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Youths with Sports-Related Concussions: A Systems Perspective

Serina Lai | Fall 2020

Abstract. Concussion injuries in children are often unrecognized when they occur. Even if acknowledged, these injuries are often mismanaged. This study used a combination of subject matter expert interviews, literature review, and “systems thinking” to arrive at recommendations that could have meaningful impacts.

Background

A concussion, or mild traumatic brain injury (mTBI), has no universally accepted definition¹. In 2017, the international Concussion in Sport Group consensus defined a sports-related concussion as a traumatic brain injury induced by biomechanical forces. It can be caused by a direct blow to the head, face, neck, or elsewhere on the body. A concussion typically results in temporary impairment of neurological functioning such as confusion or disorientation². Furthermore, there is no universally adopted set of guidelines or gold standard for concussion management.³ Despite the potential for variability, few studies have analyzed factors of variability in the concussion care continuum from a systems perspective. Large variability in care may contribute to the suboptimal pediatric mTBI management.

It is estimated that up to 1.9 million children, aged 18 and younger, sustain sport- and recreation-related concussions each year in the U.S.;⁴ however, the true incidence of this injury is unknown because many do not seek medical care.⁵ Undiagnosed mTBIs and mismanaged concussions have the potential for long-term

consequences such as prolonged symptoms and neurodegenerative diseases.⁶

This study investigated aspects of prevention and injury management across various settings: healthcare, home, school, and sports. Particular parties that may have influence over an athlete’s medical care and injury management are healthcare providers, caregivers, school personnel, and coaches. The combination of settings, people, and tools creates the system wherein the pediatric athletes reside in.

In an ideal system, a student athlete undergoes concussion training and is knowledgeable about the injury, its symptoms, and its consequences. Coaches would be knowledgeable about identifying a concussion, and take proactive steps to protect the athlete by removing the player upon any suspicion of a head injury. Coaches have a personal and authoritative relationship with athletes, putting them in a unique position to provide concussion resources and encouraging athletes to seek medical care. Medical providers guide athletes through the recovery process from a clinical perspective, validating the injury and providing backing for accommodations that athletes may need to recover. Parents and caregivers of the athlete support the athlete emotionally, physically, and mentally as well as advocating for the athlete when needed. Teachers, school nurses, and school personnel assist in managing the athlete’s academic workload according to the capabilities of the athlete and their symptoms.

An understanding of the current system was established through a collection of interviews

with athletes, coaches, and providers. Information from interviews and literature reviews revealed a siloed system that left athletes vulnerable to suboptimal recoveries. Main gaps in the system can be attributed to deficiencies in education and communication, as well as a lack of established protocols.

Prevention

In an ideal system, the athlete does not sustain a concussion. Therefore, this study aimed to identify preventative measures that may be taken to reduce the risk of concussions. Studies have shown that females have a higher risk of concussions, and sustain more severe and prolonged symptoms than their male peers.^{7,8} Research has suggested that female athletes' higher risk may be due to weaker neck strength compared to that of their male peers.⁸⁻¹⁰

At the Rutgers School of Health Professions, researchers published a paper that examines the correlation of neck strength and concussions.⁸ The lead author, Allison Brown, was interviewed about the paper and stated, "increasing neck strength and possible size could substantially reduce risk or severity of injury or outcomes." This paper recommended physical therapists and athletic trainers perform pre-season cervical spine assessments, neck pain screenings, as well as implementing neck strengthening exercises. Including cervical strengthening exercises as part of the team's workout routine may decrease the risk of concussions, especially for females.

Changes in practice routines or sport protocols may also lessen the risk for concussions. These changes should consider the risk factors of the specific sport. The Centers for Disease Control and Prevention (CDC) outlined prevention tips for coaches of specific sports to implement.¹¹ For example, in cheerleading, spotters should be available when stunts are performed and the ground's surface should be soft. In the event a stunt goes wrong, the spotters are available to catch the member. Further, the soft ground may absorb some impact if a member falls,

decreasing the blow to the body and therefore, the risk of concussion. Coaches are in the position to control the team's practice environments and mitigate the risk of head injuries.

Texas Advantage Volleyball's coach Corinne Atchison shared how she suffered from concussions while playing volleyball in college.¹² She played volleyball in the '90s and sustained her first diagnosed concussion in 2012. In a span of three years, she suffered from three concussions. The injury had her almost fainting every day. Her days were spent coaching or lying in bed. Headaches and cognitive fog plagued her every second of the day. In 2015, Atchison started a series of Botox injections in an attempt to reduce her migraines. Her symptoms were still affecting her daily life and some had even worsened by 2016. She began attending vision, occupational, speech, and vestibular therapy. By 2018, six years after her first mTBI, Atchison's condition has improved; however, she still suffers from concussion symptoms that affect her daily functioning.

Due to Coach Atchison's experiences, she became highly sensitive to the risk of mTBIs in volleyball. It motivated her to change the expectations of her team. For example, Coach Atchison requires the balls to be hit in one direction across the net. Players are not allowed to run under the net and risk having their back to a hitter or server. Atchison shared other safety precautions in a newsletter,¹² urging other coaches to consider the risks and consequences of concussions.

Coaches' preventative efforts in workout and practice routines may not only reduce the risk of concussions, but also provide an opportunity for coaches to discuss the reasoning behind such changes and educate athletes on concussions.

Education

A lack of effective education regarding concussions has been identified as one of the

main weaknesses in the system. Student-athletes' lives usually gravitate between three settings: home, school, and sports. In each environment, adult figures oversee the activities a youth undergoes. Therefore, in order to protect and support children, the supervising adults should be knowledgeable about mTBIs. Knowledge gaps about symptom manifestation, return to play (RTP) protocols, return to learn (RTL) protocols, and long-term consequences were present in athletes, parents, coaches, and school personnel.¹³⁻¹⁴

General education should be implemented across all settings for those that may interact with children at risk for concussions. *Figure 1* includes particular elements of concussion education that may be considered valuable for each stakeholder. Efficacy of education is key. Videos that portray how debilitating mTBI symptoms are and stressing the higher risk of neurodegenerative diseases may encourage all stakeholders to consider concussions as a serious injury.

