Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Healthcare 9 (2021) 100590

Contents lists available at ScienceDirect

Healthcare

journal homepage: www.elsevier.com/locate/healthcare

STAT: Mobile app helps clinicians manage inpatient emergencies

Andrew L. Chu [a,c,d,*], Joshua C. Ziperstein [b,d], Blake A. Niccum [b,d], Melvin G. Joice [b,d], Eric M. Isselbacher [b,c,d], Jared Conley [a,c,d]

[a] Department of Emergency Medicine, Massachusetts General Hospital, 55 Fruit Street, Boston, MA, 02114, USA
[b] Department of Medicine, Massachusetts General Hospital, 55 Fruit Street, Boston, MA, 02114, USA
[c] Healthcare Transformation Lab, Massachusetts General Hospital, 50 Stanford Street, Boston, MA, 02115, USA
[d] Harvard Medical School, 25 Shattuck St, Boston, MA, 02115, USA

ARTICLE INFO

Keywords:
COVID-19
Pandemic
Digital health
Health IT
Mobile application
Innovation

ABSTRACT

In response to the unprecedented surge of patients with COVID-19, Massachusetts General Hospital created both repurposed and de-novo COVID-19 inpatient general medicine and intensive care units. The clinicians staffing these new services included those who typically worked in these care settings (e.g., medicine residents, hospitalists, intensivists), as well as others who typically practice in other care environments (e.g., re-deployed outpatient internists, medical subspecialists, and other physician specialties). These surge clinicians did not have extensive experience managing low frequency, high acuity emergencies, such as those that might result from COVID-19. Physician-innovators, in collaboration with key hospital stakeholders, developed a comprehensive strategy to design, develop, and distribute a digital health solution to address this problem. MGH STAT is an intuitive mobile application that empowers clinicians to respond to medical emergencies by providing immediate access to up-to-date clinical guidelines, consultants, and code-running tools at the point-of-care. 100% of surveyed physicians found STAT to be easy to use and would recommend it to others. Approximately 1100 clinicians have downloaded the app, and it continues to enjoy consistent use over a year after the initial COVID-19 surge. These results suggest that STAT has helped clinicians manage life threatening emergencies during and after the pandemic, although formal studies are necessary to evaluate its direct impact on patient care.

1. Background

In April 2020, Massachusetts had become a hotspot for coronavirus, with the third-most reported number of cases in the nation despite being the country's 15th most populous state.[1,2] This phenomenon was tied to an international Biogen Corporate Conference held in February 2020 at the Boston Marriott Long Wharf Hotel. The two-day event would herald one of the nation's first super-spreader events, and while Massachusetts accounted for most of the virus's early spread, the Biogen conference would ultimately lead to the infection of an estimated 300,000 people.[3]

During this time, Massachusetts General Hospital (MGH) had the highest number of COVID-19 confirmed admissions within the state of Massachusetts, and daily hospitalizations from coronavirus were projected to continue rising.[4] In preparation for the anticipated escalation in patient volume, hospital leaders proactively transformed existing inpatient clinical spaces into areas that could effectively and safely care for COVID-19 patients.

The primary workforce covering these units was the existing inpatient medicine staff, which included internal medicine (IM) residents, hospitalists, and intensivists. However, in order to maintain adequate staffing amidst the surge of COVID patients, the hospital re-deployed clinicians—attendings, residents, and advanced practice providers (APPs)—from other specialties, including primary care, medical subspecialties, pediatrics, diagnostic radiology, orthopedics, and neurology. These clinicians had a wide range of depth and recency of experience with managing adult inpatient emergencies such as myocardial infarction, respiratory failure, pulmonary embolus, cerebrovascular accident, and cardiac arrest, including amongst patients with COVID-19.[5–9]

Each redeployed staffing group was buttressed with clinical oversight from hospitalists; however, given the time-sensitive nature of these emergencies (where seconds often matter), it was deemed crucial to empower the initial responding clinician with immediate access to clinical guidelines for life-threatening medical emergencies, consultants who could provide definitive treatment, and tools for managing cardiac

* Corresponding author. Department of Emergency Medicine, Massachusetts General Hospital, 5 Emerson Place, Suite 101, Boston, MA, 02114, USA.
E-mail address: achu7@partners.org (A.L. Chu).

https://doi.org/10.1016/j.hjdsi.2021.100590
Received 21 March 2021; Received in revised form 27 August 2021; Accepted 28 September 2021
Available online 23 October 2021

arrests. Surge providers—including redeployed clinicians—would then be able to more efficiently and effectively manage common inpatient medical emergencies, as well as decrease the chance of putting patients at risk of adverse outcomes due to delays in care—all while responding to COVID-19.

