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Pandemic Influenza: Implications for Preparation and Delivery of Critical Care Services

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Abstract

In a five week span during the 1918 influenza A pandemic, more than 2,000 patients were admitted to Cook County Hospital in Chicago with a diagnosis of either influenza or pneumonia; 642 patients, approximately 31% of those admitted, died with deaths occurring predominantly in patients twenty-five to thirty years of age.¹ This review summarizes basic information on the biology, epidemiology, control, treatment and prevention of influenza overall, and then addresses the potential impact of pandemic influenza in an Intensive Care Unit setting. Issues that require consideration include workforce staffing and safety, resource management, alternate sites of care surge of patients, altered standards of care and crisis communication.

Keywords

Influenza; Pandemic; Intensive Care Unit; Virology; Patient Surge

Introduction

In a five week span during the 1918 influenza A pandemic, more than 2,000 patients were admitted to Cook County Hospital in Chicago with a diagnosis of either influenza or pneumonia; 642 patients, approximately 31% of those admitted, died with deaths occurring predominantly in patients twenty-five to thirty years of age.¹ This overwhelming scenario is what public health officials, health care administrators and health care personnel feared with the recognition of avian H5N1 influenza A in 2003. The subsequent emergence of a novel H1N1 virus of swine origin in Mexico in the spring of 2009 has further underscored the need for contingency planning in the event of a new pandemic virus. Recognized in late

April 2009, this novel H1N1 virus spread so rapidly that it was officially recognized by the World Health Organization in June 2009 as the fourth global pandemic since the beginning of the 20th century.² As of 4 April 2010, there have been more than 440,000 laboratory confirmed cases of pandemic novel H1N1 influenza A worldwide, with over 17,700 deaths reported.³

The purpose of this manuscript is to review our basic understanding of pandemic influenza and to assess the potential impact on health care delivery. The 1918 influenza pandemic, long considered a “worst case scenario”, has frequently been used as a blueprint for pandemic planning.^{51–56} Although the current H1N1 virus appears not to have been as virulent as the 1918 pandemic virus, this most recent outbreak has provided a “real world” test on the strengths and the vulnerabilities in our abilities to respond to a major infectious disease crisis.⁴⁷ Hospitals are urged to continue to plan for a worst case scenario as this will help them prepare not only for a severe pandemic, but indeed for any catastrophic scenario in which demand exceeds available resources.

BACKGROUND

Virology

Influenza A viruses are negative stranded RNA viruses that are known to infect a broad range of species, including a large variety of fowl, swine, and humans. The viral genome is composed of eight gene segments that encode eleven proteins including two surface proteins, hemagglutinin (HA) and neuraminidase (NA). Though the other proteins have been shown to contribute to viral pathogenicity,^{4–7} the HA and the NA proteins are the principal targets of the immune response, and immunity to the virus is based on the development of type specific antibodies to these proteins. The HA protein is responsible for mediating virus entry into the cells by binding to sialic acid residues on host cells, while the NA protein is responsible for facilitating cell to cell spread of virus. Antigenic drift, which influences influenza epidemics and must be taken into account when strains are being considered for vaccine design, results as the HA or the NA proteins acquire mutations in their surface antigens leading to suboptimal binding of pre-existing antibodies and more efficient spread of the virus in a partially immune population. Influenza A pandemics occur in the context of antigenic shift which results from the replacement of an HA or NA protein in an influenza A virus with a novel subtype that has not been recently present in the human population such that the majority of the population lacks any cross-reactive protective antibodies against the new virus.⁸

The first influenza A pandemic of the twentieth century occurred in 1918, and was due to an avian H1N1 virus that subsequently circulated seasonally for approximately forty years. It was replaced in 1957 by a new human-avian H2N2 reassortant virus, resulting in the 1957 Asian influenza pandemic.² This was followed by the Hong Kong pandemic of 1968 where H2N2 viruses were supplanted by an H2N2 human/H3 HA avian reassortant.² After disappearing in 1957, influenza A (H1N1) reappeared during the 1977–1978 influenza season and has co-circulated with influenza A (H3N2) ever since. In 1997 and later in 2003, an outbreak in birds of a new highly pathogenic avian influenza A H5N1 resulted in recognized casualties of humans with avian influenza viruses.⁹ The H5N1 virus has

distinguished itself by its increased pathogenicity as well as its continued but non-sustained transmission to humans with high mortality rates.² As of April 2010, there have been 493 confirmed human infections from H5N1 resulting in 292 deaths.¹⁰ The novel H1N1 influenza A virus identified in 2009 was a quadruple reassortant that consisted of a triple reassortment of human/avian/swine viruses that emerged in 1997 and Eurasian avian-like swine viruses.¹¹ These viruses possessed the PB2 and the PA genes of NA avian virus, a PB1 gene of human H3N2 virus origin, the HA (H1), NP and NS genes of classical swine virus origin and NA (N1) and the M genes of Eurasian avian-like swine virus origin.

Modes of transmission

Using household studies and statistical modeling, it has been estimated that 30 to 40% of influenza transmission occurs in households, about 20% in schools, and the remainder in other settings such as workplaces and the general community.¹² Three modes of transmission for influenza have been described including: large droplet transmission from sneezing, coughing or talking, self inoculation of the nasal mucosa from contaminated hands and airborne (droplet nuclei) transmission from small droplets generated from procedures such as intubation, respiratory treatment or bronchoscopy.¹³ Using RT-PCR assays, influenza virus RNA has been detected in aerosols generated by naturally infected subjects¹⁴ and in aerosol samples collected in an emergency room during influenza season.¹⁵

Animal studies have been informative in understanding the environmental factors that underlie influenza transmission. Using a guinea pig model, Lowen et al. studied the effects of temperature (−5°C, 20°C and 30°C) and relative humidity (20%–80%) on the efficiency of influenza virus spread.¹⁶ Airborne transmission was demonstrable with lower temperatures and lower relative humidity, while only droplet or contact transmission appeared to occur at higher temperatures and higher humidity. Cooler temperatures are thought to increase the viscosity of the nasal mucosa which affects ciliary beating and increases the stability of virus in the upper airways¹⁷ while the effect of lower humidity may be related to an increase in virus stability. Though further study is needed, these findings provide an explanation for the seasonal epidemics of influenza during the winter months in temperate regions and the more limited year-round transmission of influenza in tropical climates. Experimental models for influenza have also been developed in ferrets to test the aerosol transmission capabilities of influenza viruses.¹⁸

Infection control

Infection control management in the setting of the appearance of a novel strain of influenza should be aimed at decreasing influenza morbidity, mortality and social disruption.¹⁹ The level of preparedness in a pandemic situation is most likely related to the strength of the strategy that is already in place for the management of interpandemic influenza. Planning should include recommendations on employee and visitor screening, isolation precautions for patients, rules for transfer of infected patients, the implementation of administrative and engineering controls and the use of personal protective equipment (PPE) to protect employees and other patients from infection.¹⁹ The type of PPE recommended will vary depending on the characteristics of the influenza virus involved. Hospital policy considerations during a pandemic should include not only recommendations on when ill

workers should be sent home but also recommendations on when these workers are fit to return to work. Administrative controls include the vaccination of patients and healthcare personnel, the upgrade of hand washing sinks, tissue dispensers and soap sanitizers, and education on respiratory hygiene etiquette (covering one's mouth and nose when coughing and sneezing or the use of masks) to both patients and staff. Engineering controls include the partitioning of areas in the emergency room to separate coughing patients from patients without influenza-like illnesses and the implementation of proper room ventilation controls. In the setting of a novel strain of influenza, infection control management should be maximized at the onset.²⁰ Response plans should be flexible and evolve as the situation rapidly unfolds and new information is obtained.