Educational Topics	ATHLETES	PARENTS	COACHES	SCHOOL PERSONNEL
Injury & Mechanism of Injury	✓	✓	✓	✓
Symptom Management	✓	✓	✓	✓
School/RTL protocols as place and codes	✓	✓	✓	✓
Youths' anecdotes of positive/negative support during mTBI recovery		✓	✓	✓
Characteristics of patients at higher risk	✓	✓	✓	
RTP protocols	✓	✓	✓	
Consequences of "toughing it out"	✓	✓	✓	
Counseling/support groups available	✓	✓		
Behaviors/Manifestations that may signify symptoms/organization in athletes		✓	✓	✓
Sport-specific prevention measures			✓	

A check mark indicates this role should receive education on the particular topic.

Figure 1

Athletes have a high rate of underreporting mTBIs¹⁵⁻¹⁶ which have been linked with lack of knowledge, failure to recognize symptoms, and failure to receive medical attention.¹⁵⁻¹⁷ Symptoms such as headache, light and noise sensitivity, nervousness, and fatigue may easily be attributed to other conditions if an athlete is uneducated. Three student athletes were interviewed for this study and all revealed that they did not receive any education regarding concussions. In one interview Nicole (the name

has been changed to protect the interviewee's privacy), a student athlete, explained that she had symptoms consistent with a concussion due to a hit in the head during a 2016 volleyball practice. She felt nauseous when she stared at a digital screen. Sitting in bright lights caused her to have headaches. Nicole was unusually tired. Assuming she was dehydrated and overworked with extracurricular and academic responsibilities, Nicole pushed through the injury. She delayed seeking medical care for over a week until her symptoms became debilitating. Nicole's symptoms persisted longer than expected due to her delay in care. Her experience with a prolonged recovery coincides with a study that found athletes who seek medical care within the first week recovered faster than those who didn't receive care until eight days to three weeks after injury.¹⁸ A family medicine physician stated in an interview that some patients have delayed seeking care, depending on the family or patient's concern.

Given Nicole's story, which happens all too often, it is imperative that athletes are educated about concussions and the potential fatal outcomes.²⁰ Doing so may increase awareness and reporting. Athlete education should be implemented at the beginning of every sports season by knowledgeable individuals or evidence-based videos such as TeachAids's concussion CrashCourse program.²¹ The frequent education may enforce the gravity of the injury as well as provide an opportunity to update athletes on the latest concussion signs and organization protocols.

Coaches are in an influential position to encourage athletes in reporting their injuries because of their unique relationship. Student athletes are motivated and dedicated to their sport's team. It is part of their identity. Due to this, concussion-educated athletes may not come forward with an injury. In fact, up to 65% of patients with concussions did not seek healthcare services at all.⁵ This is due to a lack of "perceived seriousness and fear of being removed from competition."¹⁹ Overcoming the

“tough” culture in sports is a significant barrier in athletes reporting injuries.

Therefore, as the second line of defense in reporting mTBIs, coaches must have effective training in recognizing and managing concussions. However, studies suggest that coaches may not possess adequate knowledge. As of 2017, only 34 states required concussion-specific training for coaches.¹⁴ Furthermore, state legislations vary regarding the frequency of training as well as the content. The scientific community continually learns more about mTBIs and changes management protocols accordingly. Coaches with infrequent training sessions may not be equipped with the latest knowledge, putting the athletes at risk.

Athletes involved in non-interscholastic sports may be at higher risk because only 23 states and Washington D.C. included these sports under concussion education laws for coaches.¹⁴ In interviews with two franchise owners of a prominent youth sports organization in New York and New Jersey, it was revealed that the volunteer coaches are not educated about concussions. The organization instructs adults to sit the child out if “in doubt.” The vague protocol leaves room for interpretation as to what signs indicate a child should be removed from play.

Standardized concussion-specific training for all coaches and adults involved in overseeing organized youth sports should be implemented each year. Discussions about how to best support athletes may be valuable such as conversations that encourage athletes to prioritize their long-term health over sports and other responsibilities. Athletes recovering from an mTBI identified athletic trainers as a key factor in their recovery because trainers validated their injury, stressed the importance of sitting out, and showed positive support.²² With only 37% and 28% of public high schools and private high schools, respectively, having access to a full time trainer,²³ the importance of the coach’s mTBI knowledge becomes crucial for

identifying concussions and managing an athlete’s return to play protocol.

Training on implementing the gradual return to activity listed in the return to play protocol will familiarize coaches with the guideline. Educating coaches on mannerisms that an athlete may demonstrate if symptoms are aggravated during RTP may be valuable. Identifying the point in which symptoms are present is crucial because the key to recovery is symptom management. Once symptoms are present, the activity should be stopped because it is the body’s response that it is being pushed too hard.^{1,24}

Educators who do not understand the seriousness of concussions contribute to the difficulties that athletes have in receiving appropriate academic accommodations (AA).^{22,25} In an interview with a primary care concussion specialist, the physician stated that patients perceived as “good” students before their injury were more likely to receive academic support while those that did not fall in this category faced challenges in compliance with physician-recommended accommodations. In a 2019 qualitative study, a student claimed that it took letters, meetings, and “convincing” to receive academic support.²²

Patients falling behind in academics may cause mental stress, thus, contributing to a possible prolonged recovery.^{26,27} Education for school personnel may increase awareness of the injury as well as increase support and adherence to AA.

Parents should also receive mTBI education to understand the emotional strength and “adult power” recovering youths need as support.²⁵ Children recovering from concussions reported that parents who advocated for them in the academic and healthcare setting lessened their burden when they struggled to cope with the injury and its symptoms.²⁵ Education in mTBIs will provide a foundation for caregivers to understand the repercussions of the injury and the support their child may need during

recovery. Parents who understand the emotional, psychological, and cognitive needs of the child may decrease mental stress, and therefore, decrease the risk of prolonged recovery.

