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Learning from the first wave: Lessons about managing patient flow and resource utilization on medical wards at providence health during the COVID-19 pandemic

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\textbf{ABSTRACT}

We report the successful implementation of a modified Traffic Control Bundling (TCB) protocol called “Red, Yellow and Green” on the inpatient medical units at St. Paul’s Hospital in Vancouver, Canada during the first wave of the coronavirus disease 2019 (COVID-19) pandemic. The modified TCB protocol demonstrates an important example on how hospitals can rapidly reorganize operational and clinical processes to reallocate existing capacity to minimize exposure, improve traffic flow and reduce nosocomial transmissions of COVID-19 to health care workers (HCWs) and other patients. Preliminary evidence demonstrates the benefits on how an existing facility can be redesigned for adjustable ward capacity to provide disease containment under a context of uncertainty of disease transmission and varying patient load. Important lessons in preparation for the evolution of the pandemic fall into categories of risk management, capacity and demand management.

1. Background

As of August 13th, 2020, there are just over 21 million officially reported confirmed cases of the novel coronavirus infection causing coronavirus disease 2019 (COVID-19) throughout the world. The global pandemic is continuing to rapidly spread throughout the world as shown by a continued high record of 285,486 officially reported confirmed cases per day. In Canada, there have been 121,414 officially confirmed cases with 4,274 cases from British Columbia, of which 552 required hospitalization.

In terms of the scale of transmission and exerted impacts within the first wave of this pandemic (January 2020–June 2020), countries could be classified into three main groups: one first group (e.g., Germany, Italy, Canada, New Zealand) had reached and passed a peak of the pandemic (in terms of daily confirmed cases) and had decreasing transmission rates.\textsuperscript{1} The second group (e.g., Brazil, Iran) was in the process of hitting a peak and transmission rates were plateauing. The third was still experiencing a substantial increase in daily confirmed cases and had increasing transmission rates (e.g., India, Columbia).\textsuperscript{2} Many countries in the first category were effective in “flattening the curve” of the virus by implementing a wide variety of policy and preventative measures. These measures, designed to slow the spread of the virus, included time-based quarantines, border closures, mandatory lockdowns, travel bans, social distancing and hand washing among others. The economic costs and the scale of social consequences of these measures varied widely and as many countries in the first group relaxed preventative measures and re-opened economies, there was a growing need to specifically target measures with maximum impact and minimal economic cost in preparation of potential subsequent waves.\textsuperscript{3} The cycle of community – health care facility – community transmission has been an important source of viral propagation and interventions designed to limit the size and scope of outbreaks at these facilities are particularly important opportunities.

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to intervene. This focus on community – health care facility – community transmission is important not just for the health and wellness of our front-line workers, but also because it represents a major source of potential super-spreading events like we have seen in previous SARS infections.

In this paper, we report the experience of adapting the operational and planning systems used on the inpatient medical units at St. Paul’s Hospital in Vancouver, BC during the first wave of the pandemic in our Province. Our aim during this first wave was to develop a scalable, flexible system of managing patient flow on our wards that provided the necessary level of biocontainment and safety for both patients and health care workers, thus minimizing the potential for nosocomial transmissions. More, we report on the lessons of our modified Traffic-Control-Bundling protocol for managing diagnostic and operational uncertainty, improving patient flow, and minimizing nosocomial transmission of COVID-19 to health care workers (HCWs).

Reporting on these lessons is needed. There has been very little shared information within the international medical community on planning and operational procedures used to mitigate the spread of COVID-19 within hospitals. Given the risk of subsequent waves of infection, this research is useful for healthcare providers working in countries in any stage of their outbreak. Furthermore, as we highlight in section 2.0, while patient flow protocols for COVID-19 learn and build on protocols for other respiratory pathogens such as the flu and SARS, prior research on this has focused on building new facilities to aid containment. With our case, an existing facility was reconfigured to be adjustable to attain disease containment in conjunction with uncertainty about disease transmission and varying patient load on the facility.

1.1. COVID-19 in British Columbia, Canada

In Canada, by April 28th, an estimated 10–20% of all officially reported confirmed cases were frontline healthcare workers. By this date, 428 healthcare workers represented about 21% of the virus cases reported in the province of British Columbia (BC), the jurisdiction of our study. Other nations reported similar healthcare worker exposure rates with up to 10% of reported cases in China and 9% of reported cases in Italy, though the hardest hit regions such as Spain reported rises up to 20%.