2. Organizational context

MGH is a large quaternary-care academic referral center and Level-1 trauma center located in the heart of the city of Boston. It is the oldest and largest hospital in Massachusetts, with 1059 staffed beds, and a teaching affiliate of Harvard Medical School. It is also part of Mass General Brigham (MGB), the largest integrated healthcare system and private employer in the state, and affiliated with the Massachusetts General Physicians Organization (MGPO), which represents over 2600 clinicians.

In early spring, MGH had the highest number of COVID-19 confirmed cases in the state, with rates of infection continuing to rise.[4] Consequently, its Hospital Incident Command System (HICS) led massive restructuring initiatives to transform existing inpatient clinical spaces, including post-anesthesia care units and operating rooms, into surge units that could care for both floor-level and ICU-level patients. All institutional resources were prioritized to support surge efforts, with the singular goal of meeting the longitudinal standard of care in the hospital. During non-pandemic times, HICS is responsible for preemptively identifying needs and developing strategies for various disaster scenarios (e.g. active shooter, hurricanes, earthquakes), overseeing general emergency preparedness and response capability, and training staff through simulations and hospital-wide drills.

3. Personal content

The hospital's Healthcare Transformation Lab (HTL) is a healthcare delivery innovation center. One of its functions is to serve as an incubator for the rapid creation of practical solutions for departmental or hospital-wide problems. It is comprised of a multidisciplinary team, bringing together an eclectic mix of clinicians, graphic designers, software engineers, data scientists, and product managers. The paper's authors are comprised of physician innovators within HTL and within the Department of Medicine, and they recognized the urgent need for a rapidly deployable, scalable, and intuitive solution to help surge clinicians manage bedside emergencies during a pandemic. This team partnered with key physician-leaders across multiple departments (e.g., Internal Medicine, Interventional Cardiology, Neurology, and Anesthesiology) as well as specialty-specific committees to find an answer to this pressing problem.

4. Problem

In general, hospitals have standardized guidelines for many low frequency, high acuity inpatient emergencies. Because these emergencies are so infrequent, all clinicians, from trainees to experienced attendings, benefit from having these guidelines readily accessible at the point-of-care. Unfortunately, they often come in the form of e-mails, PDF files, internal program websites, or sheets of paper taped to the walls of provider stations. The authors quickly recognized that this approach could lead to delays in care, errors in treatment, and outdated information since what is most needed is rapid access to this information *while* at the bedside. In addition, these algorithms are somewhat dynamic (especially during a pandemic) and require active updating. These barriers can be overcome with mobile applications that increase clinician familiarity with, access to, and applicability of disease-specific guidelines.[10,11] Although the authors had brainstormed a digital solution to address this issue prior to the pandemic, COVID-19 accelerated the impetus given new surge clinicians, necessitating its rapid creation.

From the onset, it was clear that a provider-centered digital health solution in the form of a mobile smartphone application (app) would be the most effective approach in addressing this specific problem since it could be developed quickly and deployed broadly across the hospital.[12] Anecdotally, clinicians did not routinely use smartphone apps when treating patients with acute, life-threatening emergencies at the point-of-care. Such a digital tool would require a behavior change; therefore, any solution would need to offer significant value in addition to being practical and easy to use during high-stress scenarios.

The authors selected nine high-acuity, time sensitive diagnoses based on informal surveys of inpatient physicians: myocardial infarction, respiratory failure, pulmonary embolism, cerebrovascular accident, cardiac arrest, modified cardiac arrest algorithm for patients with known or suspected COVID-19, unstable tachycardia, unstable bradycardia, and post-cardiac arrest care. Each of these clinical guidelines already had a protocolized standard of care, having previously been vetted by their respective specialty-specific committees—these algorithms were collected, organized, and modified by the authors (with institutional collaboration and approval) to better serve patients during the pandemic. All ACLS content was graciously approved and licensed by collaborators from the American Heart Association (AHA).