Effective education for all stakeholders is crucial to provide better protection and support for athletes. The lack of understanding regarding the injury and its impact on lifestyle is a key barrier to receiving support.²⁵ The system should implement education at least once a year for all stakeholders and include particular strategies of support for each participant. Possible topics to discuss are included in *Figure 1*. Athletes and parents may be educated during pre-season information sessions. Requiring parents to attend educational sessions before an athlete may participate in sports could ensure they receive proper education. Coaches and school personnel may include education during staff meetings before the school year begins. Concussion education may be taught by knowledgeable individuals or through videos like TeachAids's virtual reality-based education.²¹ Leading sports organizations or state governments requiring pre-participation education regarding concussion recognition and mitigation strategies may increase awareness and impact.

Provider Support Tools

Medical assessments and guidelines have changed rapidly over the past decade as the scientific community's understanding of mTBIs grew. Most notably, the recommendation for strict cognitive and physical rest until symptom resolution was overturned by the Concussion in Sport Group in 2017.² New research encouraged the change in management protocols. It is now recommended athletes only have a brief period of rest during the acute phase (24-48 hours).

Children's Hospital of Philadelphia (CHOP) acknowledged the potential gaps their physicians may have in assessing and managing mTBIs. As a response, CHOP introduced a concussion management training program for their primary

care physicians (PCPs).²⁸ CHOP's training included performance of vestibular oculomotor examination (a recent technique in concussion assessment) and education of RTP/RTL guidelines. CHOP saw large success in this initiative due to the lack of "existing or systematic approach to concussion assessment and management."²⁸

A physical therapist who specializes in concussion and vestibular rehabilitation stated in an interview that she has taught local PCPs the vestibular oculomotor exam because PCPs have found difficulty diagnosing concussions. The CHOP study and interview findings indicate a need to provide resources on mTBI assessment and management.

A concussion resource bundle for physicians may include tools and guidance to mitigate knowledge gaps. Possible elements of the toolkit include education on current best practices for assessment and management, RTP/RTL protocols, and provider tips about the possible trajectory of a patient's recovery.

For example, provider tips about symptom scales and the scales' potential to indicate prolonged recovery may be beneficial. A symptom scale is a common assessment tool in which patients report the severity of their symptoms at a given moment. Clinician guidance on the significance of symptom scores is limited because a numerical score itself cannot determine a concussion. In an interview with a family medicine physician, the physician used her best clinical judgement to determine if the patient's symptoms were of medical concern. Including evidence-based knowledge may be helpful for physicians that are not familiar with symptomatology scores and provide a basis for their decision-making. Symptom scales cautioning providers that a patient with significant initial symptom burden may indicate a prolonged recovery of over 4 weeks³⁹ could encourage the physician to follow-up with the patient more frequently.

Similarly, a higher risk for prolonged recovery has been identified in patients with histories of visual disorders, mental health or emotional conditions, learning disorders, migraines, attention deficit disorder, attention deficit hyperactivity disorder, and previous concussions.^{26,30-31} In interviews with three independent concussion specialists, each suggested beginning an early multidisciplinary approach for recovery if risk factors were present. The CDC recommends a similar approach, but suggests providers to consider intervention if patients experience unresolved symptoms after 4-6 weeks.³² With knowledge of risk factors for prolonged symptoms, providers may be able to make better decisions for their mTBI patients.

Providing resource bundles with updated best practices, training tools for assessments, and guidelines for interpreting results may equip PCPs with better guidance for quality patient care. Providing information about factors that complicate recovery may influence physicians to either intervene early or refer to concussion specialists. Developing provider checklists to ensure RTP/RTL protocols are being properly implemented may increase adherence to best practices. To develop and administer these training resources to physicians, a collaboration among state governments, the CDC, and the Accreditation Council for Continuing Medical Education may be possible. Large scale healthcare systems with access to resources may consider developing their own training initiative.

Similar resource bundles may be developed specifically for school nurses. Few studies have investigated nurses' roles in concussion management, including their knowledge and protocols. Two school nurses were interviewed independently for this study. Both nurses did not have school protocols in place for assessing or managing concussions. One nurse was mandated to call home for "any injury from the neck up." Unsatisfied with this protocol, she sought education from the CDC on her own time. Implementing concussion-specific training

and management protocols through resource bundles may increase recognition of concussions on school grounds. The two nurses interviewed lacked resources and protocols to manage pediatric concussions, suggesting this issue may be widespread within the U.S. school system. Future research in this area may be beneficial to determine if, and what, further actions are needed. If such resources may benefit school nurses, a collaboration with the National Association of School Nurses may be valuable.

Return to Learn

This study has focused on athletes returning to school after being diagnosed with a concussion because return to play protocols have received more consideration in literature. On the other hand, less emphasis has been placed on return to learn protocols.

Fortunately, most children will recover within the expected time frame without requiring significant academic accommodations. Others are not as fortunate and will require more support. Up to 30% of children have symptoms that linger after one month, negatively impacting not only their functioning at home, but also at school.³³ Yet, only nine states require schools to have a concussion management protocol for recovering students.³⁴

This study developed a framework to address the gap in return to learn protocols for athletes recovering from concussions. The framework aims to increase communication between the athlete and all stakeholders. *Appendix I* shows the lines of communication and roles of key stakeholders.

A school case manager that oversees the patient's teachers and school personnel. The case manager is the main contact, relaying relevant information from the physician to school personnel about student AA and student progress. This role ensures there is a clear line of communication between physicians, school personnel, the patient, and family. Ideally, the

role is carried out by a school nurse or staff member with a background in medicine to communicate clearly with physicians. With a case manager, the student has a delegated individual to confide in about issues regarding health, academics, or sports. If concerns arise about the student, stakeholders may engage with the case manager as the main point of contact.