Antiviral treatment

Two classes of antiviral drugs are licensed for the treatment of influenza A and B infections: ion channel inhibitors (e.g., amantadine hydrochloride and rimantadine) and the neuraminidase (NA) inhibitors (e.g., oseltamivir and zanamivir).²¹ NA inhibitors interfere with the activity of the NA protein which is responsible for the release of newly synthesized viruses from infected cells. Oseltamivir and zanamivir have shown activity against influenza A (including S-OIVs) and B viruses. Oseltamivir is an oral medication approved in adults and children one year of age and older. Zanamivir is an inhaled medication approved for treatment use in adults and children seven years and older and is contraindicated in individuals with airways disease. To date, the majority of S-OIVs have shown susceptibility to NA inhibitors in vivo and in vitro^{11, 21–22} though there have been reports of oseltamivir-resistant 2009 pandemic influenza A (H1N1) virus infection.²³

Rapid influenza tests have not been shown to be sufficiently sensitive for the 2009 H1N1 influenza virus. The lesson learned from this most recent pandemic is that rapid testing should not influence management decisions when novel influenza A strains are circulating.²⁴ Though the highest benefit for oseltamivir treatment has been shown if initiated within forty-eight hours of symptom onset,²⁵ a prospective study conducted in Canada did show a reduction in influenza mortality even if treatment was initiated after that time.²⁶ Given this data, an Emergency Use Authorization approved the use of oseltamivir and zanamivir even if therapy is initiated forty-eight hours beyond symptoms.²¹ Treatment of suspected or confirmed cases of pandemic H1N1 should be continued for a duration of five days. If epidemiologic data indicate widespread circulation of oseltamivir resistant seasonal H1N1 viruses, the CDC recommended treatment with both oseltamivir and an ion channel inhibitor. Several antiviral candidates targeting both the NA and the polymerase protein and monoclonal antibodies to HA are in different stages of development.^{27–29} Peramivir, an intravenous NA inhibitor, shown to be active in vitro against all nine HA subtypes,³⁰ was recently approved for emergency use for pandemic H1N1 infection when a patient is not responding to oral or inhaled therapy or when drug delivery by these routes is not feasible.³¹

Vaccine

In relation to a pandemic or seasonal epidemic, vaccination increases population-level immunity, lowers the spread of infection and decreases the overall illness attack rate. This in

turn lessens the impact on the health care system by decreasing the magnitude of the peak surge of patients.¹² Influenza vaccines induce the production of antibodies, primarily to HA and NA proteins. Given the possibility of mutations in these proteins (antigenic drift), vaccines are re-evaluated on an annual basis.⁸ For the 2009–2010 influenza season, immunization with both the seasonal and pandemic H1N1 vaccine has been recommended. Two forms of seasonal vaccine are available: an inactivated injectable influenza vaccine and a live attenuated influenza vaccine (LAIV) given in nasal spray form (FluMist®). Seasonal influenza vaccines include influenza A viruses of the H1N1 and the H3N2 subtype as well as an influenza B virus that were circulating during the previous influenza season. Live attenuated vaccines containing the same influenza A and B viruses as in the inactivated vaccine elicit both antibody and cellular immune responses are believed to generate a stronger and a more broad immune response and have been shown in infants and younger children to provide better protection than inactivated vaccine.³²

Vaccination and the use of antiviral drugs are intervention strategies that may lessen the impact of an emerging pandemic.³³ Preparation for a pandemic also entails identifying research gaps and developing new knowledge on the production of an effective vaccine.^{34–36} The highest priority is the development of a public health approach that would provide a blueprint for pandemic influenza preparation and response for the general public and all key response entities. The focus of the next section will specifically address hospital and ICU pandemic planning.

Pandemic Planning and Response

The U.S. Department of Homeland Security “views pandemic influenza as both the most likely and the most lethal of all threats facing the United States.”³⁷ Several previous pandemics and epidemics have strained or nearly crippled the healthcare system’s ability to deliver timely and appropriate care.^{38–50} The effectiveness of pandemic planning and response depends upon many factors including the timing of the onset of the outbreak, attack and mortality rates, and the target population. Unfortunately, these variables remain unknown until the early stages of a pandemic. An array of modeling tools have been used to help hospital and ICU planners estimate the impact of a future pandemic in terms of projected numbers of admitted patients^{51–53} and deaths^{51–52}; as well as projected needs for ICU beds,⁵² mechanical ventilation^{52–54} and antiviral medications.⁵⁵ Unfortunately, precise planning remains a challenge as these modeling tools create projections with a tremendous range⁵⁶ resulting in estimates that are, at best, only “educated guesses”.⁵⁷

With the growing array of new treatments and technologies at our disposal comes the obligation to plan for how these will be utilized⁵⁸ and possibly rationed during a future catastrophic pandemic. ICU pandemic planning cannot occur in a vacuum; while the ICU and its staff may well bear the brunt of a pandemic response, planning for this impact must be done in the context of the hospital and regional healthcare system.⁵⁶ ICU personnel need to be intimately involved with hospital and regional planning (participation in pandemic committees,^{59–60} development of plans, etc^{61–62}) and be placed in key decision-making roles before, during and after a pandemic occurs.

Regional healthcare planning is key^{47, 50, 56, 59–60, 62–77} to an effective pandemic response. Coordinated regional efforts^{59, 68, 78} between health care centers (acute care hospitals, rehab facilities, subacute nursing facilities, nursing homes, etc), public health and other agencies will help provide for the most robust response possible. A pandemic differs from most other disasters in that it is truly a global incident; assistance, therefore, may not be available from elsewhere as other regions are being affected as well.^{60, 70, 79–83}

Recent experiences with avian H5N1 influenza and SARS, have identified critical care priorities that need to be addressed in planning for any pandemic. These priorities include **workforce, resource, and process issues** that are the key limiting factors in the ability of the healthcare system to surge to a greater capacity.^{50, 56, 63, 83–86} The purpose of this section is to review the challenges associated with each of these priorities and then to outline an approach to address these issues in contingency planning that will hopefully mitigate the impact of an influenza pandemic.

Planning for a rare, catastrophic incident may seem overly burdensome, particularly when the daily struggles of simply maintaining adequate healthcare are so consuming^{87–88} and given that our most recent pandemic was a relatively mild one. This, however, should not be an excuse to not develop contingency plans for a potential future severe pandemic.

Workforce (Staffing)

Challenges—Substantial workforce reductions of all hospital staff (clinical and ancillary staff) may occur during a pandemic.^{36, 56, 59–60, 70, 87, 89–90} Estimates of workforce reduction have been recorded to be as high as 40% to 70%.^{60, 91–93} The reasons for this are multifactorial and include:

- illness^{60, 70, 87, 89, 92, 94–95}
- family responsibilities^{59–60, 70, 80, 87, 89, 92, 96–98}
- fear of getting sick^{20, 48, 59–60, 70, 87, 89, 92, 96}
- poor morale (which may be exacerbated by the high morbidity and mortality rates in a pandemic, particularly in the pediatric population)⁹⁹
- concern for personal safety and safety of family⁹⁸
- other^{95–96, 98}

These projected workforce reductions will further compound the current day-to-day staffing shortages that many ICUs and hospitals already face.^{47, 86, 90–91, 100–103} Various modeling tools indicate that the percent surge for hospital beds in a pandemic often involve numbers higher than the percent surge in available staff needed.⁹⁵ Hospitals may plan on state and/or federal staffing resources to help generate surge capacity lasting more than a few days.⁹⁵ Unfortunately, this may not be a viable option in the setting of a pandemic in which many regions or the entire country may be similarly impacted simultaneously.^{60, 70, 79–80, 82–83, 104}

