Rationale for comprehensive viral testing program in K-12 schools

Executive summary:

There is much debate about the value of viral testing program for K-12 schools. As described here, we support a comprehensive viral testing plan that returns results in less than 24 hours as part of an overall risk reduction strategy. Testing should be prioritized as follows: (1) baseline "time zero" at the start of school of all students, teachers and staff; (2) symptomatic testing of all students, teachers and staff; (3) at least weekly surveillance testing of all teachers and staff; (4) at least weekly surveillance testing of older students; and (5) at least weekly surveillance testing of younger students. While symptomatic testing is available through local hospitals, clinics and testing centers, baseline time zero testing and surveillance testing of asymptomatic individuals is not. Thus, additional investment is required to support a comprehensive viral testing program in K-12 schools.

The rationale behind this position is as follows:

(1) "Universal precautions" with masks, physical distancing, symptom checks, ventilation, and personal hygiene are foundational to keeping our schools safe for in-person education. In communities of extremely low COVID-19 prevalence, these measures alone should be sufficient to keep our schools safe, prevent outbreaks, and avoid shutdown of our K-12 schools.
(2) A comprehensive viral testing program, which includes surveillance testing of individuals without clinical symptoms, will provide objective data that universal precautions are working. These objective data will provide reassurance to families, teachers and staff that our K-12 schools are safe for in-person education.
(3) A comprehensive viral testing program will detect new infections early in the course of disease ("pre-symptomatic") and in those who never develop symptoms at all ("asymptomatic"), thereby preventing spread through our community, minimizing risk of an outbreak, and increasing the probability that our schools will remain open to in-person education.
(4) Establishing a comprehensive viral testing program now will enable the rapid adoption of new technologies such as inexpensive antigen tests that can be administered daily. The reason for this is that a comprehensive viral testing program based on molecular tests (which are more expensive and slower) will establish the infrastructure required to collect data, return results, and make decisions.

To articulate this position, we introduce the concept of a "virtual bubble", which is based on the actual bubble created by the National Basketball Association (NBA). Through their efforts, the NBA has created an environment where there have been no new infections, despite extensive physical contact while playing basketball. Core to the NBA's approach is baseline time zero testing to enter the bubble and daily testing of everyone once inside the bubble.

As additional support for this position, we reinforce the emerging science behind coronavirus infections in children. It is clear that while kids are at a lower risk of infection and are less likely to develop severe disease, kids are nonetheless able to transmit infections to others and contribute to outbreaks (see links here, here, here).

We address arguments against a comprehensive viral testing program, including concerns that surveillance testing is not needed in communities of low prevalence. The NBA, which has a prevalence of zero, continues with asymptomatic testing, as the consequences of a single new case spreading through their bubble would have disastrous consequences: complete shutdown of the NBA season. Similarly, we believe that surveillance testing for early detection of new cases will avoid disastrous consequences for our schools: complete shutdown to in-person education.

Lastly, we address the economic trade-offs of investing in a comprehensive viral testing program vs other approaches to keeping our schools safe for in-person education. We suggest how different components of a comprehensive viral testing should be prioritized relative to other investments.

Introduction – the concept of a "virtual bubble"

National Basketball Association (NBA) players knock-up against one another night after night – without risk of a coronavirus outbreak – thanks to a literal bubble that has been created around players, coaches and supporting staff. Movement in and out of the bubble is strictly controlled, with forced quarantines for those entering the bubble complex; "universal precautions" that include masks, physical distancing, symptom checks with sophisticated biometric devices, and personal hygiene are added precautions to limit spread of any masquerading virus; and frequent viral surveillance testing is implemented to ensure that all of the precautions are working. Indeed, daily, rapid testing of *everyone*, which includes 1,000-plus people living in the NBA bubble, ensures that any outbreak will be caught before the infection spreads quietly through the bubble among those who are without symptoms.

And it is working. There have been zero new coronaviruses reported to date. Repeat: zero new cases. The virtual bubble allows the NBA to play basketball safely and avoids a shutdown of the game by preventing outbreaks.

The concept of a bubble – a virtual bubble – can be extended to other areas of society, including re-opening of our schools. The goal is to create a "*virtual bubble*" that mimics features of the literal bubble created by the NBA: limited movement into and out of the bubble; universal precautions such as masks, physical distancing, high-quality ventilation, symptom checks, and personal hygiene; and frequent testing to detect new infections before outbreaks occur and to reassure those inside the virtual bubble that the system is working. Of these measures, movement in and out of the virtual bubble is the most difficult to control, which puts emphasis on universal precautions and frequent testing as the cornerstone of a virtual bubble policy for K-12 schools. While not discussed in depth in this document, it is important to emphasize the commitment of families, students, teachers, and staff to appropriate behaviors outside of the school setting (e.g., adherence to universal precautions with masks, physical distancing, and hygiene to prevent infection outside of the classroom).

