MAY 19, 2020

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Laboratory Testing for COVID-19 (Updated)

Executive Summary

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Table of Contents

Situation ***3***

Background ***3***

Assessment ***4***

Sample Collection: **4**

Outsourcing to Reference Laboratories: **5**

General Testing Methodologies: **7**

Real-Time PCR for viral diseases 7

Isothermal Amplification 7

Serological IgM/IgG Antibody Detection 8

Viral Antigen Detection 9

Commercially Available COVID-19 Assays ***9***

FDA Emergency Use Authorization (EUA) Disclaimer: **9**

Molecular Assays by real-time RT-PCR Detection for SARS-CoV-2: **10**

Table 1. High Complexity Designation with Full Walk-away Automation 10

Table 2. High Complexity Designation without Walk-away Automation *Not inclusive of all available FDA EUA open platform assays. Refer to FDA website for more assays under this designation. 11

Table 3. Moderate Complexity Designation (Available to Standard Hospital Laboratories) 12

Table 4. CLIA-Waived Point-of-Care to Moderate Complexity Designation (Available to Outpatient Clinics to Standard Hospital Laboratories) 13

Molecular Assays by Isothermal Amplification for SARS-CoV-2: **13**

Table 1. CLIA-Waived Point-of-Care to Moderate Complexity Designation (Available to Near-Patient Settings, Outpatient Clinics, and Standard Hospital Laboratories) 13

Serological COVID IgM/IgG Antibody Test (FDA, 2020): **14**

Rapid Qualitative Serology Tests: **14**

Table 1. Moderate Complexity Designation (Rapid Qualitative Single-Step Cartridge Style) 15

Quantitative or Qualitative Antibody Enzyme-Linked Immunosorbent Assay (ELISA): **15**

Table 2. Moderate to High Complexity Designation (High-Throughput Multi-Stage ELISA) 16

Antibody Neutralization Assays (Johns Hopkins, 2020): **17**

COVID-19 Antigen Test: **17**

Sofia 2 SARS Antigen FIA **17**

Budgeting for Instrument Purchase ***18***

Reimbursement Rates & Billing Codes: **18**

Table 1. Reimbursement rates for COVID-19 by molecular testing: 18

Table 2. Reimbursement rates for COVID-19 by serological testing: 18

TractManager's COVID-19 Laboratory Capital Equipment Options & Budget Planner: 18
Table 1. Molecular Platforms 19
Table 2. Immunoassay Platforms 20
Table 3. Antigen Test Platforms 20

Other Abnormal Laboratory Markers Seen in COVID-19: (Lippi & Plebani, 2020) (Cron, MD, PhD & Chatham, MD, 2020) 21

Recommendations 21

References 23

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Laboratory Testing for COVID-19

Situation

Laboratory testing for COVID-19 is crucial for early diagnosis, public health tracking, immunity status, and differentiation with other respiratory viruses. Unfortunately, the onslaught of COVID-19 appeared at the height of influenza, RSV, Strep A, rhinovirus, and cold season. Thus, demand for COVID-19 testing has been high and the inability to provide testing for all symptomatic patients has presented a perfect storm of problems and constraints for the laboratory supply chain.

Background

Although the laboratory has faced reagent kit shortages before such as during the H1N1 flu epidemic, COVID-19 has presented a unique modern healthcare challenge never seen before in the U.S. The demand for testing has been higher than the supply available.

Something as simple as swabs for sample collection have been difficult to source due to limited suppliers and a combination of high demand that started with a heightened flu season and was exacerbated by the COVID-19 pandemic. Lab professionals have been having to fight the casual use of the term “testing sites” or “testing kits” utilized by the media to reference sample collection sites or sample collection kits. This terminology caused a fundamental public and policy making misunderstanding of the multi-front supply shortage problem, concerning sample collection and U.S. laboratory testing capacity. (Johnson, 2020)

Laboratories are also facing challenges in sourcing available reagent kits for their current instrumentation to test for the increasing number of samples. The initial faltering of the original CDC kits and strict regulation by the FDA for research laboratories to develop their own tests over commercial tests set back the initial rollout phase of testing. For the standard hospital laboratory, the uneven distribution of commercial reagent kits and instrument funding to laboratories away from the “hot zones” forced many laboratories to outsource to reference laboratories. This caused unexpected specimen volumes beyond instrument testing capacity and left reference laboratories scrambling to find other testing platforms to reduce the backlog.

There have also been difficulties in supplying supporting lab consumables such as sterile plastic pipette tips, securing enough trained lab workforce personnel, and obtaining results from reference laboratories in a timely manner due to testing backlogs.

Currently, in the U.S. a managed care model has been established with a strict screening process to identify the patients in most need of the COVID-19 test in order to not constrain the hospital medical

equipment capacity and supply chain. Although not optimal for public health tracking, it buys time until more manufacturers can ramp up consumable and reagent production and alternative testing methods can be established.

Assessment

Sample Collection:
Patients now have multiple options to get sample collection done after passing initial physician screening.

1. Go to a COVID-19 “testing” site – these sites may be drive-thru or at a designated hospital facility
2. Purchase an at-home self-collection kit –
    a. As of April 28, 2020, the FDA has provided Emergency Use Authorization (EUA) to only one self-collection kit provided by Pixel and distributed by LabCorp. Patient collects their own nasal swab sample to be mailed and shipped to LabCorp for testing services.
3. Hire in-home “testing” services – collector comes on-site to screen and collect the sample.

According to the CDC, the nasopharyngeal swab submitted in viral transport media is the preferred and easiest specimen collection of choice to test for COVID-19 by molecular methods. Although lower respiratory specimens such as sputum and bronchoalveolar lavage fluid (BAL) contain higher viral loads, it also creates aerosol droplets and increases the biosafety risk to healthcare workers and thus is not the optimal specimen type. (CDC, 2020)

False negatives, which decreases the sensitivity of molecular testing, occur largely in part to improper sample collection. Molecular testing depends on viral load and swabs must reach the area where the virus resides. Proper technique requires a sterile NP swab to go beyond the nostril opening into the posterior nasopharynx region equal to the distance to the outer opening of the ear and rotating several times before withdrawing to capture enough viral particles. Extra precautions should be taken to prevent RNA contamination between sample collections while in transit to a testing laboratory.

Due to PCR inhibition, cotton swabs with wood shafts or calcium alginate swabs cannot be used. Synthetic swabs made of Dacron, nylon, or rayon are best at releasing the virus for laboratory testing.