A collaborative approach to academics could include the case manager, physician, patient, and caregiver. Two methods in managing a student's accommodations and course load are possible:

1. Physicians outline the student's initial academic accommodations based on clinical assessment. Teachers use a guided checklist and handbook to gradually increase cognitive demand as the student's capabilities increase throughout recovery. The case manager remains in contact with the physician to ensure the student's recovery is progressing as expected. The guided checklist and handbook includes decision-making tools to increase cognitive demand and revise the student's AA. A handbook similar to Nationwide Children's Hospital³⁵ may be valuable for school personnel managing the patient. Elements of this handbook and CDC's are condensed in *Appendix III*.
2. The physician suggests accommodations to best suit the recommended cognitive load for the patient during medical follow-ups. The case manager distributes the copies of this letter to all relevant parties. The case manager is responsible for ensuring the accommodations are met. Potential items for a school accommodations checklist is shown in *Appendix IV*.

In the first approach, teachers' knowledge and capabilities of managing the student must be considered because mismanagement of

symptoms and skepticism of the student's condition may increase mental stress for the student.²² The second approach may require more frequent physician follow-ups to adjust AA. A hybrid of these approaches may be possible. Roles and responsibilities of all involved should be discussed and outlined by the school and physician to ensure continuity in care. Parents and patients should be active participants in discussions about accommodations.

As the student returns to school, symptoms may vary throughout the day depending on previous activities. It may be valuable for a student to fill out a Student-Teacher Symptom Report at the beginning of every class period to communicate with teachers about their current condition and concerns, such as the severity of their symptoms or concerns about a particular topic. *Appendix II* is a sample of the type of information that may be collected. With this information, teachers may be able to gauge what type of coursework the athlete may accomplish and make adjustments as necessary. Further, the reports may be used by all parties to track the recovery of the student and their symptoms. These reports have the potential to identify which difficulties still remain and provide open dialogue between the student and teachers. If school personnel is responsible for determining accommodations and course load (method 1), then communication between the athlete and school personnel is vital in determining the athlete's capabilities and difficulties. The Student-Teacher Symptom Report establishes a process to ensure communication between teachers and students. Further, the report allows the student to communicate with teachers in an approachable manner, appealing to students that may not be comfortable with speaking about their injury or difficulties.

Conclusions

From a systems perspective, youth concussion management spans various settings: healthcare, sports, school, and home. Gaps in knowledge

were found in each setting. Education about the injury, its impact on daily life, and the gravity of mTBIs may improve prevention, injury management, and recovery outcomes. Implementation of support tools and protocols for concussion management in healthcare settings and in school are lacking, contributing to gaps in the care continuum. Those involved with athletes at risk for concussions should aim to effectively educate all who interact with athletes. Communication systems between all parties should be increased to ensure emotional, physical, and psychological support for the athlete.

This study is limited to pediatric student-athletes; however, most studies gathered were based on high school athletes. Few research studies have focused on athletes younger than those of high school ages. Further research on these populations will provide more nuanced knowledge and possible opportunities to support specific populations.

Possible opportunities for further research may also include the effects of preventative measures in sports, efficacy of school protocols in concussion management, efficacy of active rehabilitation and optimal timing of therapy intervention, care continuum for those not involved in athletics, and support for families' whose children are concussed.

Studies and research must continue to better understand and manage concussion patients. The injured may suffer from prolonged symptoms without proper management. With the full long-term effects of concussions unknown, implementing effective guidelines and support structures are crucial. The concussion care continuum for pediatric athletes is incredibly complex with many moving parts throughout the system. Potential areas of improvement were identified across the system. To close gaps within the care continuum, education, communication, and support tools must be increased for all involved in the system.

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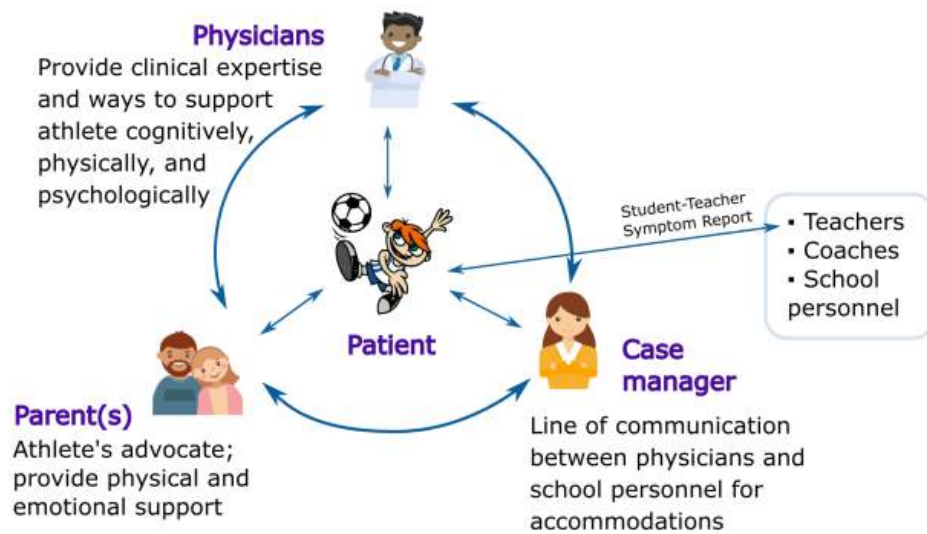
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Appendix I



Roles for each stakeholder are shown. Arrows represent lines of communication between each stakeholder. The patient remains at the center of care, communicating with all involved.

A communication mechanism for interacting with teachers is a Student-Teacher Symptom Report, shown in *Appendix II*.

Appendix II

Student-Teacher Symptom Report

Name: _____

Teacher: _____

Date: _____

Period/Course: _____

Current Symptoms

Physical

- Headache
- Dizziness
- Balance problems
- Nausea/vomiting
- Fatigue
- Sensitivity to Light
- Sensitivity to Noise

Cognitive

- Mentally foggy
- Mentally slowed down
- Difficulty concentrating
- Difficulty remembering
- Difficulty focusing

Emotional

- Irritability
- Sadness
- Nervousness
- More emotional than usual

Sleep

- Trouble falling asleep
- Sleeping more than usual
- Sleeping less than usual

Are you having a hard time with anything in this class? If so, what is it?

