[Critical Care Original Research]

CHEST

The Minnesota Critical Care Working Group 1

Monitoring and Coordinating Statewide Critical Care Surge Response in the COVID-19 Pandemic, March 2020 Through July 1, 2021

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BACKGROUND: In response to the COVID-19 pandemic and as part of the statewide health care coalition response, the Minnesota Critical Care Working Group (CCWG), composed of interprofessional leaders from the state's 9 largest health systems, was established and entrusted to plan and coordinate critical care support for Minnesota from March 2020 through July 1, 2021.

RESEARCH QUESTION: Can a statewide CCWG develop contingency and crisis-level surge strategies and indicators in response to the COVID-19 pandemic while evolving into a highly collaborative team?

STUDY DESIGN AND METHODS: CCWG members (intensivists, ethicists, nurses, Minnesota Department of Health and Minnesota Hospital Association leaders) met by audio video conferencing as often as daily assessing COVID-19 and non-COVID-19 hospitalization data, developed surge evidence reflecting contingency vs crisis conditions, and planned responses collaboratively. A foundation of collaboration and teamwork developed which facilitated an effective statewide response.

RESULTS: Pandemic surge health care system strategies included use of surge ICU beds, adapted staffing models, restriction of nonemergency procedures, augmentation of tele-ICU care, ability to recognize increasing staff shortages, use of PICU beds for younger adults, and use of noninvasive ventilation in non-ICU settings. CCWG supported development of the Minnesota Medical Operations Coordination Center, which was instrumental in load balancing and mitigating crisis conditions. Minnesota surge strategies are compared with published prepandemic and pandemic experiences regarding staff, space, supplies and medications/equipment, and system strategies. Adopted severe surge best practices included use of adapted staffing models and noninvasive ventilation in non-ICU settings. CCWG effectively developed shared strategies and facilitated ICU load balancing, which supported a regionally consistent standard of care.

INTERPRETATION: CCWG developed statewide critical care surge strategies assisting health care organization response to COVID-19 surges, providing a platform for clinical and operational activities. Collaboration, trust, and teamwork between CCWG leaders and health care organizations was essential to success and serves as a model for future events.

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KEY WORDS: allocation of scarce resources; contingency level care; crisis care conditions; pandemic best practices; surge; surge-level indicators

Take-Home Points

Study Question: Can a statewide Critical Care Working Group develop contingency and crisis surge strategies in response to the COVID-19 pandemic while evolving into a highly collaborative team?

Results: The working group developed pandemic surge strategies and facilitated ICU load balancing which supported a regionally consistent standard of care.

Interpretation: The critical care surge strategies and load balancing activities provided a platform for clinical and operational achievements, accomplished by a highly collaborative team.

The Task Force for Mass Critical Care recognized with 2014 guidance the importance and urgency of statewide and regional communication and coordination in the event of a pandemic.[1-3] These strategies have been updated based on pandemic experiences.[4]

Internationally, some countries leveraged critical care infrastructures for coordination although without outcomes data.[5,6] Domestically, some states established successful electronic dashboards and coordination centers for load balancing patients who are critically ill.[7-11] California and Nebraska provided examples of comprehensive strategies for optimizing contingency resources across the spectrum of statewide care to delay or mitigate crisis conditions.[12] Although principles for supporting health care during a severe COVID-19 surge may be similar, their application is inevitably different given different circumstances, resources, and political dynamics of care.[12]

Most states entering the pandemic had coordination infrastructure; however, some had few health care response assets.[13,14] Minnesota was among those states investing considerable resources into pandemic and disaster preparedness. This included robust public health organization and 8 substate regional health care coalitions working closely with hospitals, public health, emergency medical services, and emergency management.[14,15]

The Minnesota Critical Care Working Group (CCWG) was established as a statewide collaborative at the beginning of the COVID-19 pandemic with the mission to plan for and support Minnesota's critical care response. This paper describes CCWG experience from March 2020 to July 1, 2021, and compares it with published experience before and during COVID-19 with recommendations for future events and research objectives. A second paper describes the CCWG experience with crisis conditions and triage of scarce resource processes from July 1, 2021, to March 30, 2022, the more difficult year of the COVID-19 pandemic.[16]

These 2 papers are unique in describing statewide coordinated critical care operations during the first 2 COVID-19 pandemic years. Coupled with CCWG's contributions to the design and operation of Minnesota's Medical Operations Coordination Center (MOCC), they provide an analytical and comprehensive overview of a statewide critical care response which may help other states in future planning for disasters.[10,16]

Study Design and Methods

The Minnesota Department of Health (MDH) activated their Department Operations Center in January 2020 in response to a novel disease emerging in China. With the first confirmed Minnesota case of COVID-19 on March 6, 2020, the State Emergency Operations Center (SEOC)

ABBREVIATIONS: CCWG = Critical Care Working Group; EWG = Ethics Working Group; HFNC = high flow nasal cannula; MCEC = Minnesota COVID Ethics Collaborative; MDH = Minnesota Department of Health; MHA = Minnesota Hospital Association; MOCC = Medical Operations Coordination Center; NIV = noninvasive ventilation; PPE = personal protective equipment; SEOC = State Emergency Operations Center; SHCC = State Healthcare Coordination Center

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opened in a unified command with MDH to coordinate a statewide response.[17,18]

MDH established the Acute Care Coordination Group in mid-March 2020, a public-private partnership. MDH staffed this with liaisons from all eight Minnesota Health Care Coalitions, the Minnesota Hospital Association (MHA), and non-MHA health system chief executive officer representation. This group quickly evolved into the State Healthcare Coordination Center (SHCC) and moved to the SEOC Operations Branch (Fig 1).

CCWG was formed as an interprofessional clinical working group under the SHCC and included intensivists, ethicists, and nurses from the 5 large health systems critical care programs in the Twin Cities metropolitan region, and quickly expanded to include the 9 largest health care systems in Minnesota. Representatives from SHCC, MDH, and MHA were included. CCWG tertiary care centers represented 68% of Minnesota's ICU beds and included representatives from the pediatric specialty and smaller hospitals, emergency departments, and invited professionals.[10,19,20]

Experts in ethics, legal, and palliative care were included as a separate Ethics Working Group (EWG). Members of the Minnesota COVID Ethics Collaborative (MCEC), a statewide ethics advisory group supporting the COVID-19 response, also participated in a consulting role.[16,21,22]

CCWG meetings were held by internet audio-video conferencing weekdays from 7 to 8 AM as often as 5 times weekly during severe surge periods and met other times when undertaking specific projects. Although CCWG and EWG membership overlapped, the focus was different, and each had different chairpersons with members contributing differently based on expertise.