If wanting to submit other specimen types, contact lab services or read the assay package insert for appropriate specimen collection or other acceptable specimen types. Each laboratory has different instrumentation for COVID-19 testing and are validated for specific collection media and types.

Current manufacturers for NP swabs in viral transport media:

- BD - UVT

- Copan Diagnostics - UTM
- Thermo-Fisher – Remel MicroTest
- Puritan Medical Products

Alternatively, labs can make and validate their own viral transport media and/or source a local 3D printing service if unable to source a distributor for these swab collection kits.
https://www.cdc.gov/coronavirus/2019-ncov/downloads/Viral-Transport-Medium.pdf

Outsourcing to Reference Laboratories:
For most hospital laboratories, outpatient clinics, and physician offices, outsourcing to reference laboratories is the best option to send specimens for testing after collection. Molecular testing for COVID-19 is highly complexed and most laboratories do not have the trained personnel, budget, or instrumentation to perform the test. It can also serve as back-up supplemental support when lab supplies are low and shipment of supplies is not expected to arrive in a timely manner.

Available Reference Laboratories for COVID-19 (Not a full comprehensive list):

Visit this link to view other reference laboratories that may be available in your area.

- CDC
- State Health Department
  - Typically results in 48 hours
- Quest
  - 3 Testing Locations: San Juan Capistrano, CA, Chantilly, VA and Marlborough, MA
  - 9 Locations added by utilizing Roche cobas high-throughput automation: Dallas, TX; Lewisville, TX; Lenexa, KS; Miami, FL; Phoenix, AZ; Pittsburgh, PA; Teterboro, NJ; West Hills, CA; and Wood Dale, IL
  - ~30,000 tests/day; TAT: High demand has caused TAT to be between 4-10 days and samples are being prioritized for inpatients and healthcare workers
- LabCorp
  - 4 Testing Locations: Phoenix, AZ; Burlington, NC; South Bend, IN; and Raritan, NJ
  - ~20,000 tests/day; TAT: High demand has caused TAT to be between 4-10 days and samples are being prioritized for inpatients and healthcare workers
- Access Genetics, dba OralDNA Labs
- Accu Reference Medical Lab LLC
- Acutis Diagnostics
- Advanced Diagnostics Laboratory, National Jewish Health
- AdventHealth
- Altru Diagnostic, Inc.
- ARUP Laboratories
- Assurance Scientific
- Avellino Lab USA, Inc.
- Bako Pathology Associates/DBA Bako Diagnostics

- Baptist Hospital of Miami Clinical Lab
- Baylor Scott and White Medical Center – Temple
- Baylor University Medical Center Department of Pathology
- Baystate Medical Center Whitney Ave Laboratories
- Bedford Research Foundation
- Beth Israel Deaconess Medical Center
- Biodesix, Inc.
- BioReference Laboratories
- Boston Children's Hospital Infectious Diseases Diagnostics Laboratory
- Brigham and Women's Hospital
- The Children's Hospital of Philadelphia
- Cleveland Clinic
- Clinical Pathology Laboratories
- Diagnostic Solutions Laboratory LLC
- Diatherix Eurofins
- Eli Lilly Clinical Diagnostics Laboratory
- Emory Medical Laboratory, Emory Healthcare
- Genesys Diagnostics Inc.
- Gravity Diagnostics
- Henry Ford Health System
- HMH Hackensack University Medical Center
- Hospital of the University of Pennsylvania
- Houston Methodist Hospital
- Integrity Laboratories
- Johns Hopkins Medical Microbiology Laboratory at Johns Hopkins Hospital
- Mayo Clinic
- Medical Diagnostic Laboratories LLC
- Montefiore Medical Center
- Nebraska Medicine Clinical Laboratory
- New York Presbyterian Hospital - Weill Cornell Medicine (NYPH-WCM)
- Next Bio-Research Services LLC
- NYU Langone Medical Center
- PTC Laboratories, Inc.
- Solaris Diagnostics
- Southwest Regional PCR Laboratory dba MicroGen DX
- Stanford Health Care Clinical Laboratory
- Texas Children's Hospital Department of Pathology
- TGen North, Clinical Laboratory
- UCSF-Health
- University of Washington
- Viracor Eurofins Clinical Diagnostics

Recommendation is to seek out local and state reference laboratories and request turn-around times before sending specimens. Previous turn-around times for results with Quest and Labcorp have been reported between 4 to 10 days, with many labs reporting closer to the latter for outpatients. With

moderate complexity assays beginning to obtain FDA EUA, Quest and LabCorp will begin to add more testing locations to reduce their long turn-around times and backlog. If the continuance of delayed results occurs, outsourcing to other local reference laboratories may be an option to reduce turn-around times for results down to 1 to 3 days.

General Testing Methodologies:

There are currently 4 testing methodologies to clinically detect for viral disease:

1. Real-Time PCR
2. Isothermal Amplification
3. Serological IgM/IgG Antibody Detection
4. Viral Antigen Detection

Real-Time PCR for viral diseases

- **Advantages**:
  - Directly detects for viral RNA/DNA by molecular methods
  - High specificity and likelihood of false positives are very low unless RNA/DNA cross-contamination from sample handling occurs.

- **Limitations:**
  - Instrument, consumable and reagent costs are much higher than most laboratory assays
  - Most assays limited to laboratories with a CLIA designation of high complexity and requires specially trained pathologists and lab personnel in molecular testing.
  - Often requires intensive manual labor and less automated in comparison to other laboratory tests
  - Testing may take up to 4 to 6 hours to obtain results
  - May require additional lab equipment, consumable supply, and reagents for DNA/RNA extraction.
  - May require separate rooms, equipment, and hoods to prevent nucleic acid contamination between setup, amplification, and reading.
  - Sensitivity is greatly affected by proper specimen collection. False negatives occur with:
    - Lack of swabbing appropriate target region where virus resides
    - Timing of collection – requires time when viral load is high (symptomatic)
    - Improper shipping/storage conditions
    - RNA/DNA mutation in the region of gene target

Isothermal Amplification

- **Advantages**:
  - Directly detects for viral RNA/DNA by molecular methods
  - High specificity and likelihood of false positives are very low unless RNA/DNA cross-contamination from sample handling occurs.
  - Instrumentation has a small footprint and are inexpensive and simple to use in comparison to real-time PCR

  - Available to moderate complexity to near-patient laboratory settings
  - Extra equipment like DNA/RNA extraction and thermal cyclers are not required like in real-time PCR.
  - Rapid - Denaturization/amplification steps remain at one temperature instead of the heating and cooling steps required in real-time PCR. Thus, reducing the time-to-result for many assays. Results can be as rapid as within 30 minutes.
  - Requires less manual labor than most other molecular assays.

