

---

## Case Report

# Clinical informatics during the COVID-19 pandemic: Lessons learned and implications for emergency department and inpatient operations

Hanson Hsu<sup>1</sup>, Peter W. Greenwald<sup>1</sup>, Matthew R. Laghezza<sup>1</sup>, Peter Steel<sup>1</sup>, Richard Trepp,<sup>2</sup> and Rahul Sharma<sup>1</sup>

<sup>1</sup>Department of Emergency Medicine, NewYork-Presbyterian Hospital/Weill Cornell Medical Center, New York, New York, USA, and <sup>2</sup>Department of Emergency Medicine, NewYork-Presbyterian Hospital/Columbia University Irving Medical Center, New York, New York, USA

Corresponding Author: Matthew Laghezza, MBA, PA-C, Emergency Medicine, NewYork-Presbyterian Hospital/Weill Cornell Medical Center, 525 East 68th Street, New York, NY 10065, USA; MRL9002@med.cornell.edu

Received 7 May 2020; Editorial Decision 19 November 2020; Accepted 23 November 2020

### ABSTRACT

In response to a pandemic, hospital leaders can use clinical informatics to aid clinical decision making, virtualizing medical care, coordinating communication, and defining workflow and compliance. Clinical informatics procedures need to be implemented nimbly, with governance measures in place to properly oversee and guide novel patient care pathways, diagnostic and treatment workflows, and provider education and communication. The authors' experience recommends (1) creating flexible order sets that adapt to evolving guidelines that meet needs across specialties, (2) enhancing and supporting inherent telemedicine capability, (3) electronically enabling novel workflows quickly and suspending noncritical administrative or billing functions in the electronic health record, and (4) using communication platforms based on tiered urgency that do not compromise security and privacy.

**Key words:** COVID-19, COVID, clinical operations, clinical informatics, emergency medicine

---

### INTRODUCTION

The global coronavirus disease 2019 (COVID-19) pandemic has thrust into the spotlight the importance of disease surveillance, diagnosis, treatment, and research.<sup>1</sup> With the adoption of the electronic health record (EHR) with the American Recovery and Reinvestment Act in 2009, many health networks would have less than a decade's worth of opportunity and experience with the utility and limitations of this computer-based tool in improving healthcare quality, population health, and health system efficiency, while the medical community has been familiar with strengths and weaknesses from decades of practiced medical informatics.<sup>2</sup> Informatics, in its many forms and classifications and in association with health information management, is the ideal confluence of people, process, and technol-

ogy.<sup>3,4</sup> Many of the principles of informatics with regard to computers, software, Internet connectivity, and telemedicine have been described in the literature within the area of disaster mitigation and preparedness.<sup>5–8</sup> However, resources elucidating the practical clinical application of informatics toward a pandemic response require further exploration.<sup>9,10</sup> Swift clinical practice changes can be challenging within the confines of a large health organization, even with an abundance of research and evidence.<sup>11</sup>

We intend to describe the role of clinical informatics in aiding clinical decision making, virtualizing medical care, coordinating communication, and defining workflow and compliance during the rapidly evolving response to the COVID-19 pandemic at NewYork-Presbyterian, a nonprofit healthcare network comprising 2 academic

