Systems Analysis of a Dedicated Ambulatory Respiratory Unit for Seeing and Ensuring Follow-up of Patients With COVID-19 Symptoms

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Abstract: COVID-19 necessitated significant care redesign, including new ambulatory workflows to handle surge volumes, protect patients and staff, and ensure timely reliable care. Opportunities also exist to harvest lessons from workflow innovations to benefit routine care. We describe a dedicated COVID-19 ambulatory unit for closing testing and follow-up loops characterized by standardized workflows and electronic communication, documentation, and order placement. More than 85% of follow-ups were completed within 24 hours, with no observed staff, nor patient infections associated with unit operations. Identified issues include role confusion, staffing and gatekeeping bottlenecks, and patient reluctance to visit in person or discuss concerns with phone screeners. **Key words:** *COVID-19, symptom follow-up, systems engineering*

THE COVID-19 PANDEMIC necessitated dramatic changes in inpatient and ambulatory care practice (Armocida et al., 2020; Korr, 2020; Murray, 2020; Occhipinti & Pastorelli, 2020; Ranney et al., 2020; Wilkinson, 2020; Wosik et al., 2020; Xie et al., 2020), including rapid implementation of virtual diagnostic and care processes to minimize in-person visits of infected and

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noninfected individuals. Some health systems created specialized outpatient units for patients with COVID-19 symptoms needing in-person visits (Jacobson et al., 2020; Kricke et al., 2020; Lim & Wong, 2020), enabling primary care practices to continue seeing symptom-free patients, decrease exposures, and concentrate limited personal protective equipment (PPE) within COVID-19 units.

In April 2020, the Beth Israel Deaconess Medical Center opened a dedicated Ambulatory Respiratory Cohorted Care Unit (ARCCU) to see patients with known or suspected exposure to COVID-19. Patients were triaged to the ARCCU from a hospital-based teaching primary care practice (Healthcare Associates, HCA) that cares for roughly 40 000 patients, a hospital-licensed community health center (Bowdoin Street Health Center, BSHC), and several other Beth Israel Deaconess Medical Center community health centers. Patients from both practices were evaluated by phone for COVID-like symptoms and referred to the ARCCU if they had symptoms of sufficient concern to merit in-person evaluation.

As part of a broader study of "loop-closing" processes for tests, referrals, and worrisome symptoms, we conducted a systems analysis of processes developed within this new COVID-19 unit to understand new workflows, innovations, and lessons that might inform diagnostic loop closing in routine practice. Throughout health care, test and referral loop closing remain significant safety concerns (Institute for Healthcare Improvement, 2017; Patel et al., 2018; Schiff et al., 2009; Singh et al., 2013; Singh et al., 2017) and follow-up processes for concerning symptoms are even more variable and unreliable (Berner et al., 2014).

METHODS

To understand workflows, cross-functional process diagrams were developed from unit documentation and group interviews with referring and staffing clinicians, ARCCU triage nurses, patient service representatives, residents, and administrative and scheduling staff. Activity durations and capacities were estimated by clinical, frontline, and administrative personnel. Time delays, bottlenecks, and other problems were identified and compared with pre-COVID-19 practices.

Electronic data were abstracted for all ARCCU patient visits, diagnoses, whether seen at HCA or BSHC within 7 days prior to their ARCCU visit, sociodemographic information, test results, and referrals. Diagnoses considered to be suggestive of COVID-19 symptoms included any acute respiratory symptoms such as cough, sore throat, congestion, fever, and shortness of breath, as well as chest pain or loss of taste or smell.

Chart reviews of symptom-tracking processes were conducted on a random sample of 110 ARCCU visits (101 unique patients) during April 2020. Each chart was reviewed by 1 of 2 medically trained reviewers (fourth-year medical student, senior medicine resident) using a structured review instrument (see Supplemental Digital Content Figure S1, available at: http://links.lww.com/JACM/A101), with interrater reliability measured via dual independent review of a 10% random sample. Recorded information included patient demographics (age, gender, language spoken, ethnicity), symptoms reported consistent with COVID-19, tests ordered, subsequent result, and documentation, completion, and timeliness of any follow-up needs.