- **Limitations:**
  - Reagent costs per sample are much higher than most laboratory and real-time PCR assays
  - Not recommended for high-throughput environments as batch testing is not available; most instrumentation can only run 1 sample at a time.
  - Limited versatility – only short gene targets can be amplified; thus, # of different assays available to run on these instruments are very narrow and limited in scope in comparison to real-time PCR
  - Sensitivity is greatly affected by proper specimen collection. False negatives occur with:
    - Lack of swabbing appropriate target region where virus resides
    - Timing of collection – requires time when viral load is high (symptomatic)
    - Improper shipping/storage conditions
    - RNA mutation in the region of gene target

Serological IgM/IgG Antibody Detection

- **Advantages:**
  - Testing may be rapid and be cartridge-based similar to a pregnancy test. Qualitative results may be obtained under 15 minutes.
  - Testing sites available to point-of-care settings to moderately complex CLIA-designated laboratories (which is the standard hospital laboratory)
  - Sensitivity NOT as greatly affected by proper specimen collection due to specimen collection requirements being blood instead of swabs.
  - Instrumentation may not be required to read the results and thus, cheaper than molecular methods.
- **Limitations:**
  - Does not directly test for the presence of the virus. This methodology is dependent on the human body antibody production as a reaction to the viral invasion.
  - Positive results do not always equate to active infection but may equate to previous exposure
  - Low specificity – False positives occur with:
    - Endemic immunity or cross-reactivity with other similar viral diseases.
    - Autoimmune diseases such as Rheumatoid Arthritis and Lupus create an overproduction of antibodies that may interfere and react falsely to the antigen or capture antibody in the assay.
  - Low sensitivity – False negatives occur with:
    - Immunocompromised patients due to lack of enough antibody production

- Insufficient time elapsed for antibody immune response to rise after onset of symptoms

Viral Antigen Detection

- **Advantages:**
  - Directly detects for viral capsid proteins by utilizing monoclonal antibodies for detection
  - Testing may be rapid and be cartridge-based similar to a pregnancy test. Qualitative results may be obtained under 15 minutes.
  - Does not require steps for extraction or amplification like molecular methods.
  - Testing may be available to point-of-care settings to moderately complex CLIA-designated laboratories (which is the standard hospital laboratory)
  - Instrumentation may not be required to read the results and thus, cheaper than molecular methods.
  - Blood or swab collection may be acceptable specimens.
- **Limitations:**
  - Sensitivity may be greatly affected by proper specimen collection by swab collection. False negatives occur with:
    - Lack of swabbing appropriate target region where virus resides
    - Timing of collection – requires time when viral load is high (symptomatic)
    - Improper shipping/storage conditions
    - RNA/DNA mutation causing a different protein capsid not detectable by monoclonal antibody
  - Due to lack of amplification steps, the methodology needs to be sensitive enough and the viral load needs to be high enough to overcome the lower limit of detection.
  - Low specificity – False positives occur with:
    - Monoclonal antibody may cross-react with other similar viral diseases.

Commercially Available COVID-19 Assays

Visit this link for the most up-to-date assays that are under the FDA Emergency Use Authorization (EUA) for use in the U.S. This link also provides the manufacturer's instructions for use, supplies required, and validation studies done to determine the lower detection limit and cross-reactivity potential.

https://www.fda.gov/medical-devices/emergency-situations-medical-devices/emergency-use-authorizations#covid19ivd

In addition, this link provides pending status of assays that might be in the pipeline for FDA EUA.

https://www.360dx.com/coronavirus-test-tracker-launched-covid-19-tests

FDA Emergency Use Authorization (EUA) Disclaimer:

Tests under the FDA EUA are not considered FDA-approved or cleared as they have not undergone the FDA's rigorous review for clinical specificity or sensitivity data for each assay. Typically, FDA

clearance takes 1 to 2 years of clinical efficacy and performance studies. EUA provides early release of assays in times when the benefit of testing availability outweighs the performance risks during a public health crisis. FDA EUA assays do have small sample analytical specificity, sensitivity, cross-reactivity and lower limit of detection validation data. Evaluation for FDA clearance will be performed after the emergency use period.

Molecular Assays by real-time RT-PCR Detection for SARS-CoV-2:

Initial sensitivity data being released on real-time PCR methods for COVID-19 being as low as 60-70% in China (Kanne, Little, Chung, Elicker, & Ketai, 2020) may be falsely low due to throat swab collection methods and may be higher in the U.S. due to different collection methods and multiple COVID-19 RNA gene targets added to the newer assays. In addition, it has not been determined when viral shedding in the nasopharyngeal area decreases below the lower limit of detection for molecular assays with the virus still present in other bodily fluids such has stool and lower respiratory bronchial fluids.

Below is a summary of the available assays sorted by the test methodology and minimum CLIA lab complexity certification required to run the test. Links to the package insert of each assay is also provided that includes the analytical sensitivity and specificity that have been performed internally by the manufacturer, which may not correlate with clinical specificity or sensitivity as they are still being evaluated as testing continues in the U.S.

Table 1. High Complexity Designation with Full Walk-away Automation

Manufacturer	Test Kit	Diagnostic Equipment	Instrument Throughput	Viral RNA Extraction Equipment Required?	# COVID Viral Targets	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
Abbott Molecular	Abbott Realtime SARS-COV-2 assay	m2000rt	Moderate to High up to 384 samples per 8 hrs	Yes - m2000sp	2	96	NP or OP swab	2 – 3 hrs	https://www.fda.gov/media/136258/download
Hologic	Panther Fusion SARS-COV-2	Panther System + Fusion Module	Moderate to High up to 335 – 600 samples per 8 hrs	No	2	96	NP or OP swab	2.5 hrs	https://www.fda.gov/media/136156/download
NeuMoDx	NeuMoDx SARS-CoV-2 Assay	Options: 1) NeuMoDx 96 2) NeuMoDx 288	Moderate to High 1) NeuMoDx 96 – 144 tests per 8 hrs 2) NeuMoDx 288 – 288 tests per 8 hrs	No	2	96	NP, OP, or nasal swab	1.5 hrs	https://www.fda.gov/media/136565/download

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Table 2. High Complexity Designation without Walk-away Automation *Not inclusive of all available FDA EUA open platform assays. Refer to FDA website for more assays under this designation.

