

The Value and Institutional Impact of an In-System Laboratory Testing During the COVID-19 Pandemic

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Abstract

In-system clinical laboratories have proven themselves to be a fundamentally important resource to their institutions during the COVID-19 pandemic of the past year. The ability to provide SARS-CoV-2 molecular testing to our hospital system allowed us to offer the best possible care to our patients, and to support neighboring hospitals and nursing homes. In-house testing led to significant revenue enhancement to the laboratory and institution, and attracted new patients to the system. Timely testing of inpatients allowed the majority who did not have COVID-19 infection to be removed from respiratory and contact isolation, conserving valuable personal protective equipment and staff resources at a time that both were in short supply. As 2020 evolved and our institution restarted delivery of routine care, the availability of in-system laboratory testing to deliver both accurate and timely results was absolutely critical. In this article, we attempt to demonstrate the value and impact of an in-system laboratory during the COVID-19 pandemic. A strong in-house laboratory service was absolutely critical to institutional operational and financial success during 2020, and will ensure resiliency in the future as well.

Keywords

COVID-19, cost avoidance, finance, laboratory testing, polymerase chain reaction, revenue

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Introduction

The coronavirus pandemic of 2019 (COVID-19) is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). COVID-19 was first detected in Wuhan, China, in December 2019 and spread globally during the early part of 2020. As of mid-January 2021, about 55 million cases have been confirmed worldwide, with over 25 million cases in the United States.¹ The United States now has the most confirmed cases and deaths (456 900 on February 5, 21) of any country worldwide. Covid-19 represents an unprecedented health care challenge at many levels, the most obvious of which is patient care. Laboratories scrambled to support their colleagues

who were delivering direct patient care by implementing SARS-CoV-2 testing; other urgent needs in front-line hospital laboratories have included demands on the coagulation, core laboratories, and blood banks as they dealt with the lack of commercially available blood products and the need to collect

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convalescent plasma. The demands across our hospital systems in 2020 were tremendous.

One of the keys to slowing the spread of this disease is the availability of widespread testing so that infected patients can be quickly identified and isolated.² The publication of the first viral sequence in mid-January made the design of polymerase chain reaction (PCR) assays for SARS-CoV-2 possible.³ Widespread implementation of testing was hampered by a variety of issues over the spring and summer of 2020. Challenges with testing plagued many institutions during most of 2020.⁴⁻⁶ Many institutions were simply not prepared for the onslaught of testing for various reasons: lack of tests or testing platforms, out-sourced and under-resourced labs, regulatory issues, lack of reference materials for validation and Emergency Use Authorization (EUA) certification by the Food and Drug Administration, supply chain issues, delays in instrument servicing due to enormous demand, and other challenges. Additionally, as assays made their way to market, labs often found themselves with insufficient information about assay performance: Clear performance standards and access to reference material would have been useful in more rapid implementation of SARS-CoV-2 testing.⁴

Early in January of 2020, NorthShore University HealthSystem (NSUHS) clinical laboratories mobilized to develop and validate PCR-based testing for SARS-CoV-2. We had previously recognized the critical role that front line hospital labs play during the swine flu (H1N1) pandemic in 2009-2010.⁷ We developed and validated an in-house version of the Center for Disease Control and Prevention (CDC) assay, and launched clinical testing on March 12, 2020. We were among the earliest hospital laboratories in the United States and the first in Illinois to perform SARS-CoV-2 PCR testing. NorthShore University HealthSystem admitted the first positive COVID-19 patient on March 9, 2020; demand for testing rapidly grew and over time, we evaluated multiple other SARS-CoV-2 testing assays and platforms, adding those with suitable performance to our testing menu.

The ability to provide SARS-CoV-2 testing to our hospital system allowed us to offer the best possible care to our patients, and to provide support to neighboring hospitals and nursing homes as well. Timely testing of inpatients allowed the majority who did not have COVID to be removed from respiratory and contact isolation, conserving valuable personal protective equipment (PPE), and staff resources at a time that both were in short supply. As 2020 evolved and institutions reopened to deliver as much routine care as possible, the ability of an in-system lab to deliver timely results was absolutely critical. In this article, we attempt to define and quantify the value and impact of an in-system lab during the COVID pandemic.