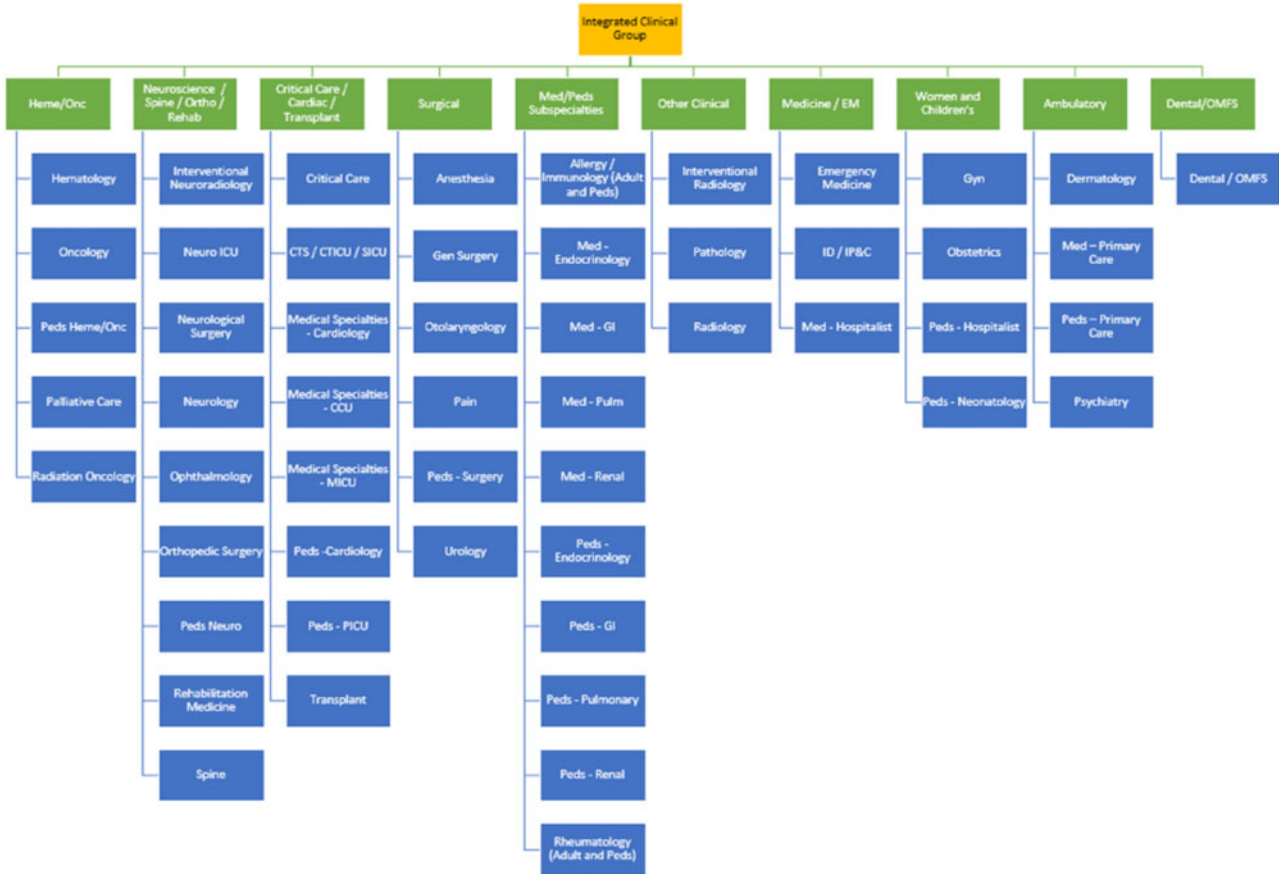


Figure 1. Informatics Clinical Leadership Group organization chart.

The screenshot shows a software window titled "Infect Ctrl Prec- Contact". At the top, there are fields for "Allergies:", "Exp D/C:", "ACO", and "PCP:". Below these are patient vitals: "Wt: kg () Dry(Dosing)Wt: kg () Ht: 152.4 cm CrCl: mL/min SCr: () BSA: sq. m BMI: kg/m2 IC:". To the right, it says "Employee Harm Risk: High (27-Feb-2020)". The "Order:" field contains "COVID-19 Isolation" and "Order ID: 00224XWQS". The "Requested By:" field is partially filled. The "Messages:" field contains "Contact/Droplet, Add N95 for aerosol-generating procedures". Below this is a section for "Isolation Category: Droplet/Contact.", "Room Requirements: Single room preferred. A negative pressure room is preferred if aerosol-generating procedures are anticipated.", "Protective Equipment Requirements: Droplet/Contact. Add N95 for aerosol-generating procedures", "Isolation Duration: Contact Epidemiology", and "Comment: Notify Epidemiology - AH 932-5219, CU 305-7025, WC 746-1754, LMH 312-5976, WD 914-997-4377". At the bottom, there are buttons for "Repeat", "View Document", "OK", and "Cancel". The footer text reads "Copyright 2021 Allscripts™ Sunrise™".

Figure 2. Isolation Orders auto-generated with placement of Covid specific test orders.

Order Set: Covid-19 Initial Workup Labs

Order Items

<input checked="" type="checkbox"/>	Complete Blood Count with Differential	T	EMER
<input checked="" type="checkbox"/>	Basic Metabolic Panel	T	EMER
<input checked="" type="checkbox"/>	Reticulocyte Count	T	Now
<input checked="" type="checkbox"/>	Liver Function Panel	T	Now
<input checked="" type="checkbox"/>	Troponin I	T	EMER
<input checked="" type="checkbox"/>	Lactate	T	EMER
<input checked="" type="checkbox"/>	PT/INR	T	EMER
<input checked="" type="checkbox"/>	Activated Partial Thromboplastin Time	T	EMER
<input checked="" type="checkbox"/>	Fibrinogen	T	EMER
<input checked="" type="checkbox"/>	Anti-Thrombin III activity	T	Now
	Test Must Be Approved by Hematology		
<input checked="" type="checkbox"/>	Lactate Dehydrogenase	T	Now
<input checked="" type="checkbox"/>	Venous Blood Gases	T	EMER
<input type="checkbox"/>	Arterial Blood Gases	T	EMER
<input checked="" type="checkbox"/>	Creatine Kinase	T	EMER
<input checked="" type="checkbox"/>	C Reactive Protein	T	Now
<input type="checkbox"/>	Erythrocyte Sedimentation Rate	T	EMER
<input checked="" type="checkbox"/>	Ferritin	T	Now
<input checked="" type="checkbox"/>	Microalbumin, Timed Urine	T	EMER
<input checked="" type="checkbox"/>	Procalcitonin	T	Now
	Use only in the context of suspected/established lower respiratory infection or sepsis to help discontinue antibiotics. Limit serial procalcitonin to intervals of 48 hours or more. See Pharmacy guideline at <a href="https://infonet.nyp.org/pharmacy/PharmacyM/ProcalcitoninUseAdults.pdf#search=procalcitonin">https://infonet.nyp.org/pharmacy/PharmacyM/ProcalcitoninUseAdults.pdf#search=procalcitonin</a>		
<input type="checkbox"/>	Blood Culture	T	EMER
<input type="checkbox"/>	Blood Culture	T	EMER
<input type="checkbox"/>	Urine Culture	T	EMER
<input checked="" type="checkbox"/>	Urinalysis, Dipstick	T	Now
<input type="checkbox"/>	Type and Screen	T	EMER

Relevant Info   Select All   Deselect All   Edit...   Change Date...