Manufacturer	Test Kit	Diagnostic Equipment	Instrument Throughput	Viral RNA Extraction Equipment Required?	# COVID Viral Targets	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
CDC	CDC 2019-nCoV Real-Time RT-PCR Diagnostic Panel	Applied Biosystems 7500 FAST Dx	Moderate up to 252 samples per 8 hrs	Yes	2	1,000 Reactions	NP, BAL, Nasal wash	3 - 6 hrs	https://www.fda.gov/media/134922/download
Thermo Fisher Scientific	TaqPath COVID-19 Combo Kit	Applied Biosystems 7500 FAST Dx	Moderate up to 252 samples per 8 hrs	Yes	3	1,000 Reactions	NP, BAL, Nasal wash	3 - 6 hrs	https://www.fda.gov/media/136112/download
Quidel	Lyra SARS-CoV-2 Assay	Options: 1) Applied Biosystems 7500 FAST Dx 2) Roche LightCycler 480 II 3) Qiagen Rotor-Gene Q	Moderate up to 384 samples per 8 hrs	Yes - Biomerieux easyMag / EMAG	1	96 Tests	NP or OP swab	3 - 6 hrs	https://www.fda.gov/media/136227/download
Primerdesign Ltd	Primerdesign Ltd COVID-19 genesig Real-Time PCR assay	Options: 1) Applied Biosystems 7500 Real-Time PCR 2)Bio-Rad CFX Connect Real-Time PCR 3) Roche LightCycler 480 II	Moderate up to 384 samples per 8 hrs	Yes	Not disclosed	96 Tests	OP Swabs	3-6 hrs	https://www.fda.gov/media/136309/download
Perkin-Elmer	Perkin Elmer New Coronavirus Nucleic Acid Detection Kit	Applied Biosystems 7500 Real-Time PCR	Moderate up to 192 samples per 8 hrs	Yes	2	48 Tests	NP or OP swab	3 - 6 hrs	https://www.fda.gov/media/136410/download
Luminex Molecular Diagnostics	NxTAG CoV Extended Panel Assay	Luminex MAGPIX	Moderate 384 samples per 8 hrs.	Yes – bioMerieux easyMag/ EMAG	3	96 Tests	NP swab	4 hrs	https://www.fda.gov/media/136500/download
Co-Diagnostics, Inc	Logix Smart COVID-19 Kit	CoDx Box	Moderate up to 192 samples per 8 hrs	Yes	1	100 Reactions	NP, OP swab, BAL, Sputum, Tracheal Aspirates	2 hrs	https://www.fda.gov/media/136687/download
Procomcure Biotech	PhoenixDx 2019-nCoV	Phoenix Detection System	Moderate Up to 50 per run	Yes	2	50 Reactions	NP, OP swab, BAL,	4 hrs	https://www.fda.gov/media/137153/download

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Table 3. Moderate Complexity Designation (Available to Standard Hospital Laboratories)

Manufacturer	Test Kit	Diagnostic Equipment	Instrument Throughput	Viral RNA Extraction Equipment Required?	# COVID Viral Targets	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
BioFire	BioFire COVID-19 Test	Options: 1) Film Array 2.0 2) FilmArray Torch	Low 1 sample per module per 50 min; Modular system	No	3	6-test kit or 30-test kit	NP swab	0.83 hr	https://www.fda.gov/media/136353/download
GenMark Dx	ePlex SARS-CoV-2 Test	GenMark ePlex	Low up to 96 tests per 8 hrs; Modular system	No	Not disclosed	12 Tests	NP swab	2 hrs	https://www.fda.gov/media/136282/download
DiaSorin Molecular	Simplexa COVID-19 Direct	LIAISON MDx	Low up to 8 tests per 1.5 hrs	No	2	24 Tests	NP swab	1.5 hrs	https://www.fda.gov/media/136286/download
Roche Molecular	cobas SARS-CoV-2	Options: 1) cobas 6800 2) cobas 8800	High 6800 @ 384 tests per 8 hrs 8800 @ 1056 tests per 8 hrs	No	2	192 Tests	NP swab	3.5 hrs	https://www.fda.gov/media/136049/download
Qiagen	Respiratory SARS-CoV-2 Panel	QIAstat-Dx	Low 1 sample per module per hr; Modular system up to 4; Detects & IDs other respiratory viruses	No	2	6 tests	NP swab	1 hr	https://www.fda.gov/media/136571/download
BD	BioGX SARS-CoV-2 Reagent	BD Max	Low to Moderate 64 samples per 8 hrs	No	2	24 tests	NP or OP swab	3 hrs	https://www.fda.gov/media/136653/download
Luminex	ARIES SARS-CoV-2	Luminex ARIES M2 or M1	Low 6 samples per module per 2 hrs	No	2	24 tests	NP swab	2 hrs	https://www.fda.gov/media/136693/download

Table 4. CLIA-Waived Point-of-Care to Moderate Complexity Designation (Available to Outpatient Clinics to Standard Hospital Laboratories)

Manufacturer	Test Kit	Diagnostic Equipment	Instrument Throughput	Viral RNA Extraction Equipment Required?	# COVID Viral Targets	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
Mesa Biotech	Accula SARS-Cov-2 Test	Options: 1) Accula Dock 2) Silaris Dock	Low 1 sample per 30 min	No	1	25 Tests	Nasal or Throat swab	0.5 hr	https://www.fda.gov/media/136355/download
Cepheid	Xpert Xpress SARS-COV-2 test	Options: 1) GeneXpert Dx 2) GeneXpert Infinity 3) GeneXpert Xpress II (POC) 4) GeneXpert Xpress IV (POC)	Low to High Modular system; 2 modules up to 80 module configurations; Infinity-80 – provides 2000 tests per day	No	2	10 Tests	NP swab or Nasal wash/aspirate	0.75 hr	https://www.fda.gov/media/136314/download

Molecular Assays by Isothermal Amplification for SARS-CoV-2:

Isothermal Amplification is a more novel molecular technique to the real-time PCR method. It provides an alternative molecular chemical approach to the amplification stage of the PCR method. The unique chemistry does not need the heating and cooling cycles of thermocycling required for amplification. Thus, it allows the instruments for these assays to be compact, easy-to-use, and rapid in comparison to traditional real-time PCR methods. On the other hand, the cost per test for the cartridges are typically more expensive and result output per hour is low in comparison to traditional real-time PCR methods. Instrument versality is also impacted due to the limited scope of other available infectious disease assays utilizing this technology.