Approach—When planning for staffing during a pandemic, it is important to consider that in addition to fewer staff being immediately available, the time required of staff may

actually be increased (due to the surge of patients, additional time taken to don and doff any necessary PPE,⁵⁶ staff working in unfamiliar environments, etc). Estimates for a moderate pandemic may involve a 14.4% staffing increase over baseline staffing.⁹⁵ Additional staff can be obtained both from within the hospital's existing resources as well as from external sources. Training of current workforce and volunteers should emphasize flexibility and interchangeability of roles. If the surge of patients predominantly involves the pediatric population, as has been the case with several previous pandemics, there may be a need to increase the capacity of pediatric ICUs in coordination with adult ICUs (staffing and resources). Adult health care workers should receive training in essential aspects of pediatric intensive care.⁹⁹ Training should optimally occur prior to the start of a pandemic and be supplemented with just-in-time refresher training as the pandemic starts.^{56, 99}

General methods to increase staffing with internal resources:

- Increase staff work hours.^{87, 105}
- Redeploy staff from administrative positions⁶⁰ and/or from cancelled elective procedures.⁹⁵
- Re-assign staff from floor wards to the ICU; critical care staff can supervise, “float and trouble shoot”.⁷² Some authors advocate for a plan where experienced intensivists coordinate the efforts of up to four non-intensivists who are each managing approximately six critically ill patients.^{75, 106}
- Re-deploy residents, hospitalists, emergency medicine physicians, hospital-based physician groups to areas where staffing is needed the most⁹⁵ and employ a “buddy-teaming” system to pair inexperienced with experienced staff members.
- Use trainees (e.g., medical and nursing students).^{60, 105}
- Use patients' family members in an ancillary healthcare capacity.⁶⁰
- Address the social barriers that may prevent some staff members from being able or willing to report to work: transportation and personal and family needs of the staff (child care, elder care, pet care),^{60, 76, 95–96, 107} provide in-home daycare to staff member's well-children using screened volunteers,⁵⁹ provide “medical daycare” for sick family members.⁵⁹
- Preferentially assign immunized staff and those that are considered immune^{36, 60}(due to recovery from infection) to units with influenza patients.⁵⁹

General methods to increase staffing with external resources:

- Use screened volunteers.^{47, 59, 69–70, 85, 90} It may be beneficial to use a “buddy-teaming” system where volunteers are paired with more experienced providers.⁵⁹ The pool of volunteers may include “medical professionals with prior clinical experience (e.g., administrators, researchers, retired clinicians), health professionals in related fields (e.g., dentists, veterinarians, emergency medical technicians), nonclinical hospital personnel, and nonclinical outside personnel”.⁵⁹
- Grant emergency privileges to qualified healthcare providers from unaffected areas.^{67, 85}

- Use mutual aid agreements such as Memoranda of Understanding (MOUs) to re-allocate certain specialty staff from regional hospitals.^{60, 90} In the setting of a pandemic in which a large portion of the affected patient population are children, these agreements may help facilitate pediatric transfers and staff coverage (particularly for pediatric ICU and surgical staff).

Workforce (Staff safety)

The ethical value of reciprocity implies that a healthcare worker's duty to care^{50, 56, 108–112} should be reciprocated with the healthcare facility's duty to provide a safe working environment.^{56, 109–110, 112–114} Duty of care is neither a fixed nor absolute concept but is heavily dependent on context. Hospitals should inform prospective staff members of what is expected in crisis situations before, rather than in the midst of, an emergency".¹¹⁵ While duty of care may seem a vague and ill defined concept,^{109, 115} the need for hospitals to provide a safe working environment for their staff is more intuitive and clear. In planning to maintain and augment the workforce during a pandemic, the need to provide staff support services cannot be over-looked or underestimated.^{50, 68, 73, 113} The psychological impact of an emerging pathogen on the workforce was dramatically demonstrated during the 2002–2003 SARS outbreaks. Healthcare workers struggled with personal fears and concern for their families and watched many of their colleagues fall ill.¹¹³ Staff safety became a "priority to maintain adequate critical care services."¹¹⁶ Hospitals should thus be charged not only with ensuring appropriate patient care but also with providing a safe environment for their staff.^{114, 117}

Ensuring staff safety and maintaining healthcare worker's confidence in their hospital's ability to keep them safe may help lessen staff anxiety¹¹⁸ and maintain a workforce despite concerns for personal safety. This section will focus on addressing staff safety through the implementation of infection control measures and through the delivery of psychosocial support services.

Previous experiences—The literature contains many reports of illness and death in healthcare workers during the 1918 pandemic,^{38, 40, 119–120} the 2003 SARS outbreaks^{45, 121–122} and the 2009 H1N1 pandemic.^{42, 123–124} See Table 1: Impact of Epidemics and Pandemics on Healthcare Workers.

The reports of healthcare workers contracting influenza and SARS secondary to exposures at work must be viewed not only in the context of the transmissibility of the virus which is often unknown during the initial wave, but also in the context of existing infection control measures. There are several reports of hospitals caring for influenza and SARS patients with few or no reports of ill staff.¹²⁵ This low level of or lack of transmission may be related to strict infection control measures,^{20, 126} though some hospitals admitted to variable use of these measures.¹²⁵ Similarly, higher numbers of ill staff have been reported in hospitals with variable use of infection control measures^{123, 127} but also in hospitals compliant with recommended precautions.¹²⁸ Given that healthcare worker infection can exacerbate workforce reduction and lower staff morale,⁵⁶ it is absolutely crucial that effective and appropriate infection control measures are instituted as early as possible.⁵⁶

Challenges—Decisions regarding the definition and the institution of infection control guidelines are complicated by several variables: unknowns regarding virus transmissibility and its clinical implications, the need to protect staff and patients, the available supply of PPE, the ability to train and fit-test staff,^{114, 124, 128} and the inconsistencies in infection control measures seen at the local, state, national and international levels.^{19, 56, 99, 114, 124, 129–132} Compliance with PPE and infection control measures may also be suboptimal,^{128, 130, 133–134} therefore potentially limiting their efficacy. In a small study (twenty-seven participants), Radonovich et al examined the tolerability of commonly worn respirators and found that a large percentage of participants (59%) were unwilling to wear the respirator ensembles (eight different respirators were evaluated) for their entire eight hour shift, even with break periods.¹³⁵ The reasons for non-compliance included difficulty communicating, facial heat/pressure, dizziness and difficulty concentrating.¹³⁵

Further compounding this issue is the fact that few clinical trials have been conducted to support infection control decisions¹³⁶ and that controversy remains as to the effectiveness and choice of PPE for influenza and other pathogens.¹³⁷ Recommendations for these measures may also change frequently,^{19, 45, 50, 116} at times on a day to day basis,¹¹³ as more is learned about the emerging pathogen. It then becomes a challenge to keep staff informed, updated and compliant.¹²⁴ An effective infection control policy not only requires the implementation of appropriate measures but also the ability to adjust to the evolving situation. Gomersall et al, based on their experience with SARS in a Hong Kong ICU argued that a “step-down approach in which precautions shown to be unnecessary are abandoned is preferable to a step-up approach, which, in the SARS epidemic, was associated with staff infections”.²⁰

Approach

Personal Protective Equipment

- Hospitals must maintain a sufficient amount of appropriate PPE for their workers.^{20, 45, 56, 61, 75–76, 95, 98, 107, 109, 123, 137–140} There are, however, varying recommendations on the stockpile that hospitals should have on hand: 48 hours (in the context of planning for bioterrorism),⁷⁵ three to seven days,⁵⁶ three weeks,⁵⁹ eight weeks.^{87, 126} Recommendations vary according to the pathogen studied and cost and storage considerations. Hashikura and Kizu developed a PPE calculation system to help hospitals decide on the size of their PPE stockpile.¹²⁶ They recommended four sets of PPE (N95 respirators, double gloves, gowns, and goggles) per day for healthcare workers in high risk groups.¹²⁶
- The use of an automated re-stocking mechanism will be helpful in monitoring supplies.⁵⁶
- Hospitals must provide for baseline training^{45, 50, 56, 59, 62, 73, 75, 77, 95, 109, 114, 128, 138, 141–142} (indications, how to don and doff, etc) and just in time refresher training.^{56, 95} Novel training modalities include the use of a “human patient biosimulator to visually demonstrate respiratory disease transmission”,¹³³ the use of online training and the use of websites as a source of updated accurate infection control measures.⁵⁰

- Assessment of competence should be performed as part of the training.⁵⁶ Lau et al found that less than two hours of infection control training and a lack of understanding of infection control procedures were associated with healthcare workers becoming ill with SARS.¹³⁸
- Hospitals should monitor staff compliance with use of PPE.^{20, 49, 56, 95, 107}
- Fit-testing of PPE, which is time consuming, should be initiated and maintained prior to a pandemic.¹¹⁴ This can be facilitated with train-the-trainer programs to ensure that adequate numbers of trainers are available who can then conduct marathon sessions for hospital staff to be tested.