And the virtual bubble will keep our schools safe for in-person education. Through these procedures, new infections will be kept to a minimum and new cases contained before an outbreak shuts down our schools again.

Here, we discuss what we know and don't know about the value of viral testing in K-12 schools, as the topic is complex and incompletely understood. There is a lot we know about the value of viral testing in community settings – which leads us to conclude that widespread viral testing is critical to protect our students, teachers, and staff. There are other things we don't yet know, which is why we believe an initial pilot program is an important first step.

We start with a brief summary of what is known about coronavirus (the formal name is SARS-CoV-2 and the disease it causes is COVID-19) in children and schools. For more detailed discussions, please see this *Scientific American* story on re-opening schools, this summary from *Journal of the Pediatric Infectious Disease Society*, and this exhaustive list of resources from Massachusetts General Hospital. In addition, the Massachusetts High Technology Council has published a "*War on COVID-19 Roadmap*", which offers many lessons for the safe re-opening of K-12 schools.

Here are key facts that inform on the value of a viral testing pilot in K-12 schools:

Kids are at a lower risk of infection. A June study in *Nature Medicine* found that people younger than 20 are half as likely as older adults to contract the disease.

Kids are at lower risk of severe disease. An August 20 summary from the American Academy of Pediatrics indicates that "*At this time, it appears that severe illness due to COVID-19 is rare among children.*" Supporting facts in the US: children were 0%-0.3% of all COVID-19 deaths, and 21 states reported zero child deaths.

Kids can transmit disease. A study in *Emerging Infectious Diseases*, published online in July, analyzed contact-tracing reports for nearly 6,000 coronavirus patients in South Korea, and found those aged 10 to 19 spread the virus as much as adults did. A study in Israel reported an outbreak in a high school 10-days are re-opening. In August the CDC described the transmission and infection among attendees of an overnight summer camp in Georgia.

Most infected kids are asymptomatic. The CDC study on the Georgia summer camp concluded: "*Asymptomatic infection was common and potentially contributed to undetected transmission, as has been previously reported.*" (Links to the referenced studies can be found here, here, here, here.)

Asymptomatic kids have high viral levels. A recent study at MGH demonstrates that children have high levels of virus despite mild or no symptoms. These findings are consistent with an August study in *JAMA Internal Medicine* which reported that the level of virus is the same as those with and without symptoms. Both studies conclude that the identification and isolation of asymptomatic individuals may be necessary to control outbreaks.

Based on these data, it should be clear that viral testing in symptomatic and asymptomatic individuals should be required to create a virtual bubble in our K-12 schools, right? Not so fast.

In a report published June 30, the CDC recommended testing of those with symptoms, but did *not* recommend asymptomatic viral testing (aka universal testing) in K-12 schools. "*Therefore, CDC does not recommend universal testing of all students and staff. Implementation of a universal approach to testing in schools may pose challenges, such as the lack of infrastructure to support routine testing and follow up in the school setting, unknown acceptability of this testing approach among students, parents, and staff, lack of dedicated resources, practical considerations related to testing minors and potential disruption in the educational environment*."

Professional societies have challenged the CDC perspective on asymptomatic testing in K-12 schools. The Infectious Disease Society of America (IDSA) has called "*for the immediate reversal of the abrupt revision of the CDC COVID-19 testing guidelines which diminish the importance of testing asymptomatic individuals who were exposed to COVID-19.*" The IDSA goes on to state: *"Evidence has clearly indicated that asymptomatic persons play a significant role in transmissions. Identifying individuals infected with COVID-19—even if they are asymptomatic—is critical to support appropriate isolation and identification of contacts, to limit spread, and to provide the data-driven, comprehensive view of community spread needed to inform effective public health responses*." A report in STAT news provides a more complete perspective on the new CDC guidelines.