Meetings had a structured agenda starting with a statewide data review including staffed inpatient bed occupancy, COVID-19 and non-COVID-19 hospitalizations, COVID-19 ICU daily census, and ventilator availability; daily MOCC placement data were added during the fall 2020 surge.[10] Open discussion of current concerns followed, and meetings concluded with next steps. An emergency contact

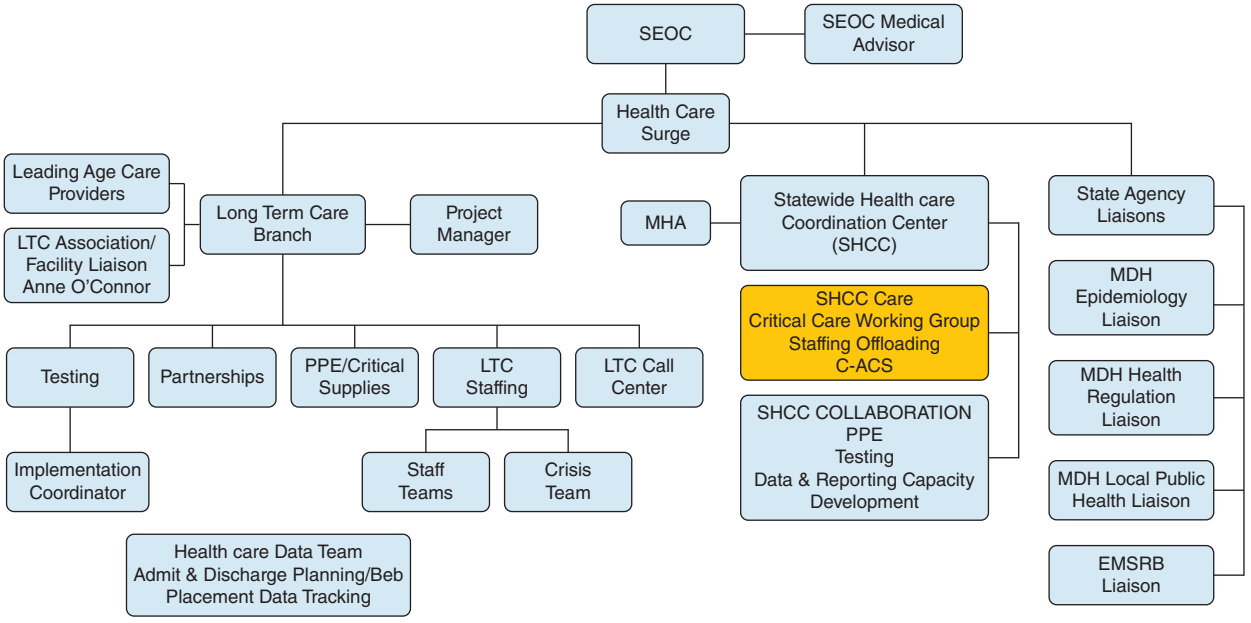

Figure 1 – *SHCC and its relationship to the Minnesota Emergency Operations Center, MDH, CCWG, and other health care entities involved in the COVID-19 pandemic response, March 2020 to June 2021. The SHCC (initially termed the Acute Care Coordination Group) was developed by MDH and the 8 Health Care Coalitions (not shown) when it was recognized that a mechanism to collaborate as a group was needed vs functioning as individual health care coalitions. The SHCC also included the MHA and non-MHA health system chief executive officer representation with the purpose of coordinating health care planning and communication and response strategies as it pertained to the delivery of health care services in Minnesota. The SHCC was staffed with incident command team members from MDH, the Minnesota All-Hazards Incident Management Team, Health Care Coalition Coordinators, and individuals employed by health systems loaned to state operations. To ensure front-line experience and information was reaching policy and decision-makers and to ensure clinical information sharing, the SHCC organized the CCWG as 1 of several working groups to support the response. CCWG was composed of intensivist leadership from the nine largest health systems' critical care programs in Minnesota, and clinical representatives from a pediatric hospital, 2 smaller rural hospitals, emergency medicine, and other invited professionals.*[10] *CCWG = Critical Care Working Group; MDH = Minnesota Department of Health; MHA = Minnesota Hospital Association; SHCC = State Healthcare Coordination Center. (Figure courtesy of the Minnesota Department of Health.)*

TABLE 1] Four Objectives of the Minnesota Critical Care Working Group

Objective and Description
1. Monitoring and surge response: develop consensus regarding surge evidence and thresholds for defining contingency and crisis care conditions for ICU capacity measures.
2. Communication and coordination: support development of a Minnesota communication infrastructure for sharing capacity information, directing patients who are critically ill to those organizations with remaining capacity, and providing support from larger systems to lower-resourced smaller organizations.[10]
3. Scarce resource allocation: support development of common approach to scarce resource allocation for use when/if crisis conditions are encountered.[16]
4. Collaboration: continue to cultivate a team of highly collaborative, interdependent critical care programs among the largest Minnesota health care systems and partners to promote and support consistency of practice and strategies during the pandemic.

Objectives 1 and 4 are covered in detail in this paper, and objectives 2 and 3 are discussed in other papers.[10,16]

system was set up through the internet-based Minnesota System for Tracking Resources, Alerts, and Communications platform to notify members via text message to check their email for an urgent meeting invitation.[19] This was used successfully throughout the pandemic.[10]

CCWG did not have a formal charter but developed a set of 4 objectives (Table 1).

CCWG functioned under the SHCC from March 2020 until July 1, 2021, when the SEOC was demobilized with expiration of the state peace-time emergency.[23] State response operations transitioned back to MDH and were housed in the COVID-19 Response Bureau. MDH continued to collaborate with Minnesota's 8 health care coalitions, MHA leadership, the MOCC leadership group, and with CCWG, which functioned independently.[10,16,24]

Formal meeting minutes were recorded and archived forming the foundation of both papers, supplemented with available data and input from CCWG and EWG members and MCEC and MDH representatives.[16]

CCWG surge evidence of contingency and crisis conditions (Table 2) were based on available data and experience and defined as actions, or strategies, used by health care organizations to respond to the level of rising patient surges. CCWG developed 2 severe surge best practices during the first pandemic year (Table 3). Severe surge best practices were established by discussion on at least 2 conference calls, written as a formal best practice, and adopted by group consensus.