Methods

NorthShore University HealthSystem is a 5-hospital integrated health care delivery system serving patients at over 140 locations across the Chicago metropolitan area. NorthShore implemented a real-time RT-PCR SARS-CoV-2 assay on the CDC

Table 1. SARS-CoV2 Assays in Use at NorthShore: RT-Polymerase Chain Reaction Targets, Limit of Detection.*

	SARS-CoV2 Target(s)	LOD
In-house COVID (CDC LDT)	N1, RNP (human, IC)	100 c/mL
Abbott m2000	RdRp, N, IC	100 c/mL
Abbott Alinity	RdRp, N, IC	100 c/mL
Cepheid GeneXpert (COVID)	E, N2	0.005 pfu/mL (N2) 0.020 pfu/mL (E)
Cepheid GeneXpert (COVID, FluA, FluB, RSV)	E, N2	131 c/mL
BD Max	N1, N2	640 c/mL
Roche LIAT (COVID, Flu A, Flu B)	ORF1a/b, N	0.01 TCID50/mL
GenMark ePlex RP2 (COVID, respiratory pathogens)	N	0.01 TCID50/mL (~250 GC/mL)

Abbreviations: CDC, Center for Disease Control and Prevention; c/mL, copies per milliliter; GC, genome copies; IC, internal control; LOD, limit of detection; pfu/mL, plaque-forming units per milliliter; TCID50/mL, tissue culture infective dose that kills 50% of cells, ITCID50 is roughly equivalent to 0.7 PFU. *Viral genome targets: N, N1 and N2, nucleocapside protein genes; RNP, Ribonuclease P; RdRp, RNA-dependent RNA polymerase; E, envelope protein; ORF 1 a/b, open reading frame1, a and b polyprotein.

designed and published protocol⁸ using primers and probe from IDT (Integrated DNA Technologies) and performed on a Roche LC480II instrument. Analytic sensitivity was established at approximately 5 viral genomes per RT-PCR reaction using in vitro transcribed RNA obtained from the Illinois Department of Public Health (IDPH) with no cross reactivity with other respiratory viral or bacterial pathogens. Analytic sensitivity was reconfirmed using Genomic RNA from NR52281, novel coronavirus 2019-nCoV/USA-WA1/2020 (4.8×10^7 genome equivalents [GE]/mL, BEI Resources) and also SeraCare standards, both of which yielded a limit of detection (LOD) of 5 copies/reaction or 100 GE/mL. Clinical sensitivity and specificity were determined using contrived patient specimens across a range of viral loads, but focusing near our LOD (40 positive and 20 negative). Twenty clinical samples were also tested in parallel with IDPH, with 100% concordance.

As the pandemic continued, testing was expanded by the addition of commercial platforms: Abbott Molecular received EUA clearance on March 20 for a higher throughput COVID-19 assay on their m2000 platform, and approval was also obtained for a higher throughput assay on the Alinity M instrument in May, further increasing our testing capacity to 2000 tests per day. Between May and December 2020, we also added rapid PCR testing platforms for SARS-CoV-2 including Cepheid GeneXpert, BD Max, GenMark ePlex, and Roche Cobas LIAT systems. The testing platforms and their relative sensitivities are summarized in Table 1. For each new platform, analytic and clinical validation studies were repeated as described above. RT-PCR results interfaced into our lab information system and electronic health record (EHR), and

fed into NSUHS DataCart to drive clinical and administrative decision-making as described in a separate paper.⁹

Patients were sampled for testing at multiple sites across our system. Symptomatic ambulatory patients were screened via a questionnaire in our EHR patient portal and directed to 4 immediate care supersites (including a drive-through facility) for nasopharyngeal swab collection. Afterward they were instructed to quarantine at home until test results were available. Patients requiring admission from an outpatient setting or via the emergency department (ED) were placed in respiratory and contact isolation with use of N95 masks until PCR results became available and precautions could be discontinued. NorthShore University HealthSystem designated one of our hospital pavilions for care of COVID-19 patients only. As the lab was able to implement faster analytic platform and reduce the time to results on inpatients/admissions, we were ultimately able to make triage decisions about admission to either this pavilion or to a COVID-free unit based on RT-PCR results, and avoid precautionary isolation almost entirely.

Results

COVID Testing

We initiated SARS-CoV-2 RT-PCR testing on March 12, 2020, using our lab developed version of the CDC assay, and added several higher throughput and automated assays as well as more rapid assays over the subsequent months; these assays and their performance characteristics are summarized in Table 1. As of January 25, 2021, we completed nearly 335 000 SARS-CoV-2 PCR tests, which included approximately 270 000 tests done on NSUHS ED patients, inpatients and outpatients, other hospitals, and nursing homes. The remainder of testing was performed in support of the IDPH testing sites. These data and positivity rates are shown in Table 2.

Financial Impact of In-House Testing

Testing from external sources represented an additional revenue stream to the institution, which was important at a time when many of our usual sources of revenue had been suspended as a result of the pandemic. The federally set reimbursement for SARS-CoV-2 RT-PCR was adjusted to US\$100 for high-throughput platforms on April 14, 2020.¹⁰ The cost of labor and materials for performing SARS-CoV-2 testing varied depending upon many variables including the assay and platform utilized. If a lab is efficient enough to keep assay costs at or under US\$90, performance of 100 000 external tests (the sum of testing performed for other hospitals, nursing homes and the state testing sites) would yield institutional income of nearly US\$1 million. This was a critical addition at a time when so many hospital and laboratory services were operating at a deficit.

