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Original Article

Laboratory testing efficiency during the COVID pandemic: Findings from the Primary Health Care Corporation laboratories in the State of Qatar

Sara Awwad [a], Mohammed Al-Hamdani [b], Atiyeh M. Abdallah [a], Marawan Abu-Madi [a,*]

[a] Department of Biomedical Sciences, College of Health Sciences, QU Health, Qatar University, Doha, Qatar
[b] Department of Public Health, College of Health Sciences, QU Health, Qatar University, Doha, Qatar

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ABSTRACT

Background: Little is known about how the COVID-19 pandemic altered laboratory testing efficiency in the State of Qatar. The aim of this study was to assess laboratory testing efficiency with respect to the total number and proportion of C-reactive protein (CRP), complete blood count (CBC), and comprehensive metabolic panel (CMP) tests completed on time in 2019–2021 in several ordinary and COVID-converted Primary Health Care Corporation (PHCC) health centers across Qatar.

Methods: Secondary data from 2019 to 2021 were accessed from the PHCC-Clinical Information System center. Six randomly selected centers from three regions of Qatar (Northern, Central, and Western), two of which were COVID-converted, were analyzed.

Results: A total of 404,316 laboratory tests were analyzed. There were decreasing, U-shaped, and inverted-U-shaped patterns in the numbers of tests conducted in different regions between 2019 and 2021 according to test type. The proportion of urgent (STAT) CBC and CMP tests increased from 2019 to 2021, and the proportion of tests completed by COVID-converted health centers increased for CRP and CBC and decreased for CMP between 2019 and 2021. Northern and Western regions in Qatar showed higher efficiency than the Central region with respect to the proportion of STAT tests completed on time in 2019–2021. COVID-converted centers completed fewer STAT CBC tests on time than ordinary centers.

Conclusion: Pandemics such as COVID-19 shift the allocation of resources from routine tests to urgent tests, as exemplified by the increase in STAT test proportions in 2019 to 2021. High population densities, as noted in the Central region of Qatar, may require additional resources during pandemics to complete urgent tests more efficiently. The conversion of centers to COVID-converted centers may not necessarily translate into higher urgent test efficiency, as exemplified by the STAT CBC test results.

Introduction

The COVID-19 pandemic emerged as a public health crisis, significantly impacting various facets of our lives [1–4]. The pandemic caused an extraordinary shift in demand for patient care and clinical laboratory testing [5], including the need for rapid development of new assays, highly trained personnel, management of reagent and supply shortages, and the risk of staffing shortages [6,7]. The Primary Health Care Corporation (PHCC) is the main primary healthcare provider in the State of Qatar [8,9] and it established quarantine and isolation facilities nationwide to isolate and treat COVID-19-positive cases. In laboratory services, precision, short turnaround time (TAT), and accuracy are all equally important [10,11]. There are different definitions of TAT, but it is often defined as the time interval between the moment when the test was ordered and the time when a treatment decision was made, and shortening the TAT is often the primary quality indicator in clinical laboratories [12,13]. The pandemic affected TATs for a variety of reasons. Initially, the pandemic increased the need for COVID-19 testing, which in turn increased demand for laboratory testing [14]. Due to this increased demand, patients who needed hematology and biochemistry testing had to wait longer, which increased the TAT [15,16]. Second, the pandemic caused problems in the supply chain for laboratory reagents and supplies, which hampered their capacity to complete tests on time [15,17]. Third, some laboratories experienced resource shortages as a result of the pandemic, which further prolonged TATs [18]. Primary healthcare laboratories receive a high volume of routine (non-urgent) test requests, making efficient collection and processing

* Corresponding author.
E-mail address: abumadi@qu.edu.qa (M. Abu-Madi).

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essential for maintaining smooth laboratory operations. STAT tests are requested by physicians in emergency cases requiring prompt decision-making and are defined as a rapid TAT, generally an hour or less from specimen receipt until test result reporting. These tests take priority over others in the queue and need to be conducted expeditiously.