RESULTS

Figure 1 summarizes the ARCCU unit process logic, sequence of activities, and responsible personnel. Patients are referred to the unit after speaking by phone with a patient services representative (PSR) or triage nurse about their symptoms and concerns. A triage nurse or primary care provider (PCP) determines an appropriate care plan based on symptom severity; patients with mild COVID-19 symptoms are scheduled for telehealth visits while patients with moderate or severe symptoms are referred to the ARCCU or the emergency department (ED), respectively. The ARCCU administrative staff, triage
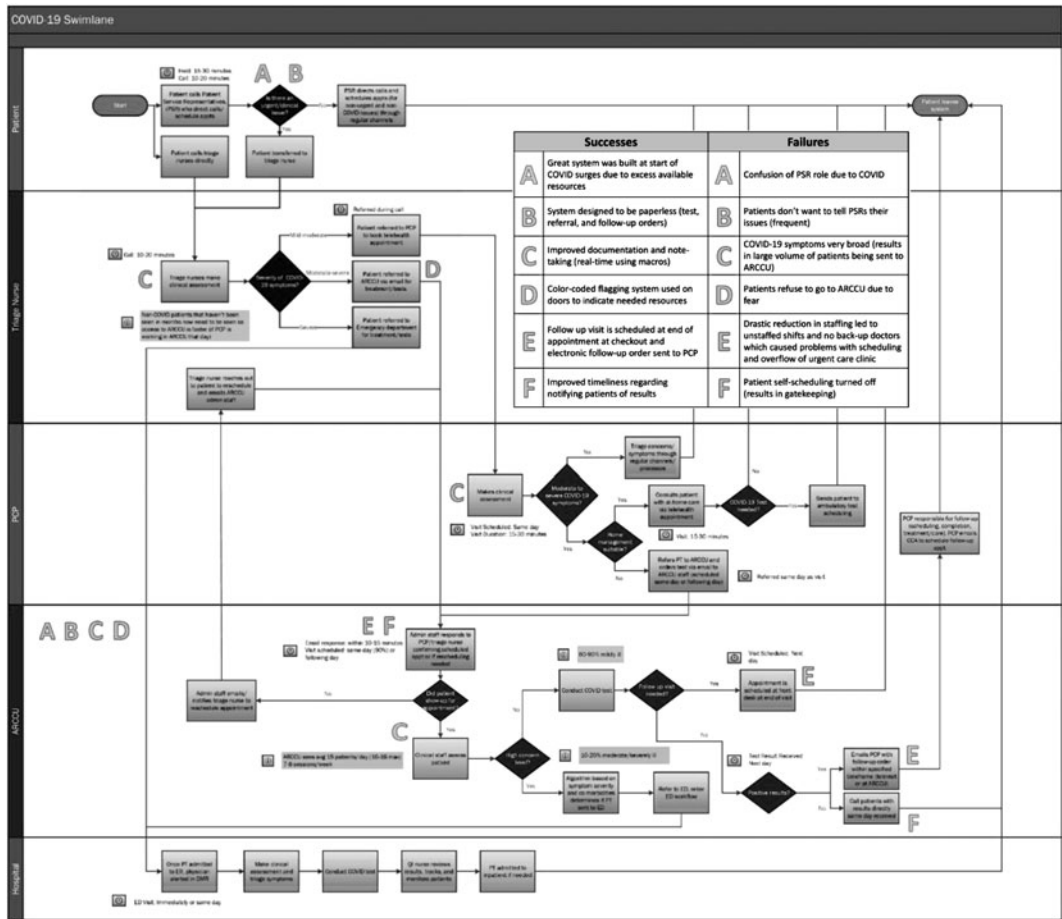
Figure 1. Cross-functional process map of the ARCCU-dedicated COVID-19 unit, showing patient triage, intake, visit, testing, and follow-up processes by location and personnel. ARCCU indicates Ambulatory Respiratory Cohorted Care Unit; CCA, clinical care assistant; ED, emergency department; PCP, primary care provider; PSR, patient service representative; PT, patient; QI, quality improvement.

nurses, or PCPs schedule same-day appointments for patients via email. Nearly all ARCCU processes are paperless to simplify and standardize tests, referrals, and follow-ups.

