

Clinical Ordering Practices of the SARS-CoV-2 Antibody Test at a Large Academic Medical Center

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Background. The novel severe acute respiratory coronavirus 2 (SARS-CoV-2) that causes coronavirus disease 2019 (COVID-19) originated in December 2019 and has now infected almost 5 million people in the United States. In the spring of 2020, private laboratories and some hospitals began antibody testing despite limited evidence-based guidance.

Methods. We conducted a retrospective chart review of patients who received SARS-CoV-2 antibody testing from May 14, 2020, to June 15, 2020, at a large academic medical center, 1 of the first in the United States to provide antibody testing capability to individual clinicians in order to identify clinician-described indications for antibody testing compared with current expert-based guidance from the Infectious Diseases Society of America (IDSA) and the Centers for Disease Control and Prevention (CDC).

Results. Of 444 individual antibody test results, the 2 most commonly described testing indications, apart from public health epidemiology studies ($n = 223$), were for patients with a now resolved COVID-19-compatible illness ($n = 105$) with no previous molecular testing and for asymptomatic patients believed to have had a past exposure to a person with COVID-19-compatible illness ($n = 60$). The rate of positive SARS-CoV-2 antibody testing among those indications consistent with current IDSA and CDC guidance was 17% compared with 5% ($P < .0001$) among those indications inconsistent with such guidance. Testing inconsistent with current expert-based guidance accounted for almost half of testing costs.

Conclusions. Our findings demonstrate a dissociation between clinician-described indications for testing and expert-based guidance and a significantly different rate of positive testing between these 2 groups. Clinical curiosity and patient preference appear to have played a significant role in testing decisions and substantially contributed to testing costs.

Keywords. antibody; COVID-19; SARS-CoV-2; serology; stewardship; utilization.

Coronavirus disease 2019 (COVID-19) is an international crisis that continues to influence every facet of human life. The novel severe acute respiratory coronavirus 2 (SARS-CoV-2) that causes COVID-19 manifested itself in December 2019 [1, 2]. As of June 27, 2020, almost 5 million people in the United States and >19 million people worldwide have been confirmed with the SARS-CoV-2 infection [3]. Over the past few months, the key to detection as well as understanding the spread of the virus has been primarily through evolving testing strategies [4].

There are 2 main clinical laboratory tests being used to monitor the widespread infection of the SARS-CoV-2 virus [4]. The first diagnostic tests for COVID-19 were based on the detection

of viral genetic material for SARS-CoV-2. These molecular diagnostic tests (ie, reverse transcription polymerase chain reaction [RT-PCR]) remain the gold standard for diagnosing active viral infection in symptomatic COVID-19 cases [5]. Several weeks after the molecular tests were implemented, antibody tests to SARS-CoV-2 became available. Over 200 antibody tests (eg, IgG, IgM, and IgG/IgM combo) flooded the market and were distributed without being properly vetted through the typical Food and Drug Administration (FDA) process [6]. This led to general concerns about antibody test accuracy, prompting the FDA to modify its stance about data review and to now require all in vitro diagnostic test manufacturers to submit their tests through the FDA Emergency Use Authorization pathway [7]. The utility and limitations of the antibody test have been at the forefront of discussions in the medical and lay communities [8–10].

The clinical and public health necessity for ordering the SARS-CoV-2 antibody test remains poorly described. To this point, the test has primarily been used in epidemiological studies to determine disease burden [11, 12]. For instance, a recent analysis of SARS-CoV-2 antibody test results from nearly 12 000 serum samples collected as part of routine or

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sick care (but unrelated to COVID-19) suggested that the COVID-19 burden may be >10 times greater than previously thought [12]. Yet, the antibody response in infected patients remains largely unknown, and the clinical value of antibody testing has not been fully demonstrated [13, 14]. Given the current lack of evidence-based guidance, guidelines from the Infectious Diseases Society of America (IDSA) based on expert opinion focused on 4 situations where the detection of antibodies could be helpful such as public health surveillance and identification of convalescent plasma donors (<https://www.idsociety.org/globalassets/idsa/public-health/covid-19/idsa-covid-19-antibody-testing-primer.pdf>). Similarly, the Centers for Disease Control and Prevention (CDC) released interim guidance that urged health care professionals to not use antibody tests as a means to diagnosis a patient with COVID-19 [15]. Despite lacking evidence-based guidance, private laboratories and some hospitals began antibody testing in early spring of 2020 [16].