During the COVID-19 pandemic, the PHCC took preventive measures to manage the spread of COVID-19 and dedicated three of its HCs as COVID-19 testing centers dedicated to handling testing and isolation during the initial three waves: Rawdat Al Khail (RAK) in the Central region, Umm Slal (UMS) in the Northern region, and Muaither (MUA) in the Western region. The PHCC acted swiftly in response to the pandemic by implementing COVID-19 testing across all primary HCs [19]. As the outbreak persisted, the PHCC introduced drive-through testing at twelve HCs. During peak periods, the PHCC focused solely on urgent services and walk-in clinics, while also introducing new alternatives like virtual/telephone consultations and home medication delivery to ensure continuous care [18]. Consequently, certain primary care services such as cancer screening and lifestyle medicine clinics were temporarily halted [20].

With respect to laboratory testing, there is limited evidence on how COVID-19 impacted laboratory efficiency. One study reported an increase in the volume of COVID-19-related tests, but overall testing volumes significantly decreased, while another highlighted the significance of laboratory information in COVID-19 management, the need for safe laboratory practices to protect personnel, and the importance of ongoing educational efforts of professional societies despite the challenges posed by the pandemic [5,21]. Nevertheless, evidence of the effect of COVID-19 on laboratory testing in the Middle East remains limited. Here we addressed this knowledge gap by conducting this study to address three main objectives: 1) to assess efficiency in the proportions of C-reactive protein (CRP), complete blood count (CBC), and comprehensive metabolic panel (CMP) tests completed in 2019, 2020, and 2021 according to each region of Qatar (Central, Northern, and Western), collection priority (routine and STAT), and center type (COVID-converted or ordinary); 2) to compare the efficiency of Central, Northern, and Western regions in terms of the proportions of STAT CBC and STAT CMP tests completed within their threshold turnaround times 2019 to 2021; and 3) to compare the efficiency of COVID-converted and ordinary centers in terms of the proportions of STAT CBC and STAT CMP tests completed within their threshold turnaround times in 2020 and 2021.

Methods

Ethical approval

The [redacted for peer review] approved access to the secondary data and its use in this study [redacted for peer review]. The data were stored in digital format on a secure computer accessible only to the researchers. The study was carried out following the PHCC's guidelines and protocols.

Study design

Secondary data from 2019–2021 were collected from the PHCC Clinical Information System (CIS-Cerner). Data were accessed from six HCs chosen randomly from different regions in Qatar (Northern, Central, and Western), two from each region, where one was "ordinary" and the other was "COVID-designated". COVID-designated centers were assigned to treat and receive only COVID patients during the pandemic, while ordinary HCs received all other patients.

We selected three in-demand tests during the COVID-19 pandemic: complete blood count (CBC), comprehensive metabolic panel (CMP), and C-reactive protein (CRP). The TATs for STAT and routine tests were included in the data.

Data stratification

To conduct the first planned analysis, we compared differences in the proportion of tests completed in each year (2019, 2020, and 2021) for each test type (CBC, CMP, and CRP) in each region (Central, Northern, and Western) by layering the data by region, year, and test type. To conduct the second planned analysis, we compared the proportions of routine and STAT tests completed in each year (2019, 2020, 2021) for each test type (CBC and CMP only, because CRP is not completed on a STAT basis) by layering the collection priority by year by test type. To enable the third planned analysis, we compared the proportion of tests completed in each year for each center type and each test, and layered center type (COVID-19-converted and ordinary), year (only 2020 and 2021, because COVID conversion of centers only happened in 2020), and test type (CBC, CMP, and CRP). For the fourth planned analysis, we compared the proportion of tests completed by turnaround threshold (within vs. above 30 min for STAT CBC and within vs. above 60 min for STAT CMP) in each region for each test type (CBC and CMP). This was achieved by layering the type of STAT test (STAT CBC and STAT CMP) by turnaround threshold and region for each STAT test. Finally, to compare the proportion of tests completed by turnaround threshold in each center type (COVID-19-converted and ordinary) and in each year (2020 and 2021) for each type of STAT test (CBC and CMP), we layered the type of STAT test for each test type by year.

Statistical analysis

The two main variables of interest were the proportions of CRP, CBC, and CMP tests completed and the proportions of STAT CBC and STAT CMP tests completed within or above TAT thresholds of 30 and 60 min, respectively. The first comparisons of interest were the differences in the proportions of tests completed by year (2019–2021) for each region (Central, Northern, or Western), priority collection type (routine or STAT), and center type (COVID-converted or ordinary), which were accomplished by layering each one of the three lab tests by the three variables as noted above and running three chi-squared tests. The second set of comparisons of interest were the differences in the proportions of STAT CBC and STAT CMP tests completed within their respective thresholds by region and center type, achieved by running four chi-squared tests. Bonferroni corrections were used to check for pairwise differences for each chi-squared test, with significant effects denoted in alphabet subscripts for groups with statistically different column proportions at a p-value of < 0.05.

