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**PANDEMIC PLANNING:
ESTIMATING DISEASE BURDEN OF PANDEMIC INFLUENZA TO GUIDE
PREPAREDNESS PLANNING DECISIONS FOR NEBRASKA MEDICINE.**

by

Angelia M. Wimberly

A THESIS

Presented to the Faculty of
the University of Nebraska Graduate College
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Emergency Preparedness
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Under the Supervision of Professor Sharon Medcalf

University of Nebraska Medical Center
Omaha, Nebraska

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Advisory Committee:

Sharon J. Medcalf, Ph.D. Theodore Cieslak, M.D.

John J. Lowe, Ph.D.

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**PANDEMIC PLANNING: ESTIMATING DISEASE BURDEN OF PANDEMIC
INFLUENZA TO GUIDE PREPAREDNESS PLANNING DECISIONS FOR NEBRASKA
MEDICINE**

Angelia M Wimberly, M.S.

University of Nebraska Medical Center, 2018

Advisor: Sharon J. Medcalf, Ph.D.

This year marks the 100th anniversary of the 1918 “Spanish Flu” outbreak that killed 50-100 million people worldwide. If a pandemic of this proportion happened today, the federal pandemic influenza plan predicts that 30 percent of the population could become infected with up to 50 percent seeking outpatient care. With Nebraska Medicine currently operating at nearly full capacity (95-97%), surge capacity for hospital space, staff, and supplies would be in severe demand and would quickly overwhelm the organization. To assess the impact of pandemic influenza in Douglas County Nebraska and Nebraska Medicine, pandemic modeling tool FluAid and FluSurge 2.0 were used to project and illustrate the demand for hospital resources during surge events. FluSurge estimates the number of hospital admissions, ICU and ventilator capacity and deaths due to pandemic influenza. Projections are made under variable duration (6, 8, and 12 weeks) and virulence (15%, 25%, and 35 %) scenarios and compares hospital resources needed during pandemic influenza with existing hospital resources. Results indicate during a moderate to severe influenza pandemic, the percentage of Nebraska Medicine’s capacity needed to care for flu patients would double by week 2. Considering the results and disease burden of pandemic influenza on Nebraska Medicine, recommendations for the hospital include topics for discussion and specific preparedness and response actions in order to increase hospital capacity and capabilities for future surge events.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	ii
LIST OF TABLES	v
LIST OF ABBREVIATIONS	vii
CHAPTER 1: INTRODUCTION	1
Background	1
H5N1	3
2009 H1N1	4
After Action Report	5
Things that went well	6
Areas for improvement	6
Current Threat	7
Statement of Problem	8
Significance of Project	10
Chapter 2: LITERATURE REVIEW	12
Burden of Pandemics	12
Influenza	Error! Bookmark not defined.
Historical Context	15
Disease Modeling Tools	19
Surge Capacity and Capabilities	21
Supplies	23
Staffing	24
Space	27
Chapter 3: METHODS	29
Data Collection	29
2017-2018 Pandemic Committee	29
Epidemiologic Measures	31
Pandemic Modeling Tools	33
Chapter 4: RESULTS/PROJECTIONS	35
Demographics	35
Initial Assessment	35
Nebraska Medicine Capacity and Capability	36
FluSurge2.0 Results	38

Demand on Hospital Resources 39

Intervention 41

Chapter 5: DISCUSSION 42

 Recommendations..... 45

 Limitations 46

 Conclusion 47

REFERENCES 49

LIST OF TABLES

Table 1. Summary of influenza pandemics key characteristics from the past one hundred years.	16
Table 2: Daily Census Staffing Report (as of 1/31/18).....	30
Table 3: Douglas County Nebraska population by age group, 2017 Census Data	35
Table 4: Douglas County Nebraska Moderate and Severe Pandemic Influenza Scenario.....	36
Table 5: Nebraska Medicine Current Capabilities	37
Table 6: FluSurge2.0 Inputs and Assumptions that can be altered.....	38
Table 7: Total Pan Flu Impact	39
Table 8: Weekly hospital admissions over 8-week duration	39
Table 9: Results: Demand for hospital-based resources: 35% attack rate: 8 weeks duration.....	40
Table 10: Results: Demand for hospital-based resources: 35% attack rate: 8 weeks duration.....	41

LIST OF ABBREVIATIONS

ARDS-	Acute Respiratory Distress Syndrome
CDC-	Centers for Disease Control and Prevention
CFR-	Case Fatality Ratio
CIDRAP-	Center for Infectious Disease Research and Policy
DCHD-	Douglas County Health Department
EVS-	Hospital Environmental Services
FAO-	Food and Agriculture Organization
FDA-	Food and Drug Administration
H1N1-	Pandemic Influenza Virus (1918 Spanish flu) (2009 Swine flu)
H2N2-	Pandemic Influenza Virus (Asian flu)
H3N2-	Pandemic Influenza Virus (Hong Kong flu)
H7N9-	Asian Lineage Avian Influenza
HHS-	Department of Health and Human Services
HPAI-	Highly Pathogenic Avian Influenza
HR-	Human Resources
ICU-	Intensive Care Unit
IOM-	Institute of Medicine
IHR-	International Health Regulations
ILI-	Influenza-like Illness
MERS-	Middle East Respiratory Syndrome
NHHC-	Naval History and Heritage Command
OSHA-	Occupational Safety and Health Administration
PACU-	Post-Anesthesia Care Unit
PPE-	Personal Protective Equipment
SARS-	Severe Acute Respiratory Syndrome
SNS-	Strategic National Stockpile
UNMC-	University of Nebraska Medicine
WHO-	World Health Organization

CHAPTER 1: INTRODUCTION

Background

This year marks the 100th anniversary of the deadly 1918 “Spanish flu” pandemic. From 1918 to 1920, one-quarter of the U.S. and one-fifth of the world was infected. Records estimate 675,000 people in the United States and between 50-100 million people worldwide died due to the influenza A (H1N1) virus (Centers for Disease Control and Prevention, 2017). Affiliates from the Armed Forces Institute of Pathology state, since the 1918 outbreak, all influenza A pandemics worldwide (excluding avian viruses H5N1 and H7N7), have been descendants (comprised of key genes) of this particular virus, making the 1918 pandemic the “mother” of all pandemics (Taubenberger and Morens, 2006). Taubenberger and Morens acknowledge the emergence of a new H2N2 (“Asian Flu”) strain in 1957, caused the direct 1918 H1N1 influenza descendants to disappear entirely from human circulation. It was not until 1977 when the human H1N1 virus “reemerged” from a laboratory freezer causing the virus to circulate endemically and epidemically (Taubenberger and Morens, 2006).

Dr. Girish Kapur, author of *Emergency Public Health: Preparedness and Response*, specifics, “public health concerns regarding emerging and re-emerging infectious diseases...have been increasing in recent years” as a result of inciting factors such as physical environmental transformations caused by climate change, encroachment into new environments previously uninhabited, and deforestation; human activities (e.g. global trade and travel, immigration, globalization of food supply, growing populations, overcrowding); social, political and economic factors (civil conflicts and war, crumbling public health infrastructures); bioterrorism; and increased resistance to drugs and antibiotics (Kapur, 2010). The World Health Organization (WHO) elaborates that pandemics spread worldwide at faster rates due to globalization. “Past influenza pandemics have spread worldwide within six to nine months. Given the heavy volume of international travel in the 21st century, it is likely that a pandemic would spread globally

within approximately three months” (WHO, 2005). These statistics demonstrate just how rapid the virus could spread, and how many people worldwide it could possibly infect. Concerns over how public health and healthcare systems will prepare and potentially respond to an influenza pandemic on the same scale as the 1918 pandemic keep health professionals examining the complex aspects of surge capacity and capability.

Rubinson et al., describes the looming threat of a severe influenza pandemic, and the debate among hospitals and critical care services on how to care for critically ill people during pandemic surge events. The article states, even with existing investments in disaster preparedness, many countries still lack "sufficient specialized staff, medical equipment, and ICU space to provide timely, usual critical care for a large influx of additional patients" (Rubinson et al., 2007). When developing disaster preparedness plans for patient surge Hick et al., identifies four key factors that contribute to effective surge response: system, space, staff, and supplies (Hick, 2009). A review of the literature indicates medical facilities would be overwhelmed during surge events. Medical Surge reports illustrate medical supplies and crisis patient care space would be inadequate for the increased demand over an extended period of time. Hick et al., expresses when refining surge and crisis capacity plans, the four described elements require contingencies for medical care spaces, staffing constraints, and supply shortages.

This thesis focuses on the major challenges of hospital capacity and capabilities during an influenza pandemic. This thesis provides a conceptual framework to characterize potential pandemic disease burden on Nebraska Medicine in Douglas County Nebraska. The framework used for this project adopts epidemiological data from historical pandemic influenza events to estimate disease burden (projections) on hospitals. The data from this framework is then used to estimate pandemic level demands for essential supplies, space, and staff during the next pandemic. The goal of this thesis is to collect, interpret, and disseminate disease burden

information to increase health-care facilities surge capacity and capabilities, and to help pandemic planning operations for future surge events.

H5N1

Between December 2003 and October 2005, The World Health Organization received reports of more than 100 human cases of avian influenza A (H5N1) virus, from Egypt, Cambodia, China, Indonesia, Thailand and Viet Nam. A study conducted by Conly and Johnston report outbreaks of the H5N1 strain in the human population caused limited but severe disease with high fatality on four separate occasions since 1997 (Conly,2004). Osterholm and Henderson's study on Respiratory Transmissible H5N1 describes the virus as having a "human case fatality rate of 60 to 80%, placing this pathogen in the category of causing one of the most virulent known human infectious diseases" (Osterholm and Henderson, 2012). Concerns over the virus's potential of becoming the next big pandemic, the first draft of the US Department of Health and Human Services' plan for pandemic influenza response and preparedness was released, providing impetus for states to strengthen their own influenza pandemic plans. The summary outlines the distinctive characteristics and events of a pandemic will strain nationwide resources. The document goes on to report that it is "unlikely that there will be sufficient personnel, equipment, and supplies to respond adequately to multiple areas of the country for a sustained period of time" (HHS, 2005).

A statement by HHS Secretary Mike Leavitt, released in the 2005 pandemic influenza plan declares, "One of the most important public health issues our Nation and the world faces is the threat of a global disease outbreak called a pandemic. No one in the world today is fully prepared for a pandemic -- but we are better prepared today than we were yesterday - and we will be better prepared tomorrow than we are today"(HHS, 2005). The best way to decrease influenza disease burden and become resilient as a nation is to create effective influenza preparedness and response plans.