During summer 2020, SHCC leadership asked Minnesota's 8 Regional Health Care Preparedness Coordinators to undertake a project to define inpatient capabilities and resources for Minnesota hospitals with information obtained via their hospital contacts. Their efforts, supported by the SHCC Patient Movement Working Group, resulted in the Minnesota State Hospital Capability Directory, completed January 1, 2021. Capabilities from 128 hospitals were included, of which 5 were tertiary care centers in neighboring states (Table 4). Directory information included beds and bed types, number of hospital-based physicians especially intensivists and hospitalists, ability to perform dialysis and other procedures, and number of respiratory support equipment including ventilators.

CCWG used the conventional, contingency, and crisis paradigm of surge planning, consistent with MDH Patient Care Strategies for Scarce Resource Situation.[2,15]

Results

Developing Consensus Regarding Surge Thresholds

CCWG's first objective was defining evidence to inform the level of Minnesota's hospital resources to guide surge response to shortages. Total ICU beds (conventional and surge) were the initial bed surge evidence but soon transitioned to occupied hospital and ICU beds (non-COVID-19 and COVID-19) because this was a more comprehensive measure of actual bed use (Fig 2).[26-28] The number of available ventilators was also chosen as surge evidence. Tracking hospital beds and ventilators was ultimately required as part of federal teletracking daily data reports.[19,20,29]

Crisis thresholds were determined by group consensus based on published data from New York City and Italy, and were a best estimate as pandemic surge worsened (Table 2).[30,31] Thresholds of 85% (red) were chosen for crisis levels of ICU beds and ventilators, and 95% to 100% thresholds respectively (purple) were added to denote when resources were nearly fully in use. No initial thresholds for contingency level care were established.

TABLE 2] Pandemic Evidence of Contingency and Crisis Conditions Developed by Members of the Minnesota CCWG

Initial Surge Evidence of Crisis Conditions (March-May 2020)	Final Surge Evidence for Contingency and Crisis Conditions (March-May 2021)
Evidence of crisis conditions • ICU beds: crisis (red) when 85% of total ICU beds (conventional plus surge ICU beds combined) in use; purple (resource nearly exhausted) when 95% total ICU beds in use. • Ventilators: crisis (red) when 85% of full featured ICU vents are in use; purple (resource nearly exhausted) when 100% of full featured ICU vents in use (only nontraditional ventilators such as transport, anesthesia machines, etc available). • Intensivists: crisis (red) when 20% of providers unable to work; purple (resource nearly exhausted) when 30% of providers unable to work.	Evidence of contingency conditions • Organization using surge ICU bed spaces • Organization using adapted staffing plans including any of the following: increased provider-patient ratios; increased intensivist overtime, use of non-ICU providers to provide care; implementation of procedure teams; increased use of agency staff[25] • Organization restricting nonemergency (elective) surgical cases or procedures • Shortage of staff resulting in the inability to use every ICU bed space; the shortage was usually in ICU nurses, but also included respiratory therapists and intensivists • New implementation or augmentation of preexisting tele-ICU services • Admission of appropriate patients into PICU beds (≤ 25-30 y of age) • Application of high-level respiratory support in non-ICU settings including HFNC/BIPAP/CPAP (eg, on telemetry or intermediate care units). Evidence of crisis conditions • CCWG consensus that there are patients not able to receive conventional or contingency standards of clinical care. This consensus standard was determined primarily by the inability to find an available ICU bed for all patients requiring it, including with MOCC assistance, and associated ED overcrowding; this was rarely encountered during the fall 2020 surge.[10,16]

Initial crisis conditions evidence for spring 2020 is the left column. The contingency and crisis conditions evidence developed by spring 2021 (right column) are dichotomous (present/not present) and are demonstrated graphically in Figure 3. CCWG evidence of crisis and contingency conditions were based on available data and experience and defined as actions, or strategies, used by health care organizations to respond to the level of rising patient surges. BIPAP = bilevel positive airway pressure; CCWG = Critical Care Working Group; ED = emergency department; HFNC = high flow nasal cannula; MOCC = Medical Operations Coordination Center.

TABLE 3] COVID-19 Pandemic Severe Surge Best Practices Developed During Fall 2020 Surge

Severe Surge Best Practices	Date Established	Detailed Description of Severe Surge Best Practices
Adaptive staffing models	December 2020 (fall 2020 surge)	Given the severity of the pandemic during the fall 2020 surge and with escalating patient care demands, CCWG members fully supported a contingency severe surge best practice whereby the development and use of extended staffing models is entirely appropriate for more efficient and effective delivery of highest quality critical care.
Application of high-level respiratory support in non-ICU settings including HFNC, BIPAP, and CPAP (telemetry or intermediate care units)	December 2020 (fall 2020 surge)	Patients requiring HFNC and those on NIV (BIPAP/CPAP) may be routinely and safely cared for in non-ICU settings (eg, telemetry or intermediate care units), and CCWG members established this as a severe surge best practice. Working group members acknowledge this creates significant stress among caregivers not routinely familiar with the care of these patients and recommended that trained ICU professionals support non-ICU professionals in delivery of this care.

To be defined by CCWG as a severe surge best practice required discussion on at least two conference calls, being written as a formal standard, and then being formally adopted by group consensus (December 2020). BIPAP = bilevel positive airway pressure; CCWG = Critical Care Working Group; HFNC = high flow nasal cannula; NIV = noninvasive ventilation.