Results

Test proportion differences in 2019-2021 layered by region, collection priority, and center type

As shown in Table 1, the three regions had different patterns of total CRP tests completed between 2019 and 2021. The proportion of completed CRP tests in the Central region was significantly higher in 2020 (41.2%) vs. 2019 (35.9%), $p < .001$, 2021 (61.1%) vs. 2019 (35.9%), $p < .001$, and 2021 (61.1%) vs. 2020 (41.2%), $p < .001$. The proportion of completed CRP tests in the Northern region was significantly lower in 2020 (40.2%) vs. 2019 (47.7%), $p < .001$, 2021 (28.5%) vs. 2019 (47.7%), $p < .001$ and 2021 (28.5%) vs. 2020 (40.2%), $p < .001$. However, the proportion of completed CRP tests in the Western region was significantly higher in 2020 (18.6%) vs. 2019 (16.4%), $p = .002$, but significantly lower in 2021 (10.4%) vs. 2019 (16.4%), $p < .001$ and 2021 (10.4%) vs. 2020 (18.6%), $p < .001$. There were also

Table 1
Frequencies of CRP, CBC, and CMP tests in 2019–2021, layered by region.

Test	df	Chi-square (χ^2)	*p*	Region	Year							
					2019 N	%	2020 N	%	2021 N	%	Overall N	%
CRP, N = 40,042	4	1916.65	0.001	Central	1695_a	35.9	5733_b	41.2	13083_c	61.1	20511	51.2
				Northern	2253_a	47.7	5598_b	40.2	6095_c	28.5	13946	34.8
				Western	775_a	16.4	2585_b	18.6	2225_c	10.4	5585	13.9
CBC, N = 290,472	4	1596.56	0.001	Central	$44,957_a$	40.9	25598_b	35.9	37625_c	34.5	108180	37.2
				Northern	$37,373_a$	34.0	27730_b	38.9	38540_c	35.3	103643	35.7
				Western	$27,679_a$	25.2	17955_a	25.2	33015_b	30.2	78649	27.1
CMP, N = 88,791	4	428.51	0.001	Central	$22,715_a$	37.7	8855_b	33.8	955_b	33.9	32329	36.4
				Northern	$22,796_a$	37.8	11824_b	45.1	1220_b	43.2	35529	40.0
				Western	$14,777_a$	24.5	5551_b	21.2	$646_{a,b}$	22.9	20933	23.6

Note. Rows that share any letter (s) are not significantly different and those with different letters have significantly different column proportions from one another at p < .05.

different patterns of the total number of CBC tests completed by region. In the Central region, the proportion of completed CBC tests was significantly lower in 2020 (35.9%) vs. 2019 (40.9%), p < .001, 2021 (34.5%) vs. 2019 (40.9%), p < .001, and 2021(34.5%) vs. 2020 (35.9%), p < .001. The proportion of completed CBC tests in the Northern region was significantly higher in 2020 (38.9%) vs. 2019 (34.0%), p < .001, but significantly lower in 2021 (35.3%) vs. 2020 (38.9%), p < .001. The proportion of completed CBC tests in the Western region was not significantly different in 2020 vs. 2019 but significantly higher in 2021 (30.2%) vs. 2019 (25.2%), p < .001, and 2021 (30.2%) vs. 2020 (25.2%), p < .001. The proportion of completed CMP tests in the Central region was significantly lower in 2020 (33.8%) vs. 2019 (37.7%), p < .001, and 2021 (33.9%) vs. 2019 (37.7%), p < .001, as well as significantly higher in the Northern region in 2020 (45.1%) vs. 2019 (37.8%), p < .001, and 2021(43.2%) vs. 2019 (37.8%), p < .001, with no significant differences between 2020 and 2021. Further, the proportion of completed CMP tests were significantly lower in 2020 (21.2%) vs. 2019 (24.5%), p < .001, in the Western region, with no significant differences observed between 2021 and 2020 or 2021 and 2019.

