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EDITORIAL

Cooperation under Pressure: Lessons from the COVID-19 Swab Crisis

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ABSTRACT The early months of the COVID-19 pandemic were marked by a desperate need for nasopharyngeal swabs to test for SARS-CoV-2, with demand far outstripping supply. April marked the anniversary of an unprecedented nationwide multibusiness/multihospital partnership that successfully met this need, a fitting occasion to review lessons learned. Here, I briefly recount the key events, constraints, and thought processes surrounding the effort in order to better inform responses to future crises. Overall, the experience was a strong validation of Joy's Law and illustrated the utility of recognizing temptations to avoid, in order to reap the rewards of cooperation. I conclude by summarizing lessons learned.

KEYWORDS COVID-19, Joy's Law, NP swab, SARS-CoV-2, cooperation

The COVID-19 pandemic caught the world unprepared. By mid-March 2020, the United States was already in dire need of testing. Yet even as clinical laboratories scrambled to bring more testing online, we were hit with yet another crisis: a nationwide shortage in nasopharyngeal (NP) swabs, which are needed for collecting patient material for testing. Copan Diagnostics, the leading swab maker, was in Italy, one of the hardest-hit countries, and could not keep up with demand despite adding shifts. Puritan Medical Devices, a supplier in Maine, also lacked the bandwidth to meet demand and was further constrained by federal emergency-management requisitioning, or so conversations with personnel at the company led us to believe (a representative from the U.S. Food and Drug Administration would later claim no knowledge of such requisitioning). China was still idled, with an unknown timetable for return to meaningful capacity. After long hours which had become routine for health care workers, we in the clinical microbiology laboratories at the Beth Israel Deaconess Medical Center (BIDMC) had just succeeded in becoming the largest in-house COVID-19 testing center in Boston, MA. Our reward: a swab supply that would not last a week. The following is an account of the 3 weeks it took to get on top of this crisis and how we survived until we did.

WEEK 1

The swab crisis was what happens when a supply chain is stretched to a single breaking point, and then effectively snaps, as demand emergently outpaces supply. We could not afford another single point of failure, so at the hospital we got started on multiple fronts. First off, we scrounged. We put out a call to every department and clinic for every Copan and Puritan swab on the FDA's approved list. Private practitioners raided exam-room drawers. A microbiology office became a walk-in donation box. We considered other swab types, too—throat, urogenital—to see if we could repurpose them. That first week we were on the phone around the clock with receiving, infectious disease, respiratory therapy, talking to people we did not know from places we half-forgot existed, MacGyvering and turning stones. The effort brought us the warmth of solidarity but only about another 2 weeks of swabs.

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More manufacturing was the only lasting solution. Therefore, that same first week, even as we scrounged and repurposed, we also started reverse engineering the swabs we had, to see if we could make them from scratch. An NP swab is a 15-cm stick of plastic about 3 mm in diameter consisting of a head, neck, and shaft. It is inserted almost horizontally into a patient through the nose and then placed into a fluid-containing vial for transport to the lab. (Transport media were also in short supply, but that is another story.) For most swabs, the head has tiny glued-on filaments called flock. Swabs must be neither too stiff nor too flexible. They must not break inside a patient. They come individually packaged and sterile. We figured we needed around 10,000 a week at our hospital, and perhaps 1,000 times that for the country. This was the spec we sought to hit.

It was a hard problem. Luckily, a few years earlier I had helped run a study showing that a far-flung group of "journeymen-strangers" could solve a seemingly impossible problem in 2 weeks by sharing openly and working together (1). It was a case of Joy's Law: no matter who you are, the best person for the job is probably somewhere else. If we were going to figure out how to make swabs, that previous experience would be the roadmap. Unfortunately, people usually do not work that way. Academic medicine is a market, just like industry. Ideas are currency; secrecy is a competitive advantage. "Cooperation" is usually the emperor's new clothes. It happens that my old PhD thesis advisors were experts on the science of cooperation, including the temptation of an individual to sucker a group for personal gain ("temptation" and "sucker," as well as "defect," are formal defined terms in this field of study) (2). So, coming into this crisis I had perhaps a special perspective on how useful, but also how fragile, cooperation could be.

I set about nucleating a team of journeymen-strangers. I hit the jackpot in that the first people I reached out to from outside BIDMC all happened to be paragons of selflessness and ingenuity. They included the director and an instrumentation engineer at Harvard Medical School's Research Instrumentation Core Facility, a mechanical engineering consultant in Seattle, and two San Francisco Bay Area electrical engineers/entrepreneurs. Like me, almost all of them were alumni of the Massachusetts Institute of Technology. All of them were engineers. Almost all were in industry. Some were makers. None were medical doctors. To my knowledge, none of us had any academic or financial pretensions regarding swabs—certainly not at the time—which avoided some of the usual temptations and made cooperation easier. All were cheerful and energetic, and all were first-rate problem-solvers.