TABLE 4] Data From the Minnesota State Hospital Capability Directory, January 1, 2021

Resource/Availability	High-Acuity Hospitals (n = 26)	Mid-Acuity Hospitals (n = 48)	Hospitals Without Designated ICU (n = 58)
Intensivist support			
24/7 in-house support	22 (85)	0 (0)	NA
On-call support	3 (12)[a]	3 (6)	NA
Telemedicine support	2 (8)[a]	18 (38)	NA
No intensivist support	0 (0)	24 (50)	NA
No data available	0 (0)	6 (12)	58 (100)
Hemodialysis availability			
Hemodialysis available	24 (92)	1 (2)	NA
Hemodialysis not available	2 (8)	47 (98)	NA
No data available	0 (0)	0 (0)	58 (100)

Values are No. (%). In partnership with the patient movement working group, the 8 Regional Health Care Program Coordinators contacted representatives from 128 hospitals within their health care coalitions via email, email survey, or personal contact to obtain data, which were then collated to form the Minnesota State Hospital Capability Directory. Included in the directory were the number of hospital-based physicians (especially intensivists and hospitalists), capability of performing dialysis among other procedures, and number of available machines including ventilators and dialysis equipment. The database was intended to be updated with changes over time and there was no validation of the data beyond what Regional Health Care Program Coordinator was able to obtain. The data were available to Minnesota hospitals, and the Medical Operations Coordination Center and State Healthcare Coordination Center leadership. Hospitals were divided into 3 categories; high acuity which included all level 1 and 2 trauma centers and those known to provide specialty services (26 hospitals), hospitals without ICUs (58 hospitals), and other hospitals (48 hospitals), termed mid-acuity. There were 3 hospitals for which there were no data available, and they were not included in the table. Of 26 high acuity hospitals, 5 were in neighboring states (North Dakota: n = 3; South Dakota: n = 2). Note that the Minnesota Hospital Association listed 141 acute care hospitals in Minnesota in 2020, and most were included in this directory (Minnesota's Hospitals – Minnesota Hospital Association [https://www.mnhospitals.org]). For mid-acuity hospitals, only 3 of 48 (6%) had on-call intensivist support, 18 of 48 (38%) had telemedicine support, 24 (50%) had no support, and for 6 of 48 (12%) no data were available. There was no intensivist data available for the 58 hospitals with no ICU beds but given the limited intensivist support available to mid-acuity hospitals, it would seem likely that intensivist support to non-ICU hospitals was even more limited. For dialysis availability, 24 of 26 high-acuity hospitals (92%) provided inpatient dialysis and 47 of 48 of mid-acuity hospitals (98%) did not provide inpatient dialysis. For hospitals with no ICU beds, 58 of 58 (100%) had no data available, and it would seem likely that few if any were able to provide inpatient dialysis. Although Minnesota State Hospital Capability Directory data provided important information, there were opportunities whereby the data could have been more effectively leveraged (eg, using the resources of lower-level ICUs for less severely ill patients). NA = not applicable.

[a]For Intensivist support: All 26 (100%) of high acuity hospitals had intensivist support and most 22 (85%) had 24/7 onsite support, 3 (12%) had on-call availability, 2 (8%) had telemedicine support; one had both on-call and telemedicine support.

Ventilator availability was always > 50%, never posing a threat to Minnesota hospitals from March 2020 through March 2022 (data not shown), and tracking was eventually stopped. One facility had an issue with ventilator availability (November 2020) which was addressed with state-purchased ventilators.[19,20]

Crisis levels of intensivist staffing, available numbers of providers, were defined by CCWG consensus (Table 2), but these data were not kept electronically at state or federal levels and were held separately by programs.

The effect of the spring 2020 surge was lessened by Minnesota governor's executive orders including social distancing restrictions and curtailment of nonemergency surgeries and procedures.[18] The peak occurred about May 20 coinciding with an ICU staffing crisis at a CCWG trauma center. This was resolved with an urgently called CCWG meeting facilitated with the Minnesota System for Tracking Resources, Alerts, and Communications emergency contact system resulting in 6 patients in the ICU transferred to other CCWG member organizations.[10,19]

The fall 2020 surge was larger despite further social distancing restrictions, raising CCWG member concern for Minnesota's capacity to provide critical care services to all patients requiring it.[18] The Minnesota State Hospital Capability Directory (Table 4) showed only high acuity hospitals could provide inpatient dialysis and onsite intensive care, with intensive care services available to only about one-half of mid-acuity hospitals predominantly via telemedicine.[10,19,20] The MOCC had been opened August 1, 2020, and was available to support patient transfers.[10]

Once most hospital and ICU beds were (nearly) fully occupied, bed numbers were less helpful. During the fall of 2020, surge non-COVID-19 hospitalizations decreased inversely with increasing COVID-19 hospitalizations, suggesting postponement of