Copyright 2021 Allscripts™ Sunrise™

OK   Cancel   Help

Figure 3. Laboratory orders with default selections for ease of entry.

medical centers within 1 affiliate hospital serving the New York City metropolitan area. Of note, the healthcare system is currently transitioning to a single unified EHR (Epic Systems, Verona, WI) by a phased implementation approach that began in 2018 and is due to be completed by the first quarter of 2022. Clinical departments across the network have been tasked to standardize practice as one of the guiding principles of the project. Practicing clinicians, with predefined roles within governance committees, participate in the clinical informatics process as a volunteer or as a designee by their respective clinical departments. All clinical departments participate in the informatics governance process.

#### COVID-19 diagnostic and treatment order sets

Computerized provider order entry (CPOE) has been described as introducing several types of unintended adverse consequences, many of

which revolve around creating new workflows and workflow demands on clinicians.<sup>12</sup> Order sets, defined as collective grouping of diagnostic or treatment orders within a CPOE system for a particular medical condition or purpose have been widely adopted for guidance, ease of use, and efficiency advantages despite the paucity of studied evidence.<sup>13-16</sup> Default settings and preselection of orders have been shown to reduce variability and drive clinician ordering habits.<sup>17</sup>

Our healthcare system decided to rapidly introduce COVID-19 testing and initial workup, emergency department (ED) COVID follow-up, and postintubation order sets despite the inherent barriers of interoperability between different EHRs at different hospitals. A COVID-19 informatics committee was formed with weekly meetings that included key stakeholders and clinical experts from appropriate departments (emergency medicine, laboratory medicine, infectious disease, hospital medicine, pulmonary medicine, and criti-



cal care). Debates concerning clinical utility were resolved by consensus to provide a consistent user-centric experience. Consensus decision making followed a Quaker-based model (Figure 1).<sup>18</sup>

As the disease process became further elucidated, these order sets were continuously updated based on the most recent data and policy. Availability of a specific test or treatment (high-sensitivity troponin, interleukin-6) within each hospital compendium was denoted to ordering providers at each site. Order set updates were reviewed weekly by the committee for consistency with up-to-the-minute policy updates and testing guidelines. Clinical decision support for the documentation of quarantined travel advisories and the suggested

ordering of rapid-resulting (hours) vs standard-resulting SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) tests according to patient symptoms were introduced. While the COVID-19 testing and initial workup order set had been utilized over 24 000 times since inception in March 2020 (third most frequently used order set), a formal user evaluation system had not been instituted.

Current ED order set for initial workup examples:

1. Isolation orders auto-generated with placement of COVID specific test orders (Figure 2)
2. Laboratory orders with default selections for ease of entry (Figure 3)
3. Radiologic orders with COVID precautions (Figure 4)


RADIOLOGY		Copyright 2021 Allscripts™ Sunrise™	
Order	Pertinent Clinical Info (Exam Reason)	Diagnostic Code	F
-  RADIOLOGY - 1 item(s)			
<input type="checkbox"/>  XR Chest 1-View (Ap), Portable	COVID-19 PRECAUTION...		

Figure 4. Radiologic orders with COVID precautions.

BestPractice Advisory - Test, Test

**Important (1)**





Does the patient have **ANY** of the following:

- Fever
- Cough
- Shortness of breath
- Chills
- Headache
- Sore throat
- Myalgias
- Diarrhea
- ! - Loss of taste or smell

If so, have the patient put on a mask and put the patient on Droplet and Contact isolation.

If the patient has traveled in the last 14 days to an [area of high risk as determined by New York State](#) or internationally, then please select the 'COVID-19 Travel Quarantine' order as well as Droplet and Contact isolation, regardless of testing status.

If the patient has had a known high risk exposure to COVID-19, then please select the 'COVID-19 High Risk Exposure' order as well as Droplet and Contact Isolation.

Order	Do Not Order	 Initiate Droplet Isolation
Order	Do Not Order	 Initiate Contact Isolation
Order	Do Not Order	 COVID-19 High Risk Exposure
Order	Do Not Order	 COVID-19 Travel Quarantine

Acknowledge Reason \_\_\_\_\_

Pt does not have any of the above sympto...

Not able to assess isolation need

© 2021 Epic Systems Corporation

✔ Accept

Dismiss

Figure 5. Documentation of symptoms and exposure.

Figure 6. Indications for testing.

Added clinical decision support examples:

1. Documentation of symptoms and exposure (Figure 5)
2. Indication for testing (Figure 6)

Facing the possibility of increased ED visits, a safety measure for discharged ED patients was introduced. The ED COVID follow-up order had been created to be placed by the treating provider for our nurse practitioner (NP) pool to initiate a follow-up telephone call the next day. The telephone call served 2 purposes: (1) to relay postdischarge results and (2) to provide a safety net for the subset of patients that show more severe symptoms as the disease progresses. The follow-up calls had been conducted daily, 7 days a week, with the option of transitioning from a telephone call to a telehealth video visit as per the discretion of the NP. This measure was implemented in the early stages of the pandemic as a response to the conservation of inpatient beds with stricter admission criteria and have been used on average 3.5 times per day throughout the pandemic.