After compilation of the content, creation of the app, and thorough beta-testing, the main challenges anticipated by the team were two-fold. The authors needed to convince key stakeholders within these specialty-specific committees, various hospital departments (e.g., Medicine, Neurology, Anesthesiology), and the AHA of the significant advantages of using a novel digital health approach to managing these emergencies at the point-of-care. In addition, they needed to find a way to make the app rapidly available to frontline clinicians despite a lengthy review process for all new digital tools—this process required vetting and approval from the hospital's information technology (IT), risk review (RR), and mobile application review teams, which, on average, normally took weeks to complete.

5. Solution

The authors recognized that a lack of familiarity with time-sensitive inpatient emergencies could potentially delay life-saving interventions. Their goal was to design, develop, and distribute a digital health solution that could aid all surge clinicians in managing patients with acute, life-threatening emergencies at the bedside. To do this, clinicians on the development team mapped out the typical workflow, experiences, and challenges of responding to emergencies at the bedside. Residents within the group expressed that medical crises were often fear-inducing and disorienting given their own lack of experience, and these anxieties were elevated due to the pandemic.[13] Moreover, in a setting in which powerful emotions often cloud judgment, it was clear the app would

Table 1
Team composition, hours & cost estimates for STAT.

Title	Role	Hours	Cost
UI/UX Designer	Design front-end that optimizes user experience	20	$34/hour
Junior Software Engineer	Develop software program	45	$43/hour
Resident Physician	Approve clinical guidelines; beta-test app and give user feedback	100	Volunteer
Attending Physician		40	$150/hour
Estimated Project Budget of $8615			

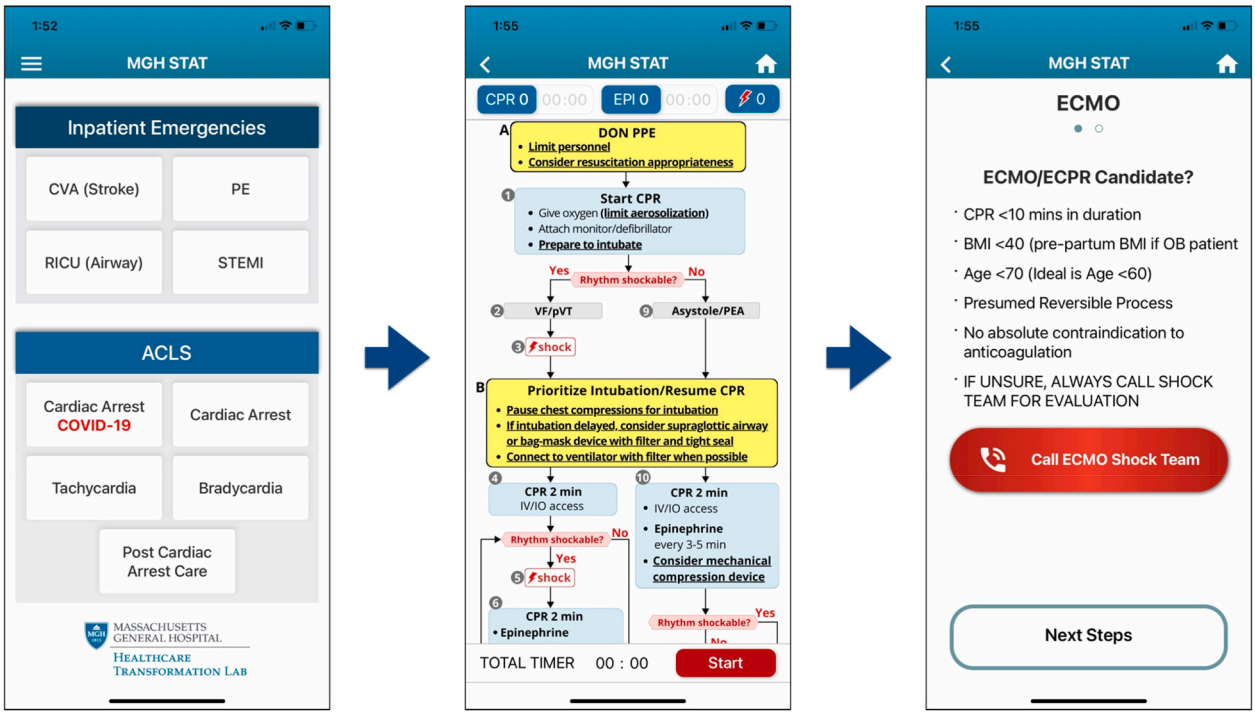

Fig. 1. MGH STAT cardiac arrest COVID-19 screens.