Widespread availability of the SARS-CoV-2 antibody tests with limited guidance on appropriate testing indications within the clinical environment may lead to significant health care waste and potential misinformation as the pandemic continues. Excessive laboratory testing is a known driver of unnecessary costs and resources that can negatively impact clinical outcomes [17]. The SARS-CoV-2 antibody test is currently estimated to cost between \$30 and \$50, a price that increases to between \$120 and \$175 when administration costs are included [18]. America's Health Insurance Plans (AHIP) estimates that widespread antibody testing could cost the United States between \$5 and \$19 billion [18]. Yet, incomplete evidence on how the test currently is or should be used limits an accurate estimate of cost in a time when the resource implications of widespread antibody testing are of the utmost importance.

Clinicians and insurance providers are seeking answers as to the value of SARS-CoV-2 antibody testing. A number of US hospitals have issued perspective communications hoping to address employee and patient concerns related to a lack of guidance on the necessity of antibody testing [19]. Similarly, infectious disease and public health leaders recently published an opinion piece expressing concerns over the lack of specific clinical indications following the establishment of SARS-CoV-2 antibody testing in England [20]. In a recent letter to Secretary of Health and Human Services Alex Azar, the National Association of Insurance Commissioners (NAIC) wrote:

Centers for Medicare and Medicaid Services (CMS) guidance has indicated testing should be covered by insurers when medically necessary, but there are still many questions about the application of medical necessity standards and FDA guidance is less clear about the value of various tests. States, local governments, employers, and carriers would benefit from a consistent and clear message about

what tests are approved for what uses and in what circumstances they should be covered by insurers [21].

This uncertainty around coverage could undermine Congress' testing mandate and may lead to significant costs for hospitals and private laboratories that could ultimately be passed on to patients.

Herein, we describe the indications for SARS-CoV-2 antibody testing immediately following testing availability at a large academic medical center. As one of the first medical centers in the United States to provide antibody testing capability to individual clinicians, we hope our experience serves as a guide for clinicians at other medical centers utilizing SARS-CoV-2 antibody testing and informs policy-makers aiming to define testing indications that promote high-value care to patients and the public at large.

METHODS

Data Collection

The University of Virginia Health System (UVAHS) began SARS-CoV-2 antibody testing on May 14, 2020. Antibody testing was performed in our central clinical laboratory on the Abbott Architect i2000 analyzer utilizing the EUA nucleocapsid-based SARS-CoV-2 IgG antibody immunoassay [22, 23]. Before any patients were tested, the SARS-CoV-2 IgG antibody test was validated as previously described [24]. In addition, limitations of IgG antibody testing such as false-positive and false-negative results were distributed through an emergency "lab medicine update" to the emails of all potential ordering providers at the UVA. We conducted a retrospective chart review of patients who received antibody testing at the UVAHS from May 14, 2020, to June 15, 2020, to identify the indications for testing as described by the ordering clinician in the electronic medical record (EMR). Chart review was performed under a protocol that was approved by the University of Virginia Institutional Review Board (IRB-HSR #13310).

To identify patients to be included in the retrospective chart review, we developed an automated report that identified SARS-CoV-2 antibody test orders within the EMR. This report included fields for order identification number, date of order, ordering clinician, patient location, laboratory procedure number, medical record number (MRN), test result, result time, and result status. Prisoners, patients tested for test validation, and patients with charts that were locked from outside review due to privacy concerns were excluded.

When available, the patient MRN was used to access and review patient charts within the EMR to identify the indication used by the clinician to order the SARS-CoV-2 antibody test. To do this, we reviewed recent patient encounter documentation including patient charts, MyChart communications, and laboratory orders. We looked for documentation by the ordering

clinician indicating the purpose for ordering the SARS-CoV-2 antibody test, reviewing as far back as January 1, 2020. If there was not enough information available for the reviewer to identify the indication the ordering clinician was using, then a “no indication provided” label was assigned to that test.

Beyond the indication used for antibody testing, we collected additional information including age, sex, timing for onset of symptoms as reported by the patient, and any records of COVID-19 viral RT-PCR tests ordered before the SARS-CoV-2 antibody test with the associated date and result of the test. Due to the retrospective focus of the study, we did not include RT-PCR tests in our data that occurred on dates after the SARS-CoV-2 antibody test.

A subset of the laboratory orders included in the automated report did not have an associated MRN, preventing us from performing chart reviews to identify the indication for antibody testing. However, using the ordering clinician information included in the report, we were able to identify the indication for testing without reviewing the chart. Within our study, there were 2 scenarios that required this approach. The first was a small subset of SARS-CoV-2 tests ordered for efficacy evaluation of this newly developed antibody test. These orders were excluded from our data set (n = 3). The second scenario was related to

epidemiologic studies evaluating the prevalence of COVID-19 by public health entities (n = 222). One patient stated that they were a part of this study, and therefore they were added to the total of the second group of tests (total n = 223). This second group of tests was included in our analysis, as epidemiologic studies fall within the current guidelines for ordering antibody testing.