Without them, the rest of this story would have unfolded differently.

We got started. Week 1 of swab manufacture was a flurry of back-and-forth emails, calls, and texts at all hours. I was also fielding not-yet-desperate inquiries from hospital leadership as our own swab supply dwindled. Ideas were floated, shot down, resurrected, and repurposed. In the end we saw just two options: either find sticks, flock, and glue and a scalable means to assemble them into swabs, or else find a way to make a stripped-down swab in a single go, without the need for assembly. The first option seemed to call for a volunteer army, which seemed organizationally complicated and would invite problems with quality control. So, we favored the second option, which we thought we might be able to do by 3D printing. 3D printing capacity was widely available at companies large and small. We each tapped our networks. 3D printing is not the only approach we considered; injection molding and extrusion are others. But 3D printing has advantages in speed of development and in the variety of structures it can make, and we were on the clock.

We navigated our social and professional networks, letting manufacturers know about the swab crisis and what we needed from them to solve it. We set up a free publicly viewable knowledge base online in the form of a GitHub repository—a type of website usually used by software engineers to collaborate on coding projects—to share everything we knew with everyone who might want to know it (3). This was critical for lowering the activation energy for anyone who wanted to join the effort, by letting them see and (in tech-speak) "grok" the spec. By the end of week 1, prototypes were rolling in. BIDMC was still working out the lockdown loading-dock schedule, so mostly prototypes came to my front porch, at all hours. I was there 7:30 one Sunday morning to receive prototypes that had been made the night before and driven up from Connecticut, 2 h away. The manufacturers were taking the crisis as seriously as we were. That was nice to see.

WEEK 2

As the MD of the group, I volunteered to develop protocols for testing prototypes, and began drafting a team at BIDMC to help. Again, I lucked out with tireless, selfless people full of cheerful ingenuity. These included two biology research technicians from BIDMC, who volunteered to help with the COVID-19 effort instead of staying home, as well as several PhDs from the research laboratories of BIDMC's microbiologists and a pair of Clinical Microbiology fellows. Over the course of week 2 we became a smooth-running machine for swab R&D. We put first 10, then 50, then 100 prototypes through their paces (with details reported online [3] and previously in this journal [4]). These came from two dozen companies, academic laboratories, and individuals. Some did better than others. Swabs are simpler than prosthetic valves or knees, but they are not trivial. One prototype we received looked the part but shattered with bending—"explosively brittle," per one of our team—not something anyone wants stuck halfway into their head. We were giving manufacturers feedback and suggestions one day and receiving new prototypes the next. We put our protocols and results online.

We spoke directly and often with the relevant decision-makers of BIDMC's Institutional Review Board, whose help and quick feedback were indispensable for cutting through red tape. We put our IRB-approved protocol online as well, to save time for others. We obtained the blessing of our technology ventures office, that the evaluation we were performing and feedback we were giving to manufacturers would not constitute intellectual property, haggling over which would incur needless suspicion and waste precious time (for minimal potential gain). Patients being tested for COVID-19—many of them health professionals themselves—volunteered almost without exception to help us test the new swabs. Other hospitals started building on our efforts and contributing their own. In the background, scrounging and repurposing of swabs continued, keeping the hospital just ahead of our needs. Week 2 was my third straight week of 14-h days, but the plan was working. There are worse ways to spend a pandemic.

WEEK 3

By week 3 we had about 10 days of swabs left and a few prototypes ready for testing on volunteers. Success felt within reach. But with the end in sight, the mood outside our group was changing. Success has a thousand fathers. That week it seemed carpetbaggers started lining up to claim paternity. Temptations from money and ego came into play. We got wind of backchannels and preorders on unvalidated materials. We saw glossy brochures with our name on them that we had not approved. There was grandstanding to the press. Academics jockeyed to publish first. In all there was a sense of scheming to win the peace, even though the war was still on—still is. One of the lessons from studying cooperation is that committing to it without having a way to enforce norms is a sure-fire way to invite defection. This is the tragedy of the commons. For all of us across the country who worked so hard to address the swab crisis over those 3 weeks, it was the price of success.

By the end of week 3 we had validated one prototype for clinical use; we validated three others shortly after (4). (We shared the results.) Together we believed these four manufacturers had the capability to produce over a million swabs per day in reasonably short order, but we were aware that, as ever in this pandemic, tides could change quickly. In the weeks and months after we completed this project, the major manufacturers started coming back online. By the end of the summer, millions of the swabs our coalition helped design, vet, and mass produce had been sold and used for COVID-19 testing not only across the United States but in Europe as well (5, 6). It was still choppy seas the rest of the year as our own focus turned to other urgent matters (7, 8), but the tide had turned at this particular beachhead of the pandemic.