Is there anything that I can do to support you?

The tool provides an opportunity for the student to disclose current symptoms and concerns about the class. Teachers may make accommodations or provide support accordingly.

The tool's main goal is to communicate with teachers in an approachable manner for students who may not be comfortable speaking about their difficulties or injury. Further, tracking reports throughout the day may document the patient's recovery progress. Tracking symptoms may provide insight on what particular activities or courses worsen symptoms, and indicate the progress of recovery.

Note: This document has been inspired by publicly available symptom reports for concussions. The report has been created for this report and is not a validated tool.

Appendix III

The following has been adapted from Nationwide Children’s Hospital “[An Educator’s Guide to Concussions in the Classroom \(2nd Edition\)](#)” and the Centers for Disease Control and Prevention’s “[Returning to School After a Concussion: A Fact Sheet for School Professionals](#)”

School Personnel Management of Accommodations

Common Concussion Symptoms

Physical	Cognitive	Emotional	Sleep
Headache Dizziness Balance problems Nausea/vomiting Fatigue Sensitivity to light Sensitivity to noise	Feeling mentally foggy Feeling slowed down Difficulty concentrating Difficulty remembering Difficulty focusing	Irritability Sadness Nervousness More emotional than usual	Trouble falling asleep Sleeping more than usual Sleeping less than usual

Symptom management is the key to a speedy recovery. The goal of the return-to-school framework is to allow the student to participate and learn without worsening symptoms. Worsening the symptoms may delay healing.

Checking in continuously with the student about their symptoms and what challenges they still face. The questions should be made course specific. For example, a math teacher could ask if remembering formulas has been difficult. An English teacher could ask if reading has any effect on headache or other symptoms.

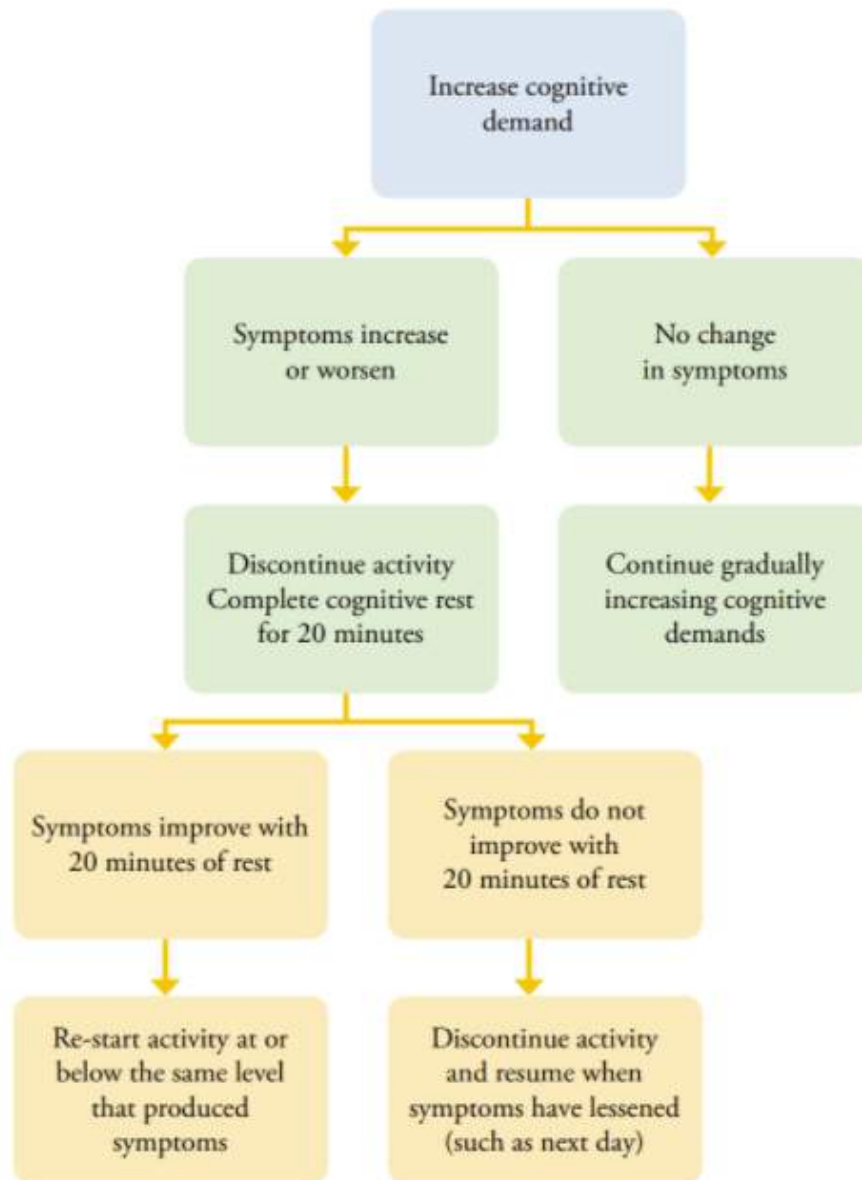
Managing Symptoms with a Gradual Return-to-School

1. As the student improves, gradually increase demands on the brain by increasing either:
 - a. The amount of work
 - b. The length of time spent on the work
 - c. The type or difficulty of work (this may be identified by student specific difficulties, such as memorization or multi-step math problems, and their symptom triggers)

**** IMPORTANT NOTE: Change only ONE of these things at a time**

2. If symptoms do not worsen, demands may continue to be gradually increased.
3. If symptoms do worsen, the activity should be discontinued for at least 20 minutes and the student is allowed to rest.
 - a. If symptoms are relieved with rest, the student may re-attempt the activity at or below the level that produced symptoms.
 - b. If symptoms are not relieved with rest, the student should discontinue for the day and re-attempt when symptoms have lessened (such as the next day)

Below is a decision-making flow chart of what to do if increasing cognitive demand worsens symptoms.