Statistical Analysis

All data were de-identified and collected in Microsoft Excel. The range, mean, standard deviation, and median were determined. The unpaired *t* test, assuming equal variance with an alpha value of .05, was used to compare the means of 2 unmatched groups, those testing indications consistent with IDSA or CDC guidance, and those testing indications inconsistent with such guidance.

Review of Evidence

Current IDSA and CDC expert-based recommendations for antibody testing were reviewed to formulate a list of possible testing indications (Table 1). Indications noted in the EMR that were not included in the CDC or IDSA guidelines were added to the list (Table 1). There were 11 indications in total.

Table 1. SARS-CoV-2 Antibody Test and SARS-CoV-2 RT-PCR Test Results by Indication Used to Order the Antibody Test

Indication	Total, No.	Nega- tive Test Result, No.	Positive Test Result, No.	Pos- itive Result Rate, %	No. of Patients With Prior PCR Tests, No.	Nega- tive PCR Tests, No.	Positive PCR Tests, No.	Pos- itive PCR Result Rate, %
Indications Recommended by IDSA/CDC								
A. Public health epidemiology studies of disease prevalence	223	219	4	2	0	0	0	-
B. Detection of RT-PCR-negative cases, such as for patients who present late with a viral load below the detection limit of RT-PCR assays, or when lower respiratory tract sampling is not possible	20	19	1	5	20	20	0	0
C. Testing when patients present with late complications of COVID-19 illness, such as multisystem inflammatory syndrome in children	12	11	1	8	8	8	0	0
D. Identification of convalescent plasma donors	5	1	4	80	4	0	4	100
E. Vaccine verification	0	0	0	-	0	0	0	-
Indications Outside of IDSA/CDC Recommendations								
F. Testing for patients who have recovered from COVID-19-compatible illness but never had RT-PCR testing	105	98	7	7	0	0	0	-
G. Testing because an asymptomatic patient is believed to have had close contact with a person with COVID-19-compatible illness in the past	60	55	5	8	3	3	0	0
H. No indication provided	49	47	2	4	2	0	2	100
I. Other	5	5	0	0	0	0	0	-
J. Used to support a diagnosis of COVID-19 in a symptomatic patient in the absence of RT-PCR testing	4	4	0	0	0	0	0	-
K. Used to determine immune status (return to work, school use, etc.) outside of epidemiologic investigation	1	1	0	0	0	0	0	-

The indications used to order SARS-CoV-2 antibody tests are listed in column 1. The total numbers of tests using each indication are listed in column 2. In columns 3 and 4, the number of negative and positive antibody test results for each testing indication are listed, and the positive antibody result rate as a percentage is in column 5. Column 6 lists the number of patients who had viral RT-PCR testing before antibody testing. The count of negative RT-PCR results, positive RT-PCR results, and the positive result rate as a percentage of RT-PCR testing are listed in columns 7, 8, and 9, respectively. Indications were grouped into subsections for those recommended by the IDSA, CDC, or both and those that were not recommended by either organization.

Abbreviations: CDC, Centers for Disease Control and Prevention; COVID-19, coronavirus disease 2019; IDSA, Infectious Diseases Society of America; RT-PCR, reverse transcription polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Indications A–E were provided by the IDSA, CDC, or both. Recommendations F–K were based on chart review. Once a clinician-described indication was identified through chart review, the indication was matched to the list of testing indications developed by our team. The positive antibody result rate was then calculated for these patients.

Cost Analysis

An estimated cost analysis of the SARS-CoV-2 antibody test was performed utilizing all reviewed tests between May 14, 2020, and June 15, 2020. Test and test administration (ie, office visit, urgent care) cost data from the AHIP were used to determine total estimated costs in both low and high cost situations (Table 2) [18]. This information was further used to determine the breakdown costs associated with antibody testing within or outside current expert-based guidance.

RESULTS

We reviewed a total of 449 SARS-CoV-2 antibody tests collected for 447 patients over a 1-month time period. Five patients were excluded. Half of the remaining patients (n = 220) were stratified by age and sex. Males (n = 93) and females (n = 127) were further separated into 5 distinct age groups (0–20, 21–40, 41–60, 61–80, and >80 years). The age brackets

41–60 and 61–80 contained the most antibody tests for females (n = 48) and males (n = 35), respectively. Race and ethnicity information were not collected for this study, as these variables were often inconsistent or missing in the EMR. The remaining (n = 222) patients and the additional patient (n = 1) described above were grouped into public health epidemiology studies (total n = 223), and the EMR did not contain any demographic or additional patient information.