Table 2 presents the frequencies of CBC and CMP tests based on their collection priority and year. Both exhibited the same pattern: the proportion of completed STAT CBC tests (4.8%) and STAT CMP tests (3.7%) was significantly higher in 2020 vs. the 2019 counterparts (STAT CBC: 3.0%, p < .001, and STAT CMP: 0.3%, p < .001,) yet significantly lower than the 2021 counterparts (STAT CBC: 5.3%, p < .001, and STAT CMP: 5.6%, p < .001).

Table 3 displays the total counts for each type of test conducted by COVID-converted and ordinary centers in 2020 and 2021. The proportion of CRP and CBC tests completed by COVID-converted centers was significantly higher in 2021 (CRP: 76.6% and CBC: 39.1%) vs 2020 counterparts (CRP: 74.3%, p < .001, and CBC: 22.5%, p < .001,), while the proportion of CMP tests conducted by ordinary centers was significantly higher in 2021 (80.4%) vs 2020 (66.0%), p < .001.

STAT CBC and STAT CMP test proportion differences across regions layered by turnaround threshold for 2019-2021

Table 4 shows the frequencies of tests for 2019–2021 by the turnaround threshold (within vs. above 30 min for STAT CBC and within vs. above 60 min for STAT CMP). In 2019, there were no significant differences in the proportions of STAT CBC tests completed on time across the three regions. However, in 2020, the Northern region had a significantly higher proportion of STAT CBC tests completed within the acceptable threshold (30 min) (97.9%) relative to the Central (77.4%), p < .001, and Western (77.4%), p < .001, regions. In 2021, the Northern region had a significantly higher proportion of STAT CBC tests completed within the acceptable threshold (95.9%) relative to the Central region (90.9%), p < .001, but there were no differences between the Central and Western regions nor the Northern and Western regions in the proportions of STAT CBC tests completed on time.

In 2019, there was a higher proportion of STAT CMP tests completed within the 60-minute threshold in the Central region (89.9%) relative to the Northern region (54.8%), p < .001, and the Western (85.5%) region relative to the Northern region (54.8%), p = .002. However, there were no differences in proportions of STAT CMP tests completed on time between the Central and Western regions. In 2020, the there was a higher proportion of STAT CMP tests completed within the 60-minute threshold in the Northern (79.5%) vs. Central region (67.5%), p = .029, and Western region (77.9%) vs. Central region (67.5%), p = .045, but there were no differences in proportions of STAT CMP tests completed on time between the Northern and Western regions. In 2021, the Western region had a significantly higher proportion of STAT CMP tests completed within the 60-minute threshold (76.9%) relative to the Northern region (52.4%), p < .001. However, there were no differences between the Central region and the other regions.

Table 2
Frequencies of CBC and CMP tests in 2019–2021, layered by collection priority.

Test	df	Chi-square (χ^2)	*p*	Priority	Year							
					2019 N	%	2020 N	%	2021 N	%	Overall N	%
CBC, N = 290,472	2	810.58	0.001	Routine	106762_a	97.0	$67,894_b$	95.2	$103,349_c$	94.7	278,005	95.7
				STAT	3247_a	3.0	3389_b	4.8	5831_c	5.3	12,467	4.3
CMP, N = 89,339	2	1788.11	0.001	Routine	60101_a	99.7	$25,258_b$	96.3	2664_c	94.4	88,023	98.5
				STAT	187_a	0.3	972_b	3.7	157_c	5.6	1316	1.5

Note. Rows that share any letter(s) are not significantly different and those with different letters have significantly different column proportions from one another.

Table 3
Frequencies for CRP, CBC, and CMP tests in 2020–2021, layered by center type.

Test	df	Chi-square (χ^2)	*p*	Year							
				Centre type	2020		2021		Overall	
					N	%	N	%	N	%
CRP, N = 35,319	1	24.36	0.001	COVID	10341_a	74.3	16398_b	76.6	26739	75.7
				Ordinary	3575_a	25.7	5005_b	23.4	8580	24.3
CBC, N = 180,463	1	5376.94	0.001	COVID	16065_a	22.5	42669_b	39.1	58734	32.5
				Ordinary	55218_a	77.5	66511_b	60.9	121729	67.5
CMP, N = 29,051	1	237.79	0.001	COVID	8907_a	34.0	554_b	19.6	9461	32.6
				Ordinary	17323_a	66.0	2267_b	80.4	19590	67.4

Note. Rows that share any letters(s) are not significantly different and those with different letters have significantly different column proportions from one another.