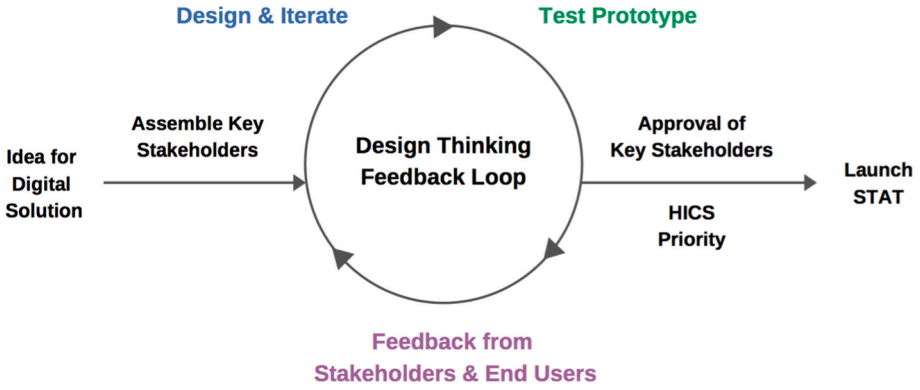

Fig. 2. STAT development process from ideation to launch.

need to be very easy to use, while minimizing the number of button options to press, the number of words to read, and the complexity of diagrams.

With this perspective in mind, the innovation team brainstormed a front-end interface for the app that its primary users could easily navigate. This team was comprised of user interface/user experience (UI/UX) designers, a software engineer, residents, and attending physicians, and their roles and estimated costs are provided in Table 1. The conceived design underwent multiple rounds of rapid iterative changes based on regular feedback from clinicians who would subsequently beta-test each new version under simulated conditions. The final design layout for the cardiac arrest COVID-19 guideline is shown in Fig. 1. The app was appropriately named STAT, a Latin-derived parlance meaning "immediately" that is commonly used during medical crises.

The development team proactively sought multi-departmental stakeholders for the MGH STAT app early on. These stakeholders were composed of resident physicians, senior faculty, clinical guideline committee members, and department chairs, all of whom were informed opinion leaders and trusted sources for implementing innovative ideas. They were involved throughout the app design, development, and dissemination process. Their feedback led to productive design changes and, once those were incorporated, the revised app was re-sent to collaborators in what would be multiple iterative cycles of testing and design enhancements (see Fig. 2).[14] This process also allowed for discussions between departmental representatives, resulting in improved changes to existing protocols. For example, conversations between the Department of Medicine and Department of Anesthesiology led to changes to the COVID-19-specific emergency airway algorithm. This approach allowed the team to balance the resource limitations and concerns of various departments while optimizing patient safety (see Fig. 3).

Once all stakeholders approved of the design, content, and features of the app, the authors asked leaders of MGH's emergency response system, known as the Hospital Incident Command System (HICS), to make the launch an institutional priority, given its potential to improve patient care across the entire hospital. MGH STAT was deemed a HICS

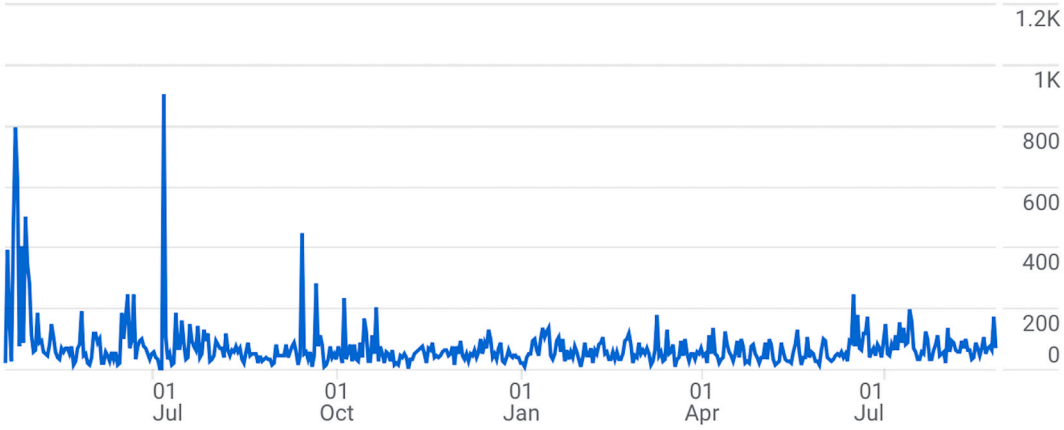

Fig. 3. Graphical representation of daily interactions from 4/19/20 through 8/26/21.