During the scare of the H5N1 outbreak, Nebraska Medicine, the University of Nebraska Medical Center (UNMC), and UNMC-Physicians worked together to create an intensive influenza pandemic plan using HHS pandemic planning assumptions. The departments were divided into the following planning committees: support staffing, equipment and supplies, triage and altered standards of care, infection control/vaccination, palliative care, infrastructure and security, communication, behavioral health, and clinical staffing and surge. Since influenza affects all aspects of hospital operations, the plan also incorporated and utilized resources from several operations within Nebraska Medicine, UNMC and the Douglas County Health Department. The teams' used strategies and operations from inpatient, ambulatory, morgue, behavioral health, and student surge plans; altered standards of care roadmaps; documents of facility lockdown measures; and non-healthcare and volunteer delegation of duties listings. The pandemic plan prioritized response actions into seven main goals: preserve the lives and safety of our staff members and students; sustain our mission to provide healthcare for the community; protect the integrity of campus assets including property and information; minimize the financial impact to the campus entities; protect research resources; sustain the educational mission; and assist the community in mitigating adverse effects of a pandemic and facilitate community response and recovery. The process was complex and took nearly two years to complete.

2009 H1N1

Although the hospital's pandemic plan was not utilized during H5N1 (as the virus never became transmissible from person to person), it was used four years later during the 2009 H1N1 outbreak. This particular strain of H1N1 had never previously been identified as a cause of infection in humans, this new strain presented local and national public health agencies with a complicated set of circumstances. Reports from the WHO record that "antigenic analysis has shown that antibodies to the seasonal H1N1 virus do not protect against the pandemic H1N1 virus" (WHO, 2010). Additionally, the new virus showed death and illness patterns inconsistent

with previous recorded influenza infections. This shift in conditions signified major limitations in the healthcare system's capacity and capabilities to respond to pandemics. A report from the 2009 H1N1 Surveillance Group concludes the H1N1 pandemic was the first test of the local, national, and global pandemic response plans since the re-emergence of human avian influenza cases back in 2003. The group specifies that future pandemic response decisions be based on "estimates of the transmissibility and, in some cases, the severity of the novel infection" (Lipsitch, 2011).

The study further entails that, "rapidly generated transmissibility and severity estimates are essential for predicting the scale and time course of a pandemic-with influenza, most important are measures of severity per infected individual—that is, the probability of death, hospitalization, or other severe outcome" (Lipsitch, 2011). These measures will allow for pandemic response related plans to better estimate the demand for appropriate resources and supplies (such as vaccines, PPE, ventilators, staffing, and available space). Additionally, estimating the severity of a virus can help calculate disease burden on hospitals (e.g. amount of patient hospitalizations, ICU admissions, ventilator usage, and death). Data collected from previous pandemic reports (such as the information above) has shown to significantly improve pandemic response efforts (Lipsitch, 2011).

After Action Report

By early May 2009, CDC reports signify a total of 2,254 confirmed cases of the H1N1 in the U.S. in 44 different states. The WHO monitored virus activities during phases 1-3 (predominantly animal infections with few human infections), and phase 4 was declared when the virus had sustained human-to-human contact. By June 2009, the WHO raises the alert status to Phase 5-6, officially declaring H1N1 a pandemic. Reports state this action was a reflection of the spread of the new H1N1 virus, not the severity of illness caused by the virus (WHO, 2010). This was the first pandemic declaration in over 40 years (WHO, 2010). During this notification period, Nebraska Medicine implemented their pandemic plan as the basic framework and foundation of

response efforts and activities. Once the plan was in place the hospital quickly took notice and began to document the plan's successes and limitations in an after actions report. The hospital and campus after action report illustrates what went well, what lessons were learned, and opportunities for improvement:

Things that went well:

- Communication (quick, efficient use of Intranet-internal; employee forums; external public webpage and hotline)
- Pandemic Planning Team- met promptly; action items
- Quick updates to Key Leaders
- Defined process to watch resources (PPE, antivirals)- “hotlist”
- Letter to physicians regarding the proper use of antivirals
- Vaccination Distribution Process/Decision Making

Areas for improvement:

- The situation did not fit the current plan
- Patient surge plan not adequate
- Limited available resources (PPE, vaccines, hospital beds)
- Allocation of resources
- Opportunity for a “Teachable Moment”: PPE donning and doffing
- Challenge with getting continuously updated guidance out to clinicians
- Most cases were outpatient, the ER quickly became overwhelmed
- Need additional organizational PPE and Antivirals guidance
- N95 mask Fit testing of hospital personnel is a “gap”
- Community attention to standardizing Outpatient strategy and Altered Standards of Care
- Additional flu clinic set up

(Hospital and campus after-action report, 2009)

The report concluded, the 2009 H1N1 influenza pandemic occurred against a backdrop of pandemic response planning at all levels of government including years of developing, refining, and exercising response plans. However, the preparedness efforts were largely based on a scenario of severe illness, often with deadly results, caused by an avian influenza (H5N1) virus.

Despite differences in planning scenarios and the actual 2009 H1N1 pandemic, many of the systems established through pandemic planning were used and helpful for the response. Final comments were made stating the H1N1 response was guided by "previously written pandemic influenza and Strategic National Stockpile (SNS) Plans, though this specific incident proved the need for more flexible development of these plans" (Hospital and campus after-action report, 2009).

Current Threat

Avian influenza A(H7N9) virus is one subgroup of influenza viruses that circulate among wild birds (WHO, 2013). The H7N9 virus has been detected in the past but this particular strain has never been previously seen in animals or humans. The first human case of avian influenza A(H7N9) was reported to the WHO on March 31, 2013. Now that the virus has been reported to have sustained animal to human transmission (those who have had recent exposure with infected poultry), health organizations such as the WHO, the CDC, and the Food and Agriculture Organization (FAO), are closely monitoring the virus for evidence of sustained human-to-human transmission. This new strain is of particular concern to healthcare professionals because of those who do test positive for the virus become severely ill. In most cases, infection with A(H7N9) is characterized by high fever, cough, shortness of breath and rapidly progressing severe pneumonia. Complications include acute respiratory distress syndrome (ARDS), septic shock and multi-organ failure requiring intensive care (WHO, 2017).

By July 2, 2013, the WHO reported 133 laboratory-confirmed cases of the H7N9 virus in 8 China Provinces, during this time 43 deaths were reported due to ILI complications. Of these, 80% either had direct contact with infected chicken or were in close proximity to live bird markets (WHO, 2013). According to Silva et al., H7N9 has infected humans in China in four waves; the first being in the spring of 2013; the second, third, and fourth waves were during winter-spring of 2013-14, 2014-15 and 2015-2016. The fifth wave of H7N9 has been the most

widespread, being reported in 23 provinces compared to 12 in the fourth wave (Silva et al., 2017). Yang et al., a study on H7N9 clinical and epidemiological characteristics report, medical complications to include acute respiratory distress syndrome, have caused prolong hospitalization with reports of most patients being admitted to the ICU with severe illness, later succumbing to the virus (Yang et al., 2017). Results from Yang et al., data collection illustrates that of the 256 laboratory-confirmed H7N9 hospital patients, the proportion the proportion of ICU admission was 65.6% and the fatality rate of these confirmed cases was 39% (Yang et al., 2017). The most recent report (during the fifth wave) of H7N9 shows a total of 1,625 confirmed human cases of H7N9 with 621 deaths (FAO, 2018), this gives the virus a case fatality rate (CFR) of 38.5%.

Although there have been no reports of sustained human-to-human transmission, a recent article published by Zhou et al., explains limited human-to-human transmission between two individuals cannot be ruled out (Zhou et al., 2017). Due to the fact that fifth epidemic wave is still ongoing, the potential for this virus to become the next pandemic is of great concern. After an extensive literature review on the current outbreak of H7N9, Nebraska Medicine decided to recommission their 2008 pandemic planning committee along with UNMC officials to update previous pandemic plans and operations.

Statement of Problem

The Department of Health and Human Services (HHS) 2005 Pandemic Influenza Preparedness and Response Plan reports that an influenza pandemic has a greater potential to cause rapid increases in death and illness than virtually any other natural health threat (HHS, 2005). Unlike most viruses, influenza is not restricted to specific geographic locations, it attacks willfully and does not discriminate against persons. The Department of Health and Human Services describes pandemic influenza, not as a theoretical threat; rather, a recurring threat. HHS further acknowledges, “An emerging influenza pandemic virus can place extraordinary and sustained demands on public health and healthcare systems and on providers of essential

community services across the United States and throughout the world” (HHS, 2017). Research on influenza has shown the virus to be extremely unpredictable. Each recorded influenza pandemic has differed in duration, severity, and impact. Past events have revealed the healthcare system is not prepared to respond nor mitigate a severe influenza pandemic or to any similarly global, sustained and threatening public health emergency (Fineberg, 2010).

Concerns over the possibility of another influenza pandemic have accelerated worldwide planning and preparedness efforts. Since the recent outbreak of influenza A(H1N1) in 2009, and the re-emergence of other infectious diseases over the past decade (SARS, MERS, Ebola), emergency management specialists are meticulously reexamining their emergency/disaster preparedness plans. Hospital capabilities during a severe infectious disease outbreak are questionable at best. Adequate and necessary supplies, space, and staff are already limited during seasonal influenza events, a pandemic of extreme severity could devastate and cripple the already stressed healthcare system. Effective and successful response efforts require engagement from the entire health community, and healthcare assets from across the spectrum of care in order to meet increased pandemic demands (CDC, 2017).

Response efforts become further complicated when considering economic implications (e.g. medical cost, lost productivity, insurance premiums) and interruptions to essential services (e.g. food, water, facilities and environmental services (EVS), hospital occupancy, staff, transportation, etc.). The rapid arrival of another pandemic would be an enormous threat to the current public health and healthcare infrastructure. The demand for medical necessities and lifesaving equipment would render items like drugs, ventilators, patient beds, and personal protective equipment (PPE), rare commodities during a pandemic crisis. Existing hospital supplies would be inadequate, placing health security at risk. This project addresses this challenge by developing a general methodology and applying a basic disease modeling tool providing an influenza pandemic scenario in Douglas County Nebraska.

Significance of Project

It is important to remember that the public's health depends on its healthcare systems ability to effectively prepare, respond, and successfully treat ongoing health threats. This project was conceptualized based on Nebraska Medicine and UNMC's mission to "lead the world in transforming lives to create a healthy future for all individuals and communities through premier educational programs, innovative research, extraordinary patient care and commitment to preserving the lives and safety of all its members". In order to obtain the best possible health outcomes, hospital and campus-wide preparedness planning are critical to the community's sustainability. In many cases, pandemic preparedness plans are already in place, the goal is not to develop new ones, but rather strengthen existing ones. In their ongoing determination to accomplish their mission, this project is being used to enhance their preparedness efforts. This thesis increases those efforts by synthesizing influenza epidemiological data, pandemic preparedness research, literature reviews, historical reports from previous pandemic response events, and disease modeling.