As shown in Fig. 1, the first wave of COVID-19 infections in BC started in early March and lasted until early June 2020. The first case of community spread was reported by public health on March 9th. The first local hospital outbreak occurred at Lions Gate Hospital on 13th March 2020. The first major measures to mitigate spread included a ban on mass gatherings of more than 50 people on March 16th, followed by a voluntary lockdown 2 days later on 18th March 2020.

It is likely that nosocomial outbreaks (i.e., infections caught in the hospital) play an important role in amplifying local outbreaks, and that the magnitude of this impact increases when health care facilities are forced to operate above capacity due to the massive escalation in load that comes with a health crisis.

1.2. Traffic Control Bundling

Literature on implemented protocols for improving patient flow during pandemic times are scarce. In this section, four protocols will be discussed to contrast the approach taken by St. Paul’s Hospital. The common objective of all these protocols is to control patient flow to effectively reduce infection rates among health care workers (HCWs). Characteristics of TCB include an outdoor triage to separate infected from non-infected patients, the use of isolation wards or hot zones where infected patients are quarantined into individual rooms and the transfer of infected patients using tightly controlled dedicated routings.

![Fig. 1. B.C. Daily reported cases of COVID-19 (7-day moving average).](image)
According to authors, the implementation of CRRI effectively reduced the burden of the hospital in Europe. The hospital established an intensive care unit (ICU) section for COVID-19 positive patients while maintaining the normal ICU operation. Pre-triage assessment outdoor; Staging Area separated.

The fourth protocol we discuss was used at the Policlinico Maggiore Hospital in Milan Italy. This region was one of the most impacted areas in Europe. The hospital established an intensive care unit (ICU) section for the COVID-19 positive patients while maintaining normal ICU operation for other patients. The key difference with this protocol was the use of a pre-triage assessment, carried out in an ambulance or a shelter unit outside the ER, to identify patients with and without respiratory symptoms. While having similar characteristics of TCB, it is unique as it recommissioned an entirely separate building for COVID-19 patients.

While having similar characteristics of TCB, it is unique as it recommissioned an entirely separate building for COVID-19 patients. Flexibility allows yellow and red wards to expand or contract in order to adapt to varying levels of COVID-19 patient admissions. Reduced risk of nosocomial infections on yellow wards for patients and staff. Enables best available evidence and up to date clinical factors to inform patient flow in the hospital by developing probability thresholds to guide risk assessments. Clinical heuristics and probability estimates can be locally adaptable. Generalizable to other service locations and infectious diseases (Flu) to prevent nosocomial transmission within existing hospital infrastructure.

Table 1
Hospital pandemic protocol comparisons.