We now return to the *virtual bubble* concept and make an argument for frequent, surveillance viral testing in K-12 public schools. It is important to re-emphasize that testing is necessary but not sufficient in the absence of "universal precautions" (e.g., masks, physical distancing, symptom checks, ventilation, hygiene). The argument for a comprehensive viral testing, which is based on the facts listed above, is as follows:

(1) Most kids and many adults do not have symptoms when infected with SARS-CoV-2.
(2) Asymptomatic kids and adults can spread the virus.
(3) Outbreaks occur when coronavirus spreads silently through communities, which include K-12 schools. The key to stopping outbreaks is early detection of new infections.
(4) Once an outbreak occurs, the solution is to lockdown. For K-12 schools, this means closing schools and shifting to remote learning. If such a shutdown occurs, it may mean that our schools will be closed for a prolonged period of time. Testing minimizes the risk that our K-12 schools will be shut down again by detecting infections in relatively few individuals.
(5) Therefore, the best way to ensure the safety of teachers, staff and students is to create a *virtual bubble*, which includes (a) universal precautions (e.g., masks, physical distancing, symptom checks, hygiene, ventilation) to limit spread should an individual within the virtual bubble unknowingly become infected and (b) surveillance

testing among students, teachers and staff within the virtual bubble to identify new infections before an outbreak occurs and shuts downs our K-12 schools again.

(6) Further, testing enables a data-driven approach for decision-making, even in the setting of communities in which there is a low prevalence of infection.

This model of comprehensive viral testing builds on the observation that the greatest success in countries that have contained COVID-19 are those that have *over-tested despite low prevalence,* as such over-testing reduces early spread of disease and guides public health decision-making (see slide #43 here).

What type of viral testing should be used to create a virtual bubble? Here we highlight four important K-12 cohorts, each differing by time, symptoms and age. We list these in order of priority to create the virtual bubble, which is important when considering practical and financial implications of instituting a viral testing program.

1. **Baseline "time zero" testing.** Before entering the virtual bubble, it is important to document that there are no active infections among students, teachers and staff without symptoms. Such testing will provide reassurance that our schools are safe from the start. Further, testing will provide a population estimate of infection prevalence, which will guide public health interventions over the course of the school year.

2. **Symptomatic testing and contact tracing.** Once inside the virtual bubble, it is essential to determine if any new symptoms consistent with COVID-19 (all of which are non-specific, including fever, aches, cough, skin rash) are indeed due to infection with SARS-CoV-2. Once confirmed, direct contacts of infected individuals should also be tested, consistent with CDC guidelines. Importantly, rapid turnaround of test results (e.g., < 24 hours) is important to minimize the amount of time in quarantine, and therefore the amount of time missed for in-person education.

3. **Surveillance testing of teachers and staff.** Because adults are at increased risk of severe disease relative to children, it is valuable to identify individuals early in disease course – often referred to as "pre-symptomatic" – as symptoms may take 4-5 days to develop after an infection takes hold. Early diagnosis will not only minimize spread to other individuals within the virtual bubble, but will also maximize the window for therapeutic intervention. For example, anti-viral therapies such as remdesivir appear to be most effective if administered early in disease. That is, early diagnosis of pre-symptomatic infections is yet another measure to ensure the safety of our teachers and staff.

4. **Surveillance testing of students.** Surveillance testing of students is more controversial. As described above, kids are at a lower risk of infection and are less likely to develop severe disease. At the same time, kids contribute to transmission, including those who are infected but lack clinical symptoms (i.e., asymptomatic). Any parent will tell you that kids are less likely to adhere to stringent universal precautions such as masks, physical distancing and personal hygiene. Given these considerations and given that there are generally 5-10 times as many K-12 students as adult teachers and staff in schools, it is logical to conclude that kids will be an important source of transmission within a virtual bubble. Thus, it is also logical to conclude that surveillance testing of K-12 students is an important component of the virtual bubble.

How frequently should surveillance testing occur?

The optimal frequency of surveillance testing is dependent on factors such as test sensitivity and specificity, speed of reporting, and cost. As with the NBA, daily testing with rapid turnaround time of highly sensitive PCR-based molecule tests is the gold-standard. Unfortunately, such testing is not possible today in K-12 schools, largely due to cost and operational infrastructure required for molecular tests.

Today, there are no established standards the frequency of surveillance testing. The Massachusetts Higher Education Testing Group, in collaboration with others, has studied mathematical models as a means of acquiring some insight into surveillance testing frequency (see here and here for full reports). As reported by this group: "*While the models differ in terms of their assumptions and approach, they all conclude that surveillance testing, in addition to other layers of protection to reduce transmission, is a robust and promising strategy for identifying and isolating people from the community while they are contagious. All of the current models suggest testing frequency paradigms ranging from testing every 2 days to every 12 days, with relative frequency depending on factors such as the risk of infection and rate of transmission. One way of operationalizing these findings is to consider testing the populations most at risk every 2 to 7 days with the outer limit being 12 days under the most favorable circumstances*."