Planning for pandemic influenza is necessary to successfully strengthen the health care system's ability to respond, and to efficiently allocate scarce hospital resources (Zhang et al., 2006). Given the focus of this thesis is estimating influenza disease burden on Nebraska Medicine's capacity and capabilities of patient surge, essential staff, and supplies, an assessment framework was used to calculate projections on the hospitals demand during an infectious disease outbreak or pandemic event. This thesis investigates the factors hindering hospital sustainability during a pandemic influenza outbreak. This project also places an emphasis on pandemic influenza planning as a global approach to better prepare healthcare systems for the impact infectious disease outbreaks can have on essential services of care.

Kapur states that healthcare and facility-based surge capacity during an infectious disease outbreak is usually limited due to financial constraints that prohibit healthcare institutions from

stockpiling of equipment and supplies, and due to the existing shortage of healthcare providers and ancillary staff (Kapur, 2010). Central to this project is addressing the dilemma that hospitals nationwide experience during a pandemic. The information provided in this thesis can be used to make a case for federal funding to increase Nebraska Medicine's surge capacity and capabilities such as: stockpiling vital supplies and equipment, procuring proficient health care workers, and providing sufficient space for patient care during a pandemic. This is needed to ensure improved patient health outcomes, and decrease morbidity and mortality rates due to influenza.

Additionally, the data from this thesis can provide critical records of disease burden in Douglas County Nebraska, and Nebraska Medicine to request an increase in the production and distribution of essential supplies and scarce resources from local, state, national, and federal government agencies.

Chapter 2: Literature Review

Burden of Pandemics

Experts have identified several viruses that have the potential to cause the next global pandemic. Over the past few decades, the world has experienced the emergence and re-emergence of global infectious diseases such as Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola, and Influenza. In November of 2002, a SARS outbreak spread over 26 countries affecting over 8,000 people, killing 775. Since April 2012, the WHO reports there have been 2,100 laboratory-confirmed cases of MERS in the Kingdom of Saudi Arabia including 813 associated deaths (case-fatality rate: 38%). For over 40 years the Ebola virus has plagued Central and West Africa, killing 50 to 90% of those who became infected. Between 2014 and 2016, West Africa experienced one of the largest and most complex outbreaks of Ebola (Zaire ebolavirus species). As of 2017, The Democratic Republic of the Congo has reported a total of 1,060 cases with 811 reported deaths (WHO, 2017).

The frequency in which infectious disease outbreaks have occurred (nearly one every decade) has public health officials proclaiming we are becoming increasingly susceptible to another pandemic event (WHO, 2017). While a majority of these diseases are typically confined to specific geographic locations, SARS (Asia), MERS (Saudi Arabia), and Ebola (Central and West Africa), influenza is a global threat. When UNMC's co-director of the Global Center for Health Security Dr. James Lawler was asked what he worries about when it comes to the next pandemic threat, his response was, "Most significantly I worry about flu," "The projections regarding a 1918-like pandemic in the modern world are truly catastrophic and so to me, that's still the biggest single threat" (UNMC Newsroom, 2018). Dr. Michael Osterholm, director of the Center for Infectious Diseases Research and Policy (CIDRAP) at the University of Minnesota carries the same sentiment stating, "There's nothing really that can impact on a national level — or for that matter on an international level — more quickly than influenza" (Osterholm, 2017).

Influenza

The CDC defines influenza as “a contagious respiratory illness caused by influenza viruses that infect the nose, throat, and sometimes the lungs that can cause mild to severe illness and even death”. It is believed that the flu virus is spread “mainly by tiny droplets made when people with flu cough, sneeze or talk” (CDC, 2016). Individuals infected with a flu virus typically develop mild symptoms which are often confused with the common cold seeing as the virus affects the upper respiratory system. It is characterized by fever (or feeling feverish/chills), fatigue, headaches, cough, sore throat, runny or stuffy nose, and in some cases, vomiting and diarrhea are reported (CDC, 2016). The CDC reports that most individuals who are infected with the flu normally recover within a few days, although, some complications may last for one to two weeks. In this case, the virus is considered to be more severe.

The CDC explains that individuals who develop more severe symptoms due to the influenza virus experience more serious health complications such as; “infection of the upper respiratory tract (nasal passages, throat) and lower respiratory tract (lungs), asthma, pneumonia, inflammation of the heart (myocarditis), brain (encephalitis) or muscle (myositis, rhabdomyolysis) tissues, and multi-organ failure (for example, respiratory and kidney failure)”. Additional reports have shown, “Flu virus infection of the respiratory tract can trigger an extreme inflammatory response in the body and can lead to sepsis, the body’s life-threatening response to infection”, these conditions are considered critical and require immediate hospitalization (CDC, 2016).

According to the World Health Organization, there are four types of influenza viruses: types A, B, C and D. Influenza A viruses infect humans and many different animals. Influenza B viruses circulate among humans and cause seasonal epidemics. Seasonal influenza is expected and therefore healthcare systems can prepare for such events. During a typical year of seasonal flu, anywhere from 10-20% of the U.S. population becomes infected with the influenza virus,

hospitalizing on average between 200,000 and 700,000 people. Recent data collected from 47 countries show between 291,000 and 646,000 people worldwide die from seasonal influenza-related respiratory illnesses each year, higher than a previous estimate of 250,000 to 500,000 (CDC, 2017). This increase in mortality is being attributed to poorer nations experiencing greater flu-associated deaths related to a reduction in flu vaccination programs. Additionally, the influenza virus has affected the older population especially hard which create or exacerbate other health factors (e.g. heart disease, stroke, endocrine disorders, and those with a weakened immune system due to disease or medications) (CDC, 2017).

Furthermore, the CDC reports several studies during the 2009 pandemic noted a high prevalence of obesity among persons with severe illness attributable to A(H1N1). One example provided by the CDC details a case-cohort study that illustrates, "among persons aged ≥ 20 years, hospitalization with illness attributable to laboratory-confirmed influenza A(H1N1) was associated with extreme obesity (body mass index [BMI] ≥ 40) even in the absence of other risk factors for severe illness (odds ratio [OR]: 4.7; 95% CI = 1.3–17.2) (94). Death was associated with both obesity, defined as BMI ≥ 30 (OR: 3.1; 95% CI = 1.5–6.6) and extreme obesity (OR: 7.6; 95% CI = 2.1–27.9)" (CDC, 2017). Lastly, the 2009 pandemic highlighted racial and ethnic disparities. Reports state this might be attributable to specific groups having higher prevalence of underlying medical conditions, barriers to health care access, and delayed receipt of antivirals (CDC, 2017).

The emergence of a new and substantially different influenza A virus is most concerning due to its ability infect people and have sustained human to human transmission. An influenza pandemic occurs when a novel influenza virus emerges that can infect and be efficiently transmitted among individuals because of lack of pre-existing immunity in the population (HHS, 2017). During a flu pandemic, we see infection rates double and in some cases even triple. The attack rate (i.e. gross clinical attack rate) refers to the percentage of the population that becomes

clinically ill due to pandemic influenza. The U.S. Census Bureau reports the current population is approximately 325.7 million people (U.S. Census, 2017). If the U.S. Department of Health and Human Services is correct in estimating pandemic influenza clinical disease attack rate of 20% to 30%, then nearly 97.5 million people in the United States could develop the disease. The federal Pandemic Influenza Plan report shows of those who become ill, up to 50% will seek outpatient medical care (HHS, 2017). Using these calculations to estimate disease burden, the United States can expect between 32 and 48 million people in need of outpatient medical care; between 800,000 to 11.5 million people needing to be hospitalized; and between 160,000 to 3.5 million people requiring ICU care (depending on severity-moderate (1958/68-like) to very severe (1918-like)) (Reed et al., 2013). An outbreak of this magnitude can cripple hospital infrastructure and disrupt national operations such as transportation and public safety due to widespread illness, absenteeism, and death, as well as public concern about exposure to the virus (HHS, 2017).

Historical Context

Over the past one hundred years, there have been four influenza pandemics: the 1918 Spanish flu, 1957 Asian flu, the 1968 Hong Kong flu, and most recently, the 2009 H1N1 outbreak (debatably known as the “swine flu”). The most virulent strain of influenza A(H1N1) occurred in 1918 during World War I killing close to 100 million people worldwide. Influenza (H2N2) appeared in China in 1957, killing nearly 2 million people; in 1968, influenza pandemic (H3N2) significantly impacted Hong Kong and killed between 500,000 to 2 million people worldwide. The most recent influenza pandemic occurred less than ten years ago. Influenza A(H1N1) first appeared in Mexico during early spring of 2009 lasting until mid-August 2010 killing over 575,000 people (summary provided in table 1) (Centers for Disease Control and Prevention, 2017).

According to Dr. Ali Khan, author of *“The Next Pandemic: On the Front Lines Against Humankind's Gravest Dangers,”* If a flu pandemic occurred today on the same scale as the 1918

Spanish flu outbreak, with the current population being almost four times larger, the United States could expect to have close to 2 million people dead"(Khan, 2016). Globally, with the current (2018) total population standing at 7.8 billion (World Population Clock, 2018), it is estimated that anywhere between 75 and 370 million people worldwide could die. The thought of an outbreak on a scale of this degree is terrifying, but understanding the circumstances surrounding each pandemic outbreak provides imperative guidance for preparing, planning, responding to, and mitigating the next pandemic.

Table 1. Summary of influenza pandemics key characteristics from the past one hundred years.

Description	Year	Strain	Suspected Origin	Approximate deaths	Pandemic
“Spanish flu”	1918-1920	H1N1	China	50-100 million	Major
“Asian flu”	1957-1958	H2N2	China	1-2 million	Severe
“Hong Kong flu”	1968-1970	H3N2	China	500,000-2 million	Moderate
“Swine flu”	2009-2010	H1N1	Mexico	575,000	Moderate

Source: Centers for Disease Control and Prevention

The 1918- “Spanish flu” outbreak is one of the most notorious pandemics on record. The virus was first identified in military personnel during World War I. This particular virulent strain of influenza quickly spread across nations simultaneously affecting North America, Europe, and Asia. During the peak of the pandemic, US Naval Hospitals were vigorously trying to combat the virus but were quickly overwhelmed. They were forced to rely on quarantine or infectious disease stations to contain the outbreak and relied on doctors, hospital corpsmen, and nurses to care for the daily needs of the patients (Naval History and Heritage Command (NHHC), 2015). The NHHC provides records of real-life accounts from several navy medical professionals who treated patients around the country.