| Author, Date | Name of Protocol (Date, Location, Pandemic Application) | Protocol Characteristics | Advantages | Possible Limitations |
|--------------|--------------------------------------------------------|--------------------------|------------|---------------------|
| Schwartz et. al., (2020) | Traffic Control Bundling (TCB) (2003, Taiwan, SARS-I) | Outdoor Triage; Isolation Ward (hot zone); Clean Zone; Transition Zone; Designated Route; Protocol Training; Regular Disinfection. | Authors report effective at reducing nosocomial transmission | Modifications needed for COVID-19 due to it being highly contagious and the manifestation of symptoms can vary quite a lot between patients, therefore requires an intermediate zone |
| Yen et. al., (2020) | Enhanced Traffic Control Bundling (eTCB) (2020, Taiwan, COVID-19) | Outdoor Triage; Isolation Ward (hot zone); Clean Zone; Transition Zone; Quarantine Ward (Intermediate Zone); Designated Route; Protocol Training; Regular Disinfection. | Compared to the foundational TCB, eTCB has a quarantine ward which target at isolating PUs that show atypical symptoms or have inconclusive test results. Changes further minimize the risk of nosocomial transmission | Potential to experience scale-issues when a large surge of COVID patients occurs |
| Augustin et. al., (2020) | Coronavirus Rapid Response Infrastructure (CRRI) (2020, Germany, COVID-19) | While sharing the same traits with eTCB, CRRI recommissions an entirely separate building for COVID-19 patients | Using an entirely separate building further reduces the chance of nosocomial transmissions between COVID patients and non-COVID patients; enables the hospital to have normal daily operations while dealing with COVID-19 | Very effective yet might incur some operational challenges for other hospitals to adapt. Not all hospitals have the capacity of quickly re-commission or commission a separate building |
| Carenzo et. al., (2020) | Protocol by Policlinico Maggiore Hospital (2020, Italy, COVID-19) | While sharing the same traits with eTCB, this protocol establishes an ICU section for COVID positive patients while maintaining the normal ICU operation. Pre-triage assessment outdoor; Staging Area separated. | The Staging Area with isolation in place allows patients to wait for the test results without having too much contact with each other or HCWs | Potential to experience scale-issues when a large surge of COVID patients occurs |
| Current Authors | Red, Yellow, Green Protocol (2020, Canada, COVID-19) | While having similar characteristics of eTCB patients admitted to yellow wards can be effectively moved to green spaces when risk of COVID-19 is felt to be low enough. Use of enhanced universal precautions on green wards (mandatory mask and face shield for all patient interactions, reduced visitation privileges). | Flexibility allows yellow and red wards to expand or contract in order to adapt to varying levels of COVID-19 patient admissions. Reduced risk of nosocomial infections on yellow wards for patients and staff. Enables best available evidence and up to date clinical factors to inform patient flow in the hospital by developing probability thresholds to guide risk assessments. Clinical heuristics and probability estimates can be locally adaptable. Generalizable to other service locations and infectious diseases (Flu) to prevent nosocomial transmission within existing hospital infrastructure. | Potential to experience scale-issues when a large surge of COVID patients occurs that is greater than hospital bed capacity. Costs: 1 extra handover of patients by nursing and physicians. Increased administrative burden to facilitate extra intra-site transfers. Increased administrative burden to adjust ward sizes/risk profiles to up to date clinical evidence. |

completely separate from clean zones. In addition, TCB advocates the use of transition zones between the clean and hot zones. The transition zones have directional signs, regular training of HCWs on TCB protocols and controlled disinfection in the clean and transition zones with necessary cleaning of fomites for hot zones to further reduce risks of transmission. As it effectively reduced nosocomial transmission for Taiwan during the SARS outbreak, these researchers anticipate that TCB will work effectively against COVID-19 with a marginal enhancement.

Enhanced Traffic Control Bundling (eTCB) extends the standard protocols of TCB but also establishes a quarantine ward or intermediate zone in which patients with atypical symptoms are required to stay for the entire incubation period. This protocol also advocates checkpoints for hand disinfection, requires mandatory face masks for visitors along with enhanced hospital cleaning and disinfection. eTCB is anticipated to break the community-hospital-community transmission cycle as TCB did with SARS.

The University Hospital Cologne in Cologne Germany recently implemented the COVID-19 Rapid Response Infrastructure (CRRI) as a protocol for managing patient flow. While the CRRI shares common traits with eTCB, it is unique as it recommissioned an entirely separate building for its purpose and all patients suspected of infection were to approach CRRI directly for initial triaging with nasopharyngeal swab and other preliminary tests. According to authors, the implementation of CRRI effectively reduced the burden of the hospital’s ER department while increasing the numbers of tests being conducted.
geographic and temporal variability, and the high infection rates among HCWs around the world. We describe a system of modified Traffic Control Bundling within the existing hospital infrastructure that is both flexible and scalable making it specifically designed to handle the increased uncertainty that exists during a pandemic. This system more effectively allows hospitals to utilize existing resources, minimizes erroneous resource allocation, and allows more effective matching of their supply and demand.

2. Organizational context: Clinical Teaching Unit at St. Paul’s hospital

St. Paul’s Hospital is an inner-city tertiary care center located in downtown Vancouver, BC Canada. It is a referral center for patients located in both BC and the Yukon Territories. There are 5 Internal Medicine run Clinical Teaching Units (CTU) that admit patients to beds located on 4 separate wards (7a through d) with overflow capacity to other off-service wards. Each ward consists of 5 private rooms, 4 semi-private (2 beds per room), and 3 group (4 beds per room) rooms. CTU teams would typically be divided geographically, with one team per ward and one roaming team with patients on all 4 wards, given capacity constraints it is common for these teams to have patients admitted to other off-service wards.