STAT CBC and STAT CMP test proportion differences between center types layered by turnaround threshold for 2020-2021

Table 5 shows the frequencies of STAT CBC and STAT CMP tests for 2019–2021 by the turnaround threshold. In 2020 (96.7%) and 2021 (95%), ordinary centers completed a higher proportion of STAT CBC tests on time relative to the proportions completed by COVID-converted centers in 2020 (80.5%), p < .001 and 2021 (91.7%), and p < .001. The proportion of STAT CMP tests completed on time was not different between COVID-converted and ordinary centers.

Discussion

This study shows that efficiency in the total number of tests differed each year for each region depending on the test. The Northern and Western regions seemed to have shown an ability to maintain higher testing capacity in 2020–2021 vs. 2019 for CBC and CMP but not for CRP, while the Central region showed the opposite. These differences may be related to prioritizing certain tests in some regions compared with others. Alternatively, the population density of the Central region and the high number of tests completed by the center may have been impacted by COVID-19 restrictions. The population-weighted density impacts the reproduction number of COVID-19, explaining why a higher population density increases infection rates, potentially overwhelming local healthcare systems and resulting in a shortage of ICU beds and essential medical supplies, further complicating the outbreak response [22].

The proportion of STAT CBC and STAT CMP tests completed increased consistently from 2019 to 2021, suggesting increased efficiency for emergency requests. This may reflect the heightened preparedness and response prompted by the development of the pandemic. COVID-converted centers completed a higher proportion of CRP and CBC tests, while ordinary centers completed a higher proportion of CMP tests in 2021 vs. 2020, which may suggest that dedicating a center to conducting tests for pandemics is one way to increase efficiency in the number of tests completed. Overall, the Northern and Western regions showed higher efficiency relative to the Central region in terms of the proportion of STAT tests completed on time. This may suggest that centers with a high cluster of patients experienced increased pressures that reduced their efficiency.

Further research is needed to investigate the reasons underlying the differences in testing patterns and priorities observed during the pandemic [23], perhaps by examining how the pandemic affected patient behavior, healthcare provider decisions, and healthcare utilization [24]. Understanding these factors could help to inform the development of more effective testing protocols and procedures adapted to the needs of patients and healthcare providers during times of crisis [25]. Second, additional research is needed to assess how the pandemic affected other commonly performed tests, such as those for infectious diseases or chronic conditions [26], by studying the test complexity, specimen type, sample transportation, storage conditions, and pre-analytical variables that may affect TATs. Third, our study highlights the importance of investing in laboratory infrastructure and technology to improve the capacity and efficiency of laboratory testing processes during times of crisis, such as the need for greater automation and digitization of laboratory processes to reduce the burden on laboratory staff and ensure that testing can be conducted quickly and accurately, even in the face of high demand [27,28]. Future research and policy initiatives could focus on identifying specific areas where technology and infrastructure investments could be most effective in improving the capacity and efficiency of laboratory testing processes during emergencies [29]. Fourth, research is needed to assess the impact of TATs on patient outcomes and public health interventions, especially the association

Table 4
Frequencies of STAT CBC and STAT CMP tests in each region layered by turnaround threshold for 2019–2021.

	Year	df	Chi-square (χ^2)	*p*	Threshold	Region							
						Central		Northern		Western		Overall	
						N	%	N	%	N	%	N	%
STAT CBC	**2019,** N = 3242	2	3.64	0.161	Within	1400_a	98.6	1254_a	99.0	543_a	97.8	3197	98.6
					Above	20_a	1.4	13_a	1.0	12_a	2.2	45	1.4
	2020, N = 3385	2	330.77	0.001	Within	639_a	77.4	1658_b	97.9	670_a	77.4	2967	87.7
					Above	187_a	22.6	35_b	2.1	196_a	22.6	418	12.3
	2021, N = 5829	2	43.40	0.001	Within	3275_a	90.9	1695_b	95.9	$430_{a,b}$	93.7	5400	92.6
					Above	327_a	9.1	73_b	4.1	$29_{a,b}$	6.3	429	7.4
STAT CMP	**2019,** N = 186	2	23.71	0.001	Within	80_a	89.9	23_b	54.8	47_a	85.5	150	80.6
					Above	9_a	10.1	19_b	45.2	8_a	14.5	36	19.4
	2020, N = 970	2	7.42	0.02	Within	81_a	67.5	236_b	79.5	431_b	77.9	748	77.1
					Above	39_a	32.5	61_b	20.5	122_b	22.1	222	22.9
	2021, N = 156	2	15.70	0.001	Within	$11_{a,b}$	52.4	38_b	34.9	20_a	76.9	69	44.2
					Above	$10_{a,b}$	47.6	71_b	65.1	6_a	23.1	87	55.8