Address Psychosocial Issues

- Maintain open and honest communication with staff members.^{59, 113, 141}
- Provide psychosocial support services to staff members.^{60, 73, 76, 97, 140, 143} Coordinating these activities with other regional hospitals may increase the services available.^{59, 141}
- Maunder et al discussed the success of a measure as simple as a “drop-in lounge with soothing music, comfortable chairs and snacks” available to staff during the Toronto SARS experience.¹¹³
- Prior to a pandemic, inform and educate the staff on the hospital’s preparedness plans and support services⁹⁶ and encourage personnel to complete family preparedness plans.⁶⁸
- During and after a pandemic, provide staff with the opportunity to participate in professionally conducted Critical Incident Stress Management (CISM) debriefing sessions. CISM sessions provide an opportunity for staff members to discuss their reactions to the stress of working during a pandemic; the program aims to mitigate acute symptoms and to “provide a sense of post-crisis psychological closure”.¹⁴⁴

Resources: General

Critically ill influenza patients are resource-intensive. The rapidity^{40, 99, 114, 119, 123, 145–150} and severity of the respiratory failure¹⁵¹ that occurs often requires extensive and prolonged therapies (intensive both in terms of resources and staffing)^{42, 44, 145, 148, 152} and may require rescue therapies not widely available (nitric oxide,⁴⁴ high-frequency oscillation,⁴⁴ Extracorporeal Membrane Oxygenation [ECMO]).^{44, 153–154} Resource management during a pandemic will be a tremendous challenge but must be pursued robustly. During previous U.S. disasters, “hospitals that did the best during and after a disaster were those that planned most carefully concerning logistical issues, including what supplies they would need and how they would secure those supplies in times of crisis”.⁸⁰

Challenges—There are several challenges involved with managing resources for a pandemic.

- Just-in-time supply chain operations^{36, 47, 93, 141, 155–157} will undoubtedly limit the ability of hospitals to adequately respond to a surge in patients using the supplies they have immediately available.
- Reliance on off-shore suppliers¹⁴¹ may limit access to resources during a pandemic as these suppliers may not be available secondary to global need and transportation issues.
- Pandemics have historically impacted certain patient populations more than others. For example, in previous epidemics and pandemics as well as the 2009 H1N1 pandemic, pediatric / young adults,^{11, 38, 42, 57, 60, 67, 99, 114, 123, 146, 148–149, 154, 158–163} pregnant women,^{43–44, 119, 153–154, 159–160, 164–173} obese^{42, 154, 159} and morbidly obese^{148, 159–160} patients have been significantly impacted. These populations require special resources, not often stockpiled by hospitals.

Approach

- Given the challenges to resource management discussed above, regional efforts may provide the most beneficial approach⁶⁰ for a hospital to be able to adequately supply its community with healthcare resources during a pandemic. This approach would be particularly useful for specialized items (e.g., high-level ventilators) that may only be available at specialized centers and not be available in national stockpiles. Despite some barriers to inter-hospital collaboration,⁸⁷ hospitals should plan as a region be able to surge up to 200% of existing hospital capacity.⁸⁷
- Detailed plans for resource management need to be developed. These plans should address operations, communications, training, administration and planning as well as strategies for using and conserving the following materials: oxygen, medication administration, hemodynamic support and IV fluids, mechanical ventilation, nutrition and staffing.¹⁷⁴

Resources: Ventilators

Previous Experiences—A summary of the impact that previous influenza pandemics have had on critical care services is provided in Table 2: ICU Impact of Pandemic H1N1 Influenza A

Challenges—One major limitation in a hospital and ICU's ability to provide an adequate standard of care to a high volume of patients during a pandemic would likely be the available supply of ventilators.^{72, 83, 111, 175} As seen by the statistics in Table 3: Mechanical Ventilators in the United States, an average influenza season places almost 100% of the available ventilators into use. The U.S. Department of Health and Human Services' Pandemic Influenza Plan⁶⁰ uses the estimate of a more than 25% increase in demand for intensive care unit beds and assisted ventilation services during a pandemic, while others place the estimate even higher (33% increase).⁵⁴ It is easy to imagine that the Strategic National Stockpile (SNS) reserve supply of ventilators could quickly be depleted by a surge of pandemic influenza patients with acute respiratory failure.⁸⁶ Without a doubt, the current

ventilator supply in the United States is nowhere near sufficient to meet the projected needs of a pandemic similar to the 1918–1919 influenza pandemic.^{176–177}

In reviewing these statistics, it is important to keep in mind that these numbers do not necessarily indicate the number of ventilators that would be immediately available for hospital use. Hospitals have enough ventilators on hand to respond to their typical critical care patient volume; however, they often need to rent additional ventilators to respond to demand peaks.⁸⁶ A 2006 study found fewer than six ventilators available for immediate use at anytime in the entire Los Angeles area.¹⁷⁸

However cost prohibitive, these numbers suggest, at the very least, that it might be wise to increase the stockpile of ventilators. However, there are other major limiting factors in providing mechanical ventilation to critically ill patients in addition to the supply of ventilators. The benefit of having additional ventilators available is only achieved if trained staff are available to operate them.^{62, 91, 156, 176, 179} This is particularly true with non-conventional ventilator modalities such as ECMO which are not only a limited resource but also require more specialized training.¹⁸⁰ Gomersall et al argue that “equipment purchases should be proportionate to availability of reserve staff”⁵⁶ as opposed to the estimated number of patients in need of mechanical ventilation. However, the availability of staffing during a pandemic or epidemic is largely unknown, so purchasing equipment based on this factor may be as rough an estimate as basing it on projected numbers of patients. Another operational requirement for ventilators is a supply of oxygen. Most hospitals rely on large storage tanks of liquid oxygen. If this source runs low, oxygen must be trucked in from a supplier. The number of suppliers of medical grade oxygen in North America is limited as are the number of tanker trucks available to transport oxygen”.⁹³

Approach

Ventilator allocation plans: Hospitals and ICUs should have ventilator allocation plans in place prior to a surge of pandemic patients. These allocation plans should include a range of ventilators (including conventional full- and limited-feature ventilators, as well as ECMO, high-frequency oscillatory ventilation⁴⁴ and inhaled nitric oxide⁴⁴) that may be needed to respond to the complex respiratory illnesses associated with pandemic influenza. Ventilator and resource allocation plans will be discussed in the Crisis Standards of Care section.