One recorded statement came from Navy nurse Josie Brown stationed in Great Lakes, Illinois. She described seeing “morgues packed to almost the ceiling with bodies stacked one on

top of another. The morticians worked day and night." She later detailed soldiers dying so quickly that, "We didn't have the time to treat them. We didn't take temperatures; we didn't even have time to take blood pressure". Records from the Navy Department Library chronicle a total of 121,225 Navy and Marine patients were admitted to Navy medical facilities, of which, 4,158 died from complications of the virus, totaling more deaths than actual war-related fatalities (NHHC, 2015). A historical analysis of the 1918-1919 "Spanish flu" illustrated the pandemic had death rates 5-20 times higher than expected (Taubenberger and Morens, 2006).

Ninety-one years later the influenza A (H1N1) virus would emerge in North America once again. Uniquely, this specific strain contained a combination of genes not previously identified in animals or people (CDC, 2017). Concerns quickly arose in April 2009, as numerous ILI cases were being reported in Mexico and several U.S. states, as well as several countries including the United Kingdom, Spain, Germany, the Netherlands, and Israel. As the virus became geographically widespread hospitals around the world were on alert, preparing and prepping for the intense impact that was to come. Unfortunately, after action records collected from several healthcare organizations throughout the U.S. exemplify public health and healthcare organizations were ill-equipped to handle the extent of cases they saw. The demand for supplies, space, and staff showcased the limited availability of necessary resources (Nebraska Medicine, 2010; Wisconsin Division of Public Health, 2010; Maine CDC, 2010; Texas Department of State Health Services, 2010; Prima County Arizona, 2010; North Carolina Public Health Agency, 2010).

During the beginning stages of the outbreak, Domínguez-Cherit et al., conducted an observational study of 899 ILI hospitalized patients in Mexico. Of which, 58 of those patients presented critical illness such as severe acute respiratory distress syndrome. One section of the study describes the immense burden of H1N1 on emergency departments (ED) and intensive care units (ICU). The report determined as a result of increased patient volumes, numerous patients

experienced delays ICU admission. The sudden increase of patients and delay in admissions caused four patients to die while waiting in the ED (3 within 8 hours and 1 within 24 hours of arrival). The study further annotated, during the course of hospitalization, all but two critically ill patients required mechanical ventilation (48 invasive, 22 noninvasive, 16 both). The report resolved, “The usual capacity to care for critically ill patients was exceeded, necessitating care in other patient care areas and the addition of ICU beds and ventilators on 2 occasions” (Domínguez-Cherit et al., 2009). The study outlined median length of ICU stays to be 13.5 days for survivors and 7 days for non-survivors. Duration of ventilation was 15 and 7.5 days respectively. Within 4 to 14 days, 83% of critically ill patients died while in the ICU.

An additional study conducted by Reed et al., demonstrates the reported cases of laboratory-confirmed influenza A (H1N1) is likely a significant underestimation of the total number of actual illnesses that occurred in during the 2009 pandemic. Their study calculations determine that through July 2009, 1.8 million to 5.7 million symptomatic cases of pandemic (H1N1) 2009 occurred in the United States, resulting in 9,000–21,000 hospitalizations. These results further assume that the number of deaths was underreported to the same extent, and estimate the total number of individuals infected with the H1N1 virus in the United States during April–July 2009 "may have been up to 140× greater than the reported number of laboratory-confirmed cases" (Reed et al., 2009).

The US government pandemic response to the H1N1 outbreak was almost immediate. In late April, under the rules of the International Health Regulations (IHR), the Director-General of the WHO declared the 2009 H1N1 outbreak a “Public Health Emergency of International Concern” (CDC, 2017). Recommendations included countries “intensify surveillance for unusual outbreaks of ILI and severe pneumonia”. After the IHR declaration, the US government determined H1N1 was a nationwide public health emergency. Soon after, the CDC released 25% of their Strategic National Stockpile (SNS), allocating supplies based on state population. Reports

indicate, “11 million treatments of antiviral drugs, and PPE including over 39 million respiratory protection devices (masks and respirators), gowns, gloves and face shields” were delivered to states all over the U.S. (CDC, 2010).

Experts from HHS looked at surge capacity and capability and the impact pandemics have on the healthcare system. They determined initial emergency preparedness efforts need to include procuring essential staff, space (hospital infrastructure, alternate care sites), and supplies (personal protective equipment (PPE), such as N95 masks, influenza testing kits (nasal swabs), vaccines, ventilators, beds, etc.) (HHS, 2017). The Department of Health and Human Services defines surge capacity as a “health care system’s ability to meet an increased demand for medical care that challenges or exceeds normal operating capacity”. Medical surge capability refers to the ability to manage patients requiring unusual or very specialized medical evaluation and care. Additionally, surge capability includes, “the ability to treat patient problems that require special intervention to protect medical providers, other patients, and the integrity of the healthcare organization” (HHS, 2012).

Disease Modeling Tools

Using disease modeling as tools to strengthen influenza surveillance and preparedness has become increasingly popular over the last few decades. Since the 2009 H1N1 pandemic, disease modeling tools have evolved to not only estimate disease burden to monitor epidemiologic trends, but to plan and allocate resources, promote vaccination, project influenza-related hospitalization and mortality rates, and estimate influenza-related outpatient medical visits and symptomatic illness in the community (Rolfes et al., 2017). Gambhir et al., state, "the rising importance of infectious disease modeling makes this an appropriate time for a guide for public health practitioners tasked with preparing for, and responding to, an influenza pandemic" (Gambhir et al., 2015). A statement by Greenhalgh and Day explain that "compartmental models of infectious-disease transmission have proven to be an invaluable tool for the prediction of

disease progression and the evaluation of public health policies and interventions" (Greenhalgh and Day, 2017).

Gambhir et al., elaborate by reporting during the 2009 H1N1 pandemic, traditional methods of epidemiological methods were enhanced by computational techniques such as disease modeling. The article further explains that there are limited published studies that attempt to bring together questions being asked by public health officials and infectious disease modeling methods that can be used to address questions such as: what is the case-fatality ratio? What is the case-hospitalization ratio? When will the disease incidence reach its peak? Who in the population should be prioritized for vaccination or antiviral treatment? How transmissible is the disease? and what is the basic reproduction number (R_0)? (Gambhir et al., 2015). Greenhalgh, Day, and Gambhir et al., agree that modeling is a complementary activity and is not a substitute for other analyses. The idea behind disease modeling is to strengthen current methods and better serve public health and healthcare pandemic preparedness and response plans (Gambhir et al., 2015; Greenhalgh and Day, 2017).

The disease modeling tool for this project provides hospital administrators and public health officials' estimates of hospital-based services in demand during pandemic influenza surge events. The projections from this model estimate varying hospital variables that have effects on healthcare and health outcomes. The CDC introduced pandemic modeling tool FluSurge 1.0 in July 2004 which estimated the number and duration of influenza-related hospitalizations. Improvements and updates to this model have been released which now incorporate planning for influenza burden on a community, lab surge for specimen testing, work loss, and assisting state and local level planners by providing estimates of potential impact specific to their locality (CDC, 2015).

These types of models have been used in the National Pandemic Strategy for global, federal, state and local resource planning. The CDC also details these models now allow users to

change variables that impact estimates of the number of duration of influenza-related hospitalization, assumed average length of hospital stay and the percentage of hospitalizations that will require a stay in the Intensive Care Unit (ICU). These updated tools were created to make variables flexible due to the unpredictability of influenza, and to be used as a starting point for pandemic planning (CDC, 2015). The WHO and HHS have incorporated disease modeling tools to coordinate and improve efforts to effectively respond to influenza viruses with pandemic potential. The WHO details using modeling data to aid in decision-making, especially in vaccination production and distribution.

Surge Capacity and Capabilities

Dr. John Hick was one the first individuals to begin focusing on the complex aspects of surge capacity and capability (Kearns, Cairns, and Cairns, 2014). Events such as the H5N1 outbreak led Hick et al., to begin focusing on how to leverage staff, equipment, and treatment areas to ensure vital resources would be available for critically ill patients during medical surge operations (Agency for Healthcare Research and Quality [AHRQ], 2012). The Hick et.al article recommends, "examining surge capacity primarily in the context of responses within the hospital's physical structure or on its grounds that are managed and staffed by the hospital (i.e., do not rely on outside supplies or assistance)" (Hick et al., 2009). Hospitals should focus on being self-reliant as many resources may not be available from local healthcare organizations as they may not be in a position to assist others. A pandemic will likely affect several, if not all hospitals in the localized area, therefore, supply and demand for essential materials will be a challenge for all healthcare systems.

During novel influenza outbreaks (where disease burden estimates are significantly lower) routine clinical operations are running at 95-100% capacity (Lawler, 2018). Recent flu season reports detail hospitals reaching capacity limits and having no room for a surge in patients in the emergency room or inpatient care clinics. If a severe influenza outbreak were to happen

tomorrow, healthcare facilities and public health organizations would become severely stressed and ill-prepared to care for an influx of patients.

In the U.S., critical care workgroups recommend preparing for surge capacity of 200% over usual critical care capacity (Hick et al., 2008). Because emergency departments (ED's) are considered frontline services for patients entering the healthcare system, ED's see the most patients per day during everyday operations than any other department or healthcare facility (Hick, et al., 2008). Due to the ED's frequency of emergent care cases, the department is often overwhelmed by patient surge during infectious disease outbreaks. Sugerman et al., conducted a survey of 26 emergency departments in Atlanta during the peak (July-October 2009) of H1N1. Because ED surge causes extensive overcrowding without adequate physical space or personnel, the central elements of this study was of ED surge capacity to include; space (e.g., number of beds and physical size of the ED), staffing systems (e.g., admitting process, clinical information systems, and ancillary services), and supply-demand (Sugerman et al., 2011). For the duration of the study participating ED reports show the mean monthly ILI visits more than tripled during the H1N1 outbreak. Of the 26 hospitals surveyed, 58% were forced to call in extra staff, 65% report having physical space limitations, and 64% show having to revise triage plans to improve capacity to respond to patient surge (Sugerman et al., 2011). Further results identified the length of patient stay increased by 58% (15 days) and the number of patients leaving without being seen by a provider increased by 54%. After the study concluded, Sugerman et al., report that "despite implemented influenza plans, the increased demand for ED care outstripped space and supplies." One facility that was contacted after the survey went on record stating, "we should have had a plan in place sooner and drilled that plan" (Sugerman et al., 2011).