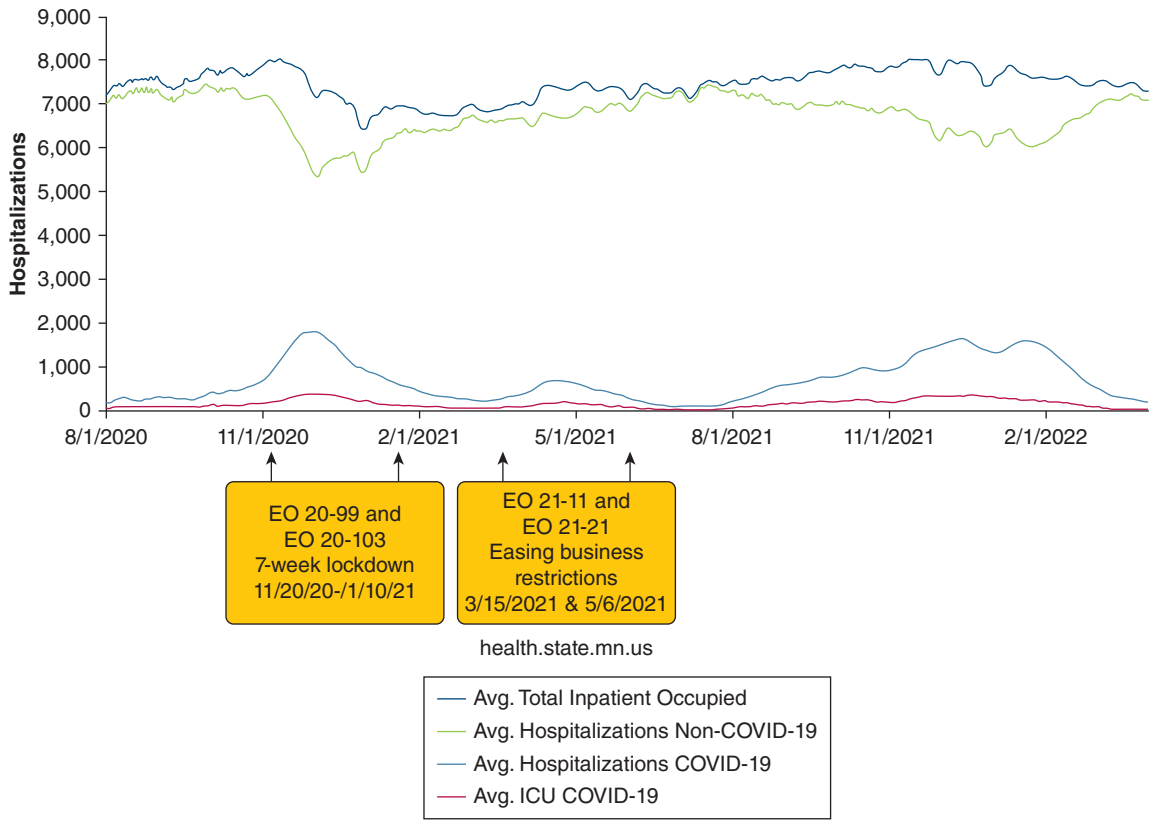

Figure 2 – *Average weekly hospitalizations (all inpatients; patients with COVID-19 and patients without COVID-19; and patients in the ICU with COVID-19), August 1, 2020 through March 31, 2022. Each data point is a weekly average (Monday-Sunday) for each variable, which was chosen to facilitate a smoother graphic presentation of the data. These curves were constructed using federal teletracking data for occupied bed spaces, which most likely represented maximum bed availability especially during severe surge periods. Federal teletracking data also tracked staffed bed spaces which for Minnesota were consistently greater than occupied bed spaces and may have represented a theoretical maximum had staffing (or other) resources been more available.*[19,20,25,26] *Also shown on the horizontal axis is the 7-week interval during which businesses were largely closed due to the Minnesota governor's executive orders (November 20, 2020-January 10, 2021).*[18] *Minnesota governor's executive orders easing business restrictions (March 15, 2021) and rescinding most COVID-19 restrictions (May 6, 2021) are also shown.*[27] *It is noteworthy that non-COVID-19 hospitalizations declined corresponding with the surge of COVID-19 hospitalizations, especially fall 2020 and fall 2021. This suggests nonemergency surgeries and procedures declined and seemed to match the rising patient with COVID-19 surges despite there being no Minnesota governor's executive order mandating this. There was only 1 such executive order in March 2020 which expired later that spring.*[18] *Avg. = average; EO = Minnesota governor Executive Order. (Figure courtesy of the Minnesota Department of Health and reprinted with permission from CHEST, Baum et al.*[10]*)*

nonemergent procedures despite the absence of a government directive or patients discharged early or not being admitted (Fig 2). Additional surge strategies were arising in response to rising patient surges.[16]

These surge strategies (Fig 3, Table 2) were dichotomous variables (present/not present) and included use of surge ICU bed spaces (rather than numbers of occupied conventional and surge ICU beds), implementation of adapted provider staffing tactics (rather than the number of provider staff), presence of other ICU staff shortages (especially nurses) which prevented further ICU bed expansion, and restriction of nonemergency (elective) procedures. More extreme contingency strategies included the addition of new tele-ICU services or augmentation of those already present, use of PICU beds for appropriate adult patients (up to 25-30 years of age), and application of high-level respiratory support in non-ICU settings including high flow nasal cannula (HFNC) and/or noninvasive ventilation (NIV) (bilevel positive airway pressure or CPAP).[4,16]

Surge strategies were shared across CCWG organizations and reflect adaptations in care driven by clinical leaders to maintain contingency and avert crisis conditions.[4,12] There was no formal coordination among CCWG organizations, and each organization chose independently the strategies to implement; CCWG members were intensivist leaders and led their organization's efforts. There were no data kept for which strategies or implementation sequence each organization used nor when de-escalation occurred. Success was

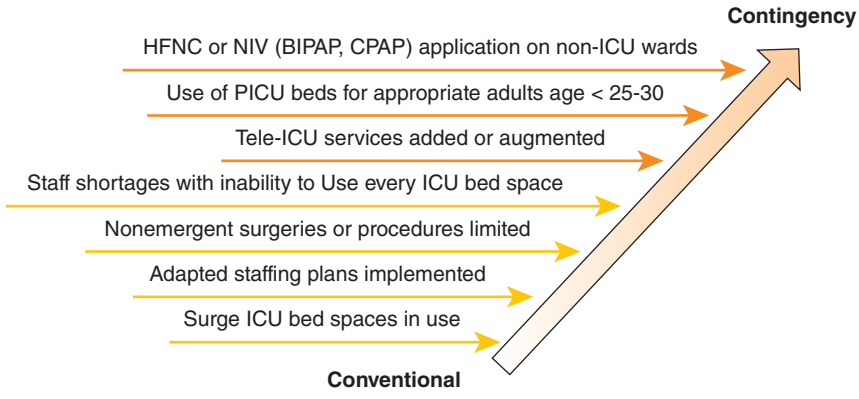

Figure 3 – *Surge indicators that ultimately evolved during the fall 2020 surge were operational strategies that Critical Care Working Group member organizations implemented and which described advancing levels of contingency conditions. These indicators were developed as dichotomous variables (present/not present) and seemed to follow a stepwise progression from conventional to contingency with more measures implemented as the level of surge increased, and strategies higher along the arrow considered more extreme. These indicators however were often complementary and not necessarily sequential. Crisis care levels are not shown but may still occur at times during this progression.*[16] *BIPAP = bilevel positive airway pressure; HFNC = high flow nasal cannula; NIV = noninvasive ventilation.*

determined by sufficient organization or statewide capacity to provide ICU care.

The use of any of these strategies by individual health care organizations constituted contingency conditions, with levels more severe as more strategies were implemented (Fig 3). Not surprisingly, CCWG organizations' use of contingency strategies was tracked together. Contingency level care was determined by CCWG consensus and was present throughout November and December 2020. Crisis conditions during the fall 2020 surge were also determined by group consensus, although were rarely encountered. The duress experienced during fall 2020 led CCWG to establish severe surge best practices for two common care adaptations: implementation of adapted staffing models and application of high-level respiratory support in non-ICU settings (Table 3).