Increasing the supply of ventilators

- Additional ventilators may be made available by using anesthesia and recovery room ventilators which may become available as elective procedures are cancelled during a pandemic surge.^{53, 91}
- “Positive pressure ventilation equipment purchased for surge capacity should at a minimum accomplish the following: (1) be able to oxygenate and ventilate most **pediatric and adult** patients with either significant airflow obstruction or ARDS; (2) be able to function with low-flow oxygen and without high-pressure medical gas; (3) accurately deliver a prescribed minute ventilation when patients are not breathing spontaneously; and (4) have sufficient alarms to alert the operator to

apnea, circuit disconnect, low gas source, low battery, and high peak airway pressures.”¹⁰⁶

Ventilator “alternatives”: If there is the potential for the demand for ventilators to outstrip the supply of ventilators, then consideration should be given to what alternative technologies and devices are available. No clinical data exists on this, but conceivably at least, some of these alternatives may be better than nothing. Many make the argument that in the setting of complex pulmonary illness associated with influenza, no realistic alternative to full-feature ICU ventilators exist.^{93, 179} There is limited published guidance to assist in the selection and use of alternative modes of ventilation.⁸⁶ Use of any alternatives will undoubtedly lower the standard of care delivered⁶³ and should be done in conjunction with appropriate crisis standards of care guidelines (discussed in Crisis Standards of Care section).

Many alternatives to full-feature ventilators have been suggested for use in austere environments, such as that created by a pandemic surge, as seen in Table 4 The Use of Ventilator Alternatives During an Influenza Pandemic.

Physical Space

Previous Experiences—Alternate sites of care have been used during previous disasters to provide healthcare, including during the 1918 pandemic.¹⁰⁵ There is, however, very limited experience, literature and direct evidence to support mass casualty critical care practices in non-hospital settings.⁸² During a pandemic, critically-ill patients should be managed in a hospital; alternate sites of care may be feasible for those who are mild to moderately ill.¹⁸¹ These areas should be studied as part of a hospital’s pandemic response plan.

Challenges—The real challenge during a pandemic will likely be to increase ICU-level capacity. Approximately 20% of a hospital’s total rooms would be needed in order for the hospital to double or triple its ICU capacity.⁷⁵

Considerable requirements are needed for a physical location to be used to provide ICU level critical care⁹³:

- oxygen^{63, 83} with the availability of piped gas is a major determinant of where temporary ICU beds can be placed⁵⁶
- electricity
- vacuum / suctioning capabilities
- monitoring equipment
- sufficient physical space, given infection control parameters, for equipment and patient management

Approach—Potential alternate sites of care for ICU-level patients will likely only provide a small number of additional beds.⁷⁵ Examples of such areas include:

- operating rooms⁵⁹

- post-anesthesia care unit^{59, 63, 75, 93}
- catheterization lab^{59, 63} and recovery area⁵⁹
- step-down unit⁷²
- endoscopy unit^{59, 63, 75}
- chest pain observation unit⁶³
- outpatient surgery areas^{63, 75}

Another approach, though perhaps incompatible with infection control measures during a pandemic, is to place more patients in currently used areas, by using cots and/or portable beds to convert single patient rooms into double or triple occupancy rooms.⁴⁷

Processes: Surge of Patients

There are varying definitions of surge capacity,¹⁸² but the concept that surge capacity must encompass a surge of staff, resources and physical space is agreed upon by many.^{64, 69, 72, 90, 156, 182–185} For the purposes of this paper, the definition from the Joint Commission serves as the best example:

Surge capacity encompasses potential patient beds; available space in which patients may be triaged, managed, vaccinated, decontaminated, or simply located; available personnel of all types; necessary medications, supplies and equipment; and even the legal capacity to deliver health care under situations which exceed authorized capacity.¹⁸⁴

Previous Experiences—Historically, the surges associated with pandemic influenza have been abrupt in onset,¹⁸⁶ consistent with a rapid rate of influenza spread.^{83, 161, 187–190} Overall, the surge is usually prolonged (often lasting for several weeks to months)^{60, 65, 71, 95, 154, 191} with a surge peak lasting one to three weeks.^{41–42, 105, 153, 192} Pandemics have also often occurred in waves.^{155, 162, 193} Table 5: Impact of Epidemic and Pandemic Surges on the Healthcare System summarizes several examples of patient surges associated with epidemics and pandemics.

The U.S. healthcare system has limited experience in dealing with significant surges in patient volume.⁶⁴ Previous to the 2009 pandemic concerns, much of disaster planning and exercises had focused on a response to an abrupt and brief incident (e.g., mass casualty trauma). While the Joint Commission standard requiring an acute care facility to be self-sufficient for ninety-six hours and incidents like Hurricane Katrina have forced planners to look into sustaining their responses, few are prepared or capable of a lengthy prolonged response in the setting of potential infra-structure damage or collapse.¹⁹⁴ Length of ICU stays were prolonged in the setting of the SARS epidemics; the average ICU stay for SARS patients in Toronto was 10.5 days⁴⁵ and 18 days for SARS patients in Singapore.¹⁹⁵ Despite the challenges to creating surge capacity, the importance of doing so is framed by Rubinson and O'Toole's statement that during an epidemic, "the toll of death may be inversely proportional to the ability to augment critical care capacity".⁶² The U.S. Department of

Homeland Security reiterates that surge capacity is a “national priority” for disaster and pandemic preparedness.

Challenges—The lack of surge capacity in our current healthcare system,^{36, 39, 61, 77, 141, 157, 196–201} and particularly the lack of capacity to provide intensive care to large numbers of patients^{74, 83} has been discussed extensively in the literature. There are a number of reasons why our system lacks the capacity to handle a surge in patient volume; among the most important of which are the intertwined limitations in staffing and bed supply. Extra beds and resources are not useful if they cannot be staffed.⁸⁵ Various modeling tools have indicated that the percent surge for hospital beds often involve numbers higher than the available percent surge in staff.⁹⁵

Much of the literature on surge capacity focuses on emergency department and/or hospital surge capacity in general. There are few published evidence-based guidelines¹⁵⁶ or clinical trials pertaining to ICU expansion⁵⁶ or on the specialized needs of surging for a pediatric population⁶⁷ in the setting of an epidemic or pandemic.

In the setting of current ICU staffing shortages,^{47, 86, 90–91, 100–103} healthcare professionals, particularly nurses, physicians, and respiratory therapists are a significant rate limiting factor in the ability of the healthcare system to mount an effective surge.^{50, 61, 72, 83–84, 202} In addition, over the past several years, the overall number of hospitals and hospital beds in the United States has been decreasing^{46, 83, 141, 198, 203} and associated with consistently high critical care bed occupancy rates.²⁰³ At any given time, it is estimated that only 4% to 6% of U.S. hospital beds are available.¹⁹⁸ During an influenza pandemic, not only will staffed ICU beds be needed^{50, 63, 72, 77, 83, 86, 201–202, 204} but these ICU beds may need to be equipped with respiratory isolation.⁷³ According to the Trust for America’s Health 2006 data, half of the states would run out of hospital beds within two weeks of a moderately severe pandemic influenza outbreak. In the situation of a severe pandemic similar to that in 1918, almost all (forty-seven states) would run out of hospital bed capacity within two weeks.”^{70, 205}

Approach

Pre-incident planning is vital: As the demand for critical care resources during a pandemic will likely be sudden and occur over a short time frame⁹¹ it will be too late at that point for a hospital and ICU to create a plan to respond to the surge in volume of critically ill patients. To facilitate planning, some states, (e.g. California) have created ‘fill-in-the-blank’ templates for their hospitals to use to create surge guidelines.²⁰⁶ Given the potential need for critical care resource allocation, intensivists will play a key role in responding to a pandemic, and thus should also play a key role in planning for one.^{59–62}

Surge Plans: Various recommendations have been made for pandemic hospital and ICU surge planning:

- Surge capacity planning must apply to beds, equipment, personnel and special capabilities⁹⁵ and must take into consideration high numbers of patients with respiratory⁴⁶ and critical illness associated with pandemic influenza