For scientific and practical reasons, we recommend weekly testing with <24-hour turnaround times as a reasonable solution at this point in the pandemic. The scientific justification is that it often takes 4-5 days for symptoms to appear in newly infected individuals. The practical justification is that an infrastructure is required to schedule testing for large communities of individuals, and anything other than a regular schedule (e.g., daily, Monday-Wednesday-Friday, weekly, monthly) will be challenging to implement at scale.

As pilot programs are instituted in K-12 schools, the optimal frequency will be refined based on data. In some schools, where infection prevalence is high, more frequent testing may be required (e.g., daily). In other schools, where prevalence is low, less frequent testing may be required (e.g., weekly testing of population subsets such that the entire population is tested monthly).

Finally, it is worth noting that he development of new technologies in the near future should enable cheap, daily, rapid testing for communities to enable virtual bubbles. As described below, such technologies are not yet widely available, and we do not believe that a pilot viral testing program should wait until the technologies are widely available.

What are the arguments against viral testing as a component of the virtual bubble?

1. **We don't know if this will work.** The bulk of the evidence, as described above, suggests viral testing will help keep our schools safe. The question is not if viral testing will help but *how much viral testing will help* relative to other investments. An indirect, qualitative benefit of a comprehensive viral testing program is that objective data will provide reassurance to teachers and families that universal precautions (e.g., masks, physical distancing, ventilation, symptom checks, hygiene) are indeed working to keep our schools safe. This reassurance should not be underestimated. Finally, the reason we propose a pilot at this time is to determine the best way to deploy viral testing in other K-12 school settings based on objective data.

2. **Community prevalence is too low to justify testing.** For most public schools, students live in the same community in which they go to school. However, for many public K-12 schools, teachers and staff live in other communities and commute to the school in which they work (e.g., 90% of teachers and staff live outside of the school community). If the extended community has incredibly low prevalence rates, then one could argue that a particular threshold of infection could be used to justify when to initiate surveillance testing. However, for most K-12 schools, the prevalence rate of the extended community is too heterogeneous to make this argument. Further, the prevalence rate in the NBA bubble is essential 0%, but surveillance testing is still performed given the consequences of even a single positive case. A similar case can be made for our schools: the cost of shutting down in-person education due to asymptomatic spread of infection is large and includes consequences that extend into our economy and social fabric.

   In addition, a comprehensive testing program will strengthen public health data that community prevalence is indeed low, especially among those who would participate in K-12 in-person education.

Currently, few children are tested as may are asymptomatic. Thus, a comprehensive testing program will document the exact prevalence in the community that matters most: K-12 classrooms.

As mentioned above, comprehensive viral testing builds on the observation that the greatest success in countries that have contained COVID-19 are those that have *over-tested despite low prevalence*, as such over-testing reduces early spread of disease and guides public health decision-making.

3. **Test performance will result in false positive and false negative results.** No test is perfect. The performance of PCR-based molecular tests is quite high, with sensitivity and specificity estimated to be 99% or greater. (These numbers are difficult to estimate, however, as current tests are measured by their ability to detect a minimum number of copies per volume, as described in this *Nature Biotechnology* article.) At a population prevalence of 1%, there would be an equal number of true positives and false positives, with very few false negatives. Given the ease of repeating a test, it should be straightforward to repeat a test to determine if it is a false positive or a true positive result (see this online calculator to estimate positive and negative predictive value). And given rapid turnaround of test results, the implications of a false positive are minor relative to the benefits of a true positive test – keeping the virtual bubble intact.

   More important is the value of a negative test (i.e., the negative predictive value, or NPV). If a test with 99% sensitivity and specificity in a community with a population prevalence of 1% is returned as negative, it is nearly certain that the test represents a true negative result. Thus, a negative test will provide reassurance to our community that universal precautions are working to keep our schools safe within the virtual bubble.

4. **The operational logistics are complicated.** This is also part of the CDC's argument against asymptomatic testing. If you read the CDC's statement carefully, they highlight that "*testing in schools may pose challenges, such as the lack of infrastructure to support routine testing and follow up in the school setting".* However, if logistics can be supported then this argument essentially disappears. Fortunately, there are companies that now specialize in operational logistics to enable viral testing at scale in schools. Early adoption with a pilot program will further de-risk this concern before broader implementation occurs.