CCWG advocated with SHCC leadership for greater public communication regarding the duress health systems were experiencing during the fall 2020 surge.[32]

Medical Operations Coordination Center

CCWG provided leadership for and intensivist coverage to the Minnesota MOCC, as previously described.[10] The MOCC was instrumental in ensuring patients were transferred to open ICU beds during the fall 2020 surge, accomplishing CCWG's second objective (Table 1).

Allocation of Scarce Resource Processes

The EWG, with advisory contributions from MCEC representatives, developed a COVID-19 clinical allocation tool available during the fall 2020 surge, but implementation was not required. This was subsequently updated during the fall 2021 surge contributing to CCWG's third objective and is discussed elsewhere.[16]

Discussion

US health care systems adapted to the accelerating COVID-19 pandemic with surge strategies to address shortages of clinical staff, inpatient care areas, supplies, and ventilators and respiratory therapy and dialysis equipment.[1,2,4,31,33,34] Pre-COVID-19 guidance and assumptions did not accurately predict the challenges faced nor needed solutions.

CCWG experience combined with others illustrates COVID-19 surge responses with a wider range of actions and greater flexibility than previously expected, and are compared with pre-COVID-19 guidance (Table 5).[1-4,12,35-45]

Health care staff were a significant limiting factor not foreseen in disaster plans, particularly for a long-term incident. The staffing strategies listed in Table 5, and there were undoubtedly others, demonstrated resilience and creativity expected by prepandemic planning.[1,2] Minnesota's CCWG organizations used virtually all of these, and still experienced shortages of ICU professional staff as the pandemic progressed, especially nurses, also reported by others.[4,26,39-42] Surge strategies evolved with the goal of maintaining and sustaining the workforce.[4,37-41,43]

More extreme adaptations, including limiting continuous renal replacement therapy duration to support more patients or specific ventilator choice based on lung disease severity was a paradigm shift driven by necessity.[1,4,37,40]

Minnesota experience included delivery of critical care outside of a conventional ICU, reinforcing the focus on providing critical care support independent of an ICU location.[46]

TABLE 5] Pre-COVID 19 Pandemic Suggested Surge Strategies Compared With Strategies Developed During the COVID-19 Pandemic to Augment Hospital Surge Capacity Regarding Staff; Equipment, Medication, and Supplies; Space; and System

Resource	Pre-COVID-19 Suggested Surge Strategies[1-3,35,36]	Strategies to Augment Hospital Surge Capacity During the COVID-19 Pandemic[4,12,37-44]
Staff	• "Hospitals use adaptive measures to compensate for reduced staffing, such as additional shifts, workload, and changes in shift structure/time and should be planned with collaboration with critical care staff representatives." • "Hospitals should implement measures to mitigate preventable causes of staff shortage, including sheltering of staff and family, provision of mental health support, measures to mitigate fatigue, access to transportation services, and maintenance of a safe work environment." • "Critical care nurse-to-patient ratios in an event requiring critical care surge be determined by provider experience, available support (ancillary staff), and clinical demands." • "Hospital staff preparedness to support critical care surge response include training in the use of standard operating procedures, role definition, use of hospital incident command system, cross training of additional staff, and situational awareness tools, particularly those that can assist in decision-making regarding critical care surge planning, operations, response, and recovery." • "Critical care physicians should provide oversight and direction of clinical teams providing critical care services including scheduled patient assessment and treatment plan evaluation; remote consultation may be used."	• Authorize ICU staff working significant overtime (> 50% above normal)[a] • Alter patient/staff ratios for HCWs[a] • Adjust clinical expectations based on the number/level of experience of ICU staff (especially RNs and RTs) • Create tiered staffing models led by intensivists/critical care providers[a] • Create team care models (nursing)[a] • Create specialized procedure teams[a] • Add non-ICU providers to ICU teams[a] • Add temporary clinical staff (agency, moonlighters, etc)[a] • Expand responsibilities for trainees in clinical care[a] • Reduce redundant and nonessential documentation[a] • Implement measures to increase resiliency and support health care workers[a] • Create just in time training for non-ICU staff deployed to ICU, especially use of PPE
Equipment, medication, and supplies	• "Hospital support services, includ[ing] pharmacy, laboratory, radiology, respiratory therapy, and nutritional services, be included in critical care surge planning." • "Facilities should ensure adequate availability of disaster supplies through supply-based caches with vendor agreements and understanding of supply chain resources and limitations." • "Regional and hospital stockpiles should include equipment, supplies, and pharmaceuticals that can be used to accommodate the needs of unique populations likely to require critical care including pediatrics, burn, and trauma patients."	• Triage types of mechanical ventilators or ECMO based on severity of underlying lung disease • Use of alternative ventilators (eg, transport ventilators, anesthesia ventilation equipment) • Centralized health system triage for allocation of resources • Repurpose NIV devices to be used as mechanical ventilators • Use HFNC or high-level NIV in non-ICU settings[a] • Prioritize or restrict duration or types of dialysis (hemodialysis, continuous renal replacement therapy, peritoneal dialysis) to provide care to more patients • Purchase or borrow additional ventilators and/or noninvasive ventilation devices (CPAP, BIPAP, HFNC)[a] • Prioritize use of diagnostic tests (ultrasound, echocardiograms, bronchoscopy, CT scan or MRI scan, lumbar puncture, or paracentesis) • Shortage of PPE requiring reuse (N95 masks, face shields, gowns, PAPR, or CAPRs)[a] • Prioritize use of testing supplies in times of shortage

(Continued)