### Virtualization of services

Telemedicine and virtualization of medical services had been described as near-perfect milieu for enabling social distancing and practicing quarantine measures.<sup>19,20</sup> Telemedicine has relied

heavily on medical informatics principles with regard to providing patient-specific information remotely in conjunction with rapidly accessible epidemiologic and statistical information.<sup>21</sup> The ED telehealth program at our institution consisted of (1) ED Express Care in which patients presenting to the ED would be treated by a remote physician<sup>22</sup> and (2) a direct-to-consumer telemedicine service for at-home patients. NYP OnDemand allows patients to consult directly with our board-certified emergency physicians as an Internet-based virtual healthcare service (Amwell; American Well, Boston, MA).<sup>23</sup> Our direct-to-consumer telemedicine visits at our institution jumped from 30 calls daily to over 300 calls daily (Figure 7), which correlated to the rise of COVID-19 cases in New York City (Figure 8).<sup>24</sup>

Pragmatically, the increased call volume to our direct-to-consumer virtual urgent care telemedicine service required increased physician staffing, primarily filled with emergency medicine physicians. Our institution's executive order to cancel elective and non-emergent surgical cases led to an enterprise-wide strategic staffing model to redeploy physicians to areas of highest need. These new medical providers required provisioning and onboarding with the EHR systems to function, needed access to our telehealth Web application and information systems, and desired ongoing briefing and education about evolving COVID-19 guidelines.

# Virtual Urgent Care Volume

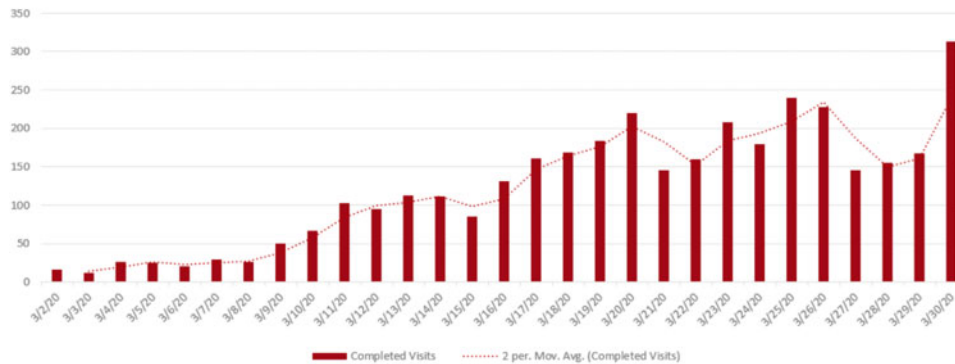


Figure 7. Virtual Urgent Care Volume.

## Positive Cases of COVID-19 in New York City

By Reporting Date

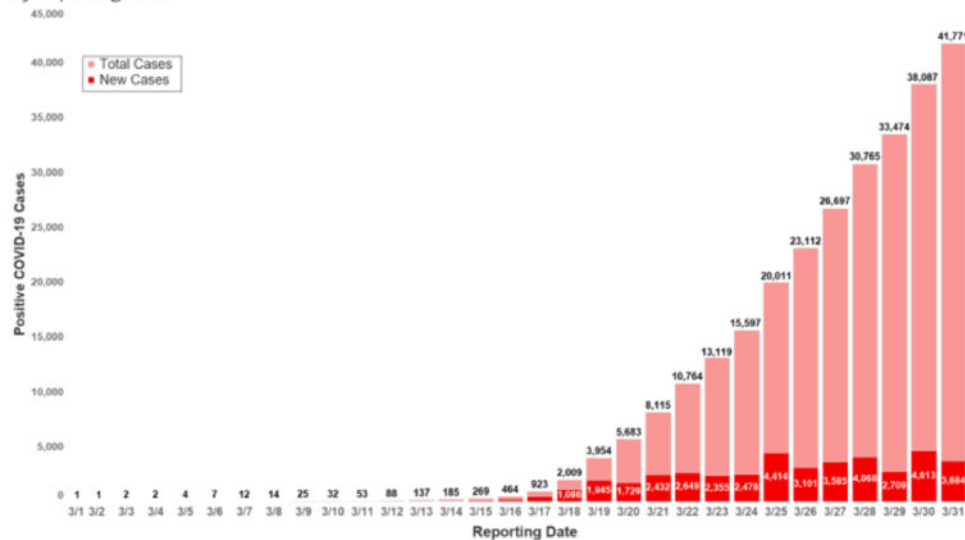


Figure 8. Positive Cases of COVID-19 in New York City by Date.

Despite evidence contrary to the quality of templated or copied notes,<sup>25</sup> the large influx of patients primarily concerned with COVID-19 symptoms and treatment favored the use of templated notes and patient instructions as an expeditious method of visit documentation and treatment plans. These templated notes and treatment plans, as Microsoft Word documents, have been easily updated and distributed through the ED’s wiki (Confluence 6.6.16; Atlassian, Sydney, Australia) as guidelines evolved throughout the pandemic. The ED COVID-19 Response Committee (chaired by an ED physician) had been charged with the maintenance and content update of uploaded documents which were made available to both ED and telehealth patients (Figures 9 and 10).

Beginning in March 2020 and over the next 2.5 months, there were over 60 redeployed physicians across 15 medical specialties that cared for over 2500 patients on our virtual urgent care telemedicine service. Determination of the impact of this service toward a reduction of ED visits is difficult to quantify, but we believe that, at a minimum, a certain percentage of these patients would have sought care at an ED, as primary care physicians had yet to ramp up their own telehealth capabilities.<sup>26</sup>

Additionally, existent videoconferencing technology was co-opted for telemedicine evaluations (Avizia [American Well] and, Cisco Jabber [Cisco Systems, San Jose, CA]), allowing physicians and other medical providers to interview patients in the ED while

**COVID- 19 Symptoms and Education\***

**ONSET OF ILLNESS:** Most people who are infected by COVID-19 develop symptoms within 2 -14 days after exposure, with most people experiencing symptoms within 5 days. Some people may never develop symptoms (asymptomatic).