CTUs at St. Paul’s Hospital are just one of the medical services admitting patients to a maximum on and off-service medical bed capacity of 120 beds. Patients are admitted via one of three routes: direct admits from the emergency department, in transfer from the ICU, or in transfer from an alternate admitting service. Separate measures to isolate and limit spread of COVID-19 were undertaken by various services including the ICU and Emergency Departments under the guidance of a COVID-19 Emergency Operations Committee (EOC) that was created to lead and coordinate the COVID-19 strategic response. From early March 2020 to end of May 2020, this paper focuses specifically on the changes made to patient flow on our inpatient medical wards in response to the uncertainty resulting from the pandemic as an example for other inpatient services.

3. Problem

The novel nature of COVID-19 means that not only is it new to society, but our understanding of disease diagnosis and how it is transmitted (i.e., is it aerosolized or not, and under what circumstances might it be aerosolized) is limited. This in turn impacts our understanding of how to manage patient flow to prevent nosocomial spread. While a number of cohort studies on patients from China, 4 Italy, 14 and New York 15 have improved our understanding of the clinical features of the disease, there is yet to be a set of clinical features that precisely and accurately predicts one’s likelihood of COVID-19. Clinical and epidemiologic factors continue to be the most important indicators of probability of a given patient having COVID-19. These diagnostic challenges are exemplified on medicine wards where patients often suffer with similar symptoms from sepsis and other systemic illnesses, further highlighting the need for effective diagnostic testing. This testing was performed via a combination of nasopharyngeal swabs, oral/throat swabs, sputum cultures, and stool samples however, a lack of pre-existing well validated test characteristics for these methods meant that uncertainty as to a patient’s post-test probability of having COVID-19 infection often remained even after initial tests were performed. This uncertainty was one of the major challenges we would need to overcome to effectively mitigate spread of this disease to our vulnerable inpatient populations.

Furthermore, with baseline hospital operations on medicine wards typically operating at or exceeding capacity, the increased uncertainty and variability in capacity and demand as a result of the spreading COVID pandemic also represent potential challenges when allocating resources to efficiently match supply with demand.

4. Solution: “red”, “yellow”, “green”. A modified traffic controlled bundling protocol at St. Paul’s hospital

To address the challenges of patient flow during the COVID-19 pandemic, the Internal Medicine service at St. Paul’s Hospital has initiated a “Red”, “Yellow”, “Green” strategy, a modified TCB, to designate inpatient spaces on its medicine wards where most non-critically ill confirmed COVID-19 and persons under investigation (PUIs) are admitted. Admitting physicians are tasked with developing a system of stratifying patients in 1 of 3 risk profiles. These risk-profiles are then assigned to specific wards based on pretest probability of disease. “Red” spaces are reserved for patients confirmed to have COVID-19, “Green” spaces are reserved for patients felt to be of low enough diagnostic probability for COVID-19 infection that they can be cohorted as usual with universal precautions, and “Yellow” spaces are reserved for patients felt to be of great enough diagnostic probability for COVID-19 infection that additional infection control precautions are felt to be warranted. Red and Yellow wards have the strictest infection control measures involving reduced density of patient cohorting, access restrictions for health care providers, restrictions on medical student and learner access, etc. as guided by local Infection Prevention and Control Staff. These wards represent possible locations of nosocomial spread and often require additional resources (bed spaces, altered nursing ratio/physician ratios, increased consumption of PPE etc.) to adequately prevent these infections. Green wards, manned by our existing CTU teams, operate with enhanced universal precautions for infection control and are characterized by normal hospital operations, patient density, and resource allocation, but with some universal enhancements such as mandatory face masks and eye protection for all patient interactions and reduced visiting privileges for patients. Patients admitted to Red and Yellow wards are cared for by designated COVID teams to limit potential spread to HCW and patients in Green zones. A triage process is decided upon by the admitting service to guide patient flow through these wards. The operational goals of the system are to limit the length of stay and number of patients located in yellow zones as these also represent possible opportunities for nosocomial spread. Patients that don’t have COVID-19 infection are exposed to a high-risk environment, and patients with COVID-19 have an increased chance of spreading their disease to other patients. Because the pre-test probability of disease for a given admission to hospital changes so rapidly during a pandemic, the admitting team must remain astute to these changes and clearly/reliably update their processes for designating patients to various wards.

The following is an example employed at St. Paul’s Hospital during the first wave of cases: As shown in Fig. 2, patient arrivals for suspected COVID-19 patients occur through the Emergency Department, through Intensive Care Units, or from another medical unit. The majority of suspected cases related to COVID-19 are admitted through the Clinical Teaching Unit (CTU) where depending on their diagnosis, are classified as low, moderate or high-risk patients.