During an ARCCU visit, clinical staff determine whether a COVID-19 test and follow-up phone visit are needed, with patients informed of their test result during scheduled follow-up appointments the following day. For positive results, an electronic follow-up order is sent to the PCP within the electronic health record (EHR) indicating whether a subsequent telehealth visit or ARCCU visit is needed and within what time frame. For symptoms needing follow-up, the ARCCU

physicians use a standardized template added to the EHR that requires specifying how follow-up should be conducted (eg, phone vs in-person visit) and by when (eg, within 48 hours). This information is emailed to a clinical assistant responsible for scheduling follow-ups. Patients wear surgical masks provided during their visit or their own cloth, surgical, or N95 mask. The ARCCU staff follow standardized precautions that include gowns, eye protection, and surgical (non-N95) masks, each generally consuming 1 new mask daily. No new staff, nor patient infections were reported related to time spent in the unit.

Reliability and failure analysis results are denoted on the process map, with green lettering indicating activities that function with high reliability (notably all within the ARCCU) and orange lettering denoting common failure points. Process innovations include 100% paperless ordering, standardized documentation, manual scheduling of follow-up visits, protocols for timely patient notification of test results, and systematic symptom follow-up. Visit note templates were developed to standardize patient information collection, follow-up, and telephone management of potential COVID-19 patients by HCA and BSHC nurses. Templates were updated as new information on presenting symptoms of COVID-19 became available. A color-coded flagging system is used on ARCCU examination room doors to signal any needed resources such as COVID-19 tests or treatment equipment. Needed follow-up visits are scheduled during checkout before a patient leaves the ARCCU.

Common identified failures include confusion about PSR roles among patients and staff, patients not wanting to discuss health concerns with PSRs, challenges capturing the broad range of potential COVID-19 symptoms, patients declining to visit the ARCCU to avoid infection, ARCCU staff scheduling difficulties due to personnel reductions, and bottlenecks due to gatekeeping intended to mitigate demand volume but causing flow problems (via PSRs, triage nurses, disabled self-scheduling system). As nonclinical staff, PSRs initially were unsure how to assess symptom criticality and whether telehealth or ARCCU visits were more appropriate, resulting in many calls transferred to triage nurses, thus increasing patient delays and nurse burden. Any scheduling or protocol changes often were not communicated efficiently to PSRs, creating process confusion and inconsistencies. Given the myriad of COVID-19 symptoms, initially most phone-triaged patients were sent to the ARCCU even if COVID-19 was unlikely. High and changing ARCCU visit volume resulted in patients being unable to be scheduled until the following day or being sent to urgent care. The HCA's regular patient self-scheduling system was inactivated to enable staff to prescreen patients to determine the appropriate type of visit (telehealth or ARCCU).

Table 1 summarizes key identified differences between ARCCU and HCA processes, responsibilities, and timing. Overall, the ARCCU's standard procedures and roles helped ensure higher follow-up and referral completion rates. At HCA, documentation of tests, referrals, and follow-up orders occur in a variety of paper and electronic manners differing between PCPs, whereas the ARCCU completes all these electronically following a uniform process. The HCA providers also may document notes individually between visits or later in batches, whereas ARCCU providers type their notes during the actual visit, utilizing script macros to increase efficiency. Most referrals initiated by the HCA are ordered via their EHR, whereas the ARCCU places most referrals via email. Appointments at HCA are scheduled in a variety of ways by hospital staff or patients, depending on clinicians, urgency, and included departments, whereas all ARCCU appointments are scheduled by dedicated internal staff.

Most appointment no-shows for HCA-ordered referrals trigger no follow-up actions, whereas any patient who does not attend an ARCCU appointment an email is sent to the ordering staff the same day. Test results are sent to the HCA providers in multiple ways (emails, phone calls, faxes, EHR) and without a defined timeline, which then are reviewed and patients notified on the basis of criticality; in contrast, all COVID-19 test results are received by the ARCCU in an EHR test tracking module the day after ordered, with patients called by an ARCCU provider within 1 to 2 days of receipt. Lastly, the HCA processes by which follow-ups and scheduling are conducted can vary on the basis of each provider's preference and relationship with their patients, whereas all ARCCU providers send all follow-up orders to the patient's PCP and all subsequent ARCCU appointments including televisits are scheduled at the time of checkout.