All patients were separated into distinct testing indications. This allowed 9 separate categories for ordering indications for the SARS-CoV-2 antibody test and 2 additional groupings broken down as “other” or “no indication provided.” Each ordering indication was further classified by antibody test result and positive result rate as well as molecular test information, when available (Table 1). The 2 most commonly described indications for ordering the antibody test were epidemiologic studies (n = 223, 50%) and patients with a resolved COVID-19-compatible illness (n = 105, 24%) who never had a molecular test. The highest percentage positive result rate (n = 5, 80%) was to identify convalescent plasma donors. No testing was done on patients to determine vaccine response (ie, indication E), owing to the fact that vaccines to the SARS-CoV-2 virus are not currently available. Overall, the rate of positive SARS-CoV-2 antibody testing among all indications ranged from 0% to 80%

Table 2. High- and Low-Cost Scenarios for Different Segments of SARS-CoV-2 Antibody Testing

Test Segment	All Reviewed Tests Performed From 5/14/20 to 6/15/20		All Reviewed Tests Performed From 5/14/20 to 6/15/20 Outside Current Guidelines		All Reviewed Tests Performed From 5/14/20 to 6/15/20 Within Current Guidelines	
	Low cost	High cost	Low cost	High cost	Low cost	High cost
Total tests	444	444	186	186	258	258
Cost scenario	Low cost	High cost	Low cost	High cost	Low cost	High cost
Antibody test cost, US\$	40.00	65.00	40.00	65.00	40.00	65.00
Test administration cost, US\$	90.00	155.00	90.00	155.00	90.00	155.00
Total cost, US\$	5 757 720.00	9 797 680.00	2 424 180.00	4 040 920.00	3 333 540.00	5 656 760.00
Positive test rate, %	5	5	5	5	4	4
Cost per positive test, US\$	2886.00	4884.00	2418.00	4092.00	3354.00	5676.00
Test Segment	All Reviewed Tests Performed From 5/14/20 to 6/15/20 for Public Health Epidemiology Studies ^a		All Reviewed Tests Performed From 5/14/20 to 6/15/20 Within Guidelines Excluding Public Health Epidemiology Studies			
Total tests	223	223	35		35	
Cost scenario	Low cost	High cost	Low cost		High cost	
Antibody test cost, US\$	40.00	65.00	40.00		65.00	
Test administration cost, US\$	90.00	155.00	90.00		155.00	
Total cost, US\$	2 828 990.00	4 949 060.00	4550.00		7700.00	
Positive test rate, %	2	2	17		17	
Cost per positive test, US\$	7247.50	1 212 265.00	758.33		1283.33	

In Table 2, cost estimates for SARS-CoV-2 antibody testing are outlined. Different testing segments were identified based on the indications used to order the antibody test. The segments included all testing, testing outside expert-based guidance, testing within expert-based guidance, testing within expert-based guidance excluding public health epidemiology studies, and testing for public health epidemiology studies. The total tests for each segment are listed in line 2. Next, low and high testing costs were identified. This cost included the antibody test cost and cost to administer the test (ie, office visit). A low and high cost estimate for each item was used. Our low-end estimate utilizes the AHIP's low-end Medicare testing estimates, and our high-end estimate utilizes the AHIP's high-end commercial testing estimates [18]. Once low and high total costs to perform a single test were identified, total low and high testing costs for each segment were calculated by multiplying the total cost for a single test by the total number of tests in a segment (line 6). Next, the positive result rate of each segment was calculated as the number of positive test results out of total tests for a segment. This is listed as a percentage in line 7. Finally, the cost per positive test for the low and high cost scenarios of each segment was calculated (line 8). This was done by dividing the total cost of testing by the number of positive test results in each segment.

Abbreviations: AHIP, America's Health Insurance Plans; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

^aTesting costs may vary within public health epidemiology studies.

with a median of 5%. Notably, when testing for epidemiological studies was removed, the rate of positive SARS-CoV-2 antibody testing among those indications consistent with current IDSA and CDC guidance was 17%. In comparison, the rate of positive SARS-CoV-2 antibody testing among those indications inconsistent with current IDSA and CDC guidance was 5% ($P < .0001$).

Time periods were identified by chart review for patients who self-reported COVID-19-like symptoms. Sixty-six percent of patients ($n = 146$) either reported having symptoms in a specific month as far back as November 2019 or indicated more broadly that they felt ill in late 2019 or early 2020 (Figure 1). From January 2020 to May 2020, the positive result rate ranged from 7% (1 of 15 tested in January) to 13%, with a median of 12%. Positive result rates were 0 in all other reported time frames.