high priority project, allowing it to quickly proceed through the IT, RR, and mobile application vetting process. By obtaining high priority status, the team was able to accelerate the project—this workflow, which would typically take weeks to months, was completed in just a few days. The approved app was then successfully uploaded onto the hospital's internal app catalog. The primary team created a simple informational one-page document about MGH STAT, and the stakeholders within the various departments attached this document to an e-mail informing their constituents about this new digital health tool.

Based on data provided by Google Analytics, as of August 2021, there are roughly 1100 clinicians across a broad range of specialties who have STAT installed on their phones. It is not known how many users are attendings, APPs, or resident physicians because demographic information was not collected. From 4/19/2020 through 8/26/21, there were approximately 35,000 user-mediated interactions, defined as actions like opening the app, navigating new screens, and pushing buttons. On average, this translates to approximately 70 interactions per week, although the highest levels of user activity occurred during the initial COVID-19 surge in 2020. From 1/1/2021 through 8/26/21, there were approximately 63 interactions per week.

To gain a better understanding of the physician user experience with MGH STAT, the team anonymously surveyed IM resident physicians within the Department of Medicine (82 of 210) 6 months after the app was launched. The survey had 5 questions related to the app's perceived usefulness, using a Likert scale with choices ranging from "Strongly Disagree" to "Strongly Agree" (See Supplemental File). It was delivered to these clinicians using a Google Forms survey tool, which solicited subjective feedback regarding the utility and user-experience of STAT. These clinicians included interns, junior residents, and senior residents. The development team also incorporated a back-end analytics platform, called Google Analytics, to track the total number of users and user behavior. The results of these findings are provided as follows:

- 100% (82 of 82) of all surveyed users either agreed (n = 15) or strongly agreed (n = 67) that they would recommend the MGH STAT app to others, especially interns, junior residents, and non-medicine attendings.
- 100% (82 of 82) of all surveyed users either agreed (n = 19) or strongly agreed (n = 63) that MGH STAT was easy to use.
- 97.5% (80 of 82) of all surveyed users either agreed (n = 23) or strongly agreed (n = 57) that MGH STAT would help them better manage acute life-threatening emergencies at the bedside.
- 91.4% (75 of 82) of all surveyed users either agreed (n = 14) or strongly agreed (n = 61) that MGH STAT would improve patient outcomes for acute life-threatening emergencies at the bedside.
- 96.3% (79 of 82) of all surveyed users either agreed (n = 12) or strongly agreed (n = 67) that apps like MGH STAT would be useful at other hospitals and healthcare settings.

6. Unresolved questions & lessons for the field

STAT was rapidly designed and launched by an in-house innovation center during COVID-19 to help clinicians manage inpatient emergencies at the point-of-care. It provides immediate access to up-to-date clinical guidelines, the ability to call or page consultants to expedite therapeutic management, and the benefit of code-running tools (e.g. timer, intervention log, contact ECMO consultant). Its popularity and positive reception among surveyed resident physicians may be in part due to a general acceptance of medical apps by healthcare professionals to help guide patient care.[15–18] Survey results also show that all users would recommend STAT to less experienced clinicians, since the vast majority felt it was easy to use, helped them better manage emergencies at the point-of-care, and would lead to better patient outcomes.

It is worth noting that while the app was initially created for use by surge clinicians not as familiar with inpatient medical emergencies during a pandemic, usage of the app has continued to be steady all the way to the present day, well after the first COVID-19 surge. This pattern suggests that even clinicians who regularly manage inpatient emergencies find the app to be helpful and continue to use it. In fact, by October, re-deployed clinicians were no longer staffing the floors—user engagement of the STAT app after this point was attributed to regular use by inpatient IM clinicians. These outcomes provide further support for the use of digital health tools as adjuncts to improving patient care. Although clinician-users had an overwhelmingly positive perception of its effect on treatment, its actual impact on patient outcomes is unknown, and formal studies are necessary to evaluate this.