Table 1. Comparison of Processes and Roles Between Existing 2 Primary Care Clinics and New COVID ARCCU Clinic Related to Follow-up and Loop-Closing Processes

Function	HCA/Bowdoin	Who	When	ARCCU	Who	When
Documentation	Semipaperless (test/referral/follow-up orders on paper)	Care team	N/A	Paperless (test orders, referrals, follow up all electronic)	Care team	N/A
Taking notes	Variable, dictating/bulking with other notes	Provider	Variable	Typed, utilizing macros	Provider	During visit
Referrals	Referrals ordered through EMR (then faxed to specialties)	Provider	End of visit	Referrals to ARCCU ordered through email	Nurse/provider	End of call/visit
Scheduling appointments	Variable: admin staff, departments, or patients schedule appt. Triage nurses/PSRs can schedule directly for all providers	Variable	Variable	Dedicated internal staff schedules for ARCCU. Better access: same/next day scheduling	Dedicated internal staff	Same day
No-show counter actions	None (except radiology)	Internal team	Email 1×/mo	Staff emails triage nurse/PCP if no-show on same day	ARCCU staff	Same day
Reviewing test results	Results/notes received with larger time delay (via fax, messages tab, test tracker tab). Patients notified via letters or calls (dependent on criticality)	Provider	Depends on criticality	Results received next day (via test tracker tab). Patients notified via call within 1-2 d of test (for all patients)	ARCCU provider	1-2 d of results
Follow-up and scheduling	Variable: no SOP	Variable	Variable	ARCCU provider sends electronic follow-up order to PCP. Schedule follow-up appt with front desk at checkout	Front desk	During checkout

Abbreviations: appt, appointment; ARCCU, Ambulatory Respiratory Cohorted Care Unit; HCA, Healthcare Associates; N/A, not applicable; EMR, electronic medical record; PCP, primary care provider; PSRs, patient services representatives; SOP, standard operating procedure.

All HCA and BSHC patients with suspected COVID-19 symptoms or exposure were managed via telehealth or referred to the ARCCU or the ED depending on concern level. For HCA patients seen virtually, roughly 20% (1358) had symptoms consistent with COVID-19, were triaged by a HCA nurse, and scheduled for a televisit with their PCP if there was any safety concern. Counseling about isolation, self-care, and testing options was done during these nurse or physician phone encounters. Between 40% and 50% of HCA telehealth visits addressed COVID-19 concerns (either as a primary issue or as a secondary issue). Since mid-April, BSHC offered on-site COVID-19 polymerase chain reaction (PCR) testing to their patients and community members, with 1423 patients tested between April and July 2020.

Table 2 summarizes visit volumes and demographics of all 712 patients seen in the ARCCU between April 7, 2020, and July 15, 2020; 22.8% were older than 65 years, 64.6% were female, and 29.5% self-identified as African American. Approximately 13.2% of patients (n = 94) had multiple ARCCU visits with an average of 1.16 visits per patient (SD = 0.45, range: 1-4 visits).

Primary care volumes and visit modality (telehealth, episodic in-person, ARCCU) exhibited significant changes over the study time frame (Figure 2). The vast majority of primary care visits were via telehealth, increasing from less than 10% in early March 2020 to roughly 90% in May 2020, followed by a slight decline to approximately 82% by summer. While ARCCU visit volume remained fairly consistent, averaging roughly 57 patients per week, roughly 30% of all visits were to the ARCCU during April 2020, decreasing to roughly 5% thereafter due to significantly increased HCA telehealth visits (40%-60% during April 2020, 80%-90% thereafter). Differences in visit type by age, gender, and primary language all were statistically significant (χ^2, $P < .001$), with a slightly higher percentage of elderly (older than 65 years), male, and English-as-primary-language patients using telehealth visits.