5. **We should wait for cheaper, rapid tests.** The FDA just granted emergency-use authorization of a rapid "antigen test" from Abbot and the US government agreed to invest nearly a billion dollars in making these tests available. The test is reported to cost $5 with a turnaround time of 15 minutes. As these tests become widely available, rapid tests will likely transform viral testing in K-12 schools. However, these rapid tests are not available today – there is even an X-Prize for the development of rapid tests. Thus, the choice today is to wait for these cheaper tests – which is likely months away – or start with more expensive molecular tests.

   The upside of starting with more expensive molecular tests today, especially in the form of a pilot program, is that the basic operational infrastructure of testing, collecting results, returning data to individuals and schools, and decision-making based on results is very similar between antigen tests (results in minutes) and molecular tests (results in <24-hours). That is, the operational issues can be ironed out with molecular tests and then transitioned to rapid antigen tests once available.

6. **Opportunity cost.** It would cost over 1 million dollars a month to conduct a comprehensive weekly surveillance program using a PCR-based molecular test ($50 all-in cost per test) for a K-12 school of ~6000 students, teachers, and staff. Are there other components of the virtual bubble that would benefit from this level of investment? Would it be better to invest in high-end ventilation systems? Outdoor tents? Or even sophisticated technology to make remote learning more effective?

We believe that a robust viral testing program should be funded *after* necessities to promote universal precautions – personalize protective equipment (PPE), infrastructure to enable physical distancing, and ventilation systems – but before other interventions that simply offer "hygiene theater" (e.g., temperature scanners, fomite cleansing).

Conclusions

In essence, the value of viral testing for K-12 schools becomes an economic argument relative to other investments required to maintain the virtual bubble and keep our K-12 schools safe. To maintain its actual bubble, the NBA has spared no expense: mandatory quarantines and viral testing to enter the bubble, followed by universal precautions (e.g., masks, physical distancing, ventilation, symptom checks, personal hygiene) and daily surveillance testing while inside the bubble. The reason for this expense is that an outbreak would have disastrous consequences for the NBA: the season would end, as it did before.

What is the value to K-12 schools of early detection and the avoidance of an outbreak? In addition to giving teachers and families objective data that demonstrates in-person education is safe, a comprehensive viral testing program would allow early detection of new infections, reduce the risk of outbreaks, and increase the probability that our schools will remain open to in-person education this year. **In other words, a comprehensive viral testing program represents our best shot at avoiding another school shutdown.**

To create and maintain the virtual bubble, schools should start with the basics (PPE, physical distancing, ventilation, symptom checks, viral testing for symptomatic individuals) and work towards more comprehensive measures that include (in order or priority): (1) baseline "time zero" testing to start school; (2) weekly surveillance of adult teachers and staff (especially those who live and work in high prevalence areas); (3) weekly surveillance testing of older students; (4) weekly surveillance testing of younger students; and (5) daily testing of everyone inside the virtual bubble.

We know that kids get infected and kids can transmit disease to others, and we know that some kids can even suffer from very severe COVID-19. What we don't know yet is the impact of a comprehensive viral testing program to re-open our schools to in-person education. The data to date supports such measures, if the finances are available to support testing. With implementation and data generation as part of a pilot viral testing program, we will refine the best way to deploy viral testing for our K-12 schools. An added benefit is that testing will provide reassurance to our community that universal precautions are indeed effective at keeping our schools safe.

Written in collaboration with the "*Safer Teachers, Safer Students*" committee (August 29, 2020)
Jesse Boehm, PhD
Helen Boucher, MD
Doug Golenbock, MD
Robin Ingalls, MD
Robert Plenge, MD, PhD

NBA bubble links
https://theundefeated.com/features/the-nba-bubble-is-a-grand-experiment-in-epidemiology/
https://www.businessinsider.com/nba-bubble-oura-smart-ring-used-by-quarter-of-campus-2020-8
https://www.mensjournal.com/sports/nba-bubble-successfully-curtails-covid-19-what-the-world-can-learn/

School re-opening
https://www.scientificamerican.com/article/schools-have-no-good-options-for-reopening-during-covid-19/

Coronavirus in kids
https://www.nature.com/articles/s41591-020-0962-9
https://wwwnc.cdc.gov/eid/article/26/10/20-1315_article
https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.29.2001352
https://www.idsociety.org/news--publications-new/articles/2020/idsahivma-statement-on-changes-to-cdc-guidance/

Other links
http://www.mhtc.org/wp-content/uploads/2020/05/2020.5.22-MHTC-Main-Deck-vFinal.pdf
https://www.plengegen.com/wp-content/uploads/Final-Report-of-the-MA-Higher-Education-COVID-19-Testing-Group.pdf
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