Kearns et al., describe that during pandemics, hospitals should include characteristics of "contingency surge capacity," this includes; relying on *space* that is not typically used for emergent patients (e.g. conference rooms, fitness centers, medical offices). Kapur adds,

designated alternative sites of care for an increased number of patients consist of what he deems "flat spaces" this includes lobbies, waiting rooms, stadiums, or mobile units to accommodate the evaluation and treatment of surge patients (Kapur 2012). The Kearns study compiled with Kapur's statements demonstrate the need to identify facility space capabilities for patients, personnel, and supplies during large-scale infectious disease outbreaks (Kearns, Cairns, and Cairns, 2014). Addressing this issue entails identifying local areas that may also be used as "alternative care sites", these sites can include, (but should not be dependent on) ambulatory care facilities, local shelters (via Emergency Support Functions (ESF) 6 and 8), and nursing homes.

Supplies

Research conducted by Kearns et al., explain the pandemic of 2009 highlighted a gap between the equipment and supplies available versus what was needed as well as adequate policies and processes being in place to aid in this decision-making process (Kearns, Cairns, and Cairns, 2014). The Institute of Medicine (IOM) declares "the better prepared the institution and the more resources available, the longer a facility can stay in conventional and contingency mode before the shift to crisis standards of care becomes necessary, when the threat of morbidity and mortality to patients becomes significant as a result of the lack of resources" (IOM, 2017). Even a slight disruption to services and normal operational functions could have distressing consequences. Research articles regarding healthcare resources (e.g. medical supplies (PPE), equipment, and personnel) demonstrates critical supplies were exhausted within a matter of two to three weeks during a moderate to severe pandemic event.

Like most concerned hospitals, stockpiling supplies and equipment became an intricate part of emergency plans. An issue that quickly arose was that "storage of supplies proved to be among the most resource-intensive components of cache-building" (Radonovich et al., 2009). Some medical supplies also have a short shelf life (expiration date), so purchasing a large number of items (which is often times expensive) is not a feasible option for a majority of hospitals.

Radonovich et al., elaborate by stating, "Stored items would also need to be inspected regularly and rotated through the storage facility on a regular basis" (Radonovich et al., 2009). A suggested solution for this problem is to hire a full-time employee to handle logistics management of the inventory. While this solution is good in theory, the issue of staffing and cost remains a significant limitation to such an idea. Furthermore, affirming PPE shortage predictions will prepare institutions in calculating supply needs, including what, when, and how much should be purchased according to recorded disease burden and the rate at which (i.e. how quickly) supplies are being used and disposed of. Previous outbreaks of infectious disease proved to cripple the supply-demand within 2 weeks. If we look at usage rates of essential materials during a pandemic, reports show critical supplies being used at 40-50 times the normal rate. If during the next pandemic hospitals are using supplies at this high of a rate, it will be impossible to keep up with supply and demand that is needed for pandemic surge (Lawler, 2018).

Staffing

Hospital equipment and supplies are only useful if there are suitable health-care personnel to provide patient services and care. It has been estimated that only 10 to 20 percent of all medical personnel would be available at any given time for surge capacity (Ajao et al., 2015). This number significantly declines due to the shortfall of adequately trained staff capable of treating infectious disease outbreaks. Nebraska Medicine acknowledges the issue of providers not being confident in their skills to adequately take care of infectious patients. Considering this issue, when hospitals have provider shortages, nurses and doctors may be asked to work extended shifts and to work more frequently to compensate for worker absenteeism and lack of trained staff.

Many experts agree that America's healthcare system is only as strong as its employees. Pandemic influenza would test this principle and severely challenge the healthcare workforce. The Occupational Safety and Health Administration (OSHA) reports, during an influenza

pandemic, as many as 40 percent of the workforce would not show up to work. Employees could be absent due to being sick themselves, caring for sick family members, school and daycare closures, or fear of coming to work (OSHA, 2010). Levin, Gebbie, and Qureshi conducted a survey of more than 6,400 health-care workers in 47 facilities in the New York metropolitan region which asked the question would they be willing to report to work during a SARS outbreak. Only 48.4% stated they would show up to work.

Balicer et al., administered a similar anonymous survey from January-March 2009, to Johns Hopkins Hospital employees asking about attitudes/beliefs toward emergency response. Of the 3426 respondents, one-in-four or 28% of hospital workers indicated they were not willing to respond to an influenza pandemic scenario if asked but not required to do so, and only an additional 10% were willing to respond if required by their employer (Balicer et al., 2010). The Executive Director of Emergency Management & Bio preparedness at Nebraska Medicine states that providers are not required to work during a pandemic and high absenteeism rates are expected, especially if the disease has a high fatality rate.

Infectious disease outbreaks are particularly daunting. The biggest factor for staff unwillingness to respond was described as fears for personal and family safety; particularly their children (Levin, Gebbie and Qureshi 2007; Balicer et al., 2010). Because patient surge quickly runs through supplies, hospital staff express concerns of not feeling adequately protected and envisioning falling ill themselves and eventually infecting family and friends. Statements regarding worker safety show staff greatly value the provision of adequate PPE and clear, repeat training and routines to protect themselves. Kearns et al., states that staffing issues surrounding pandemics may call for clinicians with “traditional credentials” such as dermatologists, ophthalmologists, psychiatrists, pathologists; or nursing staff that now work in administration or serve outside of the traditional clinical setting who may not be accustomed to managing acutely

ill or critically injured patients, to now taking unconventional roles and expanding their scopes of practices for patient treatment and care (Kearns et al., 2014).

Previous pandemic reports showcase the need to delegate care, duties, and responsibilities. The delegation of care and services may include staff members leveraging just-in-time (JIT) training to efficiently care for patients. Nebraska Medicine's support services and human resource team have considered the option of mapping out essential services that could possibly be delegated (with supervision) to other personnel as well as medical and healthcare students currently attending UNMC (based on current year and field of study, and credentials/certifications) to meet clinical demands. Some duties may include basic initial patient assessment (height, weight, temperature, recording symptoms, etc.), to more complex services such as manual patient ventilation (handheld resuscitation device, e.g. Ambu, VentiSure, etc.) if mechanical ventilation is not available or feasible. It is important to note that these suggestions are only being considered in the event of a pandemic due to legal aspects and concerns. This is all in attempt to provide the greatest good for the greatest number of people.

Pandemic planning should also consider non-clinical hospital staff that are critical to the operation such as cooks, facilities and equipment technicians, and security staff. Hospitals rely on several service departments to aid in the continuing operations of care. Patients, families, and staff need to be fed, equipment and hospital rooms require maintenance, and the security of hospital infrastructure, patients, staff, equipment, and supplies must be secured. Staffing issues are not just restricted to hospital personnel. In order to keep hospitals and healthcare clinics operational, outside companies who manufacture and deliver essential products are also affected by a pandemic. For example, the healthcare system depends on external sources to produce linen, PPE, and specimen kits, food manufacturers, sanitation and waste management, as well as transport companies to distribute necessary supplies.

HHS describes an influenza pandemic will cause the supply chain to become vulnerable and hospitals will begin to see shortages of essential goods (e.g. food water, medicines, PPE, etc.), as a result of decreased production, reduced international and national transport, and missed deliveries due to absenteeism (HHS, 2017). While healthcare organizations may consider all personnel essential, it will be difficult to address the issue of work loss of external services. Nebraska Medicine addresses this challenge by establishing strong relationships early on with local vendors and supply distributors (e.g. Cardinal Health, Nebraska Sysco, Sodexo, etc.) but admit they are reliant on contracts and good faith that staff will show up and critical resources will be supplied.

Space

A study on Emergency Department facility design for mass-casualty incidents conducted by Hicks et al. demonstrated that physical space for supplies, equipment, and patient surge is one of the most intricate areas of pandemic planning. This issue is described as hospitals having a difficult time with space creation and flexibility, leaving little reserve space available during pandemic surge (Hick et al., 2009). Research on hospitals and insufficient space detail that if hospitals were being built today, the design and layout would look very much different; they would now consider patient surge operations in their initial design to be more functional and practical, allowing for better patient flow and processes of care. Hick et al., states, "As hospitals remodel or expand, construction of spaces as "dual purpose" is critical". He later admits, "most federal grant (including the Hospital Preparedness Program) funding typically restricts funding for new construction", but points out that low-cost modifications can "often be integrated into new projects, provided that there is early and consistent advocacy for these changes from administration and project planners" (Hick et al., 2009).

Because space is a critical concept of planning, experts suggest during times of pandemic and patient surge, hospitals understand the expansion/surge plans for their department and region,

including triaging of patients to other locations or the opening of other clinical areas for emergency care (Hick et al., 2012). Experts also describe utilizing the maximal use of facilities for patient overflow. This may include conversion of private rooms to semi-private, using other areas of a hospital (Post Anesthesia Care Unit [PACU], lobbies, hallways, parking lots, classrooms), and accessing other healthcare organizations such as the American Red Cross, Medical Reserve Corps, and local health care coalitions (Hick et al., 2012). In other cases, some reports demonstrate adequate space (including size) but lacking vital items in that space. A few accounts detail not having HEPA filters or proper ventilation; insufficient oxygen ports, complex room design/set up, leading to a diminished standard of care. Due to 20-50% of critically ill influenza patients requiring extensive support, Manuell et al., state, there are several critical requirements needed for a physical location to be used to provide ICU level critical care. These items include piped gas for ICU beds, adequate electricity, vacuum/suctioning capabilities, monitoring equipment, and sufficient physical space, given infection control parameters, for equipment and patient management (Manuell et al., 2011).

Given these limitations and the known fact of pandemics lasting for several weeks to even months, these spaces would prove to be insufficient for prolonged treatment of patients (7-14 days). Discussions surrounding hospital occupancy rates estimates that only 4-5% of hospital beds are available at any given moment (Lawler, 2018) and the fact remains the number of hospitals in the United States is swiftly diminishing, increasing the demands on already stressed healthcare organizations. Healthcare providers declare during a real-life pandemic event, hospitals would have to be placed on lockdown to control the surge of patients due to space constraints and hospital regulations.

Chapter 3: METHODS

Data Collection

Starting at the beginning of April 2017, the pandemic planning process included planning committees meticulously examining the 2008 Pandemic Plan and appendices. The focus was to identify gaps in previous response objectives and activities and update the 2008 plan to reflect recent literature information and what experts in the preparedness field are currently suggesting. An extensive literature review was conducted over a 12 month period to obtain the most recent reports on lessons learned from previous pandemic response plans, disease burden of infectious diseases, disease modeling, and decision support tools for pandemic preparedness. This thesis synthesizes the reviewed literature and provides specific, independent calculations and estimates for potential pandemic influenza disease burden in Douglas County Nebraska and on Nebraska Medicine's healthcare services. The results from this thesis will provide the basis for the 2018 Pandemic Preparedness Plan, and assisting planning committees and hospital departments with pandemic surge projections in order to aid in the decision-making process for scarce resources in the event of a pandemic.