Total cost estimates for all tests performed during the first month of testing ranged from \$57 720 to \$97 680 (Table 2). The tests were broken up into segments by the indications used to order the test. Out of these total costs, \$24 180 to \$40 920, or ~42%, were from testing that was inconsistent with current expert-based guidance. Costs per positive test were also identified in each segment. The relationship between each testing segment's low cost per positive test estimate and share of testing was represented in a bubble graph (Figure 2). The size of each bubble was proportional to a segment's positive result rate. The lowest cost per positive test (\$758.33 to \$1283.33) was seen when clinician ordering practices were indicated by current expert-based guidance, excluding epidemiologic study

data. Though testing consistent with current expert-based guidance, excluding epidemiologic study data, had the lowest cost per positive test, it represented the lowest share of testing (8%). Epidemiologic study had the highest cost per positive test (\$7247.50) and was the indication for half of all testing (50%).

DISCUSSION

Apart from public health epidemiology studies of disease prevalence, the most common reason for a clinician to order SARS-CoV-2 antibody testing was to determine presumed immunity in patients with resolved COVID-19-compatible illness. These patients never received SARS-CoV-2 RT-PCR testing at the time of illness. The second most common reason for a clinician to order SARS-CoV-2 antibody testing was to determine presumed immunity in asymptomatic patients believed to have had a past exposure or contact with a person with COVID-19-compatible illness. Neither of these commonly documented indications are consistent with current expert-based guidance from the IDSA or CDC. Because the rate of positive SARS-CoV-2 antibody testing among those indications inconsistent with current IDSA and CDC guidance was significantly lower than the positive rate among expert-backed indications, such inconsistent testing indications are unlikely to change management decisions or be of much clinical value. The prevalence of these inconsistent testing indications suggests that clinical curiosity and patient preference played a large role in initial testing decisions.

The next most commonly identified indication for SARS-CoV-2 antibody testing was detection of RT-PCR-negative

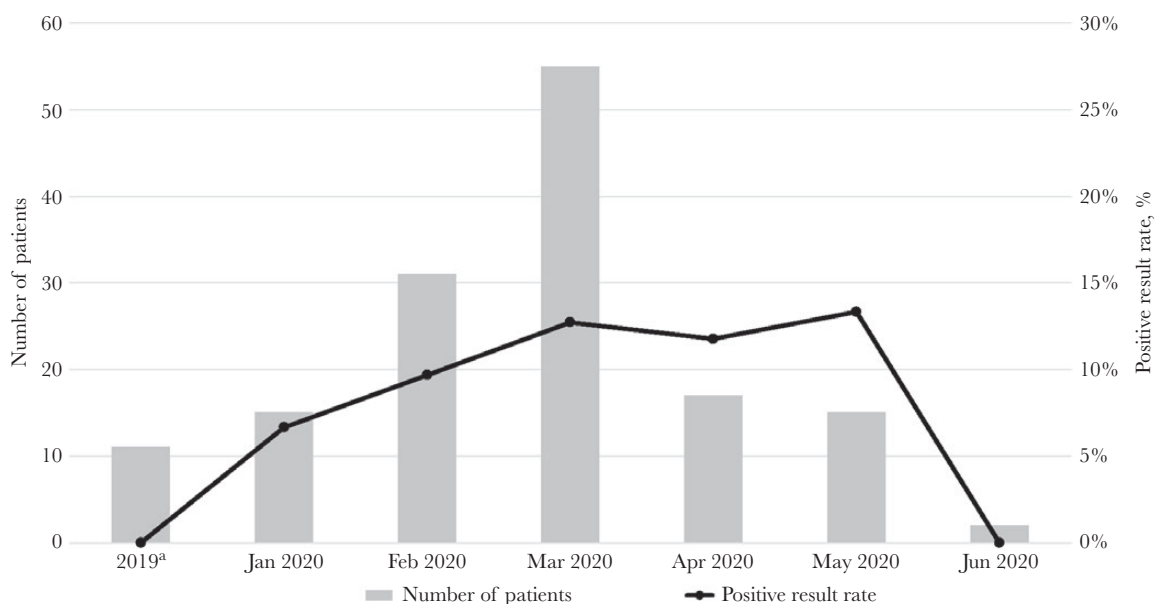


Figure 1. Patient-reported frequency of onset of coronavirus disease 2019 (COVID-19)-like symptoms and positive result rate. The left and right y-axis represents the number of patients who reported COVID-19-like symptoms and the positive result rate as a percentage, respectively. The x-axis includes the month and year when patients reported COVID-19-like symptoms. ^aIncludes patients reporting symptoms at any time within the year 2019.