Table 1. CLIA-Waived Point-of-Care to Moderate Complexity Designation (Available to Near-Patient Settings, Outpatient Clinics, and Standard Hospital Laboratories)

Manufacturer	Test Kit	Diagnostic Equipment	Instrument Throughput	Viral RNA Extraction Equipment Required?	# COVID Viral Targets	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
Abbott Diagnostics	ID NOW COVID-19	ID NOW	Low – 1 sample per 15 min	No	1	24 Tests	NP, Nasal, or Throat swab from kit	0.25 hr	https://www.fda.gov/media/136525/download

May 14, 2020 – FDA alerted the public to early data that suggest potential inaccurate results from using the Abbott ID NOW point-of-care test to diagnose COVID-19. Specifically, the test may return false negative results. Abbott followed-up the same day stating, “While we understand no test is perfect, test outcomes depend on a number of factors including patient selection, specimen type, collection, handling, storage, transport and conformity to the way the test was designed to be run. ID NOW is

intended to be used near the patient with a direct swab test method. Viral Transport Medium (VTM) is no longer recommended for collection – direct swabs should be used. Additional recommendations will be monitored, as this story continues to develop.

Many facilities still do not have access to this test. Instruments continue to be manufactured for first time users.

Serological COVID IgM/IgG Antibody Test (FDA, 2020):

On April 9, 2020, the FDA provided some clarification about the distribution of the serological IgM/IgG tests. In summary, the FDA will categorize these serological tests under Policy C or Policy D. (Johnson M., 2020)

- Policy C serological tests –
  - Undergone the validation evaluation and are FDA EUA
  - Rapid qualitative detection tests are available to the point-of-care setting for the purpose of determining patient immunity and prior exposure.
  - Temporarily CLIA-waived under EUA time frame if the test is designated for point-of-care settings.
- Policy D serological tests –
  - **Not FDA EUA authorized**
  - Sensitivity and specificity performance have not been verified
  - Can only be performed in high complexity labs and must proceed through Policy C to be considered point-of-care.
  - Providers must remain wary of the serological non-FDA EUA tests being advertised heavily to U.S. physician offices as many of these kits are falsely displaying the FDA logo due to initial misunderstanding of Section IV. D of the FDA's policy for diagnostic tests. (Azad, 2020)

Test reports for serological assays under Policy C and D must include the following disclaimer: (FDA, 2020)

- This test has not been reviewed by the FDA unless it has evaluated under Policy C.
- **Negative results do not rule out SARS-CoV-2 infection**, particularly in those who have been in contact with the virus. Follow-up testing with a molecular diagnostic should be considered to rule out infection in these individuals.
- Results from antibody testing should not be used as the sole basis to diagnose or exclude SARS-CoV-2 infection or to inform infection status.
- Positive results may be due to past or present infection with non-SARS-CoV-2 coronavirus strains, such as coronavirus HKU1, NL63, OC43, or 229E.

Rapid Qualitative Serology Tests:

These tests are cartridge-based and look similar to pregnancy tests in that it utilizes colored lines to indicate positive or negative results. Results are rapid and often obtained within 15 minutes.

Currently, there are only two FDA EUA tests in category Policy C under the moderate complexity CLIA certificate and roughly over 90 other non-FDA EUA tests under the Policy D on the market. The FDA has reported that many of the non-FDA EUA tests are falsely claiming that they are FDA approved or falsely claiming that they can be utilized for diagnostic purposes. (Hanh, 2020)

Studies from Spain are reporting some of these rapid serology kits from China have a sensitivity of only 30% at detecting positive COVID-19 patients. (Dibble, 2020) The U.K. is also reporting the same issues with false negatives and false positives. (Smith, 2020) Initial studies are showing IgM antibody responses not peaking until 9 days after symptom onset and IgG after 11 days, which may indicate that molecular and antigen testing are a better early diagnostic indicator and serological testing is a better later diagnostic indicator or indicator for immunity. (The Native Antigen Company, 2020) Further studies still remain to determine full characterization of how long these antibodies persist during and after infection and whether these antibodies have the capability to provide neutralizing effects after first exposure to the virus.

Table 1. Moderate Complexity Designation (Rapid Qualitative Single-Step Cartridge Style)

Manufacturer	Test Kit	Cartridge Reader Required?	Methodology	% Positive Agreement vs. PCR	% Negative Agreement vs. PCR	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
Cellex	qSARS-CoV-2 IgG/IgM Rapid Test	Not Needed	Single-Use Lateral Flow Chromatographic Immunoassay	93.80%	96.0%	3 Kit Sizes: 20, 50, 100	Plasma, Serum, or Whole Blood	0.25 hr	https://www.fda.gov/media/136625/download
ChemBio Diagnostic System, Inc	DPP COVID-19 IgM/IgG System	Options: 1) DPP Micro Reader 2) DPP Micro Reader II	Single-Use Lateral Flow Chromatographic Immunoassay	93.5%	93.5%	20 tests	Plasma, Serum, or Whole Blood (Lithium Heparin or EDTA)	0.25 hr	https://www.fda.gov/media/136963/download
Autobio Diagnostics Co. (Distributed by Hardy Diagnostics)	Anti-SARS-CoV-2 IgM/IgG Rapid Test	Not Needed	Single-Use Lateral Flow Chromatographic Immunoassay	88.15%	99.04%	50 tests	Serum, Plasma	0.25 hr	https://www.fda.gov/media/137367/download

Quantitative or Qualitative Antibody Enzyme-Linked Immunosorbent Assay (ELISA):
These assays are generally high-throughput, lab-based, and can provide qualitative or quantitative antibody results. All major clinical lab diagnostic vendors have or are currently developing IgM and/or IgG serology tests to be run on their current immunoassay platforms. Immunoassay instruments required to run these tests are widely prevalent and already available at most hospitals with the trained lab personnel. Limitations to bringing this assay in-house will mostly be with reagent availability and whether the hospital can maintain turnaround times for other critical immunoassay tests like cardiac markers in conjunction with the high demand for COVID-19 serology tests.