- The focus of surge planning should be on patient-care capacity, rather than on increasing supplies and beds.¹⁸² Expansion plans should be based on estimates of feasibility rather than estimates of requirements.⁵⁶
- The target percentage for surge capacity is not well established.⁵⁶ A commonly cited recommendation is that hospitals aim to surge 30% of their listed bed capacity within one week^{39, 59, 87, 141} and double their licensed bed capacity within two weeks.^{59, 141} As daunting as that may sound, it appears to be an achievable target: The New York Institute of All Hazard Preparedness (NYIHP) hospitals have developed a regional integrated plan that enables them to create a bed surge capacity of 25% for Central Brooklyn.⁶⁴

Creation of surge capacity

- Reduction and/or cancellation of elective procedures and admissions^{46-47, 56, 63, 75, 91} which allows reassignment of anesthesia and surgical staff to areas of staffing need.⁵⁶ The ability of this measure alone to create sufficient hospital and ICU beds for even a mild pandemic, however, is limited.⁸¹
- Early discharge of stable inpatients.⁶³
- Conversion of private rooms to double occupancy.⁶³
- Use of hallway areas to board in-patients.²⁰⁷
- Use of alternate care sites.⁶³
- Cohorting of influenza patients.^{60, 70}
- Relaxation of staff versus patient ratios in conjunction with appropriate agencies and authorities.^{46, 59, 69}
- Regional use of resources.⁶⁸

Processes : Crisis Standards of Care / Resource Allocation

Any review of pandemic influenza must address the sensitive and controversial subject of altering the standard of care in response to a catastrophic incident. This concept falls under several terms: altered standards of care, emergency mass critical care^{62, 75} and, most recently, crisis standards of care⁷² as described below in Table 6: Definitions of Standards of Care.

The difficult and essentially untested transition from providing care based on each individual's needs to a more community-based approach of trying to do the "greatest good for the greatest number" in the setting of a catastrophic event such as a severe pandemic has been explored by several authors and published in several guidelines and planning documents:

- Lin and Anderson-Shaw¹⁷⁵
- Hick and O'Laughlin⁸³
- Task Force for Mass Critical Care⁸²

- New York State Workgroup on Ventilator Allocation^{111, 176}
- Ontario Health Plan for an Influenza Pandemic²⁰⁸
- Utah Pandemic Influenza Hospital and ICU Triage Guidelines²⁰⁹
- Colorado Department of Public Health and Environment¹⁰⁸
- Minnesota Department of Health^{83, 174}

While many guidelines have been developed or are in process of being developed,⁷² none have yet to be fully operationalized.

Medical Care during Catastrophes—A major shift in focus occurs in the response to a catastrophic public health emergency, such as a severe pandemic. Rather than the focus of healthcare provision being on the individual patients, it becomes necessary to focus on the provision of healthcare to the collective society.^{87, 182, 210–212} This has the potential to create tremendous conflict for the healthcare provider who may need to deny care to or withdraw care from an individual patient (actions contrary to their everyday practice)²¹³ in order to use resources for the best of the overall population.^{109, 112, 210–211} It is important to remember, however, that the majority of altered standards of care guidelines are based on an ethical framework. Many ethical principles guide the daily practice of modern day medicine; this will not change during a disaster as “health care professionals are always obligated to provide the best care they reasonably can under given circumstances”.⁷²

The importance of establishing Crisis Standards of Care—Healthcare professionals strive to ensure that as many patients as possible can be offered critical care services.¹⁵² With critical care resources, a large portion of patients who are critically ill with pandemic influenza can survive.^{44, 152–153, 155, 214} This has “important societal implications”⁴⁴ given the predisposition pandemic influenza often has for affecting young, previously healthy individuals. Alternatively, it is predicted that a reduction or lack of critical care resources could substantially increase mortality.^{86,93,99,215}

Given the lack of experience with instituting crisis standards of care, as well as the lack of national or international consensus guidelines and the dire circumstances of having to allocate scarce resources during a catastrophic pandemic, it should be clear that prior planning for the use of crisis standards of care may help reduce the stressful impact on those tasked with enforcing these guidelines. Advanced planning also provides the opportunity for these guidelines to be vetted to both the medical and non-medical communities for their input and discussion and perhaps their acceptance. Previous attempts to allocate scarce resources (e.g. during Hurricane Katrina in 2005) in the absence of pre-established guidelines resulted in extensive controversy and debate.^{152, 216} Planning can also help prevent “crisis decision making”²¹² and allow for a standardized and simplified process to allocate resources and perhaps provide legal protection for healthcare workers as well.^{72, 76, 82–83}

Challenges: Several challenges exist in creating guidelines for crisis standards of care:

- On an international level, basic standards of care are remarkably different.

- While national guidelines exist,^{72, 76} national standards such as the Joint Commission⁸⁰ and specific federal guidance on this subject are limited.^{47, 78, 193, 211, 216–220} The ethics of allocating scarce resources are not addressed in the Homeland Security Council's National Strategy for Pandemic Influenza or in the Pandemic and All-Hazards Preparedness Act. Furthermore, there are few incentives for states to pursue this time-consuming planning.⁴⁷
- Because the availability of critical resources and therefore the standard of care that can be offered will likely be fluid and evolve as pandemic progresses,⁵⁹ guidelines will need to be flexible.
- Triggers will need to be identified for activating various stages of altered standards of care.⁷⁸
- Strategies for implementation of these standards will need to be established.²⁰⁸

While the healthcare system has limited experience allocating scarce resources during a catastrophe, the critical care system has experience with the rationing of ICU beds in daily operations.²⁰⁰ While some of this experience may translate to a better understanding and ability to ration scarce resources during a pandemic, several challenges to this theory exist. Several studies have shown that there is no standard process for deciding who does and who does not get an ICU bed; differing criteria are used for triaging admissions to ICU beds.^{200, 221} Also, hospital guidelines for ICU admissions, when they exist, are often not followed.^{84, 222} Thus, the translation of this triage process from daily use to application during a catastrophe may be difficult given the apparent lack of a standard even under normal operations.

Approach: Guidelines for crisis standards of care must be in place prior to the next catastrophe.^{72, 83, 218} This allows for the time needed by the general public to understand and hopefully accept these standards.⁸⁷ By involving healthcare providers in the process, they can be advocates for the policy as they explain changes in care to their patients. Front-line physicians play an important role in conveying to the public that emergency public health measures are necessary and fair."²¹⁰

Characteristics of crisis standards of care guidelines should include

- The acknowledgement that an alteration of standards may need to occur in the setting of a catastrophic incident.^{47, 60, 62–63, 69–72, 75–76, 87, 108, 111, 208}
- Crisis standards will need to include a process that allows for revision,^{82–83, 208, 223} appeals^{175–176, 208, 213} and a retrospective, systematic review process^{82, 111} as the catastrophe evolves.⁶³
- A phased allocation of resources.^{74, 108, 175, 208–209}
- A tiered approach to response (hospital → regional → national levels).^{83, 87}
- Crisis guidelines need to be standardized for acute care facilities across the region,⁸³ state^{176, 209} and country^{72, 224} with a process for them to be implemented uniformly.⁶³