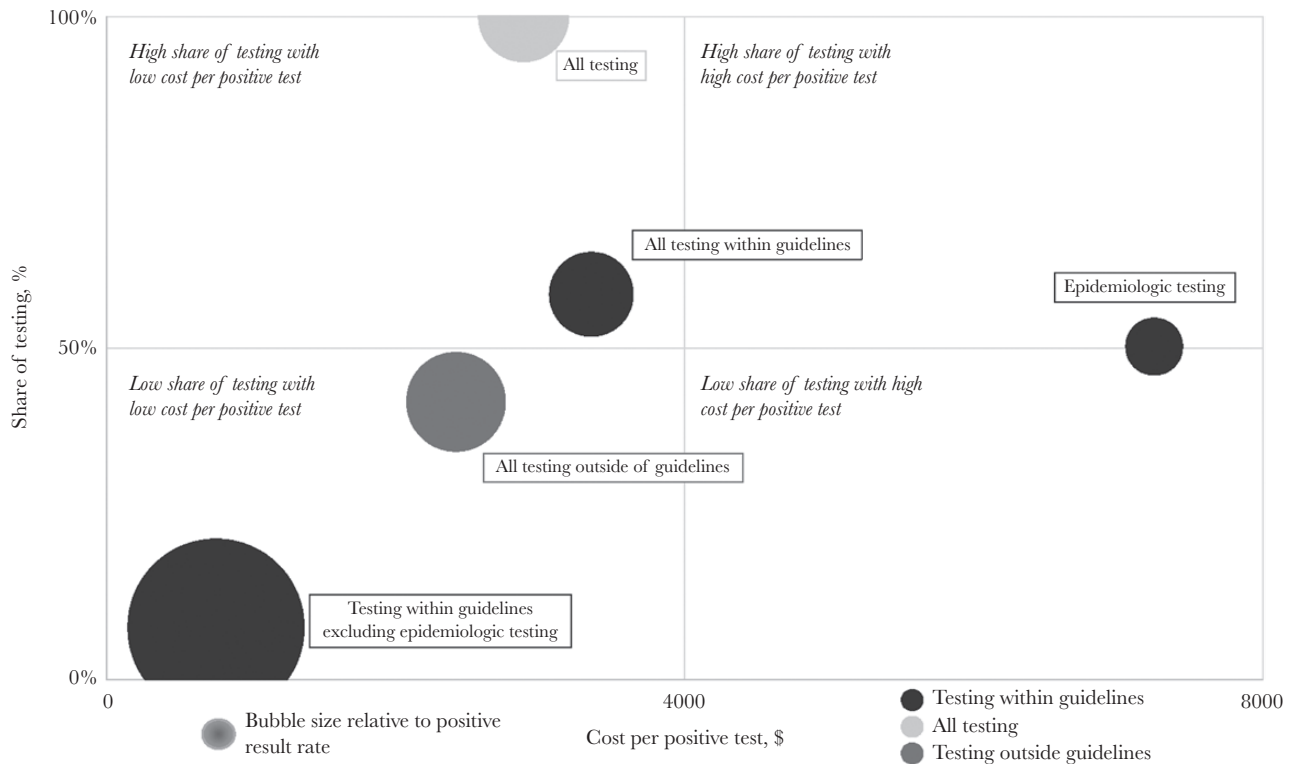


Figure 2. A comparison of the testing scenarios by the cost per positive test and its share of testing. On the x-axis, the cost per positive test is represented in US dollars. The share of testing is displayed on the y-axis as a percentage. The relative positive result rate percentage is represented by bubble size.

cases, especially for patients who presented late in the course of illness and potentially had a viral load below the detection limit of RT-PCR assays or when lower respiratory tract sampling was not possible. This was followed by testing to help establish a diagnosis when patients presented with late complications of COVID-19 illness and testing to identify convalescent plasma donors. All 3 are indications consistent with expert-based guidance from the IDSA or CDC. This was followed by an indication of supporting a diagnosis of COVID-19 in a currently symptomatic patient in the absence of RT-PCR testing and to determine immune status (eg, return to work, school use) outside of an epidemiologic investigation. Both of these indications are inconsistent with current expert-based guidance from the IDSA or CDC.

Two patients with prior positive SARS-CoV-2 RT-PCR tests received antibody testing during prolonged inpatient stays of 18 and 25 days. After initial clinical improvement, both patients had intermittent fever without a clear source. SARS-CoV-2 antibody testing, positive in both cases, was obtained in order to provide supporting evidence of a prior history of COVID-19 infection rather than active SARS-CoV-2 infection or reinfection as a source of the new fevers. This reason for testing is inconsistent with the indications described in this study; whether it represent a valid and clinically meaningful use of the SARS-CoV-2 antibody test remains to be determined.