This decision-making chart is developed by Nationwide Children's Hospital

Managing the mental health and emotions of a student is important. The chemical changes occurring in the brain can affect the student's school performance and daily activities. It can lead to undue emotional distress that can worsen overall symptoms and complicate recovery.

- Allow the student to take mental health breaks
- Provide support from school administrators (i.e. guidance counselor, school psychologist, school nurse, etc.) or allow the student to call a family member if needed.

Management Tips for Behavioral/Social/Emotional Symptoms

- If student is frustrated with failure in one area, redirect him/her to other elements of the curriculum associated with success
- Provide reinforcement for positive behavior as well as academic achievements
- Acknowledge and empathize with the student's sense of frustration, anger, or emotional outburst: "I know it must be hard dealing with some things right now."
- Remove a student from a problem situation, but avoid characterizing it as a punishment and keep it as brief as possible
- Establish a cooperative relationship with the student, engaging him/her in any decisions regarding schedule changes or task priority setting
- The student may feel social isolation from peers due to the injury and accommodations. Attempt to remove stigma and encourage normal social peer interactions; avoid singling out the student.

Signs that may indicate a student is having difficulty with classwork:

- Greater irritability
- Increased problems paying attention or concentrating
- More emotional than normal/emotional reactions that are disproportionate to situation
- Less ability to cope with emotions than normal
- Increased difficulty learning or remembering new information
- Difficulty organizing tasks
- Increased forgetfulness
- Inappropriate or impulsive behaviors during class
- Repeating themselves
- Fatigue
- Difficulties handling a stimulating school environment (i.e. noise, lights, etc.)
- Increased physical symptoms (i.e. headache, nausea, dizziness, etc.)

Appendix IV

Health Care Provider Recommended School Accommodations

Duration of Recommendations: 1 week 2 weeks 4 weeks Until further notice

The patient will be reassessed for revision of these recommendations in _____ weeks.

School Case Manager Contact: _____

Area	Accommodations
<p>Visual stimulus</p>	<ul style="list-style-type: none"> <input type="checkbox"/> Move away from windows <input type="checkbox"/> Dim lights/draw shades <input type="checkbox"/> Allow sunglasses/hat in class <input type="checkbox"/> Limit screen time for the student, such as on computers, tablets, etc. <input type="checkbox"/> Reduce brightness on monitors/screens <input type="checkbox"/> Provide written notes for school lessons and assignments with enlarged print (18 font)
<p>Audible Stimulus</p>	<ul style="list-style-type: none"> <input type="checkbox"/> Remove from loud environments, including loud classes (i.e. music, band, shop class, gym, cafeteria, etc.) <input type="checkbox"/> Lunch in a quiet place with a friend Reduce classroom noise <input type="checkbox"/> Allow earplugs or headphones if bothered by noise <input type="checkbox"/> Allow class transitions before the bell <input type="checkbox"/> Allow for quiet place to take rest breaks throughout the day
<p>School Work</p> <p>(symptoms may include: mentally foggy, difficulty with concentration and attention, easily fatigued, difficulty remembering)</p>	<ul style="list-style-type: none"> <input type="checkbox"/> Change classroom seating as necessary <input type="checkbox"/> Provide extended time to complete school, homework, or take tests <input type="checkbox"/> Prorate workload (only core or important tasks)/ eliminate non-essential work <input type="checkbox"/> Simplify tasks <input type="checkbox"/> Give breaks between tasks (5 minutes, or as needed) <input type="checkbox"/> Shorten task duration <input type="checkbox"/> Work/test in a quiet room <input type="checkbox"/> Provide class notes <input type="checkbox"/> Provide memory aids <input type="checkbox"/> Use planner for schedule and due dates <input type="checkbox"/> Check comprehension for instructions <input type="checkbox"/> Reduce the amount of homework <input type="checkbox"/> Will attempt homework, but will stop if symptoms occur <input type="checkbox"/> Provide written instructions and help for homework and classwork
<p>Breaks</p>	<ul style="list-style-type: none"> <input type="checkbox"/> If symptoms appear/worsen during class, allow student to go to quiet area or nurse's office. If no improvement after 30 minutes, allow dismissal to home

	<input type="checkbox"/> Allow breaks during day as deemed necessary by student or teachers/school personnel <input type="checkbox"/> Water bottle in class/snack every 3-4 hours
Mental health (symptoms may include: irritability, nervousness or anxiety, sadness, and generally more emotional)	<input type="checkbox"/> Allow mental health breaks <input type="checkbox"/> Provide support from school administrators (i.e. guidance counselor, school nurse, etc.) or allow call to family member
Testing	<input type="checkbox"/> Additional time to complete tests <input type="checkbox"/> No more than one test a day <input type="checkbox"/> Postpone classroom tests and standardized testing until _____ <input type="checkbox"/> Allow for scribe, oral response, and oral delivery of questions, if available
Physical exertion	<input type="checkbox"/> No physical exertion/gym/recess <input type="checkbox"/> Allow only walking in gym class or recess <input type="checkbox"/> No after school sports

Additional accommodations:

- Give ibuprofen or acetaminophen to help with headaches (as needed)
- _____
- _____
- _____
- _____

Student is reporting most difficulty with/in:

- All subjects
- Science
- Reading/Language Arts
- Music
- History
- Mathematics
- Foreign Language
- Other _____

Teachers and school personnel may benefit from seeing specific accommodations associated with particular areas of difficulties for athletes. School personnel may get a better understanding about potential symptom triggers for athletes and suggest their own accommodations they think may be helpful for the athlete.

Note: This document has been inspired by publicly available symptom reports and academic accommodation forms for concussions, as well as by literature review and interview findings. The report has been created for this report and is not a validated tool.