For the 101 chart review patients, demographics were representative of the larger ARCCU patient population, with good interrater consistency in determining whether follow-up occurred ($\kappa = 0.64$, $P = .002$; 95% confidence interval [CI], 0.31-0.99). Most of these patients presented to the ARCCU with symptoms classic for SARS-CoV2 infection (Table 3) with the most common symptoms being cough (81%), shortness of breath (62%), and myalgia (51%). Additional symptoms documented in free text but not listed on EHR checkboxes included chest pain/pressure, chest tightness, anorexia, and fatigue. More than half of presenting symptoms were considered mild by ARCCU clinicians, and hypoxemia at the time of presentation was rare (ie, oxygen saturation at room air was 92% or below in only 2% of cases). More than 70% of patients had one or more significant medical comorbidity, such as diabetes or chronic pulmonary disease (eg, asthma, chronic obstructive pulmonary disease), that placed them at a higher risk of complications. Approximately 42.7% of chart reviewed visits occurred within 10 days of symptom onset while the remaining 57.3% occurred after 10 days of onset.

Approximately 64.5% of reviewed cases were deemed by the ARCCU clinician to warrant COVID-19 nasopharyngeal swab RT-PCR testing, based on institutional guidelines that evolved over this time period; initially, only higher risk symptomatic patients were referred for testing, given limited testing capacity. Two patients within this group declined testing, and of those tested 34.8% had positive results (see Supplemental Digital Content Table S1, available at: http://links.lww.com/JACM/A102). Approximately 29.2% of those who tested positive at the ARCCU also had a prior positive RT-PCR. Thirteen patients had ED visits within 2 weeks of their ARCCU visit, four of whom were referrals made by the ARCCU physicians. Nine patients visited the ED due to symptoms felt to be related to suspected worsening COVID-19 infection. No failures in symptom follow-up were identified in this subgroup except one case for which the ARCCU physician did not

Table 2. Patient Volumes and Demographics, Specialized COVID-19 Respiratory Clinic

	All Visits (4/15-7/15/20)		Chart Reviews (4/7-5/5/20)	
	N	%	N	%
Total	828	...	110	...
Unique patients	712	...	101	...
Patients with 1 ARCCU visit	618	86.8	94	93.1
Patients with 2 ARCCU visits	75	10.5	6	5.9
Patients with 3 ARCCU visits	16	2.2	0	0
Patients with 4 ARCCU visits	3	0.4	1	1
Gender				
Female	460	64.6	67	66
Male	252	35.4	34	34
Age grouping, y				
≥65	162	22.8	16	16
<65	550	77.2	85	84
Primary language				
English	640	89.9	90	89
Spanish	33	4.6	5	5
Russian	8	1.1	0	0
Haitian	7	1.0	1	1
Cape Verdean	4	0.6	2	2
Others	20	2.8	3	3
Insurance				
Commercial	397	55.8	...	
Medicare/Medicare advantage	160	22.5	...	
MassHealth	98	13.8	...	
SCO	32	4.5	...	
HSNO/MassHealth Limited	15	2.1	...	
Kidney transplant recipient	5	0.7	...	
Self-pay	5	0.7	...	
Race				
Native American	3	0.4	0	0
Asian	41	5.8	5	5
Black/African American	210	29.5	38	38
White	383	53.8	42	42
Declined/not reported	11	1.5	1	1
Other/unknown[a]	64	0.0	15	15
Ethnicity				
Hispanic	77	11.0	12	12
Non-Hispanic	585	83.4	88	87
Unknown/not reported	39	5.6	1	1

Abbreviation: ARCCU, Ambulatory Respiratory Cohorted Care Unit.
[a]Ethnicity: 37, listed as Mexico, Central America, and Caribbean Islands.

document whether follow-up was indicated. Three of the ED visits resulted in hospital admissions.