Finally, we assessed total cost estimates for each testing indication and cost per positive test. “Runaway costs” for the COVID-19 pandemic have been a major concern for the global community—with laboratory testing being a key factor [25–27]. In this study, clinical testing consistent with current expert-based guidance had the lowest cost per positive test. Yet, almost half of the total costs were due to testing indications that were inconsistent with current expert-based guidance. If testing were to continue at the same rate for 1 year, these inconsistent testing indications would account for almost \$500 000 in our hospital. Fortunately, stewardship of laboratory testing is not a new concept [17, 28]. Well-designed and carefully thought-out testing strategies have been shown to help increase the awareness of limitations (ie, false positivity and negativity rates) and of the appropriateness of a specific test. A possible evidence-based approach to control unnecessary SARS-CoV-2 antibody testing may be in the development and implementation of clinical decision support (CDS) tools that leverage the EMR [29]. This would restrict clinicians to ordering the test under options of CDC and IDSA guidance only until more evidence becomes available.

This study has some limitations. First, retrospective review of clinical documentation is inherently subjective. To counter this limitation, we maintained a conservative threshold for including any single testing indication

within a given category. In this study, 11% of testing indications were categorized as “no indication provided,” a frequency consistent with other published literature reliant on retrospective chart review [30]. Second, the duration of antibody response following infection is unclear, and asymptomatic individuals may not develop a positive antibody response [14]. Third, IDSA and CDC guidance on testing may change based on evolving literature. Finally, there are concerns about increased false-positive antibody tests due to the low prevalence of COVID-19 in our patient population. However, the use of the EUA Abbott Architect SARS-CoV-2 IgG antibody test in this study provides stronger assurance than previously described studies [31, 32]. It is important to note that antibody testing in a low-risk population is not only not cost-effective, but can lead to issues such as a false sense of security to those who are positive.

In summary, this investigation identified clinician-documented indications for SARS-CoV-2 antibody testing immediately following testing availability. To our knowledge, we are the first to describe these testing indications from the standpoint of the ordering clinician during the COVID-19 pandemic. Our findings demonstrate a dissociation between clinician-described indications for testing and expert-based guidance and a significantly different rate of positive testing between these 2 groups. Clinical curiosity and patient request appear to have played a significant role in testing decisions. Perhaps this should be expected given the lack of established clinical testing guidelines and the inherent fear and uncertainty driven by the global COVID-19 pandemic. However, without evidence-based guidance, further expansion of SARS-CoV-2 antibody testing availability for clinical purposes may lead to higher health care costs with unclear benefit.