- The acknowledgement that these guidelines will be activated^{208–209} only after all attempts to acquire resources have failed.^{82–83, 111, 208}
- Identification of triggers for activating and discontinuing the guidelines,^{60, 62, 72, 75, 108, 208} including protocols for both the initiation and withdrawal of resources (e.g., ventilators)^{59, 75, 82–83, 108, 175–176, 209}
- Consistent and equitable use of guidelines for all patients, not just influenza patients.^{56, 72, 82–83, 108, 111, 208, 211}
- Crisis guidelines should be uniformly ethically-based.^{47, 59, 72, 82, 108, 111, 175, 208, 211, 218, 225–227} Examples of ethical principles include justice,^{56, 111, 175, 208} transparency,^{56, 58, 63, 72, 76, 78, 82–83, 111, 176, 194, 208, 213, 226–227} distributive justice,^{111–112, 226, 228} beneficence,¹⁷⁵ equity,^{56, 112, 208, 218, 225, 228} utility,⁵⁶ fairness,^{72, 76, 208, 213, 226} duty of compassion and care,^{72, 111, 208, 225} and duty to steward resources.^{72, 111, 225}
- A decision-making model for allocation of scarce resources.^{49, 59, 70, 72, 82–83, 87, 108, 112, 141, 175–176, 194, 208–209}
- Process for reassessment of need for ICU and /or ventilator use at designated intervals.^{111, 194, 209}
- Inclusion and exclusion criteria for hospital and ICU admission.^{63, 87, 108, 111, 194, 208–209}
- Use of a triage officer and/or committee^{82–83, 89, 111, 175–176, 194, 208–209} to serve as decision-makers for triage of resources.^{56, 63, 82, 208} These clinicians are not to be involved with direct patient care. Establishing triage officers provides role sequestration that will help sustain clinicians who serve during disasters. Without such measures, the “secondary effects of the disaster on clinicians, including burnout and stress, may prove more corrosive than the original trauma.”¹¹¹
- A support system to implement and manage the triage process.^{49, 71, 82, 89}
- A regional triage process.^{75, 82, 194}
- Palliative care protocols.^{82, 111, 175–176}
- Plans for use of alternate care sites.⁸⁷
- Priority setting (e.g., patients with the best survival probability are given the highest priority.)^{49, 58, 63, 75, 83, 194}
- Legal and liability protections for healthcare professionals providing care under these standards.^{72, 76, 82–83}

Hospitals should convene a Pandemic Preparedness Committee.^{59, 141} Membership should include the key leaders during a pandemic response who will be responsible for decisions made before, during and after a pandemic. Committees such as these help to form working relationships in the planning phase which will ease transition into the response phase.

Robinson et al recommend the following guidelines for the creation and use of Emergency Mass Critical Care (EMCC) ⁷⁴:

- All hospitals with ICUs should prepare to deliver EMCC for a daily critical care census at three times their usual ICU capacity for up to ten days.
- Hospitals with ICUs should plan and prepare to provide EMCC every day of the response for a total critically ill patient census at least triple usual ICU capacity.
- Hospitals should prepare to deliver EMCC for ten days without sufficient external assistance.

Processes: Communication

Communication is a frequent challenge in disaster preparedness and response.⁸⁰ The need to provide accurate, consistent and timely information to the responders and to the general public cannot be underestimated. During a pandemic, the public will need to be kept informed about illness symptoms, how to prevent getting sick, when to seek treatment⁴¹ as well as to be informed about potential changes in how healthcare is being delivered. Healthcare providers will need quick and easy access to up-to-date and accurate treatment recommendations and other vital medical information.

Previous Experiences—The positive effects of good communication as well as the destructive impact of ineffective communication were well illustrated by the SARS experience in Toronto in 2003.

Initially, several hospitals encountered unchecked rumors, staff distrust and confusion⁴⁹ secondary to a lack of a “clear system-wide communication strategy”.⁵⁰ This was further compounded by the fact that SARS (like a pandemic influenza) was a new illness and information about the virus and management recommendations were frequently being updated and changed.⁵⁰ As the response to SARS progressed, several successful communication strategies were implemented, and have since been recommended for use in the critical care community for responses to future epidemics and pandemics:

- Regular teleconference calls¹¹³ (three times a week, involving critical care clinicians, infection control, infectious disease consultants, public health, government, hospital administration).⁴⁸
- Web-based information, training and education^{48, 50, 229} and the use of a hospital’s intranet.¹¹³
- Daily e-mails to staff with updates on SARS information, procedural changes, modes of transmission, clinical presentation, number of hospitalized patients, number of staff in quarantine or admitted; these daily e-mails were also used to “express praise and gratitude to all staff for their contributions”¹¹³

Challenges

- Multiple sources of information²³⁰ often lead to inconsistencies.

- A major challenge to effective and efficient communication during a pandemic is the paucity of information about the disease early in the course²³¹ and then the subsequent rapidly changing information and guidance that evolves as more is learned about the virus.

Approach

- Hospitals need to establish reliable, accurate, consistent communication methods for internal and external communications.⁷⁸
- ICUs should develop a crisis communication plan and designate an ICU spokesperson.⁴⁸
- Communication of and quick access to clinical management guidelines and physician resources will be vital for healthcare providers during a pandemic.
- During the 2003 SARS outbreak in Toronto, a group of tertiary care intensivists made themselves available via a 24 hour on call government sponsored toll-free line.⁴⁸
- The development and use of pre-printed disease-specific order forms may help to speed patient care delivery and standardize care during a surge of patients.⁷⁵ The forms will need to be updated as necessary and should incorporate new treatment modalities with which clinicians may not be familiar (e.g., Emergency Usage Authorization changes to medications, indications for unconventional modalities such as ECMO, etc).

Conclusion

A review of past and current epidemics and pandemics demonstrates the significant impact that emerging infectious diseases can have on the healthcare system. Intensive Care Units often bear the brunt of this impact and thus critical care specialists need to be aware of influenza virology and epidemiology and be intimately involved with pandemic planning and response. Challenges identified during previous pandemics and therefore priorities for further focus include resource management, maintaining adequate staffing and the creation and use of crisis standards of care. The lack of surge capacity in the current US healthcare system makes pandemic response a daunting task; however, as healthcare providers we are obligated to plan for a potentially catastrophic situation in order to provide the best care possible for our critically-ill patients.

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Table 1

Impact of Epidemics and Pandemics on Healthcare Workers

Epidemic / Pandemic	Impact on healthcare workers	Comments
1918 influenza pandemic	<p>Cook County Hospital, Chicago:</p> <ul style="list-style-type: none"> more than 50 nurses, 12 resident physicians and 4 lab assistants contracted influenza; 3 RN's died³⁸ <p>St. Luke's, Manila:</p> <ul style="list-style-type: none"> One third of the nursing staff and one half of the orderlies and attendants became ill²⁰ 	
SARS 2002–2003	<p>Rate of infected HCWs:</p> <ul style="list-style-type: none"> 21% of all confirmed cases were healthcare workers¹²² 19% in China, 22% in Hong Kong, 20% in Taiwan, 43% in Canada, and 41% in Singapore¹²² <p>Hong Kong</p> <ul style="list-style-type: none"> 2.67% of ICU staff developed SARS²⁰ 	<p>Authors "believe that the personal protective procedures adopted in our ICU were effective when rigorously applied and that this was responsible for the relatively low infection rate amongst our staff."²⁰</p> <p>A nurse was stationed at the ICU entrance to monitor and ensure compliance with PPE</p> <p>Infection control measures were limited in hospitals represented here for a variety of reasons^{45,127}</p>
2009 H1N1 influenza pandemic	<p>Toronto</p> <ul style="list-style-type: none"> \$1 million worth of PPE used in the first week alone²³² Seven of the thirty-eight (18%) critically-ill patients studied were healthcare workers who contracted SARS secondary to ICU transmission⁴⁵ In two University ICUs: 164 healthcare workers were quarantined and 6 staff members developed SARS⁴⁵ The probability of contracting SARS infection was 6% per shift worked¹²⁷ Secondary transmission closed nearly one-third of the community and academic medical center ICU beds for some period during the outbreak⁴⁸ <p>Mexico</p> <ul style="list-style-type: none"> 22 out of 190 (12%) healthcare workers from the ED and ICU developed influenza-like illness within one week of first three cases of pandemic H1N1¹²³ 40 of 6755 (0.6%) healthcare workers in the Dominguez-Cherit study became ill with H1N1⁴² <p>United States</p>	<p>The hospital studied by Perez-Padilla et al had no further staff illness after infection control measures were "strictly enforced"¹²³</p> <p>Dominguez-Cherit et al explained their low rate compared with others because their ICU patients presented later in the course of their illness (median 6 days after disease onset), when they are presumably less infectious.⁴²</p>