For ARCCU visits in which the patients presented with concerning symptoms, 86 (78.2%) of the 110 reviewed charts had a physician-specified plan for follow-up, 15 (13.6%) were deemed by the physician to not require follow-up (ie, met low-risk criteria), and 9 (8.2%) had incomplete documentation
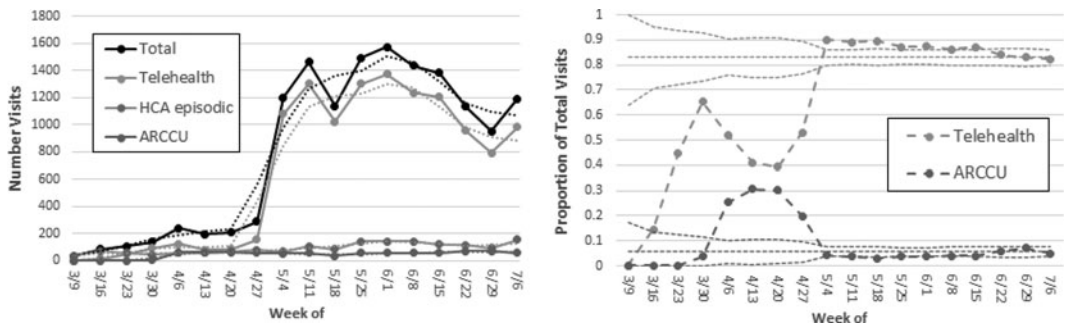
Figure 2. Longitudinal trends in ARCCU, telehealth, and in-person HCA episodic visits, April 15 to July 15, 2020. Left-hand figure: Total visit volume by type (dotted lines: 3-week moving average). Right-hand figure: Proportion of visits by type (dashed lines: statistical control limits, indicating statistical significance or stability. ARCCU indicates Ambulatory Respiratory Cohorted Care Unit; HCA, Healthcare Associates.

regarding follow-up (ie, physicians did not complete the relevant template section). Patients for whom English was not their primary language had roughly 16.4 times higher odds (95% CI, 3.0-121.5; $P = .002$) of experiencing a failure to follow up on symptoms as specified; patients not meeting criteria for COVID-19 testing had roughly 8.2 times higher odds (95% CI, 1.9-44.7; $P = .007$) of not having a specified follow-up documented as completed (Table 4).

Among the 86 patients for whom follow-up was deemed warranted, home monitoring via check-in phone calls from the patient's ARCCU or primary care physician was selected in 92% of cases, with 8 of these (9.3%) experiencing a follow-up delay (ie, follow-up call conducted after the designated time period). No delays, however, exceeded 72 hours and none resulted in identifiable adverse outcomes. In most delay cases, the specified follow-up should have occurred during a weekend but instead was completed the following Monday. Only 3 patients assessed during their initial ARCCU visit were asked to return for an in-person follow-up.

Table 3. Patient Characteristics at the Time of Presentation to the Ambulatory Respiratory Cohorted Care Unit (Based on Chart Review)

Symptoms	N (%)
Cough	87 (81)
Shortness of breath	67 (62)
Other symptom(s)	65 (59)
Myalgia	55 (51)
Headache	51 (47)
Fever	45 (42)
Diarrhea	29 (27)
Sore throat	28 (26)
Nausea/vomiting	21 (19)
Anosmia/ageusia	20 (19)
Severity of symptoms	
Mild	61 (58)
Moderate	41 (39)
Sever	3 (3)
Number of medical comorbidities	
0	31 (28)
1	27 (34)
2	22 (20)
≥3	20 (18)
Days from symptom onset	
<5	20 (19)
5-9	24 (23)
10-14	24 (23)
15-29	14 (14)
≥30	21 (20)
Pulse Ox at room air (%)	
≤92	2 (2)

DISCUSSION

Specialized outpatient units can serve important roles to safely and efficiently care for suspected COVID-19 patients. Our study of one such unit found that new processes could be developed and implemented to efficiently and reliably follow up on symptoms, test results, and referrals. Space was rapidly identified and retrofitted, clinicians and staff recruited, and new paperless workflows

Table 4. Predictors of Failure to Follow up on COVID-19 Symptoms as Specified by Provider (Multinomial Logistic Regression Results; n = 86 Patients Seen in Acute Respiratory Covid Clinical Unit With a Follow-up Specified in Their Medical Record

Characteristic	Odds Ratio	95% CI	*P*
Gender			
Female	0.78	0.17-3.3	.7
Male			
Race			
White	1.12	0.25-5.5	.9
Other			
Ethnicity			
Hispanic/Latino	2.34	0.33-27.1	.4
Not Hispanic nor Latino			
Primary language			
English	16.4	3.0-121.5	.002[a]
Other			
Met criteria for COVID-19 testing			
Yes	8.2	1.9-44.7	.007[a]
No			

Abbreviation: CI, confidence interval.
[a]Statistical significance.

created including specialized encounter templates. Although follow-up was still less than 100%, the COVID-19 clinic effectively implemented new and reliable systems, particularly for symptom follow-up (an aspiration seldom achieved in routine care). Improvements to address the identified language and workflow barriers, for example, included referring health centers taking over follow-ups of their own patients and use of interpreters in other cases.