2017-2018 Pandemic Committee

Nebraska Medicine identified eight pandemic influenza committees; 1) Triage and Crisis Standards of Care and Clinical Staffing Locations and Strategies 2) Palliative Care 3) Support Services (EVS, patient care equipment, HR, food services, morgue surge, security, risk management, facilities, linen) 4) UNMC Research 5) UNMC Education 6) Infection Prevention and Medical Countermeasures (pharmacy, employee health, DCHD) 7) Communications (PIO, call center) and 8) Behavioral Health and Support. Committees are comprised of physicians, physician's assistants, nurses, specialist in their dedicated field, and trained and qualified UNMC student pandemic influenza volunteers. For this project, triage and crisis standards of care, clinical staffing, and support services were the specific committees worked with to obtain

pertinent data for this thesis. Several committee meetings transpired as well as personal one on one discussions with committee team leads to obtain information needed for disease burden projections on patient surge, staffing, and supplies.

To determine Nebraska Medicine's current capacity and capabilities, hospital-wide inventory of essential supplies (N95 masks, surgical masks, eyewear, gloves, gowns, needles and syringes, RT circuits, sanitizers, flu kits, and substitute items), and equipment needs (ICU and ventilator capabilities and individual hospital unit bed counts) was collected from the triage and crisis standards of care team, and the supply service committee. Information on the supply "watch list" includes item identification number and description, quantity on hand, allocation reports, the quantity of the item ordered, and quantity received, and manufacturer listing). Data on total max capacity hospital beds, ICU beds, current census and capacity, and occupancy percentage, was obtained from Nebraska Medicine's Daily Census Staffing Report shown in Table 2.

Table 2: Daily Census Staffing Report (as of 1/31/18)

Area	Max Possible Capacity	Current Census	Anticipated D/C	Held Beds	Transfers	Current Capacity	Occupancy Percentage
ICU Beds	72	67	2	0	15	72	93%
M/S Beds	441	414	86	5	3	436	95%
TNMC Total	590	513	90	8	18	582	88%
TNMC Med/Surg, Tele, ICU Total	513	481	88	5	18	508	95%

ICU capacity was gathered from hospital administrator reports showing average annual patient admission into the unit. Morgue capacity was also included in this data. Current data illustrates that at any given time, morgue space allows for a maximum of 64 deceased. This number includes all current available spaces, so it is noted that this number will fluctuate

depending on occupancy by non-pandemic related deaths. Before planning projections could begin monthly meetings with all committee members and a tabletop exercise was conducted to cross-reference each committee's plan to make sure all pandemic planning activities coincided with one another's before being included in project projections.

Staffing listings (i.e. pandemic planning headcount) included: staff name, job title, department, function, position level, status description, location, and title of all hospital and support staff (e.g. adjunct faculty, administrative staff, ambulatory services, college professors, security, nursing staff, supply manufacturers, EVS, physicians, etc.). This information was retrieved from clinical staffing locations and strategies committee and Nebraska Medicine's human resources operations. During a pandemic period, Nebraska Medicine considers all hospital personnel essential and expects all its workforce to respond to work if called upon. Therefore, information was collected on all current employed Nebraska Medicine and UNMC medical staff. As previously noted, hospital infrastructure is a complex area to plan for. Due to space and availability constraints, each department identified current location capacity and previous surge plan operations.

Epidemiologic Measures

Considering the differing levels of influenza severity, an extensive review of historical pandemic influenza literature and data was collected from the past four influenza pandemics (1918, 1957, 1968, and 2009). Epidemiologic characteristics of influenza such as transmissibility of the infection in the population (low, moderate, high), clinical severity and duration of the virus, and gross attack rate were identified and used for a pandemic influenza scenario throughout the state of Nebraska and Douglas County Nebraska. Because Nebraska Medicine is located in Douglas County, the county was purposefully selected in order to calculate a more precise estimate of disease burden on Nebraska Medicine's staff, space, and essential supplies.

Data collection from previous pandemic influenza investigations and studies included analysis of case fatality rates, symptomatic case-hospitalization ratio, and the ratio of deaths to hospitalizations. This information collected was used to develop the basis of clinical severity for this project. Measures of transmissibility included secondary and clinical attack rates, an estimated R_0 , and peak hospital visits due to ILI. An important transmissibility parameter for infectious disease models tends to be R_0 (pronounced “R naught”), i.e. basic reproductive number. The R_0 illustrates the average number of new infections that would result from the introduction of an infectious person into a susceptible population. Because the current threat of influenza virus H7N9 has not yet been shown to be human-to-human transmittable, the calculations in this thesis used epidemiological characteristics from the 1918 H1N1 virus to identify the most severe case scenario and characteristics from the 1958/1968 (H2N2/H3N2) to demonstrate a moderate case scenario. The median R_0 of 2.0 from the 1918 pandemic and the median R_0 of 1.65 from the 1957 pandemic were used for this project to obtain sustained human transmittable scenario estimates (Biggerstaff et al., 2014).

The value of R characterizes the final number infected in the absence of an intervention (Biggerstaff, 2014). If $R_0 < 1$ each existing infection causes less than one new infection. In this case, the disease will decline and eventually die out. If R_0 equals 1, each existing infection causes one new infection. This illustrates the disease will stay alive and stable, but an outbreak or an epidemic will not occur. If $R_0 > 1$ this demonstrates each existing infection causes more than one new infection, showcasing the disease will spread between people and the likelihood that an outbreak will occur. The simulation model chosen for this thesis allows for model estimates (e.g. R_0 , CFR, attack rates, etc.) to be changed according to current pandemic data and information once the virus has sustained human-to-human transmission.

Pandemic Modeling Tools

Disease modeling tool FluAid 2.0 was used to provide an estimate of impact in terms of deaths, hospitalizations, and outpatient visits due to pandemic influenza (CDC, 2016). Data estimates provided in FluAid 2.0 was then transferred to Microsoft Excel to build FluSurge 2.0 projections. For the scope of this thesis, these tools were used to estimate the potential impact and disease burden of pandemic influenza on critical resources at Nebraska Medicine. FluAid and FluSurge 2.0 were used to calculate the percentage of hospital capacity needed, demand on hospital-based resources such as hospital beds, ventilators, ICU capabilities, and potential health outcomes (e.g. morbidity and mortality rates) associated with the next influenza pandemic. Both pandemic modeling tools were used to provide estimates intended to answer questions such as: Will there be sufficient hospital beds? Will there be enough health care providers to deal with the estimated number of outpatients? (CDC, 2016).

For this thesis, planning projections for demand on hospital-based resources during a pandemic, such as: average length of non-ICU hospital stay; average length of ICU stay; average length of ventilator usage; average proportion of admitted influenza patients that will need ICU care; average proportion of admitted influenza patients that will need ventilators; and average proportion of influenza deaths assumed to be hospitalized for influenza-related illness, were gathered from the CDC national average report on FluSurge 2.0 software. Daily percentage increase in cases arriving compared to previous day was calculated by using CDC pandemic tool: FluAid 2.0 software, in order to provide guidance on current and future pandemic development plans and improvement to preparedness tools that can aid public health practitioners in the event of an influenza pandemic.

FluSurge 2.0 requires a list of inputs and primary data. Users are asked to provide estimates of their local population in 3 age groups (0–19, 20–64, and 65+ years). Data on the Douglas County Nebraska population were obtained from the 2017 United States Census Bureau.

Age distribution provided by the Census was outlined in 4 and 9-year groupings. In order for an even distribution of data to allow for calculations with the FluSurge program, I used the default age groups set into FluSurge, (0– 19 years, 20–64 years, and 65+ years) (shown in table 5). Total hospital resources (total non-ICU hospital beds, total ICU beds, and total mechanical ventilators), and general hospital information can be collected from hospital administrators, department coordinators, and human resources. All projections were calculated using the Douglas County Nebraska population. Given that Nebraska Medicine is one of the largest hospitals in the state, the projected data may be significantly lower if residents living outside of the county travel to receive treatment at our facility.

The CDC reports during a pandemic, infection in a localized area can last about six to eight weeks, and a least two pandemic disease waves will occur. Once the primary data section is complete the user is then instructed to determine pandemic duration (duration refers to the number of weeks users assume the pandemic wave to last) of 6, 8, or 12 weeks, and pandemic attack rate (attack rate refers to the percentage of the population that becomes clinically ill due to an influenza pandemic) of either 15, 25, or 35%. FluSurge then calculates the data and provides estimates of hospital admissions and hospital (non-ICU), ICU, and ventilator capacity needed over the course of the pandemic (by week). FluSurge was also used to estimate the number of hospital admissions and deaths due to an influenza pandemic. Hospital admissions were estimated for 3 different pandemic impact scenarios: minimum or the best-case scenario (fewest possible number of hospital admissions); mean or the most likely scenario (number of hospital admissions most likely to occur); and maximum or the worst-case (1918-type) scenario (largest number of hospital admissions) (Zhang, 2006).

Chapter 4: RESULTS/PROJECTIONS

Demographics

Population estimates show Douglas County Nebraska currently has a total population of 554,995 people. (Douglas County GIS, data set, 2017). Population in FluSurge is divided into three age groups: school-aged children, working adults, and retirees. Douglas County population was structured to fit FluSurge 2.0 age group parameters shown in Table 3. Table 3 illustrates *total* population and does *not* represent adjustments made for Nebraska Medicine’s market share of 30%. The population was adjusted to reflect Nebraska Medicine’s current market share and is reflected in the final results.

Table 3: Douglas County Nebraska population by age group, 2017 Census Data

Age Group	Total Population
0-19	143,362
20-64	344,175
65 +	67,458

*Population retrieved from the U.S. Census Bureau

Initial Assessment

Because influenza creates a surge in demand for hospital-based services, the initial project assessment estimates the disease burden of influenza on outpatient medical care, hospitalization, ICU care, mechanical ventilation, and deaths for all of Douglas County Nebraska hospitals. First, the R_0 of 1.65 from the moderate 1958/1968 pandemic was used to simulate a moderate pandemic in the state of Nebraska (shown in the second column of Table 4). To provide a severe pandemic influenza scenario epidemiological characteristics from the 1918 influenza virus (shown in the fourth column of table 4) were used. For both moderate and severe scenarios, the illness (i.e. attack rate) of 35% was used as the median rate from previous pandemic influenza estimates which range from 20% to 50%.