The Future of Telehealth Regarding Physical Therapy Appointments

Nico Lastauskas | Fall 2020

Abstract. Physical therapy companies all over the world have been impacted by COVID-19. Specifically, physical therapy companies have been obligated to enforce social distancing regulations to reduce the spread of COVID-19. Due to the global pandemic, many companies have been encouraged to change the way they deliver care. Therefore, companies are beginning to deliver care in innovative methods, such as telehealth. The overall objective of this paper is to gather an understanding of the impact that telehealth will have on the future of physical therapy.

Background

Due to COVID-19, many physical therapy companies needed to alter the way that they delivered care. This was vital for patients with a high risk of contracting COVID-19 and it enabled the expansion and evolution of telehealth in our society today. According to Frost and Sullivan, telehealth is anticipated to increase 64.3% in 2020 due to the global pandemic (Frost & Sullivan, 2020).

Telehealth physical therapy can be administered in two distinct ways, synchronously and asynchronously. Synchronous telehealth requires the presence of the provider and the patient at the same time. Whereas, asynchronous appointments involve segmental communication, in which both parties can interact at their earliest convenience.

Methodology

Information used in this project was gathered by conducting interviews and reviewing relevant literature. Research was gathered from online databases and interviews were conducted over mobile devices. Seven participants were interviewed for this project. All of the participants were familiar with telehealth services and worked with at least three telehealth patients synchronously. The participants included five physical therapists, one practice manager, and one industry consultant veteran.

Physical therapy companies such as Excel Physical Therapy, ATI (Assessment Technologies Inc.) Physical Therapy, and Impact Physio were relied on heavily for the findings in this project. The key participants for this project were Dr. Nicole Ludwig from Excel, Dr. Eric Fetterman from ATI, and Teresa Salva from Impact Physio.

According to the APTA (American Physical Therapy Association), online surveys were administered to 211 participants. These individuals received a telehealth visit for lower limb injuries, pediatric neurology, or primary impairments in sports during COVID-19 (APTA, 2020). The surveys were designed to evaluate the effectiveness of a telehealth appointment and address concerns and comments associated with virtual physical therapy.

Dr. Christina Crawford, the lead telehealth representative for the department of Veterans Affairs (VA), provides virtual physical therapy to patients living in rural areas. Telehealth is the only form of care many of these patients receive since they reside in diffusely populated areas. Therefore, these patients are fully committed to getting better and appreciate telehealth for its unique services.

Results

Six out of seven participants interviewed for this project recommended in-person care over telehealth when deciding which type of care is most beneficial to the patient. Seven out of seven participants including research from the APTA, stated that telehealth will be critical to the future of therapy and medicine in general. Also, seven out of seven participants and the APTA stated that telehealth is a great complement to in-person care.

The APTA online survey showed that more than 90% of participants gave “excellent” or “good” ratings regarding concerns, therapist communication, treatment options, treatment execution, convenience, and overall satisfaction (APTA, 2020). Therefore, we can assume that patients are more satisfied than providers with telehealth services according to the participants and resources used in this project.

In addition, Dr. Crawford found that patients with impaired mobility and reduced access to care can benefit from telehealth. She connects with patients on a daily basis, who lives would be compromised without physical therapy care. 85% of rural communities are experiencing a shortage of healthcare professionals (Bell, Oguz, Larsen, 2018). This means that it is more

important than ever before to provide accessible care to these types of patients.

Based on the results, the majority of participants in this project recommended in-person services over telehealth. Although, all of the participants believe that quality care can be given over a virtual platform. Evidently, not every therapist believes this to be entirely accurate. Participants argue that the “physical” component of physical therapy cannot be administered virtually. This portrays a resistance among therapists that will continue to be debated in the future.

Furthermore, providers and patients often experience technical issues that cause computers or mobile devices to crash. These issues often lead to poor connectivity, missed appointments, and appointment overlap. According to the APTA, 31% of patients and 21% of providers lack the technology needed to receive a telehealth appointment (APTA, 2020).

It is also important to note that not every provider wants to do telehealth and not every provider is appropriate to administer telehealth according to the APTA (APTA, 2020). Telehealth physical therapy requires a unique set of skills in which many providers do not possess. The APTA states that 13% of providers are unaware of how to even begin conducting a virtual appointment (APTA, 2020).

From an operations perspective, the addition of telehealth appointments creates a new appointment type to be organized and arranged accordingly. Dr. Nicole Ludwig, one of the seven participants in this project, stresses the significance of grouping together telehealth appointments. When appointments are grouped together, patient flow is improved. In addition, overlap and technical difficulties are reduced.

Insurance companies are encouraging physical therapy companies to take part in telehealth services. Many insurance companies recognize the value of telehealth and will cover the costs of these services. (Castin, 2020) According to the APTA, physical therapy practices are eligible to bill Medicare for telehealth services (APTA, 2020) This will continue for the duration of the COVID-19 pandemic, although there is uncertainty regarding this policy once the pandemic no longer persists.

Limitations

The vast majority of patients can take part in telehealth services as long as they are fully committed and determined to get healthy. According to the APTA, there are certain types of patients that cannot receive virtual physical therapy (APTA, 2020). These patients include:

- Mentally disabled patients without the presence of a caregiver
- Children who are unable to make decisions for themselves without the presence of a parent/guardian
- Patients who suffer from complex injuries (an injury is regarded as complex based on the expertise of a physical therapist)

Post COVID-19 Physical Therapy

Once COVID-19 is no longer a burden to society, it is unclear whether in-person or telehealth services will be more commonly utilized. The majority of participants in this project believe in-person care helps patients heal at a more efficient rate. Although, there will still be numerous individuals eager to take part in telehealth because of its convenience. The

following unanswered questions will provide more insight into the future of telehealth:

- How can we improve provider satisfaction in regards to telehealth?
- Is in-person physical therapy truly more effective than telehealth?
- What will reimbursement look like after COVID-19?
- Who is liable if a patient injures themselves during a telehealth appointment?