**DURATION OF ILLNESS:** Most symptoms last between a few days up to 2 weeks. Even after recovering from the immediate Covid-19 infection, you may have residual symptoms (e.g., fatigue, loss of taste and/or smell) that last longer than 2 weeks.

**SYMPTOMS:** Majority of those infected experience mild symptoms. Some persons may develop a more severe form of illness. Commonly reported symptoms may include:

- Fever (100.4 or greater)
- Cough
- Shortness of breath
- Loss of smell
- Loss of taste
- Sore throat
- Muscle or body aches
- Headache
- Nasal congestion
- Runny nose
- Nausea
- Vomiting
- Diarrhea
- Rash
- Chest Pain
- Fatigue

**WHEN TO SEEK IMMEDIATE IN PERSON MEDICAL EVALUATION**

**Shortness of breath** defined as difficulty breathing especially if you are:  
 -unable to speak a full sentence without stopping to catch your breath and/or  
 -unable to hold your breath for 10 seconds or less

**Chest Pain**  
 Calf pain and or swelling

**Change in color of toe or fingers** (Blue, purple, redness, or blotches)

**Rashes with fever**

**Confusion**  
 Loss of Consciousness  
 Visual changes

**Decrease in strength and/or sensation in your arms or legs**

**Facial droop**  
 Fatigue severe enough to impair your ability to use the toilet or move around your home or feed yourself  
 Inability to keep any fluids down due to vomiting

**Severe lightheadedness**  
 Urinating less than two times in a day  
 Change in your ability to walk or a feeling of imbalance  
 Thoughts of wanting to harm yourself or feeling of severe depression

**MEDICATIONS OR ACHEs, PAINS OR FEVER**  
 Medications can be used for aches, pains or fever. These include acetaminophen (Tylenol<sup>®</sup>) or ibuprofen (Motrin<sup>®</sup>). You may use these as directed unless you are allergic, or your doctor instructs you otherwise.

**ACETAMINOPHEN ADULT DOSING**  
 Acetaminophen comes in a variety of doses including 325 mg, 650 mg, or 500mg. It is useful for fever and pain but taking too much can cause additional serious health problems. Here is some advice for how to use it safely.

Take acetaminophen, a total of 650mg every 6 hours only as needed for fever or pain. If you are getting fever before 6 hours, you can take a total of 650 mg every 4 hours with breaks in dosing if you are able.

If you are only able to purchase acetaminophen 500mg then please follow these guidelines: Take NO more than 2 acetaminophen tabs every 6 hours, with one of those doses ideally being only 1 tab, or skipping doses if you feel well enough.

Please try to take some form of nutrition as this will help keep your body healthy and reduce any side effects from your medications.

Ideally you avoid taking more than 3500mg/day to avoid complications of prolonged acetaminophen use.

**IBUPROFEN**  
 Please follow the instruction on the box, and take with a snack or meal to avoid stomach irritation. Also stay hydrated while taking ibuprofen. It is important to avoid ibuprofen if you have ever been told you have kidney disease.

**Do Not Forget To Take Care Of Yourself During This Time**

- Try to sleep a minimum of 7-8 hours each night
- Continue taking any other medications from your doctor unless otherwise instructed
- Drink at least 8 glasses of water a day
- Eat a variety of fruits and vegetables
- Stay connected with family and friends
- Take some quiet time to yourself each day
- Daily movement/exercise which can simply be walking around your room or home
- Avoid alcohol and recreational drugs
- Avoid smoking, use of electronic cigarettes or other inhaled non-prescription products as these may worsen illness

**ISOLATION/QUARANTINE**  
 If you are diagnosed with COVID-19, even if you feel fine, you may be contagious and able to pass the virus to others.

To avoid infecting others, please stay home for the time described above. If you must leave your home, please wear a mask over your nose and mouth and wash your hands frequently. Avoid removing your mask within 12 feet of other people. Postpone in-person social visits with friends and family until you are at least 10 days without symptoms and at least 24 hours without fever.

If you share your home with others some instructions for how to protect others within the home can be found at <https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/care-for-someone.html>

**MENTAL HEALTH**  
 It is common to feel overwhelmed and anxious during this time.

Stay in touch with family and friends to reduce isolation during this time. Having a routine is helpful.

Avoid alcohol, cigarettes, electronic cigarettes or recreational drugs as these may make your medical and mental health condition worse.

If you are feeling so anxious that you are unable to take care of yourself or sleep, or you are feeling so depressed that you have thoughts of harming yourself or wishing you die, then please seek support from a professional. You can come to the emergency department, or access some support through your local health department or the following website: <https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/managing-stress-anxiety.html>

**IF YOU ARE A CAREGIVER TO SOMEONE WITH COVID-19:**  
 Information on how to monitor someone you are caring for can be found at <https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/care-for-someone.html>

Figure 9. Sample COVID19.

maintaining isolation precautions. Remote physicians conducted histories, simple physicals, and patient education while on-site ED personnel concentrated on in-person COVID-19–related testing and procedures (Figure 11).

### Supporting novel patient care workflow creation and suspending noncritical functionality

Supporting new workflows with regard to patient care and health-care provider interaction is paramount to a well-functioning health-

care system.<sup>27</sup> Specific examples from our experience include: creating an EHR-based order for the (1) mildly symptomatic ED patient follow-up with a hospital dispensed pulse oximeter, seen via telemedicine; (2) normally admitted hypoxemic ED patient that had been discharged with remote patient monitoring and home oxygen; and (3) a newly discharged inpatient that had required close follow-up for resolution of symptoms. Each patient cohort was followed by a different discharge service depending on presenting and discharging location and disease severity, along with differing levels of EHR access and accountability (Figure 12).