In contrast, the testing performed on NSUHS patients constituted cost avoidance: the send out cost for these 235 000 tests

Table 2. Polymerase Chain Reaction Testing Populations and Results.

Indication/patient location	# Tested	Pos #	Pos %
Symptomatic	207 301	38 725	18.60
ED	16 228	3349	20.6
Inpatients	1824	287	15.7
Outpatients	122 266	24 053	19.7
Asymptomatic (preprocedural)	62 427	1595	2.6
Other hospital/nursing homes*	34 664	5455	15.7
Overall NS total	269 728	39 870	14.8
IDPH testing*	~65 000		

Abbreviations: ED, emergency department; IDPH, Illinois Department of Public Health; NS, NorthShore; Pos, positive.

*Non-NS testing: external samples and income.

would have been US\$2.35 million total. This cost could have been covered by insurance billing for outpatients, though charges for inpatients would have been bundled as part of the inpatient diagnosis-related group (DRG) payment rather than billed separately, and the charges would have been paid by the hospital. During this period, we performed 13 000 tests on inpatients, which would have cost NSUHS about US\$1 300 000 not reimbursed outside the DRG for that inpatient stay. Again, the cost and efficiency of the lab in performing this testing would dictate the true savings realized by performing this testing in house.

It is ironic that as more rapid assays became available, needed for critical decisions in the ED and upon admission, the allowed reimbursement dropped to US\$51.35⁹ as these assays were not deemed high throughput—but still were impactful and necessary, and in particular affected our admissions and isolation practices, as described below. Additionally, these reagents are often more expensive than those for the high-throughput platforms.

The performance of in-house testing led to new, non-NorthShore patients accessing our Immediate Care Centers. Of 53 014 unique patients visiting our Immediate Care centers for SARS-CoV-2 testing, 6621 (12.5%) did not have any prior interaction with NSUHS hospitals within the 2 years prior to their SARS-CoV-2 testing. While the availability of COVID testing appears to attract new patients, we do not yet know whether these patients will continue to pursue care through the NorthShore system. However, these visits did constitute a significant source of clinical and laboratory revenue.

Additionally, during the course of the pandemic, NSUHS experienced shortages of health care workers (HCWs) due to either COVID-19 infection or exposure to COVID-19 positive individuals in the community or at work. On-site testing was helpful in rapidly triaging symptomatic and exposed HCWs in a timely manner. For this employee group, nasopharyngeal swab collection was initially performed by trained personnel at 2 hospital locations, but later switched to self-collected mid-turbinate swabs. Overall, 8074 employees with symptoms were tested, with 1099 positive results yielding an average positivity rate of 13.6% (range: 5.7%-26.2%). Staff with high-risk exposure as defined by the CDC¹¹ were instructed to quarantine and

monitor symptoms at home, while those with low-risk exposures were allowed to return to work with PPE and a follow-up PCR at Day 5 postexposure. These procedures allowed for rapid identification and furlough of infected HCWs while allowing for the safe return to work for those with exposures.

Avoidance of Unneeded Personal Protective Equipment Expense

Additionally, symptomatic and at risk patients who were admitted were treated as potential COVID-19 patients until a negative SARS-CoV-2 test was resulted. This necessitated use of PPE, isolation rooms, and additional efforts on the part of staff to don and doff the PPE, which added to the cost of care for these inpatients. Publications have assessed the cost of isolation, with contact isolation reported at US\$158.90 daily and contact isolation with an N95 mask estimated at US\$68.46 per day.¹²⁻¹⁵ Clearly, isolation practices constitute a major cost to hospitals. When PPE was in short supply, it was particularly helpful to avoid wastage of these resources.

Our lab was able to maintain a turnaround time (TAT) for results of under 24 hours overall for SARS-CoV-2 testing with the exception of 2 episodes related to supply chain and instrument repair delay. From March 2020 to the present, we tested 13 236 potential COVID-19 admitted patients (symptomatic inpatients and admitted ED patients), of whom 10 283 were negative and were removed from isolation. Our average length of stay for non-COVID-19 patients during this period was 3.6 days. Thus, the availability of test results at 24 hours would have led to the saving of an average of 2.6 days of unneeded isolation for each COVID-19 negative inpatient. As we implemented faster platforms (such as the LIAT platform in December 2020), the TAT for ED patients was reduced to an average of 1 hour. For 10 000 COVID-19 negative patients, this generated a minimum of 26 000 days of isolation saved when our slower test platforms were used, and with the faster platforms, which allowed no wastage of isolation, a potential for 36 000 isolation days saved. In comparison, with a TAT for send-out SARS-CoV-2 testing of at least 3 to 4 days, few if any patients would experience timely release from isolation during their hospital stay.