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Table 2. Moderate to High Complexity Designation (High-Throughput Multi-Stage ELISA)

Manufacturer	Test Kit	Diagnostic Instrument	Antibody Measurement Type	% Positive Agreement vs. PCR	% Negative Agreement vs. PCR	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
Ortho Clinical Diagnostics, Inc.	VITROS Immunodiagnostics Products Anti-SARS-CoV-2 Total Reagent Pack	Options: 1) Vitros ECi/ ECiQ 2) Vitros 3600 3) VITROS 5600 4) XT 7600 Integrated Systems	**Qualitative Measurement** Total Ab Detection Results do not differentiate between IgM vs. IgG Ab	**83.3%**	100%	100 Tests	Serum or K2 EDTA Plasma	0.80 hrs	https://www.fda.gov/media/136967/download
Ortho Clinical Diagnostics, Inc.	VITROS Immunodiagnostics Products Anti-SARS-CoV-2 IgG Reagent Pack	Options: 1) Vitros ECi/ ECiQ 2) Vitros 3600 3) VITROS 5600 4) XT 7600 Integrated Systems	**Qualitative Measurement** IgG only	**87.5%**	100%	100 Tests	Serum	0.80 hrs	https://www.fda.gov/media/137363/download
Abbott	SARS-CoV-2 IgG	Options: 1) ARCHITECT i1000SR 2) ARCHITECT i2000SR 3) Alinity I	**Qualitative Measurement** IgG only	**96.77%** (after 14 days post-symptom onset)	99.63%	100 Tests / 500 Tests Kit Option	Serum, Plasma	0.50 hrs	https://www.fda.gov/media/137383/download
DiaSorin	LIAISON SARS-CoV-2 S1/S2 IgG	LIAISON XL	**Qualitative Measurement** IgG only	**97.56%** (after 14 days post-symptom onset)	99.3%	100 Tests	Serum, Plasma	0.60 hrs	https://www.fda.gov/media/137359/download
Beckman Coulter	Access SARS-CoV-2 IgG	Options: 1) UniCel DxI 600 2) UniCel DxI 800 3) Access 2	Assay announced but not yet released for commercial use. The product has launched but is not available yet in the United States.						
Siemens Healthineers	SARS-CoV-2 IgM/IgG Total	Options: 1) Centaur 2) Atellica	Assay announced but not yet released for commercial use. Projected availability is late May.						
Bio-Rad	Platelia SARS-CoV-2 Total Ab	Manual or EVOLIS system	**Qualitative Measurement** Total Ab Detection Results do not differentiate between IgM vs. IgG Ab	**99.6%**	92.2%	96 Tests	Serum, Plasma	0.60 hrs	https://www.fda.gov/media/137493/download
Roche	Elecsys Anti-SARS-CoV-2	1) cobas e411 2) cobas e601 3) cobas e602 4) cobas e801	**Qualitative Measurement** Total Ab Detection Results do not differentiate between IgM vs. IgG Ab	**99.8%**	100%	200 or 300 Tests	Serum, Plasma	0.30 hrs	https://www.fda.gov/media/137605/download

Antibody Neutralization Assays (Johns Hopkins, 2020):

This serology assay determines whether the antibodies actively function and are effective against the virus. It applies different concentrations of patient antibodies against a viral cell culture to quantify the titer of antibodies required to block viral growth. Turnaround time for results is typically between 3 to 5 days.

COVID-19 Antigen Test:

This test is designed for rapid detection of the COVID-19 virus. The main advantage of the antigen test over PCR is the speed of the test. Antigen test can provide results in minutes. The main disadvantage of Antigen tests is that they may not detect all active infections. Antigen tests have a high level of specificity and they are very specific for the virus. However, Antigen tests are not as sensitive as molecular PCR tests. High specificity equates to positive results that are highly accurate. Low sensitivity equates to a high chance of false negatives, therefore negative results do not rule out infection. Negative resuls from an antigen test should be confirmed with a PCR test since the result may be a false negative. Antigen tests generally have a lower cost than PCR tests.

Sofia 2 SARS Antigen FIA (Antigen Fluorescent Immunoassay):

This is the first Antigen Test to be issued emergency use authorization (EUA) for a COVID-19 Antigen Test. The EUA was issued on May 9, 2020. The test is performed on the Sofia 2 platform manufactured by the Quidel Corporation. The Sofia 2 uses immunofluorescence-based lateral flow technology in a sandwich design. The Antigen Test methodology is for the qualitative dectection of nucleocapsid protein from SARS-CoV-2. Tests can be resulted in 15 minutes. All major laboratory distributors are selling this test.

NOTE:

The Sofia 2 platform has been currently used to perform tests pertaining to Lyme Disease, FLU A+B, RSV, and Group A Strep to name a few. If you have this existing platform you will likely be one of the first to have the ability to acquire this test as an Early Adopter. If you do not currently have a Sofia 2 you will likely be on a list to have availability after all Early Adopters are taken care of. Although the test is available, you may not be able to acquire the test very quickly.

Manufacturer	Test Kit	Diagnostic Instrument	Antigen Methodology	Specificity	Sensitiviy	Tests per Kit	Collection Sample	Time to Result (Hrs)	Link to package insert
Quidel	SARS Antigen IFA	~~Sofia2~~	Lateral Flow Immunoflurore scent	**100%**	80%	25 Tests	NP or OP	0.25 hrs	https://www.fda.gov/media/137885/download

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Budgeting for Instrument Purchase

Manufacturers are currently prioritizing to distribute assays and instruments to facilities that already have proper molecular instrumentation and trained lab personnel. Laboratories looking to purchase instrumentation that have no previous experience with the vendor can expect distribution of moderately complex to highly complex instruments after the end of April when travel restrictions for the technical application specialists are lifted to be able to train lab personnel. At that time, the COVID-19 epidemic may be slowing down and laboratories must consider the business efficacy of purchasing expensive molecular diagnostic equipment beyond COVID-19 assays.

Reimbursement Rates & Billing Codes:

Table 1. Reimbursement rates for COVID-19 by molecular testing:

Billing Code:	Reimbursement Rate:
CPT Code: 87635	$51.31 per test
HCPCS: U0001 testing performed by CDC or State Health Dept	$35.91 per test
HCPCS: U0002 testing performed at laboratories and healthcare facilities	$51.31 per test
HCPCS: U0003 testing performed by CDC or State Health Dept utilizing high-throughput instruments (Roche cobas 6800, Roche cobas 8800, Abbott m2000, Hologic Panther Fusion, Cepheid GeneXpert Infinity, and NeuMoDx 288 Molecular Systems)	$100 per test
HCPCS: U0004 testing performed at laboratories and healthcare facilities utilizing high-throughput instruments (Roche cobas 6800, Roche cobas 8800, Abbott m2000, Hologic Panther Fusion, Cepheid GeneXpert Infinity, and NeuMoDx 288 Molecular Systems)	$100 per test

(Verma, 2020)

Table 2. Reimbursement rates for COVID-19 by serological testing:

Billing Code:	Reimbursement Rate:
CPT Code: 86328 Antibody Testing by Single-Step Method (Reagent-strip)	Not yet established
CPT Code: 86769 Antibody Testing by Multi-Step Method	Not yet established

(American Medical Association, 2020)

Reagent kits for COVID-19 testing can range between $1,000 - $1,500 per kit and does not include other consumables that may be required to test. Thus, cost to purchase the reagent kits may exceed the reimbursement rate.

