S., Mudhigeti, N., Alladi, M., Anju, V., Am, P., & Kalawat, U., 2022, Effect of delay in processing and storage temperature on diagnosis of SARS-CoV-2 by RT-PCR testing. *Indian Journal of Medical Microbiology* **40**(3), 427–432. https://doi.org/10.1016/j.ijmmb.2022.03.005

[4] Wu, Z.G., Zheng, H.Y., Gu, J., Li, F., Lv, R.L., Deng, Y.Y., Xu, W.Z., & Tong, Y.Q., 2020, Effects of different temperature and time durations of virus inactivation on results of real-time fluorescence PCR testing of COVID-19 viruses. *Current Medical Science* **40**(4), 614–617. https://doi.org/10.1007/s11596-020-2224-y

[5] Basso, D., Aita, A., Navaglia, F., Franchin, E., Fioretto, P., Moz, S., Bozzato, D., Zambon, C.F., Martin, B., Dal Prà, C., Crisanti, A., & Plebani, M., 2020, SARS-CoV-2 RNA identification in nasopharyngeal swabs: issues in pre-analytics. *Clinical Chemistry and Laboratory Medicine* **58**(9), 1579–1586. https://doi.org/10.1515/cclm-2020-0749

[6] Li, H., Liu, D., Zhou, Q., Rodriguez, G.D., Pietz, H., Singh, V., Konadu, E., James, K.K., Lui, C., Shao, M., Chen, J., Schreiner, A., Urban, C., Truong, J., Prasad, N., & Rodgers, W.H., 2025, Comparative analysis of RT-PCR and a colloidal gold immunochromatographic assay for SARS-CoV-2 detection. *Diagnostics* **15**(11), 1362. https://doi.org/10.3390/diagnostics15111362

[7] Engelmann, I., Alidjinou, E.K., Ogiez, J., Pagneux, Q., Miloudi, S., Benhalima, I., Ouafi, M., Sane, F., Hober, D., Roussel, A., Cambillau, C., Devos, D., Boukherroub, R., & Szunerits, S., 2021, Preanalytical issues and cycle threshold values in SARS-CoV-2 real-time RT-PCR testing: should test results include these? *ACS Omega* **6**(10), 6528–6536. https://doi.org/10.1021/acsomega.1c00166

[8] Rao, S.N., Manissero, D., Steele, V.R., & Pareja, J., 2020, A systematic review of the clinical utility of cycle threshold values in the context of COVID-19. *Infectious Diseases and Therapy* **9**(3), 573–586. https://doi.org/10.1007/s40121-020-00324-3

[9] Nairz, M., Bellmann-Weiler, R., Ladstätter, M., et al., 2021, Overcoming limitations in the availability of swab systems used for SARS-CoV-2 laboratory diagnostics. *Scientific Reports* **11**, 2261. https://doi.org/10.1038/s41598-021-81782-8

[10] Alfaro-Núñez, A., Crone, S., Mortensen, S., Rosenstierne, M.W., Fomsgaard, A., Marving, E., Nielsen, S.H., Jørgensen, M.G.P., Polacek, C., Cohen, A.S., & Nielsen, C., 2022, SARS-

CoV-2 RNA stability in dry swabs for longer storage and transport at different temperatures. *Transboundary and Emerging Diseases* **69**(2), 189–194. https://doi.org/10.1111/tbed.14339

[11] Rogers, A.A., Baumann, R.E., Borillo, G.A., Kagan, R.M., Batterman, H.J., Galdzicka, M.M., & Marlowe, E.M., 2020, Evaluation of transport media and specimen transport conditions for the detection of SARS-CoV-2 by real-time reverse transcription-PCR. *Journal of Clinical Microbiology* **58**(8), e00708-20. https://doi.org/10.1128/JCM.00708-20

[12] Mosscrop, L., Watber, P., Elliot, P., Cooke, G., Barclay, W., Freemont, P. S., Rosadas, C., & Taylor, G. P., 2022, *Evaluation of the impact of pre-analytical conditions on sample stability for the detection of SARS-CoV-2 RNA. Journal of Virological Methods* **309**, 114607. https://doi.org/10.1016/j.jviromet.2022.114607

[13] Beziér, C., Anthoine, G., & Charki, A., 2020, Reliability of RT-PCR tests to detect SARS-CoV-2: risk analysis. *International Journal of Metrology and Quality Engineering* **11**, 15. https://doi.org/10.1051/ijmqe/2020013

[14] Kim, N., Kwon, A., Roh, E.Y., Yoon, J.H., Han, M.S., Park, S.W., Park, H., & Shin, S., 2021, Effects of storage temperature and media/buffer for SARS-CoV-2 nucleic acid detection. *American Journal of Clinical Pathology* **155**(2), 280–285. https://doi.org/10.1093/ajcp/aqaa207

[15] Morais, O., Alves, M.R., Ramos, C., Ferreira, F., & Fernandes, P., 2022, The matrix effect in the RT-PCR detection of SARS-CoV-2 using saliva without RNA extraction. *Diagnostics* **12**(7), 1547. https://doi.org/10.3390/diagnostics12071547