Similar specialized primary care COVID-19 processes have been described by others, as well as similar challenges to balance staffing and utilization, given variable patient volumes and same-day scheduling (Institute for Healthcare Improvement, 2017; Jacobson et al., 2020; Lim & Wong, 2020). Instead of dedicated units, the Singapore health system developed separate workflows and spaces for suspected COVID-19 patients within each of its 50 general practice clinics, with electronic tracking and phone follow-up after a 3- to 5-day potential incubation period of upper respiratory tract infection (URTI) patients not suspected for COVID-19 (Jacobson et al., 2020). Alternately, Kricke et al. (2020) describe a monitoring process for patients with only mild COVID-19 symptoms caring for themselves at home that includes an electronic tracking registry, an online daily symptom self-questionnaire, and phone outreach to patients not entering questionnaire data or with now-concerning symptoms (Institute for Healthcare Improvement, 2017).

Our study complements these papers with formal systems analyses and identification of lessons that might inform improved closed loop processes in routine care. In particular, the ARCCU processes for patient evaluation and symptom follow-up appear to be fairly reliable and have the potential to be adapted more broadly in primary care. Noted additional benefits of the dedicated unit include its ability to rapidly innovate systems of care, segregate patients with potentially contagious symptoms in areas separated from the general medicine primary care clinic, conserve personal protective equipment, increase patient safety perceptions, and create efficient specialized workflows (Song et al., 2015).

While not fully "automated" follow-up per se, electronic orders and standard protocols prompted reliable manual scheduling

and loop closing by clinicians and staff. Documentation templates also were an important tool for caring for suspected COVID-19 patients and rapidly evolved as knowledge developed about presenting symptoms, management, and isolation procedures; this process of using "dynamic templates" in times of clinical uncertainty also is important for other public health exigencies. Use of systems engineering to improve primary care also remains underutilized for understanding and designing reliable care processes (Kopach-Konrad et al., 2007; Pronovost et al., 2017; Watts et al., 2013). As illustrated, process maps and failure analysis can help study performance and identify improvement opportunities in processes such as these; related design and modeling methods can help generate further insights and develop more reliable and efficient processes (Benneyan, 1997; Kopach-Konrad et al., 2007).

Our study has several limitations. While our focus on a single unit may limit generalizability of specific findings, the described processes, templates, and analysis methods could be used or adapted broadly. Our data analysis and chart review were limited to patients during the early spring 2020, whereas characteristics of ARCCU patients, visits, and symptom duration varied as the pandemic evolved. Workflows and templates similarly evolved over time to ensure that clinicians were using the best and most recent available information. While much of the follow-up reliability may be attributable to process standardization, the variety of acute symptoms presenting in a general primary care clinic may be less amenable to such standardization. That systems to monitor and close-the-loop on concerning symptoms, however, is possible even in this less-varied context is encouraging. The COVID-19 unit also was created at a time when few patients were presenting with other diseases causing respiratory symptoms. Clinic operations, performance, and patient characteristics during a winter flu season, for example, will be important to evaluate.

Nonetheless, this study illustrates that specialized primary care clinics can serve important roles during this or other epidemics to provide safe and efficient care that reliably close diagnostic and symptom-monitoring loops. Further exploration might consider whether similar clinics could provide similar benefits in routine care of other patients. More generally, this study demonstrates the value of systems engineering methods for studying primary care process workflows, reliability, sources of failure, and improvement opportunities.

CONCLUSIONS

Transformative events such as pandemics often require new care delivery processes. Creation of a specialized ambulatory respiratory unit resulted in innovative and standardized care processes that provide safe, efficient, and reliable diagnostic care and symptom follow-up by separating known or potential COVID-19 patients from others. Novel processes within this unit functioned reliably to close loops for COVID-19 testing, referral, and symptom follow-up. Adherence to precautions including gown, surgical mask, and eye protection in the COVID-19 unit appeared to offer sufficient protection against infection. Combining systems engineering with health service research methods resulted in several insights that might help implement similar units in other health systems and improve other diagnostic loop-closing processes more generally.

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