This project highlights the importance of engaging key stakeholders, including senior departmental leadership, early and often throughout the development process, since their buy-in is necessary for a successful launch and broad, hospital-wide acceptance. They can also function as physician champions for the initiative within their respective areas of influence. Additionally, clinician innovators who want to construct digital tools like STAT during a crisis event should carefully craft a compelling case to their respective institutional leaders (e.g. HICS) as to why their digital innovation should be a high priority for the institution, thereby gaining necessary resources to accelerate completion.

The successes of STAT are likely generalizable to academic medical centers and large community hospitals with the resources to invest in their own tech-enabled solutions, though possibly more difficult to replicate at small-to-medium sized hospitals. If such hospitals lack the required capital expenditures to build in-house infrastructure and staffing to execute similar projects, they could consider partnering with

nearby universities to leverage the expertise of graduate level students (e.g., computer scientists, engineers, graphic designers). These students can work with clinicians to build patient-centered products whilst gaining invaluable work experience and satisfying curricular requirements. Alternatively, there are companies that work with clients to design, build, and maintain mobile applications.

This case report demonstrates the practicality and effectiveness of applying a digital health solution like STAT to augment patient care during an unprecedented, modern pandemic. The authors believe its application can extend to other disaster scenarios that create similar operational, personnel, and patient care-related challenges for healthcare systems, such as mass casualty events, natural disasters, and future pandemics.[19,20] Hospitals should explore creative ways in which digital health tools can assist clinicians with patient care when facing present day and future healthcare disasters.[21,22] This case report provides a framework for thoughtfully designing a digital health solution around the needs of clinician users, creating a strategy for rapid hospital wide dissemination, and evaluating its impact through surveys and data analytics.

Author contributions

ALC and JC were responsible for the project's conceptualization, technological design, and implementation. ALC, JCZ, BAN, MGJ, EMI, and JC participated in the data curation, methodology, project administration, and formal analysis process. ALC and JC wrote the original draft of the manuscript. JCZ, BAN, MGJ, and EMI provided critical edits and revisions to the manuscript for important intellectual content.

Financial support

None.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank HTL members Paula McCree, Halim Chu, Jennifer Mann, and Alyssa Donovan for their significant contributions towards STAT's design, software development, and dissemination throughout MGH.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.hjdsi.2021.100590.