Significant cost avoidance was realized from these efforts. Our own data suggests the cost of isolation at US\$150 per day for materials and labor at our institution, the savings would be US\$3.9 to US\$5.4 million, depending on how quickly the results were available (standard vs rapid platform). In actuality, however, as we reduced availability of SARS-CoV-2 results for ED patients to approximately an hour, patients were triaged either into our COVID-only hospital or non-COVID pavilion for medical care. With such rapid results, precautionary isolation was not needed for those patients who were negative for SARS-CoV-2, and they were able to receive needed care in a non-COVID-19 environment.

Income From Operations With Restarting Surgeries and Procedures

In May 2020, the IDPH issued guidelines for reopening hospitals for routine care, procedure, and surgeries.¹⁶ This included the requirement for a negative SARS-CoV-2 PCR test within 72 hours before the visit or procedure. Our in-house testing capacity allowed us to meet these requirements, and in fact we were able to assist other institutions with their testing for this purpose as well. A reliance on reference lab send-out testing was insufficient for us to meet this time frame, and we would have been limited to emergency surgeries only. Our institution would have had to remain at procedural levels similar to those in April, during the shut-down, which was 15% to 20% of our usual activity levels. Clearly, this was not a sustainable option, for our patients, physicians, and institutions, and actual estimates suggest that performance of some additional surgical cases would have been necessary. Given the complexity of this scenario, we did not attempt to quantify the financial impact of this ability to reopen, but clearly this would represent a major component of hospital finances and delivery of care to its patients. We are able to perform 89% of our budgeted surgical volumes for the fiscal year as a result of in-house SARS-CoV-2 testing.

Discussion

Amid the challenges of the past year, hospital laboratories have played a central role in the clinical, operational, and financial successes of their institutions. To meet the demands of a public health crisis such as the COVID-19 pandemic, hospitals and health care systems need a strong clinical laboratory on site. As illustrated by the scenarios above, an in-system lab is needed to provide the timely results needed to provide data to guide patient care, conserve and properly utilize resources such as PPE and isolation rooms, and screen preprocedural patients to permit returning to normal operations; these data are summarized together in Table 3, and the impact is significant. Additionally, labs across the country provided whatever was needed to support their institutions through the implementation of new testing to meet a variety of needs, such as D-dimer and serology tests, expansion of blood donor programs, collection of convalescent plasma, and more. Laboratories have shown remarkable flexibility, energy, and innovation this past year, but cannot flex and adapt to provide these services without sufficient resources, staff, and support from their institutions. An investment in the lab service line will provide the foundation for institutional success, whether during a pandemic or during routine times.

Additionally, hospital labs are on the front lines of patient care, responsible for caring for the patients during a pandemic in real time. Public health labs are significant and necessary resources during a pandemic, but lack the capacity to provide the diagnostic testing needed by hospitals for care of either inpatients or outpatients. Commercial reference labs also have

Table 3. Summary of Financial Impact of an In-System Laboratory During COVID-19.*

	Number of tests	Financial impact
External testing revenue	100 000	US\$10 000 000 gross revenue [†]
Cost avoidance for NSUHS testing	220 300	US\$22 030 000 gross savings [†]
New patients attracted	6621	US\$662 100 gross revenue [†] (Plus potential other income)
Staff testing	8074 tested 6975 returned to work early	US\$807 400 gross send-out cost avoidance [†]
Avoidance of PPE use	13 236 inpatients tested 10 283 negative, released from isolation 26 000-36 000 isolation days saved (US\$150.00 per day)	US\$3.9-5.4 million saved
Reopening of our hospitals and clinics		89% of FY surgical volumes achieved

Abbreviations: NSUHS, NorthShore University HealthSystem; PPE, personal protective equipment.

*Data based on analysis of 335 000 SARS-CoV-2 RT-PCR tests performed between March 2020 and January 2021 at Northshore.

[†] Net revenue will vary by institution, based upon the in-house cost to perform the testing.

a role in providing testing during a pandemic, though the transport time required reduces their utility for timely inpatient care and preprocedural testing. For much of 2020, commercial labs struggled with delivering timely results, with reported delays of a week or more being commonplace. Reliance of a hospital system on send-out testing would have precluded timely triage and isolation decisions for hospitalized patients, and prevented a return to normal surgical and procedural operations due to the need for rapid screening test results. Ideally, these entities must work together to provide testing appropriate for all clinical needs. As we look to the future, an effective communication and cooperation of these testing entities must be established.

Declaration of Conflicting Interests

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