TractManager's COVID-19 Laboratory Capital Equipment Options & Budget Planner:

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Table 1. Molecular Platforms

Vendor	Instrument	List Price	Low Price Seen	High Price Seen	Average Price
Applied Biosystems (Subsidiary of ThermoFisher)	7500 FAST Dx Real-Time PCR Instrument	$66,900	$60,628	$66,900	$63,300
Bio-Rad	CFX96 Dx System	$38,192	$19,000	$27,700	$22,900
Roche	LightCycler 480 II	$55,000	$30,000	$52,250	$40,900
Qiagen	Rotor-Gene Q MDx	$45,806	$20,000	$36,800	$25,000
Abbott Molecular	m2000sp & m2000rt	$199,900	$169,900	$179,900	$171,000
Luminex	MAGPIX	$31,590	$21,000	$28,125	$24,600
Luminex	Aries Two Module System (up to 12 sample capacity)	$95,000	$45,000	$65,000	$55,000
Luminex	Aries M1 System (Up to 6 sample capacity)	Not disclosed	$40,300	$40,300	$40,300
Hologic	Panther system + Fusion Module	Not disclosed	$230,000	$275,000	$245,600
Hologic	Fusion Add-On Unit (For existing Panther systems)	Not disclosed	$100,000	$100,000	$100,000
Roche	Cobas 6800	Fixed Unit- $450,000 Mobile Unit - $590,000	Fixed Unit- $290,000 Mobile Unit - $350,000	Fixed Unit- $360,000 Mobile Unit - $350,000	Fixed Unit- $337,100 Mobile Unit - $350,000
Roche	Cobas 8800	$795,000	$700,000	$700,000	$700,000
BD	BD Max	$158,890	$75,000	$75,000	$75,000
BioFire	TORCH Per Module	$37,500	$19,250	$26,000	$21,900
GenMarkDx	ePlex (1 Tower, 6 bays)	$150,000	$90,000	$120,000	$110,000
Qiagen	QIAstat-Dx Base + 1 Analytical Module	Not disclosed	Base - $5,500 Module - $14,500 each	Base - $6,190 Module - $17,400 each	Base - $6,100 Module - $16,000 each
Cepheid	GeneXpert II CLIA-waived	$18,500	$17,575	$17,575	$17,575
Cepheid	GeneXpert XVI – 4 Module	$83,400	$75,060	$80,000	$76,900
Cepheid	GeneXpert Infinity 48 – 16 Module	$199,000	$177,110	$177,110	$177,110

Cepheid	Module Add-on (4 module Add-on existing units)	$30,000	$30,000	$30,000	$30,000
DiaSorin	LIAISON MDx	$60,000	$35,000	$60,000	$40,000
Abbott Diagnostics	ID Now (Formerly owned by Alere)	$9,150	$4,000	$8,500	$5,000
Procomcure Biotech	PhoenixDx System	Not disclosed	Unknown	Unknown	Unknown

Table 2. Immunoassay Platforms

Vendor	Instrument	List Price	Low Price Seen	High Price Seen	Average Price
Abbott	ARCHITECH i1000SR	$125,000	$55,000	$69,900	$62,450
Abbott	ARCHITECH i2000SR	$250,000	$98,000	$130,000	$114,000
Abbott	Alinity i	$450,000	$120,000	$150,000	$135,000
Ortho Clinical Diagnostics	VITROS ECiQ	$144,000	$69,900	$85,000	$77,450
Ortho Clinical Diagnostics	VITROS 3600	$220,000	$136,000	$150,000	$143,000
Ortho Clinical Diagnostics	VITROS 5600	$411,700	$219,900	$250,000	$234,950
Ortho Clinical Diagnostics	VITROS XT 7600	$450,000	No deals seen to determine budget pricing		
Beckman Coulter	Access 2	$149,800	$45,500	$63,000	$54,250
Beckman Coulter	UniCel DxI 600	$199,500	$120,000	$135,000	$127,500
Diasorin	LIAISON XL	$146,500	$89,000	$146,500	$99,800
Bio-Rad	EVOLIS	$65000	$33,000	$55,000	$45,000
Roche	cobas e411	$165,000	$60,000	$50,000	$52,000
Roche	cobas e601	$307,000	$125,000	$150,000	$145,000
Roche	cobas e602	$400,000	$150,000	$160,000	$158,000
Roche	cobas e801	$450,000	$180,000	$200,000	$175,000

Table 3. Antigen Test Platforms

Vendor	Instrument	List Price	Low Price Seen	High Price Seen	Average Price
Quidel	Sofia2	$798	$262	$766	$532

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Other Abnormal Laboratory Markers Seen in COVID-19: (Lippi & Plebani, 2020) (Cron, MD, PhD & Chatham, MD, 2020)

Most Frequently Seen Markers for COVID-19 patients:

- ↑ C-reactive Protein (CRP)
- ↑ Erythrocyte Sedimentation Rate (ESR)
- ↑ Lactate Dehydrogenase (LDH)
- ↑ D-Dimer
- ↓ Lymphocyte Count
- ↓ Albumin
- ↓ Hemoglobin

In Severe COVID-19 Cases, indicating cytokine storm and respiratory failure:

- ↑↑ D-Dimer
- ↑↑ Ferritin
- ↑ IL-6
- ↑ Prothrombin Time (PT)
- ↑ C-reactive Protein (PT)
- ↑ Erythrocyte Sedimentation Rate (ESR)
- ↑ Lactate Dehydrogenase (LDH)
- ↑ Neutrophil count
- ↑ Alanine Aminotransferase (ALT)
- ↑ Aspartate Aminotransferase (AST)
- ↑ Cardiac biomarkers
- ↑ Procalcitonin
- ↓ Lymphocyte Count
- ↓ Albumin
- ↓ Hemoglobin

Recommendations

Refer to the FDA and CDC website for the most up-to-date source of truth of the most current assays available and changes to regulatory guidelines.