LESSONS LEARNED

The experience suggested five useful lessons.

Lesson 1. Define the mission. First is the value of defining a simple, clear, and concrete unifying goal for the entire team, often referred to as a "mission statement": in our case, usable swabs at scale. Mission statements are often valuable for what they omit. Note that ours did not include publications, sales revenue, intellectual property (IP), or fame, goals typically considered the primary motivators of the academics, businesspeople, or bureaucrats who comprised our team. These omissions were by design: these other goals can work at cross purposes to our main one, as had become clear by the defection behavior we had started to see in week 3. If these other goals were achieved as a by-product of our actual goal, so be it. But if they were not, it was important that everyone involved understood at the outset that such an outcome was entirely acceptable, provided the mission was achieved.

Lesson 2. Establish norms. Relatedly, our experience also emphasized the value of establishing norms that support the mission and, if possible, enforcing these norms. In our case, norms were established mostly via conversations, repetition of the main message, and personal example. Conversations with engineers, entrepreneurs, bureaucrats, and others, whether public or private, often began or ended with an explicit acknowledgment of the temptation to go it alone—to leverage the information, expertise, and labor being provided so freely by the group for personal gain; to publish first, sign a contract, secure IP, etc.—and a reminder that we were not going to give in to such temptation, sometimes with self-congratulatory appeals to our egos, at achieving such restraint. Repetition provided psychological support: hearing the message over and over made it easier to comply with—and harder and more costly, reputation-wise—to violate. By accepting all comers and making all data public, we were able to show by example that we were willing to forgo potential personal competitive advantage (see lesson 4) in favor of the common goal.

Lesson 3. Leverage expertise. Goals like ours required not only the best people from outside our institution, but also the blessing of multiple gatekeepers from within the hospital's bureaucracy. In our case, relevant leadership made their offices' expertise available to us in ways that would have been considered exceptional before the crisis. For example, our clinical trials office, whose personnel have more experience with IRB paperwork than any single investigator, played to that expertise by handling paperwork that in normal times investigators had to handle themselves, saving precious days of back-and-forth. Human-resources leadership found us personnel and handled payment, again saving us time by doing what they know best. Front-office support, from the CEO on down, made it possible for these other departments to operate outside their usual parameters. Bureaucracy did everything it could do—the things it knew best—so that the rest of us could concentrate on the things that only we could do. The lesson here is that of Adam Smith and Ricardo's Rule: i.e., the value of applying division of labor and comparative advantage to their fullest, to make the most efficient use of the available expertise in the service of achieving a common goal as quickly as possible.

Lesson 4. Communicate openly and clearly. As mentioned, the value of radical openness for rapid-development goals is supported by research literature (1). Our experience validated the importance of this lesson. By eliminating the friction of gatekeeping access to information, anyone, anywhere could help move the project forward without needless overhead. Sharing is not the default for several reasons. First is the selective advantage that asymmetric information provides over potential competitors; however, in our case, there were no competitors—we were quite literally all in it together (the "pan" in pandemic). Second is the potential for misuse of shared data, for example, the fear that someone would 3D-print a swab that would stick or break off in the nasal cavity. Such concerns are the primary motivation for governance structures for the use of such data. There is no benefit without potential risk. In our case, we managed the risk with a disclaimer in our repository (crafted with the proactive assistance of our hospital's legal department). A third reason is organizational: it is often simply hard to get usable data into sharable form and keep it from the "contamination" of competing organizational schemes during group efforts. This is why we dedicated time to writing and editing entries and updating our far-flung network on public phone calls, and why we gave each participant his or her own folder in which to record their experiences according to their own preferences, file hierarchy, and so on. Data were thus shared, clear (in the eyes of each organizer), and centralized for all to use, a setup that minimized overhead and maximized ease of use.

Lesson 5. Stay positive. The final lesson was the importance of maintaining a positive mindset. None of our team—probably no one on earth—wanted to be in the situation of putting aside their usual work and goals in favor of a mission like ours. Nor was it obvious we would succeed. Facing uncertain odds, it helps to adopt the mentality of the "happy warrior": happy both for the righteousness of the cause and for the company of the like-minded.

CONCLUSION

Experience is the best teacher. We have described several lessons for maximizing cooperation in a crisis, as taught by our pandemic experience. However, we note that nothing prevents their application in noncrisis situations. Insofar as crisis equals opportunity, perhaps we all can take the opportunity afforded by this trying time to improve how we meet our everyday challenges. By doing so, we might find ourselves further along, more capable, and better prepared for when the next crisis inevitably hits.

Data availability. Data are freely available on GitHub at https://github.com/rarnaout/Covidswab/.

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