TABLE 5] *(Continued)*

Resource	Pre-COVID-19 Suggested Surge Strategies[1-3,35,36]	Strategies to Augment Hospital Surge Capacity During the COVID-19 Pandemic[4,12,37-44]
		• Substitute classes of medications due to severe shortages (sedatives, neuromuscular blockers, others)
Space	• "Hospital critical care resources are able to expand immediately by at least 20% above the baseline ICU maximal capacity for a conventional response." • "In a contingency response, hospital critical care resources are able to expand rapidly by at least 100% above the baseline ICU capacity to meet patient demand using local and regional resources." • "Hospital critical care resources are able to expand by at least 200% above baseline ICU capacity to meet patient demand in a crisis response using any combination of local, regional, national, and international resources."	• Postpone nonemergency surgeries and procedures in a tiered fashion[a] • Repurpose step-down, medical/surgical units, or other inpatient units into surge ICUs (and/or provide higher levels of care on these units)[a] • Create dedicated COVID-19 ICUs to cohort patients[a] • Use PICUs to accept appropriate patients ≤ 30 y of age[a] • Double occupancy of ICU space areas based on patient care demand
System	• "Hospital or local/regional disaster committees include a critical care expert to optimize critical care surge capacity planning." • "In-hospital placement of critically ill patients during a mass critical care event be performed by an experienced clinician who routinely makes similar decisions on a daily basis." • "A hospital's decision to restrict or expand critical care delivery should be made as part of a local/regional decision-making process, with consultation and input provided by hospital ICU leadership." • "Health care systems that have instituted a triage policy have clinicians with critical care triage training function as triage officers (tertiary triage) to provide optimum allocation of resources." • "We suggest hospitals consider the utilization of technology (eg, telemedicine) as an important adjunct to the delivery of critical care services in a disaster to serve as a force multiplier to support response to disaster events. Where no such systems are currently in place, development of a telemedicine or other electronic platform to support patient care delivery is suggested." • "Organizations with telemedicine capability (such as tele-ICUs) should have plans for how to use this resource to optimize the use of pediatric and specialty expertise across hospitals served by the telemedicine resource." • "Surge capacity plans should include predetermined standards that define minimal ongoing critical care capability in order to define the framework for decisions regarding patient transfer as the demands on the system gradually increase during a disaster or pandemic."	• Implement prioritization or triage systems or teams to determine ICU admissions, transfers, and equipment or ECMO[a] • Monitor closely for signs of critical clinical prioritization as harbinger of crisis care conditions[a] • Leadership should engage proactively to ensure close communication with and feedback from frontline HCWs, treating them as a key stakeholder, which also helps mitigate risk of burnout[a] • Implement communication strategies with HCWs (scheduled town hall meetings, daily group huddles, daily email updates, addition of physician support supervisors)[a] • Engage and empower frontline leaders to help determine level of ICU strain[a] • Implement policies to transfer patients to other hospitals when nearing full capacity[a] • Develop or participate with regional MOCCs[a] • Implement policies to accept fewer patients in transfer when transfer options exhausted[a] • Expand or introduce telemedicine programs[a] • Recognize that hospital and health care system strain often back up into EDs; engage and empower frontline ED teams and ED leaders in both large and small hospitals to help describe, adapt to, and work within their systems to manage a variable degree of ED strain[a] • Actively communicate with patients, families, and community about what resources are in scarcity at what facilities, health care system responses, whether contingency or crisis standards of care are in operation, and how that will affect care[a]

(Continued)

TABLE 5] *(Continued)*

Resource	Pre-COVID-19 Suggested Surge Strategies[1-3,35,36]	Strategies to Augment Hospital Surge Capacity During the COVID-19 Pandemic[4,12,37-44]
	• "In the presence of a slow-onset, impending disaster/threat, targets for surge capacity and capability be focused, where possible, on projected patient loads." • "More prolonged demands on critical care compared to demands placed on other sections of the hospital (ie, days rather than hours) be taken into consideration when resuming routine hospital activities requiring ICU support." • Surge capacity plans should include predetermined standards that define minimal ongoing critical care capability to define the framework for decisions regarding patient transfer as the demands on the system gradually increase during a disaster or pandemic. • "During a disaster requiring transfer of patients, transferring partners may have an initial choice of where patients are referred based on traditional referral patterns. However, state or health care coalition leadership must oversee this process and be able to intercede as both a resource and with the authority to redirect transfers based on anticipated or actual events. Defined coordination processes and transfer resources should be planned and identified ahead of time."	

Items in the middle column in quotations are direct quotes from references, and those without quotes have been paraphrased. Comparisons of prepandemic suggestions to pandemic experiences include the following. The first is staff: prepandemic guidance suggested staffing changes include critical care physician collaboration and oversight with suggestions on staffing strategies that are general in nature. The pandemic experience reinforced the importance of critical care physician engagement and leadership, with at least 10 specific staffing strategies developed and implemented with variability across organizations based on individual needs. The second is equipment, medication, and supplies: prepandemic surge planning suggested inclusion of pharmacy, radiology, respiratory, and nutritional services, and ensuring sufficient reserves of resources for both routine and specialty patient populations. Although pandemic experience validated these suggestions including substitution of medication classes, it did not foresee the necessity for extraordinary actions, termed critical clinical prioritization including sharing continuous renal replacement therapy to extend its use to more patients, triaging ventilators based on severity of lung disease, use of high-level NIV in non-ICU settings, and reusing PPE. The third is space: prepandemic suggestions for expanding space followed the paradigm of enlarging ICU capacity to 20% above baseline for conventional circumstances, up to 100% above capacity for contingency demands, and up to 200% above capacity for crisis care conditions. Pandemic experience validated this model, but also added new approaches including postponing nonemergency procedures in a tiered manner, repurposing non-ICU areas into ICUs and generating double occupancy under severe strain, admitting younger patients into PICUs, and creating dedicated COVID-19 ICUs. The fourth is system: prepandemic planning suggested a framework for using critical care clinical expertise with hospital incident command structure with focus on triage of ICU admissions, transfers, communication and coordination with a regional or statewide network, and expansion of telemedicine technology. Most of these strategies were implemented though perhaps most important was engagement with frontline clinicians and leaders to obtain information and feedback rapidly, assess level of strain, plan surge responses, assist health care system load balancing, and engage with and contribute to regional MOCCs for facilitating transfers during severe surge periods. In addition, focus on strain levels in emergency departments in ICUs was crucial in understanding regional health care system stress, and communication to the public also emerged as important priorities. BIPAP = bilevel positive airway pressure; CAPR = controlled air purifying respirator; ECOM = extracorporeal membrane oxygenation; ED = emergency department; HCW = health care worker; HFNC = high flow nasal cannula; MOCC = Medical Operations Coordination Center; NIV = noninvasive ventilation; PAPR = powered air purifying respirator; PPE = personal protective equipment; RN = registered nurse; RT = respiratory therapist.

[a]Strategies used by ≥ 1 member(s) of the Minnesota Critical Care Working Group organizations.