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References

1. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. Available at: <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020>. Accessed 6 July 2020.
2. Nicola M, Alsaifi Z, Sohrabi C, et al. The socio-economic implications of the coronavirus pandemic (COVID-19): a review. *Int J Surg* 2020; 78:185–93.
3. COVID-19 map. Available at: <https://coronavirus.jhu.edu/map.html>. Accessed 6 July 2020.
4. Patel R, Babady E, Theel ES, et al. Report from the American Society for Microbiology COVID-19 International Summit, 23 March 2020: value of diagnostic testing for SARS-CoV-2/COVID-19. *mBio* 2020; 11. Available at: <https://mbio.asm.org/content/11/2/e00722-20>. Accessed 7 July 2020.
5. Tahamtan A, Ardebili A. Real-time RT-PCR in COVID-19 detection: issues affecting the results. *Expert Rev Mol Diagn*. **In press**.
6. Harris R. FDA cracks down on antibody tests for coronavirus. *NPR*. 4 May 2020. Available at: <https://www.npr.org/sections/health-shots/2020/05/04/850195471/fda-cracks-down-on-antibody-tests-for-coronavirus>. Accessed 7 July 2020.
7. Food and Drug Administration. Policy for coronavirus disease-2019 tests during the public health emergency (revised). 2020. Available at: <https://www.fda.gov/regulatory-information/search-fda-guidance-documents/policy-coronavirus-disease-2019-tests-during-public-health-emergency-revised>. Accessed 7 July 2020.
8. Eder S, Twohey M, Mandavilli A. Covid-19 antibody test, seen as key to reopening country, does not yet deliver. *The New York Times*. 7 May 2020. Available at: <https://www.nytimes.com/2020/04/19/us/coronavirus-antibody-tests.html>. Accessed 7 July 2020.
9. Wu AHB. Screening the general population for SARS CoV-2 virus and COVID-19 antibodies: a counter-argument. *J Appl Lab Med*. **In press**.
10. Labs urge CDC to change COVID-19 antibody test guidelines. Available at: <https://www.medtechdive.com/news/labs-urge-cdc-to-change-covid-19-antibody-test-guidelines/579868/>. Accessed 7 July 2020.
11. Mathur G, Mathur S. Antibody testing for COVID-19. *Am J Clin Pathol* 2020; 154:1–3.
12. CDC. Coronavirus disease 2019 (COVID-19). 2020. Available at: <https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/commercial-lab-surveys.html>. Accessed 7 July 2020.
13. Shen L, Wang C, Zhao J, et al. Delayed specific IgM antibody responses observed among COVID-19 patients with severe progression. *Emerg Microbes Infect* 2020; 9:1096–101.
14. Long QX, Tang XJ, Shi QL, et al. Clinical and immunological assessment of asymptomatic SARS-CoV-2 infections. *Nat Med*. **In press**.
15. CDC. Information for laboratories about coronavirus (COVID-19). 2020. Available at: <https://www.cdc.gov/coronavirus/2019-ncov/lab/resources/antibody-tests-guidelines.html>. Accessed 10 July 2020.
16. Abbasi J. The promise and peril of antibody testing for COVID-19. *JAMA* 2020; 323:1881–3.
17. Eaton KP, Levy K, Soong C, et al. Evidence-based guidelines to eliminate repetitive laboratory testing. *JAMA Intern Med* 2017; 177:1833–9.
18. AHIP. New study: COVID-19 testing costs could reach \$25 billion a year for diagnostic, \$19 billion a year for antibody. 2020. Available at: <https://www.ahip.org/new-study-covid-19-testing-costs/>. Accessed 7 July 2020.
19. Vanderbilt University Medical Center. Antibody testing for COVID-19: what it tells us and what it doesn't | coronavirus (COVID-19) information for employees and patients. Available at: <https://www.vumc.org/coronavirus/latest-news/antibody-testing-covid-19-what-it-tells-us-and-what-it-doesnt>. Accessed 7 July 2020.
20. Andersson M, Low N, French N, et al. Rapid roll out of SARS-CoV-2 antibody testing—a concern. *BMJ* 2020; 369:m2420.
21. National Association of Insurance Commissioners. NAIC letter to Azar May 2020. Available at: https://content.naic.org/sites/default/files/inline-files/NAIC_Letter_to_Azar_May_2020.pdf. Accessed 7 July 2020.
22. Chew KL, Tan SS, Saw S, et al. Clinical evaluation of serological IgG antibody response on the Abbott Architect for established SARS-CoV-2 infection. *Clin Microbiol Infect*. **In press**.
23. Performance characteristics of the Abbott architect SARS-CoV-2 IgG assay and seroprevalence in Boise, Idaho. *J Clin Microbiol*. **In press**.
24. Verify Emergency Use Authorization (EUA) SARS-CoV-2 antibody tests. Available at: <https://asm.org/Protocols/Verify-Emergency-Use-Authorization-EUA-SARS-CoV-2>. Accessed 8 August 2020.
25. Lowey NM. H.R.6201 - 116th Congress (2019–2020): Families First Coronavirus Response Act. 2020. Available at: <https://www.congress.gov/bill/116th-congress/house-bill/6201>. Accessed 8 August 2020.
26. Farmer B. Insurers may only pay for coronavirus tests when they're “medically necessary.” *NPR*. 19 June 2020. Available at: <https://www.npr.org/sections/health-shots/2020/06/19/880543755/insurers-may-only-pay-for-coronavirus-tests-when-theyre-medically-necessary>. Accessed 8 August 2020.
27. US Department of the Treasury. The CARES Act works for all Americans. Available at: <https://home.treasury.gov/policy-issues/cares>. Accessed 8 August 2020.
28. Dickerson JA, Fletcher AH, Procop G, et al. Transforming laboratory utilization review into laboratory stewardship: guidelines by the PLUGS National Committee for Laboratory Stewardship. *J Appl Lab Med* 2017; 2:259–68.
29. Sutton RT, Pincock D, Baumgart DC, Sadowski DC, Fedorak RN, Kroeker KI. An overview of clinical decision support systems: benefits, risks, and strategies for success. *Npj Digit Med* 2020; 3:17.
30. Haneuse S, Bogart A, Jazic I, et al. Learning about missing data mechanisms in electronic health records-based research: a survey-based approach. *Epidemiology* 2016; 27:82–90.
31. Farnsworth CW, Anderson NW. SARS-CoV-2 serology: much hype, little data. *Clin Chem* 2020; 66:875–7.
32. Bendavid E, Mulaney B, Sood N, et al. COVID-19 antibody seroprevalence in Santa Clara County, California. *medRxiv* 2020.04.14.20062463 [Preprint]. 30 April 2020. Available at: <https://doi.org/10.1101/2020.04.14.20062463>. Accessed 8 August 2020.