References

1 IHME: COVID-19 Projections. Institute for Health Metrics and Evaluation. https://covid19.healthdata.org/united-states-of-america.
2 Levitz J. Massachusetts Ranks Third among states with most Coronavirus Cases. https://www.wsj.com/articles/massachusetts-ranks-third-among-states-with-most-coronavirus-cases-11587211201. Published April 18, 2020.
3 Lemieux JE, Siddle KJ, Shaw BM, et al. Phylogenetic analysis of SARS-CoV-2 in Boston highlights the impact of super spreading events. *Science*. 2020, eabe3261. https://doi.org/10.1126/science.abe3261. Published online December 10.
4 COVID-19 Dashboard - April 24, 2020. covid-19-dashboard-4-24-2020.Pdf | Mass.gov. https://www.mass.gov/doc/covid-19-dashboard-april-24-2020/.
5 Oxley TJ, Mocco J, Majidi S, et al. Large-vessel stroke as a presenting feature of Covid-19 in the young. *N Engl J Med*. 2020;382(20), e60. https://doi.org/10.1056/NEJMc2009787.
6 Clerkin Kevin J, Fried Justin A, Jayant Raikhelkar, et al. COVID-19 and cardiovascular disease. *Circulation*. 2020;141(20):1648–1655. https://doi.org/10.1161/CIRCULATIONAHA.120.046941.
7 Baldi E, Sechi GM, Mare C, et al. Out-of-Hospital cardiac arrest during the Covid-19 outbreak in Italy. *N Engl J Med*. 2020. https://doi.org/10.1056/NEJMc2010418. Published online April 29.
8 Bikdeli B, Madhavan MV, Jimenez D, et al. COVID-19 and thrombotic or thromboembolic disease: implications for prevention, antithrombotic therapy, and follow-up. *J Am Coll Cardiol*. 2020. https://doi.org/10.1016/j.jacc.2020.04.031. Published online April 17.
9 Edelson DP, Sasson C, Chan PS, et al. Interim guidance for basic and advanced life support in adults, children, and neonates with suspected or confirmed COVID-19: from the Emergency Cardiovascular Care Committee and get with the guidelines®-Resuscitation adult and Pediatric task forces of the American Heart Association in Collaboration with the American Academy of Pediatrics, American Association for Respiratory Care, American College of Emergency Physicians, The Society of Critical Care Anesthesiologists, and American Society of Anesthesiologists: Supporting Organizations: American Association of critical Care nurses and National EMS physicians. Circulation. 0(0). doi:10.1161/CIRCULATIONAHA.120.047463.
10 Fischer F, Lange K, Klose K, Greiner W, Kraemer A. Barriers and strategies in guideline implementation-A scoping review. *Healthcare (Basel)*. 2016;4(3):36. https://doi.org/10.3390/healthcare4030036. Published 2016 Jun 29.
11 Schwartz HEM, Stark NR, Sowa CS, Singh MK, Peabody CR. Building back better: applying lessons from the COVID-19 pandemic to expand critical information access [published online ahead of print, 2021 Mar 26]. *J Emerg Med*. 2021. https://doi.org/10.1016/j.jemermed.2021.03.014. S0736–4679(21)00297-3.
12 Keesara S, Jonas A, Schulman K. Covid-19 and health care's digital revolution. *N Engl J Med*. 2020;382(23):e82. https://doi.org/10.1056/NEJMp2005835.
13 Shanafelt T, Ripp J, Trockel M. Understanding and addressing sources of anxiety among health care professionals during the COVID-19 pandemic. *J Am Med Assoc*. 2020. https://doi.org/10.1001/jama.2020.5893. Published online April 07.
14 Altman M, Huang TTK, Breland JY. Design thinking in health care. *Prev Chronic Dis*. 2018;15:E117. https://doi.org/10.5888/pcd15.180128. Published 2018 Sep 27.
15 Mayer MA, Rodríguez Blanco O, Torrejon A. Use of health apps by nurses for professional purposes: web-based survey study. *JMIR Mhealth Uhealth*. 2019;7(11), e15195. https://doi.org/10.2196/15195.
16 Kessel KA, Vogel MME, Schmidt-Graf F, Combs SE. Mobile apps in oncology: a survey on health care professionals' attitude toward telemedicine, mHealth, and oncological apps. *J Med Internet Res*. 2016 Nov 24;18(11):e312. https://doi.org/10.2196/jmir.6399.
17 Hitti E, Hadid D, Melki J, Kaddoura R, Alameddine M. Mobile device use among emergency department healthcare professionals: prevalence, utilization and attitudes. *Sci Rep*. 2021 Jan 21;11(1):1917. https://doi.org/10.1038/s41598-021-81278-5.
18 Payne KB, Wharrad H, Watts K. Smartphone and medical related App use among medical students and junior doctors in the United Kingdom (UK): a regional survey. *BMC Med Inf Decis Making*. 2012 Oct 30;12:121. https://doi.org/10.1186/1472-6947-12-121.
19 Naguib MM, Ellström P, Järhult JD, Å Lundkvist, Olsen B. Towards pandemic preparedness beyond COVID-19. *Lancet Microbe*. 2020;1(5):e185–e186. https://doi.org/10.1016/S2666-5247(20)30088-4.
20 Morens DM, Breman JG, Calisher CH, et al. The origin of COVID-19 and why it matters. *Am J Trop Med Hyg*. 2020;103(3):955–959. https://doi.org/10.4269/ajtmh.20-0849.
21 Lai L, Wittbold KA, Dadabhoy FZ, et al. Digital triage: novel strategies for population health management in response to the COVID-19 pandemic. *Healthc (Amst)*. 2020 Dec;8(4):100493. https://doi.org/10.1016/j.hjdsi.2020.100493. Epub 2020 Oct 26.
22 Fagherazzi G, Goetzinger C, Rashid MA, Aguayo GA, Huiart L. Digital health strategies to fight COVID-19 worldwide: challenges, recommendations, and a call for papers. *J Med Internet Res*. 2020;22(6), e19284. https://doi.org/10.2196/19284. Published 2020 Jun 16.