Epidemic / Pandemic	Impact on healthcare workers	Comments
	<ul style="list-style-type: none">Approximately half of the 81 US Healthcare workers identified with H1N1 were felt to have likely acquired the infection while at work; includes one instance of presumed HCW to HCW transmission¹²⁴	

Table 2

ICU Impact of Pandemic H1N1 Influenza A

Reference	% of hospitalized patients admitted to ICU	Duration of ICU stay	% of ICU patients receiving mechanical ventilation	Duration of mechanical ventilation	ECMO use	Mortality
Seasonal influenza study Washington, DC 1999–2000 season ¹⁵¹		28±26 days		21.5 ± 20.5 days (mean 20.4 days; range 1 to 42 days)		
Initial wave 2009 pandemic H1N1: Hospitalized pts in Mexico ⁴²	6.5%		97% ICU patients received mechanical ventilation			41% “of critically ill patients” died
Initial wave 2009 Pandemic H1N1 Mexico ¹²³				Range 7 – 30 days (survivors) Range 4 – 17 days (nonsurvivors)		
Initial wave 2009 Pandemic H1N1 California 2009 ¹⁵⁹	31% (20% of admitted pregnant women required ICU care)		65%			
Initial wave 2009 Pandemic H1N1 United States ¹⁶⁰	25%		63%			28% mortality rate for ICU patients; overall 7% mortality rate
Initial wave 2009 Pandemic H1N1 Canada ⁴⁴		Median duration was 12 days (IQR, 5–20 days) 12 days for survivors (IQR 5–22 days) 10 days for nonsurvivors (IQR 4– 19 days)	81%	Median duration was 12 days (IQR, 6–20 days) for both survivors and nonsurvivors	ECMO was used in 4.2% of ICU patients High-frequency oscillatory ventilation was used in 12% of ICU patients Inhaled nitric oxide was used in 17% of ICU patients	
Initial wave of pandemic H1N1 in Australia and New Zealand (ANZ ECMO Investigators study) ¹⁵³			80%			
Initial wave of pandemic H1N1 in Australia ¹⁸⁰	6%				2% of all admissions (30% of ICU admissions) used ECMO	
Initial wave of pandemic H1N1 in Australia and New Zealand (ANZIC Influenza Investigators study) ¹⁵⁴		Median duration was 7 days (IQR 2.7 – 13.4 days)	65%	Median duration 8 days (IQR 4 – 16 days)	12% of patients requiring mechanical ventilation subsequently were treated with ECMO	14.3% mortality rate of all confirmed H1N1 patients in ICU

Table 3**Mechanical ventilators in the United States**

Number of ventilators in the United States	105,000 ventilators ^{36,179,233}
Typical everyday medical care	75,000 – 80,000 ventilators in use ^{36,157}
Average influenza season	100,000 ventilators in use ^{36,157,179,233}
Estimated need during severe pandemic (modeled like 1918 pandemic)	742,500 ventilators would be needed ^{175,179}
Cost of typical hospital ventilator	\$30,000 ^{179,233}
Estimated number of ventilators in federal Strategic National Stockpile (SNS)	4,000 – 5,000 ventilators ^{175,233}

Table 4

The Use of Ventilator Alternatives During an Influenza Pandemic

VENTILATOR-ALTERNATIVE	COMMENTS
Non invasive ventilator	<ul style="list-style-type: none"> • Readily available • In the setting of an influenza pandemic, not recommended by many as it is unlikely to provide significant benefit to patients with ARDS and may increase the risk of airborne transmission^{56,99,116}
Portable ventilator	<ul style="list-style-type: none"> • Battery or pneumatic power • Reasonable alternative⁸⁶
Disposable emergency ventilator	<ul style="list-style-type: none"> • Powered by pressure of oxygen tank and can run indefinitely on hospital's oxygen supply • Can deliver oxygen at various pressures • Relatively inexpensive [Cost approximately \$50-\$100 each] • Limited to no role for seriously ill patients
Automatic resuscitators	<ul style="list-style-type: none"> • Entails the use of family members and/or volunteers to manually ventilate intubated patients with bag-valve-mask.^{75,83,86,185} • Physically exhausting technique • Not optimal for use in patients with significant air flow obstruction or low compliance • Hyperventilation, lung overexpansion and acute respiratory alkalosis can occur • May be considered in select cases for short periods of ventilation.⁸³ • Likely increases risk of transmission to volunteers and staff and is not recommended by many.¹¹¹
Experimental	Neyman and Irvin conducted a pilot study looking at a simple, rapidly deployable modification of one Emergency Department ventilator to provide ventilation for four adults simultaneously: four 70kg adults could be ventilated this way, for a short period of time. ¹⁸⁵

Table 5

Impact of Epidemic and Pandemic Surges on the Healthcare System

Incident	Comments on surge
1918 Pandemic: St Luke's Hospital in Manila ^{23,4}	<ul style="list-style-type: none"> The hospital maintained an average census of 90 – 96 patients a day for several days despite a normal capacity of 70 patients One third of the nursing staff was out sick with influenza. <p>The number of admissions for non-influenza illness remained the same as usual.</p>
2000 Outbreak of Influenza in a NICU ²³⁵	<ul style="list-style-type: none"> Level III nursery; designed for maximum of 34 infants; patient census on day #1 of the outbreak was 38. 19 infants were infected with influenza A; 6 symptomatic cases and 1 death.
2003 SARS Toronto ⁴⁵	<ul style="list-style-type: none"> ICU staff illness and quarantine led to 10-day closures of 35 critical care beds (represented 38% of the tertiary care university medical-surgical ICU beds in Toronto); there was also a total of 38 concurrent ICU bed closures in half of the community hospitals for the same reasons. The overall impact of this was: a loss of one-third of the Toronto community medical-surgical ICU bed capacity. These closures led to cancellations of major surgeries (cardiovascular, transplantation).
2009 Pandemic H1N1 Mexico ⁴²	<ul style="list-style-type: none"> “As a result of increased patient volumes, many experienced delay in admission to the ICU, and 4 remained in the emergency department until death ... the usual capacity to care for critically ill patients was exceeded, necessitating care in other patient areas and the addition of ICU beds and ventilators on 2 occasions”.
2009 Pandemic H1N1 Australia and New Zealand ¹⁵⁴	<ul style="list-style-type: none"> The number of ICU admissions due to influenza A in 2009 was 15 times the number due to viral pneumonitis in recent years.

Table 6

Definitions of Standards of Care

Standard of Care:

The Agency for Healthcare quality and Research (AHRQ) states that “standards of health and medical care, broadly defined, address not only what care is given, but to whom, when, by whom, and under what circumstances or in what places”.⁷⁶

Emergency Mass Critical Care:

The Working Group on Emergency Mass Critical Care describes Emergency Mass Critical Care efforts as “shifting critical care disaster preparedness efforts to augment limited, essential critical care (emergency mass critical care), rather than to marginally increase unrestricted, individual-focused critical care may provide many additional people with access to life-sustaining interventions.”⁷⁴

Crisis Standards of Care:

The Institute of Medicine’s Committee on Guidance for Establishing Standards of Care for Use in Disaster Situations defines Crisis Standards of Care as a “substantial change in usual healthcare operations and the level of care it is possible to deliver, which is made necessary by a pervasive (e.g., pandemic influenza) or catastrophic (e.g., earthquake, hurricane) disaster”.⁷²