Sample Collection:

- If your collection site is running out of swabs in viral transport media, contact your referring lab diagnostic laboratory as other specimen samples types like BALs or synthetic swabs in saline may have been validated and usable for their diagnostic lab equipment.
- Alternatively, if unable to source from a distributor, making viral transport media may be a viable option if supplies are on hand and sterility equipment is available. Recipe can be found on the CDC website https://www.cdc.gov/coronavirus/2019-ncov/downloads/Viral-Transport-Medium.pdf

- Proper specimen collection is of utmost importance in preventing false negatives and positives with molecular testing. Train collecting personnel on the proper collection procedure for a nasopharyngeal collection and how to prevent DNA/RNA contamination between samples.

Outsourcing to Reference Laboratories:

- Check local and state private and public reference laboratories and national reference laboratories if testing is unavailable at the local hospital level or if supplemental COVID-19 testing is required to meet the high demands. Due to high demand, samples are being prioritized for inpatients and hospital workers at Quest and LabCorp and results may take up to 10 days until more locations, instruments, and reagents can ramp up testing capacity. Other reference laboratories may provide faster turn-around times.

Testing Methodology:

- FDA EUA does not equate to FDA-cleared or approved. Clinical specificity and sensitivity (real-world patient validation) have not been established for all current FDA EUA COVID-19 assays. These assays have only been validated by the manufacturer through controlled lab settings of known positive and negative samples, which may not correlate with the clinical environment.
- Any negative COVID-19 test result should not overrule clinical symptoms and other diagnostic indicators that may match with a COVID-19 positive patient.
- Molecular-based assays (PCR or Isothermal amplification)
    - Currently, this is the test methodology of choice for detection of the SARS-CoV-2 virus.
- Serological Rapid COVID-19 IgM/IgG tests-
    - Although being advertised and sold to physician offices and laboratories, it should **NOT be utilized for diagnostic purposes** at this time. The FDA has not reviewed many of these tests even though several companies have claimed they have. (Azad, 2020)
    - For now, these tests are more useful for research and epidemiological purposes to study serological timing of antibody production, past exposure, and immunity. They should be utilized as a supplement and not a replacement to molecular methodologies.
    - If utilizing these tests as a screening test due to lack of available testing resources, confirm all negative and positive results with molecular methods for diagnostic confirmation.

Instrument Purchase Considerations:

- Determine the throughput needed, complexity of the instrument, and workforce and education required to operate the instrument.
- Look at other assays that can be run on the instrument to secure long-term business efficacy after the COVID-19 epidemic slows down.
- Consider the reagent kit costs and number of patients that can be tested with one kit. Consumable costs may exceed the reimbursement rates.
- Take into consideration the number of COVID-19 gene targets each manufacturer's assay provides.
- Review the Instruction for Use document for each COVID-19 assay.

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References

American Medical Association. (2020, 04 15). *CPT Assistant: Official Source for CPT coding guidance*. Retrieved from SARS-CoV-2 Serologic Laboratory Testing: https://www.ama-assn.org/system/files/2020-04/cpt-assistant-guide-coronavirus-april-2020.pdf

Azad, A. (2020, 04 02). *The 'game changer' that wasn't: Company falsely claimed FDA authorization for coronavirus blood test*. Retrieved from CNN: https://www.cnn.com/2020/04/02/health/coronavirus-test-false-fda-authorization/index.html

Mark McCarty, (2020, May 15). Abbott pushes back on Langone study of ID Now test;; FDA cites possibility of swab, transport media issues. Retrieved from BioWorld.

CDC. (2020, March 25). *Interim Guidelines for Collecting, Handling, and Testing Clinical Specimens from Persons for Coronavirus Disease 2019 (COVID-19)*. Retrieved from CDC: https://www.cdc.gov/coronavirus/2019-ncov/lab/guidelines-clinical-specimens.html

Dibble, M. (2020, March 26). *Coronavirus tests Spain purchased from China fail to detect positive cases*. Retrieved from Washington Examiner: https://www.washingtonexaminer.com/news/coronavirus-tests-spain-purchased-from-china-fail-to-detect-positive-cases

FDA. (2020, March 16). *Policy for Diagnostic Tests for Coronavirus Disease-2019 during the Public Health Emergency.* Retrieved from FDA: https://www.fda.gov/media/135659/download

FDA. (2020, May 14). *Coronavirus (COVID-19) Update: FDA Informs Public About Possible Accuracy Concerns with Abbott ID NOW Point-of-Care Test.* Retrieved from FDA: https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-informs-public-about-possible-accuracy-concerns-abbott-id-now-point

FDA. (2020, May 15) *For use under the Emergency Use Authorization (EUA) only, Sofia2 SARS Antigen FIA.* Retrieved from the FDA: https://www.fda.gov/media/137885/download

Hahn M.D, S. M. (2020, March 20). *Coronavirus (COVID-19) Update: FDA Alerts Consumers About Unauthorized Fraudulent COVID-19 Test Kits*. Retrieved from FDA: https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-alerts-consumers-about-unauthorized-fraudulent-covid-19-test-kits

Johns Hopkins. (2020, 04 15). *Johns Hopkins Bloomberg School of Public Healh*. Retrieved from Serology-based tests for COVID-19: https://www.centerforhealthsecurity.org/resources/COVID-19/serology/Serology-based-tests-for-COVID-19.html

Johnson, C. (2020, March 21). Retrieved from ASCLS: https://www.ascls.org/images/Labvocate/COVID-19_ASCLS_Letter_CongressionalLeaders_FINAL.pdf

Kanne, J. P., Little, B. P., Chung, J. H., Elicker, B. M., & Ketai, L. H. (2020, 02 27). *Essentials for Radiologists on COVID-19: An Update—Radiology Scientific Expert Panel.* Retrieved from RSNA: https://pubs.rsna.org/doi/10.1148/radiol.2020200527

Lippi, G., & Plebani, M. (2020, March 2). *Laboratory abnormalities in patients with COVID-19 infection.* Retrieved from ResearchGate: https://www.researchgate.net/publication/339627510_Laboratory_abnormalities_in_patients_with_COVID-2019_infection

The Native Antigen Company. (2020, March 24). *Why We Need Antigen and Antibody Tests for COVID-19*. Retrieved from The Native Antigen: https://thenativeantigencompany.com/why-we-need-antigen-and-antibody-tests-for-covid-19/

Verma, S. (2020, 04 14). *CMS*. Retrieved from CMS-Ruling 2020-1-R: https://www.cms.gov/files/document/cms-2020-01-r.pdf