Location:  
Patient was seen and evaluated by me using telemedicine

CC: Concern for COVID19 Symptoms  
HPI:  
PMHx:  
PSHx:  
Med:  
Allergies:  
COVID19 Risk Factors:  
No known positive COVID-19 contact.  
No travel outside of NYC in the last 2 months.  
No known travel to areas with geographical clustering.  
No sick contacts at home.

VIRTUAL TELEHEALTH EXAM:  
VITALS :  
GENERAL: Awake, alert in no distress, speaking in full sentences  
HEENT: EOM intact anicteric atraumatic FROM neck normal voice  
RESP: No respiratory distress  
NEURO: patient Alert oriented moving all extremities equally  
MOOD/AFFECT: normal

A/P:  
Clinical presentation does not warrant referral to ER as this time , as patient does not have evidence of moderate or severe respiratory infection  
Patient does not meet current COVID-19 testing criteria. However, recommend them to follow up on our hotline in case our testing criteria changes.  
> Patient instructed to avoid contact with others while ill. For self-isolation at home and discharge instruction for DC of self-isolation given according to latest CDC guidelines  
> Please monitor your symptoms closely. If your symptoms worsen please contact your doctor or go to the emergency department. Please go to ER for chest pain, difficulty breathing, weakness, vomiting, headache, changes in vision, or other concerning symptoms.  
> Medications were reviewed med reconciliation was completed  
> Discharge were reviewed with patient by me and made available at MYNYP.ORG  
> Questions were answered and patient expressed understanding of discharge instructions

**Figure 10.** Clinical Documentation tool for patients seen via telemedicine.

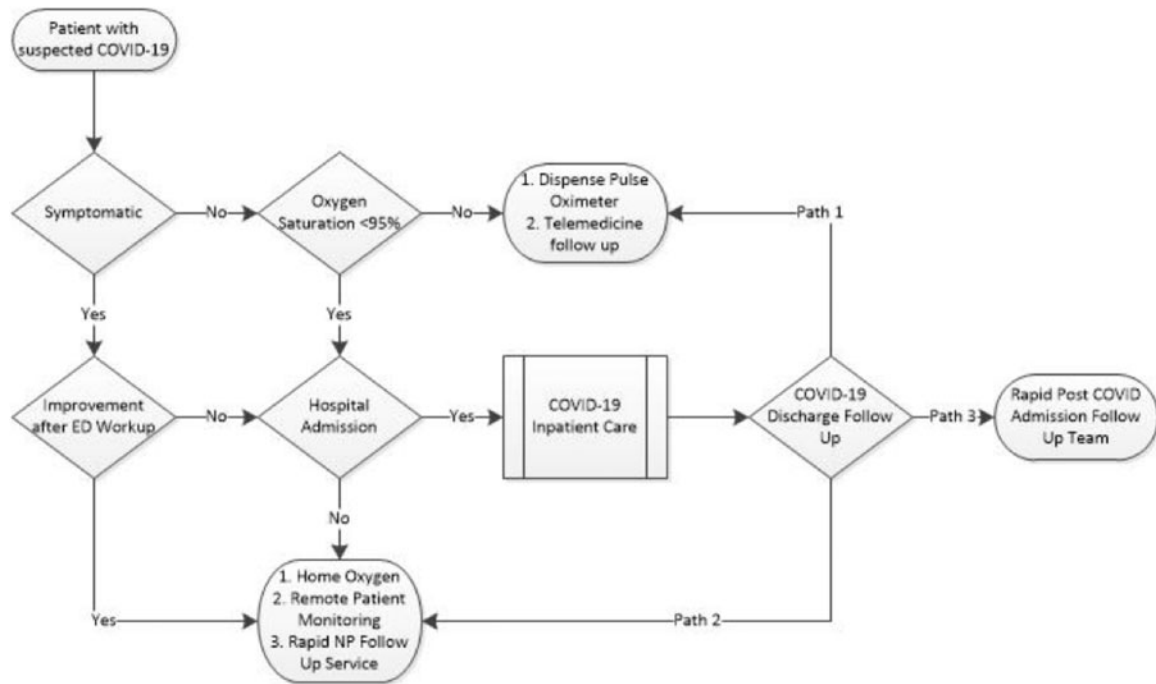


**Figure 11.** Using Telemedicine for patients presenting to the Emergency Department.

As a corollary to expediting simple and organized electronic order entry for radiologic procedures during a disaster response,<sup>28</sup> suspension of noncritical compliance requirements for CPOE had been an important factor in order to decrease alert fatigue. Alerting logic for patient location requirements for intensive care unit–only reserved medications (ie, propofol by infusion) had been removed as recovery units and floor beds expanded into overflow intensive care

units. Observation of the rights of clinical decision support (right information, right person, right intervention format, right channel, right time in the workflow)<sup>29</sup> supported the suspension of prerequisite documentation for the New York State mandate of offering HIV testing before placing a hospital admission or ED discharge order. Instituting clinical decision support reminders for providers to order COVID-19 polymerase chain reaction testing and to check for the





**Figure 12.** Pathway for patients with suspected COVID-19.

result had the potential to lead to expedited bed assignment and patient cohorting.