Note. Rows that share any letters(s) are not significantly different and those with different letters have significantly different column proportions from one another.

Table 5
Frequencies of STAT CBC and STAT CMP tests in each center type layered by turnaround threshold for 2020–2021.

	Year	df	Chi-square (χ^2)	*p*	Threshold	Centre type					
						COVID		Ordinary		Overall	
						N	%	N	%	N	%
STAT CBC	**2020,** N = 3385	1	203.89	0.001	Within	1520_a	80.5	1447_b	96.7	2967	87.7
					Above	369_a	19.5	49_b	3.3	418	12.3
	2021, N = 5829	1	19.53	0.001	Within	3800_a	91.7	1600_b	95.0	5400	92.6
					Above	345_a	8.3	84_b	5.0	429	7.4
STAT CMP	**2020,** N = 970	1	1.109	0.292	Within	660_a	77.6	88_a	73.3	748	77.1
					Above	190_a	22.4	32_a	26.7	222	22.9
	2021, N = 156	1	1.114	0.291	Within	27_a	50.0	42_a	41.2	69	44.2
					Above	27_a	50.0	60_a	58.8	87	55.8

Note. Rows that share any letter(s) are not significantly different and those with different letters have significantly different column proportions from one another.

between delayed test results and disease progression [30]. Fifth, it would be useful to examine the impact of ED workflows on TATs for emergency tests and analyze interactions between laboratory services and ED processes, including test ordering, specimen collection, transportation, and result reporting, to identify opportunities for reducing TATs in emergency situations [31].

While the COVID-19 pandemic posed numerous challenges for laboratory services, it also spurred several positive developments and innovations. Rapid test development for COVID-19 led to the creation of faster and more efficient diagnostic methods, with broader implications for diagnosing other infectious diseases [32,33]. The pandemic accelerated the adoption of telehealth and remote monitoring technologies, improving access to healthcare services and enhancing patient engagement. Collaboration among researchers, healthcare providers, and public health agencies increased, facilitating rapid knowledge sharing and global research efforts [34,35]. Laboratories embraced digital transformation, adopting automation and digital technologies to streamline operations and enhance data management [36]. Heightened awareness of public health preparedness prompted increased investment in pandemic preparedness and infrastructure [37,38]. Additionally, substantial funding was allocated to research and innovation, driving breakthroughs in medical science and paving the way for advancements in healthcare beyond the pandemic [39,40].

This study had several limitations. We included data from six out of twenty-eight health centers in Qatar, so the results may not be representative of the entire population of HCs in Qatar. Moreover, our inability to access data from 2022 stands as a noteworthy limitation, which impacts the robustness of our final conclusions. Our examination of three common tests may not be sufficient to fully capture the impact of the pandemic on all laboratory testing processes. We solely relied on TATs as the quality metric to assess the impact of the pandemic on PHCC laboratory services. However, it is important to note that there are other quality measures that can be used to evaluate laboratory testing, including accuracy, precision, and error rates.

In conclusion, the study provides valuable insights into CRP, CBC, and CMP tests conducted between 2019 and 2021 and their regional variations, collection priorities, and center types. Distinct patterns were observed across different regions and there was variability in test completion proportions within specific turnaround thresholds. Overall, these findings shed light on the complexities of test completion in different regions, centers, and with different collection priorities, which may help healthcare administrators and policymakers tailor strategies to improve test completion rates and enhance patient care, particularly in critical and time-sensitive scenarios. Further research is now needed to explore the underlying factors influencing these patterns and to identify potential interventions for optimizing test completion proportions in diverse healthcare settings.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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