Table 4: Douglas County Nebraska Moderate and Severe Pandemic Influenza Scenario

Characteristics	Moderate (1958/68-like)	% of Illness	SEVERE (1918-like)	% of Illness
Total DC** Population	554,995	...	554,995	...
Illness (35% attack rate)	194,248	...	194,248	...
Outpatient Medical Care	97,124	50%	97,124	50%
Hospitalization	1,865	0.96%	21,371	11%
ICU Care	272	0.14%	3,205	1.65%
Mechanical Ventilation	136	0.07%	1,612	0.83%
Deaths	447	0.23%	4,099	2.11%

Number of Episodes of Illness, Healthcare Utilization, and Death Associated with Moderate and Severe Pandemic Influenza Scenarios (**Douglas County, Nebraska). Table 4 results include Douglas County's *total* population.

Results in Table 4 column 2 indicate that a moderate 1958/68 like pandemic in Douglas County Nebraska could cause the hospitalizations of over 1,800 people with more than 270 requiring ICU care (136 of which would mechanical ventilation) and nearly 450 deaths. In the event of a severe 1918-like pandemic (Table 4 column 4), an excess of 194,000 would become ill with 11% (n= 21,371) of Douglas County's population needing to be hospitalized. Over 3,000 would need ICU care, 1,600 requiring ventilators, with nearly 4,100 deaths.

Nebraska Medicine Capacity and Capability

The next step was to calculate pandemic disease burden for Nebraska Medicine. On average, Nebraska Medicine operates at 95-97% capacity. Based on these percentages, the numbers shown in Table 5 represent Nebraska Medicine running at normal capacity rates. These rates were chosen to reflect how pandemic influenza affects everyday hospital operations and its burden on critical resources. Information was collected on total licensed non-ICU beds, total licensed ICU beds, and a total number of ventilators to reflect Nebraska Medicine's current capabilities. Reports collected from Nebraska Medicine (provided in Table 2) list a total of 441 licensed non ICU beds, 72 licensed ICU beds, with 55 available ventilators. Current reports of

ventilator use illustrate that at any given moment, 36 out of 55 ventilators are in use, leaving only 33% of ventilators available for use in a pandemic.

Table 5: Nebraska Medicine Current Capabilities

Total licensed non-ICU beds	441
% licensed non-ICU beds staffed:	5%
Total staffed non-ICU beds:	221
Total licensed ICU beds:	72
% licensed ICU beds staffed:	7%
Total staffed ICU beds:	36
Total number of ventilators:	55
% ventilators available:	33%
Total number of ventilators available:	18

Input assumptions for this project, demonstrated in Table 6, are based on national estimates (provided by FluSurge). National estimates (based on previous pandemics) assume that, on average, the length of non-ICU hospital stay for influenza-related illness is 5 days, the length of ICU stay for influenza-related illness is 10 days, and the length of ventilator usage for influenza-related illness is 10 days. Additionally, Table 6 illustrates the average proportion of admitted influenza patients that will need ICU care is 15%, and the average proportion of admitted influenza patients that will need ventilators is 7.5%. The model FluAid details the term "hospitalization" refers to, "those who are hospitalized due to influenza-related illness but who survive the illness (i.e., their end health outcome is hospitalization). However, a percentage of those who will die from pandemic influenza-related illnesses are likely to die while hospitalized. Thus, the total number of hospital beds required will be the sum of hospitalizations plus in-hospital deaths. The estimates of total hospitalizations given in the HHS Pandemic Influenza Plan were calculated according to the assumption that 70% of influenza-related deaths will occur in

hospital (CDC, 2012). Furthermore, hospitals can also expect to see a 5% daily increase in cases arriving compared to preceding day before.

Table 6: FluSurge2.0 Inputs and Assumptions that can be altered

	Input assumptions	Unit	Values
No. 1	Average length of non-ICU hospital stay for influenza-related illness	Days	5
No. 2	Average length of ICU stay for influenza-related illness	days	10
No. 3	Average length of ventilator usage for influenza-related illness	days	10
No. 4	Average proportion of admitted influenza patients will need ICU care	proportion	15%
No. 5	Average proportion of admitted influenza patients will need ventilators	proportion	7.5%
No. 6	Average proportion of influenza deaths assumed to be hospitalized	proportion	70%
No. 7	Daily percentage increase in cases arriving compared to previous day	percent	5%

*All values in Table 7 can be changed to reflect current data and/or specific locale information.

FluSurge2.0 Results

Results from FluSurge 2.0 contain projections based off of an influenza pandemic scenario with a 35% gross clinical attack rate and an 8-week duration. Table 7 demonstrates an influenza pandemic of this degree will most likely result in a total of 680 hospital admissions (ranging from 244 to 866), and 155 deaths (ranging from 87 to 259) at Nebraska Medicine. Table 8 contains data regarding most likely, minimum, and maximum weekly hospital admissions over an 8 week period. Results show the peak number of hospital admissions arrived at the 4th and 5th week for all scenarios. The results (shown in Table 8 and illustrated in Figure 1) ranged from 46 admissions in the minimum scenario to 165 admissions in the maximum scenario, with a total of 129 patients admitted per week in the most likely scenario.

Table 7: Total Pan Flu Impact

Pandemic Influenza Impact (8 weeks) / Attack Rate	35%
Total Hospital Admissions	
Most Likely Scenario	680
Minimum Scenario	244
Maximum Scenario	866
Total Deaths	
Most Likely Scenario	155
Minimum Scenario	87
Maximum Scenario	259

Figure 1: Weekly Distribution of Hospital Admissions

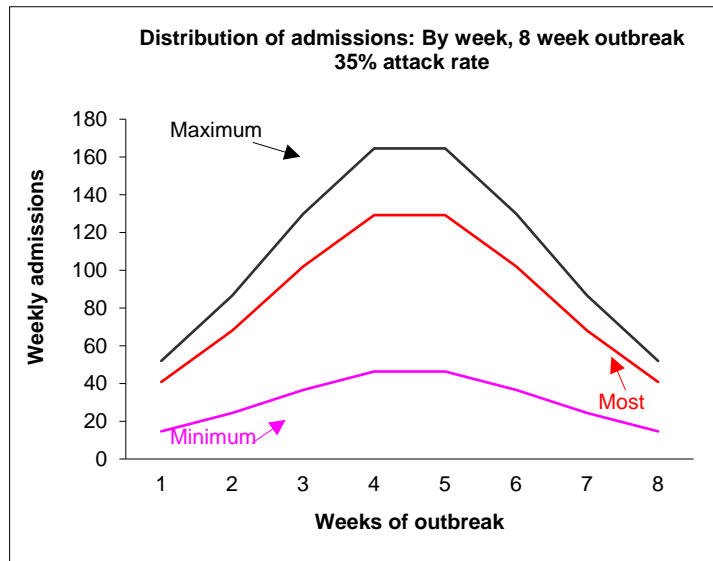


Table 8: Weekly hospital admissions over 8-week duration

Hospital Admissions	WEEK							
	1	2	3	4	5	6	7	8
Most Likely Scenario	41	68	102	129	129	102	68	41
Minimum Scenario	15	24	37	46	46	37	24	15
Maximum Scenario	52	87	130	165	165	130	87	52

*The estimated number of hospital admissions is based on death rates and hospitalization rates provided by FluAid2.0.

Demand on Hospital Resources

Table 9 presents results from the calculations using the data entered in FluAid2.0. It presents the estimates by specified pandemic duration (e.g., 8 weeks) and gross clinical attack rate (e.g., 35%), of the impact of pandemic influenza on Nebraska Medicine’s resources. FluSurge2.0 manual describes the hospital admission category includes the total number of weekly hospital admissions of influenza patients and peak admission per day. The hospital capacity category details the maximum total number of influenza patients in the hospital and

appropriate hospital capacity needed. ICU capacity indicates the maximum total number of influenza patients in the ICU, and pertinent ICU capacity needed. Ventilator capacity includes the maximum total number of ventilators used and related percentage of use. Related death estimates reflect total number of deaths and total number of influenza patients expected to die in the hospital due to influenza pandemic in a week (Zhang, 2005).

Table 9: Results: Demand for hospital-based resources: 35% attack rate: 8 weeks duration

Pandemic Influenza Impact		Weeks							
		1	2	3	4	5	6	7	8
Hospital Admission	Weekly admissions	41	68	102	129	129	102	68	41
	Peak admissions/day				21	21			
Hospital Capacity	# of influenza patients in hospital	31	51	76	97	102	85	65	43
	% of hospital capacity needed*	138%	231%	346%	438%	464%	386%	296%	194%
ICU Capacity	# of influenza patients in ICU	6	13	20	27	29	28	22	15
	% of ICU capacity needed*	121%	260%	399%	527%	575%	558%	434%	299%
Ventilator Capacity	# of influenza patients on ventilators	3	7	10	13	15	14	11	8
	% usage of ventilator	17%	36%	55%	73%	80%	77%	60%	41%
Deaths	# of deaths from influenza			9	16	23	29	29	23
	# of influenza deaths in hospital			7	11	16	21	21	16

1. All results showed in this table are based on the most likely scenario.

2. Number of influenza patients in hospital, in ICU, and number of influenza patients on ventilators are based on maximum daily number in a relevant week.

3. Hospital capacity used, ICU capacity used, and % usage of ventilator is calculated as a percentage of total capacity available (see manual for details).

4. The maximum number of influenza patients in the hospital each week is lower than the number of weekly admissions because we assume a 7-day stay in general wards.

Table 9 illustrates the demand on hospital resources peak in week 5, with a maximum of 464% of all hospital non-ICU beds, 575% of total ICU capacity, and 80% of all ventilators at Nebraska Medicine needed to respond to influenza cases presented at their hospital. Examples of the impact of changing hospital capacity are shown in Table 10. These results are based on

Nebraska Medicine’s current intervention plans being implemented during week one of a pandemic.

Intervention

The same demographics, characteristics, and assumptions were run in FluSurge2.0 again to reflect Nebraska Medicine operating at 80% (opposed to 95-97%) to demonstrate if Nebraska Medicine discharged 20% of its current patients to make room for incoming ILI patients (no other interventions were included in these calculations). Table 10 reflects the change in demand for hospital resources (non-ICU hospital beds, ICU beds) needed to respond to a pandemic event. Again, the demand on hospital resources peaked in week 5, with a maximum of 116% of all hospital non-ICU beds and 201% of total ICU capacity needed to respond to influenza cases at Nebraska Medicine. Ventilator capacity need remained at 80%. Deaths from influenza and influenza deaths in hospital also remained the same.