During Minnesota's fall 2020 surge, providing HFNC and NIV in non-ICU settings became a necessary practice, and there were periods where only patients requiring mechanical ventilation were admitted to some ICUs.[47,48] This practice, along with altered staffing models, was so different from routine care that CCWG members thought it necessary to formally support their use as a severe surge best practice (Table 3). COVID-19 pandemic evidence since supports the use of HFNC outside the ICU as having equivalent efficacy and safety, and CPAP use decreased the risk of ICU admission.[49,50] Although adding emergency equipment (eg, ventilators, triaging classes of medications or supplies) was foreseen, severe shortages and repurposing of personal protective equipment (PPE) was unexpected.[39-41]

Postponement of nonemergent procedures in Minnesota was common and reported by others.[37,44] During initial 2020 COVID-19 surges, postponement of nonemergent procedures at the Veterans Health Administration decreased surgical ICU admissions by 78% and in Mississippi resulted in a 27% decrease in admissions.[51,52] Prepandemic administrative data from New York State showed elective surgery accounting for 13% of ICU admissions, and March 2020 survey data from Australian ICUs showed elective surgery accounted for 38% of ICU admissions and 25% of all ICU bed days.[42,53] Together these studies support significant increases in ICU capacity by postponing nonemergent procedures, with likely impact on downstream non-ICU bed days as well.[53]

Noteworthy were efforts of regional children's hospitals, traditionally caring for patients < 21 years of age, expanding admission up to 30 years of age to level-load the critical care burden affecting adult ICUs. Repurposing non-ICU wards for patients who are critically ill and dedicated COVID-19 ICUs also occurred in Minnesota. The model of expanding capacity from conventional to crisis conditions held, but space was less limiting than staff and supplies.[1-4,37,42,44] However, future events may pose different challenges to surge variables, reinforcing the need for a flexible, coordinated response.

Finally, changes in health care facility and statewide system-level processes highlighted the resourceful expansion of ICU care in a step-wise manner (Fig 3).[16] Important elements of these changes included bidirectional communication between frontline health care workers and facility leadership especially in prioritizing ICU beds, system-level coordination and communication, designing and implementing a statewide MOCC (Table 4), and updating the public regarding regional or statewide surge conditions.[4,37,39-41]

Expansion of telemedicine support was an important health care response. Specialist teleconsults and tele-intensivists supported smaller hospitals, allowing them to care for higher acuity patients.[4,37] Several health systems had preexisting telemedicine infrastructures, some set up telemedicine coverage ad hoc with tablet and communication technology, and others engaged telemedicine options (eg, National Emergency Tele Critical Care Network).[54]

Maintaining contingency-level care likely prevented increased mortality, which may rise to 25% or higher under severe pandemic surge conditions.[25,55]

Disappointingly, clinical or mortality data are unavailable to validate Minnesota experience. CCWG member consensus was contingency conditions were maintained during the fall 2020 surge which required a stepwise progression of more extreme strategies (Fig 3) and was at the limit of Minnesota's capacity to provide safe and effective care. Additionally, the MOCC was able to place all patients requiring ICU care which CCWG hoped was a safeguard for patient access to dialysis or complex ventilatory care provided at tertiary care hospitals. Although the SHCC had authority to compel tertiary care hospitals to accept nontertiary hospital transfers, this was never invoked.[10]

CCWG organizations used many adaptations noted in Table 5, comparable with other US regions and countries. International studies showed more variation in resource availability, and staffing shortages became increasingly the most significant limiting factor including the United States.[41,43,56,57] The generalizability of these adaptations is limited because health care organizations respond to severe surges based on the availability and type of resources uniquely accessible to them.

To preserve contingency conditions, future research should define surge strategies with their corresponding impact on ICU strain, standardized process indicators, and outcomes.[58] Recommended indicators typically used in critical care research include organ failure requiring active support such as mechanical ventilation or NIV, vasopressor support, or renal replacement therapies. Recommended outcome metrics include mortality, hospital and ICU length of stay, discharge disposition, and functional level at discharge.[25,55,59,60] The severity of any disaster event falls on a spectrum between contingency and crisis care, and knowledge of indicators and outcomes may impact ICU strain and avoid crisis conditions.[58,61] It would have been helpful to know which adaptations each CCWG organization implemented with increasing surge, but this was not feasible given the duress all were under.

The Minnesota peacetime emergency concluded July 1, 2021, with closure of the SEOC, SHCC, and the pandemic response infrastructure.[23] Their value and the authorities provided were crucial in bringing health care systems together and coordinating a highly effective pandemic response.

Objective 4 (Table 1) was to develop a highly effective health care team. CCWG members were established

leaders in their home institutions and brought expert critical care knowledge and leadership to the working group. CCWG met frequently to advance shared understanding, objectives, and situational awareness, foundational elements of effective teams. CCWG members developed confidence and trust in each other's knowledge, skills, and abilities.[62,63]

The May 2020 real-time collaboration to find urgent ICU placement for 6 patients during a staffing crisis was a sentinel event which strengthened commitment to our collective mission, confidence in the group's shared ethical principles and moral compass, and camaraderie.[10] The fall 2020 surge tested our ability to rapidly assimilate information, effectively problem solve, and persevere. This required relentless commitment in dynamic, uncomfortable, and often ambiguous situations to arrive at shared processes and standards consistent with the best care for all patients and supporting each other.[62,64] CCWG proved a highly effective and successful team, and recommends future coordination between health care organizations and government as a critical element in disaster response.[62,63]

The strength of our pandemic response involved a closely allied statewide working group that met for the duration of the crisis, with interdependent communication and coordination an essential element of success. Meeting minutes were recorded creating a cumulative record of the groups' accomplishments. The data were primarily qualitative and based on consensus which may introduce a degree of bias but details a statewide critical care working group's experience over the first 16 months of the COVID-19 pandemic.

The limitations include having limited quantitative data to validate the analysis and no clinical and outcomes data available.

Future studies will hopefully investigate these recommended strain indicators and measure their effectiveness in clinical practice, including patient-level outcomes.

Interpretation

The Minnesota Critical Care Working group developed consensus-based pandemic surge strategies which supported responses to contingency and crisis conditions while also participating in load balancing activities. Success was due to highly effective teamwork and is a model for future disaster preparedness.

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