ED providers (physicians, physician assistants, NPs) suggested these changes through their Clinical Leadership Group representative and were instituted to respond to the growing amount of temporarily redeployed medical personnel that had been unfamiliar with routine ED workflows. Intended consequences, such as a decrease in HIV testing offers, were considered and deemed inconsequential. Other unintended consequences (increased walkouts, increased length of stay) were not observed with regulatory requirements and liability suspended by state government emergency mandate.<sup>30</sup>

### Medical provider communication

At the core of clinical (medical) informatics has been the retrieval of information coupled with knowledge base management and transmission.<sup>31</sup> With almost ubiquitous searching and instant access to medical information on the Internet,<sup>32,33</sup> the increasing acceptability of social media,<sup>34,35</sup> and the use of real-time crowdsourced communication tools,<sup>36,37</sup> the distribution of institutional and departmental policy and procedures has been paramount.

For redeployed physicians and medical providers now providing telemedicine support, a wiki-type content management system (Atlassian Confluence 6.6.16) was constructed as described. Additionally, medical providers engaged in real-time on-shift support with medical peers through an Internet-based chat mobile app (WhatsApp [Facebook, Menlo Park, CA]). The WhatsApp group was a private chat group enabled to provide real-time advice to other providers working clinically, members of our core leadership team, and our technology support team. This group chat helped respond to the needs of the new providers, giving them real-time support and “on the job” training as well as continuing education. The

use of real-time group messaging had been described elsewhere with regard to the care of diagnosis-specific patient groups with concerns over potential security and privacy settings.<sup>38,39</sup> Future operational research detailing messaging content and Health Insurance Portability and Accountability Act privacy compliance had been planned.

Medical provider communication adapted throughout the COVID-19 pandemic. The traditional departmental email listserv delivered daily updates from ED leadership concerning evolving operational issues such as personal protective equipment and staffing changes. Interactive video conferencing (Zoom [Zoom Video Communications, San Jose, CA], Cisco Webex [Cisco Systems]) was deployed and was encouraged throughout the institution as a communication tool as a substitute for in-person meetings and medical student education lectures despite inherent concerns for privacy and effectiveness.<sup>40,41</sup>

### CONCLUSION

The disruption of normal everyday workflows from the COVID-19 pandemic extends from the ED to the inpatient and outpatient clinical departments. From the evolution and universal adoption of the EHR, to the expansion of Internet-based knowledge management, and to the adoption of modern media and communication tools, it is imperative that the practice of clinical informatics guides the interaction of people, technology, and information.

In summary, clinical informatics principles need to be implemented nimbly, with governance measures in place to properly oversee and guide novel patient care pathways, diagnostic and treatment workflows, and provider education and communication.

We recognize that the “lessons learned” presented here are to be taken as one institution’s response during an unforeseen crisis and

that further study and development are required. Implications for clinical operations are interdepartmental and rely on a strong and cooperative informatics governance infrastructure.

## FUNDING

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

## AUTHOR CONTRIBUTIONS

All authors had substantial contributions and meet criteria for authorship.

## CONFLICT OF INTEREST STATEMENT

Our authors have no competing interests to declare.

## DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

## REFERENCES

- Fauci AS, Lane HC, Redfield RR. Covid-19—navigating the uncharted. *N Engl J Med* 2020; 382 (13): 1268–9.
- Blumenthal D. Stimulating the adoption of health information technology. *N Engl J Med* 2009; 360 (15): 1477–9.
- Hersh W. A stimulus to define informatics and health information technology. *BMC Med Inform Decis Mak* 2009; 9 (1): 24.
- Friedman CP. A “fundamental theorem” of biomedical informatics. *J Am Med Inform Assoc* 2009; 16 (2): 169–70.
- Kaji AH, Koenig KL, Lewis RJ. Current hospital disaster preparedness. *JAMA* 2007; 298 (18): 2188–90.
- Teich JM, Wagner MM, Mackenzie CF, Schafer KO. The informatics response in disaster, terrorism, and war. *J Am Med Inform Assoc* 2002; 9 (2): 97–104.
- Chan TC, Killeen J, Griswold W, Lenert L. Information technology and emergency medical care during disasters. *Acad Emerg Med* 2004; 11 (11): 1229–36.
- Greenwald PW, Hsu H, Sharma R. Planning for future disasters: telemedicine as a resource. *Ann Emerg Med* 2018; 71 (3): 435–6.
- Li J, Seale H, Ray P, et al. e-Health preparedness assessment in the context of an influenza pandemic: a qualitative study in China. *BMJ Open* 2013; 3 (3): e002293.
- Duley MG. The next pandemic: anticipating an overwhelmed health care system. *Yale J Biol Med* 2005; 78 (5): 355–62.
- Morris ZS, Wooding S, Grant J. The answer is 17 years, what is the question: understanding time lags in translational research. *J R Soc Med* 2011; 104 (12): 510–20.
- Campbell EM, Sittig DF, Ash JS, Guappone KP, Dykstra RH. Types of unintended consequences related to computerized provider order entry. *J Am Med Inform Assoc* 2006; 13 (5): 547–56.
- Chan AJ, Chan J, Cafazzo JA, et al. Order sets in health care: a systematic review of their effects. *Int J Technol Assess Health Care* 2012; 28 (3): 235–40.
- Maslove DM, Rizk N, Lowe HJ. Computerized physician order entry in the critical care environment: a review of current literature. *J Intensive Care Med* 2011; 26 (3): 165–71.
- Wells C, Loshak H. *CADTH Rapid Response Reports. Standardized Hospital Order Sets in Acute Care: A Review of Clinical Evidence, Cost-Effectiveness, and Guidelines*. Ottawa, Canada: Canadian Agency for Drugs and Technologies in Health; 2019.
- Bobb AM, Payne TH, Gross PA. Viewpoint: controversies surrounding use of order sets for clinical decision support in computerized provider order entry. *J Am Med Inform Assoc* 2007; 14 (1): 41–7.
- Olson J, Hollenbeak C, Donaldson K, Abendroth T, Castellani W. Default settings of computerized physician order entry system order sets drive ordering habits. *J Pathol Inform* 2015; 6 (1): 16.
- Muers R, Burton N. Can we take the religion out of religious decision-making? The case of Quaker business method. *Philos Manage* 2019; 18 (3): 363–74.
- Hollander JE, Carr BG. Virtually perfect? Telemedicine for Covid-19. *N Engl J Med* 2020; 382 (18): 1679–81.
- Smith AC, Thomas E, Snoswell CL, et al. Telehealth for global emergencies: implications for coronavirus disease 2019 (COVID-19). *J Telemed Telecare* 2020; 26 (5): 309–13.
- Clemmer TP. The role of medical informatics in telemedicine. *J Med Syst* 1995; 19 (1): 47–58.
- Hsu H, Greenwald PW, Clark S, et al. Telemedicine evaluations for low-acuity patients presenting to the emergency department: implications for safety and patient satisfaction. *Telemed J E Health* 2020; 26 (8): 1010–15.
- Sharma R, Fleischut P, Barchi D. Telemedicine and its transformation of emergency care: a case study of one of the largest US integrated healthcare delivery systems. *Int J Emerg Med* 2017; 10 (1): 21.
- NYC Health. Positive cases of COVID-19 in New York City 3/1/20 to 3/31/20; 2020. <https://www1.nyc.gov/assets/doh/downloads/pdf/imm/covid-19-daily-data-summary-03312020-2.pdf> Accessed July 6, 2020.
- Weis JM, Levy PC. Copy, paste, and cloned notes in electronic health records. *Chest* 2014; 145 (3): 632–8.
- Mann DM, Chen J, Chunara R, Testa PA, Nov O. COVID-19 transforms health care through telemedicine: evidence from the field. *J Am Med Inform Assoc* 2020; 27 (7): 1132–5.
- Russ AL, Saleem JJ, Justice CF, Woodward-Hagg H, Woodbridge PA, Doebbeling BN. Electronic health information in use: characteristics that support employee workflow and patient care. *Health Inform J* 2010; 16 (4): 287–305.
- Bookman K, Zane R. Expedited electronic entry: a new way to manage mass-casualty radiology order workflow. *Prehosp Disaster Med* 2013; 28 (4): 391–2.
- Sirajuddin AM, Osheroff JA, Sittig DF, Chuo J, Velasco F, Collins DA. Implementation pearls from a new guidebook on improving medication use and outcomes with clinical decision support. Effective CDS is essential for addressing healthcare performance improvement imperatives. *J Healthc Inf Manag* 2009; 23 (4): 38–45.
- Powell T, Chuang E. COVID in NYC: what we could do better. *Am J Bioethics* 2020; 20 (7): 62–6.
- Shortliffe EH. Medical informatics meets medical education. *JAMA* 1995; 273 (13): 1061–4. 5.
- De Leo G, LeRouge C, Ceriani C, Niederman F. Websites most frequently used by physician for gathering medical information. *AMIA Annu Symp Proc* 2006; 2006: 902.
- Shariff SZ, Bejaimal SA, Sontrop JM, et al. Retrieving clinical evidence: a comparison of PubMed and Google Scholar for quick clinical searches. *J Med Internet Res* 2013; 15(8): e164.
- Cheston CC, Flickinger TE, Chisolm MS. Social media use in medical education: a systematic review. *Acad Med* 2013; 88 (6): 893–901.
- McGowan BS, Wasko M, Vartabedian BS, Miller RS, Freiherr DD, Abdolrasulnia M. Understanding the factors that influence the adoption and meaningful use of social media by physicians to share medical information. *J Med Internet Res* 2012; 14 (5): e117.
- Riccardi MT. The power of crowdsourcing in disaster response operations. *Int J Disaster Risk Reduct* 2016; 20: 123–8.
- Gulacti U, Lok U, Hatipoglu S, Polat H. An analysis of WhatsApp usage for communication between consulting and emergency physicians. *J Med Syst* 2016; 40 (6): 130.

38. Calleja-Castillo JM, Gonzalez-Calderon G. WhatsApp in stroke systems: current use and regulatory concerns. *Front Neurol* 2018; 9: 388.
39. Corbett M, Chapman L, O'Shea J, *et al.* Effects of introducing a secure web-based messenger application for communication among Non-consultant Hospital Doctors (NCHDs). *Cureus* 2019; 11 (7): e5285.
40. Freundlich RE, Freundlich KL, Drolet BC. Pagers, smartphones, and HIPAA: finding the best solution for electronic communication of protected health information. *J Med Syst* 2018; 42 (1): 9.
41. Bertsch TF, Callas PW, Rubin A, Caputo MP, Ricci MA. Applied research: effectiveness of lectures attended via interactive video conferencing versus in-person in preparing third-year internal medicine clerkship students for Clinical Practice Examinations (CPX). *Teach Learn Med* 2007; 19 (1): 4–8.