Table 10: Results: Demand for hospital-based resources: 35% attack rate: 8 weeks duration

Pandemic Influenza Impact		Weeks							
		1	2	3	4	5	6	7	8
Hospital Admission	Weekly admissions	41	68	102	129	129	102	68	41
	Peak admissions/day				21	21			
Hospital Capacity	# of influenza patients in hospital	31	51	76	97	102	85	65	43
	% of hospital capacity needed*	35%	58%	87%	110%	116%	97%	74%	48%
ICU Capacity	# of influenza patients in ICU	6	13	20	27	29	28	22	15
	% of ICU capacity needed*	43%	91%	140%	185%	201%	195%	152%	105%
Ventilator Capacity	# of influenza patients on ventilators	3	7	10	13	15	14	11	8
	% usage of ventilator	17%	36%	55%	73%	80%	77%	60%	41%
Deaths	# of deaths from influenza			9	16	23	29	29	23
	# of influenza deaths in hospital			7	11	16	21	21	16

Chapter 5: DISCUSSION

When developing a pandemic plan, many hospitals often use a single scenario, but both disease modeling tools, FluAid and FluSurge 2.0, are flexible and have the ability to reflect several scenarios by altering variables such as gross attack rates, pandemic duration, case fatality rates, and hospital capability and capacity for any state, county, or city demographics.

Demographics from the state of Nebraska and Douglas County Nebraska were independently collected and input into FluSurge 2.0 to run pandemic influenza scenarios for both areas. Due to the unpredictability of pandemic influenza, scenarios for gross attack rates of 15%, 25%, and 35% were calculated and presented to Nebraska Medicine. This allows the hospital to prepare for events at wavering levels and showcases 3 different pandemic impact scenarios: minimum or the best-case scenario (fewest possible number of hospital admissions); mean or the most likely scenario (number of hospital admissions most likely to occur); and maximum or the worst-case (1918-type) scenario (largest number of hospital admissions). The CDC states, "for a given gross clinical attack rate, the extensive range between the minimum and maximum estimates is due to the uncertainty of how the next pandemic will spread through society, as well as to the lack of data regarding the impact of influenza in previous pandemics. Such uncertainty and the resultant wide ranges in estimated impact should serve as a warning to planners not to be overconfident in using a single estimate of impact when preparing their plans" (CDC, 2005).

This thesis explores the potential impact, disruption of services, and disease burden facing Nebraska Medicine and their capability and capacity to handle surge events. Resource adequacy during surge events is influenced by a wide range of factors including but not limited to: community demographics, intervention measures, and pandemic severity. The results depicted in this thesis were based on Douglas County's current population and adjusted in FluSurge to reflect Nebraska Medicine's current market share of 30%. The cumulative market share is based on the number of inpatient days in each facility. All hospitals in the hospital referral region

belonging to the same system are grouped together as one institution. Due to Nebraska Medicine previous influenza market share showing percentages above 30%, market share rates should be adjusted for future calculations once the exact percentage is known. The increase in percentage is likely due to the number of patients living outside of Douglas County arriving to seek medical treatment at Nebraska Medicine. In this case hospital, administrators should reflect this in their analysis to lobby for more hospital resources, stockpiling items, vaccination dose, and antiviral treatments.

Results from this study indicate that a moderate to severe influenza outbreak in Douglas County Nebraska would present considerable challenges and place extreme pressure on Nebraska Medicine's capacity and capability to care for patients. It is important to note that some hospital capacity must always be reserved for patients other than those ill from infectious diseases (e.g., maternity, trauma, burn units, unless the hospital is designated to be a flu only hospital). If an influenza pandemic were to occur, Nebraska Medicine has elected to stop all elective cases, discharge non-emergent cases, and only admit life-threatening injuries and illness to open space for ILI patients. The CDC ethics subcommittee reports, even during an influenza pandemic, adequate healthcare can, and should be provided, and although hospitals will likely reach maximum supply and equipment capacity during a pandemic, ethical considerations and decisions regarding allocation of resources need to be made in the context of the incident (CDC, 2012). During an influenza pandemic, Nebraska Medicine outlines allocating ventilators based on the standardized method of assessing multi-organ function (and failure) using the Sequential Organ Failure Assessment (SOFA) score.

Results shown in Table 6 demonstrate that because Nebraska Medicine presently operates at or close to full capacity, so meeting the needs experienced in a pandemic scenario would place a severe strain on the already stressed hospital. Projections included in Table 9 indicate that if Nebraska Medicine continues to work at 95-97% capacity, (with a 35% attack rate and an 8-week

duration) without strategic plans or interventions in place, hospital capacity and resources needed for the influx of ILI patients will double within the first couple of weeks. By week 5 (pandemic peak), Nebraska Medicine expressed vital supplies and resources will be on allocation. Nebraska Medicine's support services define this as the process of distributing supply based on priorities; when supply is constrained by the demand of an entire allocation group it is addressed through "supply distribution rules". These rules define how to resolve supply constraints within an allocation group when the supply is limited.

To evaluate hospital-resource adequacy at Nebraska Medicine disease modeling was useful as it has the ability to predict weekly patient admissions under a wide range of demographics, assumptions, and basic hospital capabilities. These results may be beneficial when appealing to public health officials, hospital administrators, and policymakers when demonstrating the demand for critical hospital services at the scale represented in this study during an influenza pandemic in Douglas County Nebraska. The information in this thesis was presented to Nebraska Medicine's Executive Director of Emergency Management & Bio preparedness and the eight pandemic planning committees to update Nebraska Medicine's 2018 Pandemic Influenza Preparedness and Response Plan.

After initial results were presented showing disease burden of pandemic influenza while operating at 95-97% capacity, each pandemic committee revised their plans to indicate preparedness activities, by week, in order to reduce the amount of current hospital capacity needed during an influenza pandemic. Pandemic actions included cancellation of elective procedures, routine admissions, and health maintenance visits; delay non-life-saving treatments for existing patients, limit incoming patient transfers, and encourage dismissal of immune-compromised patients. Committee members relayed reducing these services by 20%. FluSurge was then run with the updated information and results are shown in Table 10. These new results allowed for each team to adjust planning activities based on calculations of percentage of capacity

needed in weeks 1 through 8. All final results with adjustments made to include previous intervention strategies will be presented at the upcoming meeting. Along with the updated projections, recommendations based on these results will also be included.

Recommendations

In the case that the above interventions do not decrease the intended percentage of hospital capacity, the plans to accommodate patient surge includes activities such as: evaluating the capacity for double occupancy rooms, placing primary care staff and providers on standby to be able to set up walk-in “flu clinics”, monitor inpatient bed capacity & hospital status twice daily, transfer unaffected patients to long-term care if possible, and triage patients and implement Crisis Standards of Care. Further recommendations presented to Nebraska Medicine include:

- Create pandemic plans for week by week operations. Plans should range anywhere from 8 weeks to 12 and consider pandemic waves
- The unpredictability of pandemic influenza makes the accuracy of disease burden projections difficult, so it is important to periodically revise these projections to include current information regarding current hospital capacity and capabilities, hospital market share, and updated data as it becomes available as the pandemic is in progress
- Inventory personal protective equipment on “watch list” and order additional supplies as identified
- Consider stockpiling critical supplies such as N95 masks, gloves, gowns, and equipment (e.g. ventilators, ICU beds, cots, etc.) that allow the hospital to operate at 200% surge
- Discuss with local and state health departments how bed availability, including available ICU beds and ventilators, will be tracked during a pandemic
- List of available trained and qualified staff to operate additional ventilator(s)
- Because critical supplies and equipment will be in extreme demand during a pandemic, it is recommended to outline allocation of resources by pandemic severity, hospital capacity and capability, and high-risk populations

- As the data indicates there will be a shortage of staff. It is recommended that Nebraska Medicine develop a student pandemic volunteer site to access during pandemic events for easy credentialing and badging
- Provide Just-in-time training to assisting personnel, students, and volunteers
- Implement a family care plan to reduce absenteeism during an influenza pandemic: this form helps identify and facilitate the care and support of family members during planned and unplanned contingencies
- The literature indicates emergency rooms are the front lines of hospital care during a pandemic. ER's report becoming quickly overwhelmed and needing more space to allow for the influx of patients. It is recommended that Nebraska Medicine create a detailed sitemap for possible surge space and triage areas throughout the hospital
- The use of cots and beds in flat space areas (e.g., classrooms, gymnasiums, lobbies) within the hospital and UNMC for noncritical patients care

This project also encourages continuous emergency and disaster planning for constant improvement as public health emergencies, disease outbreaks, environments, and scenarios change. The outcome of the thesis helped to reinforce Nebraska Medicine and UNMC's capabilities in supporting Douglas County resident's health needs. While projection and recommendations apply specifically to Douglas County Nebraska and Nebraska Medicine, it is expected that certain themes and principles can be applied more broadly to other states.

Limitations

Zhang et al., state, "There is always a tradeoff between the advantages (ease of use and flexibility) and limitations (simplicity and potential imprecision) of mathematic modeling in decision making. FluSurge is limited in that only 3 broad age categories were considered and many other important epidemiologic, demographic, and behavioral characteristics were not modeled due to lack of reliable data" (Zhang et al., 2006). The FluSurge manual also addresses the issue surrounding the uncertainty of how the next pandemic will spread and the lack of data regarding the impact of influenza in previous pandemics. Zhang et al., declares that users of

disease modeling tools like FluAid and FluSurge2.0 "should not be overconfident in using a single estimate of impact when preparing their plans" (Zhang et al., 2006). Further limitations include Nebraska Medicines current market share. Due to the range of rates, the unit assumptions and demographics will need to be modified. It is possible that results in this thesis underrepresent the actual capacity needed for a future surge event. Nebraska Medicine will need to prepare and plan for the worst case scenario and adjust their pandemic action accordingly.

Conclusion

Considering the result presented in this thesis project a high influx of patients, increased demand of resources and supplies, operational constraints, and insufficient equipment during a pandemic, it is clear that pandemic planning related to space, staffing, and supplies is a vital part of Nebraska Medicine's ability to function during surge events. It will also be important to exercise and test the plan in order to identify any gaps and avoid inadvertent errors that could arise during actual pandemic events. Nebraska Medicine's decisions regarding pandemic response and operations should be adapted to reflect real-time information updates obtained during the course of a pandemic. Regular committee meetings and discussions to exchange hospital capabilities and capacity as well as current pandemic data will be vital in effective response efforts.

Although the results and projections in this study are specific to Douglas County Nebraska and Nebraska Medicine, the same methodology and disease modeling tool can be applied to any hospital in any location and would be useful for other disaster planning scenarios that could overwhelm normal hospital capacity and capabilities. State/local, federal, and global planning and preparedness efforts are a complex and lengthy process but worth considerable attention. All healthcare agencies and organizations should advocate for support to strengthen hospital preparedness plans. When advocating for additional resources (e.g. stockpiling inventory, SNS and vaccine allocation, and funding) health officials should present studies like this and

existing studies that involve pandemic modeling tools and disease burden projections to validate claims.

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