On admission the epidemiologic risk, history, physician exam, and investigations lead the admitting staff to assign a pre-test probability for COVID-19. Any patient with a positive swab goes to the red wards. Patients with low pre-test probability get admitted to the yellow ward and once their first COVID-19 swab is negative they are moved to a green ward. Patients with moderate pre-test probability require two negative Nasopharyngeal (NP) swabs 24 hours apart and consistent clinical picture to designate them low enough risk to be moved to a green zone. Patients with high pre-test probability often either stay in the Yellow zone until discharged despite negative testing or require multiple diagnostic tests and a compatible clinical diagnosis before moving to a green zone.

The St. Paul’s Hospital case is also interesting in that it involved temporarily reconfiguring an existing health care facility (i.e. no new extra space was required). Whereas the prior literature cases in Table 1 involved creating completely new facilities or required extensions.
beyond current facilities for the pandemic. This is important for public health care facilities which tend to be highly constrained for capital for new infrastructure projects.\textsuperscript{16,17} Furthermore, existing facilities need to be able to cope with changing demand for resources from other admitting services, as well as patient loads due to planning decisions for multiple hospitals in the region. In response, St. Paul’s Hospital not only reorganized the layout of its facility to have the three zones (Green, Yellow and Red), but also framed the zones using adjustable dividers. This allowed the size and capacity of each zone to be adjusted. Another key layout change involved creating a negative air pressure vacuum in the patient rooms of the Yellow and Red zones through the configuration of vents through windows to allow for greater air transfer outward than inward.

5. Unresolved questions and lessons for the field

As COVID-19 infections in health care facilities continue to occur, it has become increasingly clear that community – health care facility – community transmission is important not just for the health and wellness of our front-line workers but for entire communities.\textsuperscript{18} The uncertainty surrounding the clinical features, mechanism of transmission, and diagnostic/test characteristics of COVID-19 have posed major challenges to limiting nosocomial spread in health care facilities. The modified TCB system implemented at St. Paul’s Hospital provides one model for how to integrate operational and clinical protocols to optimize patient flow on hospital wards during a pandemic. In Table 1, we outline how the St. Paul’s Hospital protocol builds on and differs from the four comparative protocols used during pandemic times. By implementing a clinical system of triaging risk that incorporates up to date research and loco-regional epidemiological factors, we can more effectively manage the risk of nosocomial infections at health care facilities and more efficiently deploy resources. The development of hospital wide enhanced universal precautions serves as a second level of protection, effectively buffering against errors in incorrect patient allocation. Through this
implementation, the modified TCB protocol adopted at St. Paul’s Hospital was one of several factors that contributed to keeping the nosocomial transmissions of COVID-19 to zero on the Internal Medicine wards.

Lessons learned for implementing the modified TCB protocol fall into categories of risk management, capacity management and demand management. One invaluable lesson has been the overall structure of the medicine wards in their ability to refine themselves using a heuristically based system of capacity and demand management. As shown in Fig. 3, implementation of the protocol has provided the ability through which wards can expand and contract to best react to the pandemic demands while maintaining daily hospital procedures.

While we acknowledge the extra costs associated with patient handovers, they must be balanced against the costs of outbreak management and containment. The impact of this protocol on patient care, costs associated with this model are a subject of future research. Yet to be seen, is the extent to which the protocol can still be applied and provide benefit as the pandemic evolves. To-date, we find evidence that the protocol’s application is beneficial in situations where pandemic cases are not explosive, but rather COVID-19 cases are expected to experience moderate expansion and contraction over time and can be cared for within the existing capacity of local health care facilities. Given the current state of the pandemic whereby most hospitals worldwide have experienced some influx of COVID-19 patients, this protocol provides an important application on how hospitals can manage their operational and clinical processes within specific departments to mitigate spread of the virus while maintaining daily hospital processes. The modified TCB protocol adopted demonstrates one important example on how hospitals can reallocate existing capacity to minimize exposure and reduce nosocomial transmissions in circumstances where hospitals are not being built specifically for pandemic relief. Finally, we hope our study will motivate future research on the efficacy of this patient flow approach protocol compared to other protocols, the impact on length of stay of triage system on other respiratory pathogens, and the impact of the protocol on other quality and safety measures.

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.

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