Conclusion

Overall, the objective of this project was to gather a thorough understanding of the future of telehealth in the physical therapy industry. Based on the data and interviews, patients are very satisfied with telehealth services. On the other hand, providers in this project believe that telehealth is effective as a complement to in-person care. Providers prefer to see patients face-to-face bearing limitations such as:

- Difficulty accessing in-person facilities due to location or physical limitations
- The COVID-19 global pandemic and stay at home orders

This report demonstrates that providers in this project are aware of the ongoing challenges regarding telehealth. They know the future implications that telehealth will have on society and are determined to adapt along with society.

Key Takeaways

- Telehealth is readily accessible and convenient to use
- Even though participants do not recommend telehealth over in-person

services, it can be an effective way to recover from injury

- Telehealth will be the future of healthcare

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Optimizing Primary Care Telehealth Operations

Hannah Hedstrom | Fall2020

Abstract. With the impetus of the COVID-19 pandemic, telemedicine has emerged as a major player in the future of healthcare delivery. Using interviews from subject matter experts and review from current literature, this paper offers a conceptual framework of strategic decisions needed to ensure a streamlined process for primary care telehealth operations. Through this framework, the implications of telehealth adoption in the perspective of primary care clinical operations is investigated.

Background

The full and lasting impact the COVID-19 pandemic has had on the United States healthcare system is still largely unknown. It has wreaked havoc on the industry as a whole and exposed our vast unpreparedness for public health crises and instability. But one potential bright spot and opportunity from the pandemic restrictions on in person visits is the rapid implementation of telehealth services. Within weeks, virtual visits exploded, fueled by the Center for Medicare and Medicaid Services (CMS) allowing equal reimbursement for telehealth visits as in person medical visits¹.

Although the magnitude of the uptick in virtual visits depended on a multitude of factors, (geography, speciality, size of health system, etc) the number of patients being seen via telehealth is 50-175 times higher than pre-pandemic levels². As patients become accustomed to these new offerings of care and recognize the convenience of a virtual visit, demand for

telehealth is expected to continue post-pandemic. A May 2020 McKinsey and Co report estimated \$250 billion dollars of current spending in healthcare could be virtualized².

In this project, I investigate the implications of telehealth adoption in the primary care setting from the perspective of clinical operations. Encounters with primary care providers account for more than half of the one billion office visits in the US annually³. As a result of the pandemic, there was an approximately 50.2% decrease in in-person Primary Care Provider (PCP) visits during Quarter 2 of 2020 (compared to 2018-2019 levels)⁴.

It is important to remember that primary care offices have been organized and operated under the assumption of providing in-person care. Adapting to the rapid introduction of telehealth care presents challenges that had not heretofore been considered. It is expected that the patient demand for telehealth services will continue post-pandemic; thus, there will also be a need for clinics to optimize their resource allocation to maximize patient throughput and revenues. It is also important to consider how integration of delivery platforms can improve patient and provider experience while still ensuring dimensions of quality (safety, effectiveness, efficiency, access, patient-centeredness, and timeliness) are met. Standards of care, such as delivery platforms that are not fully HIPAA compliant, that were adequate for a global crisis will fall short moving forward⁵.

Appointment scheduling models and algorithms are well established in outpatient settings but have yet to widely address the impact on how the combination of virtual and face-to-face visits might alter the best practices suggested.

The primary objective of this paper is to highlight the challenges that have arisen from this rapid change in care delivery and provide some recommendations based on current best practices.

Methods

With the key goal identified in wanting to highlight the process of telehealth delivery in the primary care space it became clear that input would be needed both from established literature and healthcare professionals living through this time of massive change.

This project was not completed in conjunction with a particular clinic but instead a variety of subject matter experts (SMEs) were interviewed remotely. In total, 10 individuals were consulted. Five interviewees were PCPs, while the rest were medical assistants and telehealth administrators. Complete details about the scope of practice and experience with telehealth of those interviewed for this project are outlined in Appendix 3.

The topics covered during a series of interviews included the following: initial interviews outlined the clinic's history adopting telehealth operations and what problems they faced. I then dug into the literature regarding outpatient scheduling that could be used to gather feedback from SMEs. Matulis et al (2020)⁶ outlined the five common primary care scheduling templates and their advantages/disadvantages (Shown in Appendix 1). The PCPs then were asked to

comment on their current practice template and how telehealth might fit into this.

Another aspect of formulating the deliverable of a conceptual framework came from literature review of telehealth. Given telemedicine's rapid rise to relevance, it was important to search for the most recent publications on these issues. Papers with case studies on clinic implementations of telehealth programs such as Smith et al's paper²³ of their telemedicine journey were instrumental in creating recommendations.

Analysis and Recommendations

Using a combination of recommendations from literature and anecdotal evidence from interviews with SMEs, a decision support framework was created and presented in Appendix 2. This deliverable is intended to serve as a guide for primary care clinics as they look to integrate and refine their workflows for providing virtual care. The framework is broken up into four categories of decisions to consider: overarching goals of virtual care, pre-visit scheduling, day of visit, and post-visit. Appendix 2 provides a high-level overview of considerations for each operational component. We can now dive further into the recommended course of action for each key strategic decision.

Overarching Goal

Before diving into specifics, a given clinic needs to define baseline objectives for their telehealth practices. This central thread will help guide all of the other decisions that follow. The key question practices need to answer is how to ensure that every patient has expert assistance and access to select the optimal type of visit for their individual needs. Empowering a patient to

decide the mode of delivery that is best for them is a mark of achieving patient-centered care.⁶

Traditionally, telehealth metrics have been adoption-based. For example, goals are centered on metrics such as number of patient virtual visits or app downloads versus quality metrics like cost savings due to decreased time for travel or missed work.⁷ Hollander and Neinstan (2020)⁷ argue for the maturation of adoption metrics to quality metrics for telemedicine. Using the National Quality Forum Telemedicine Measurement Framework, they provide examples of metrics to operationalize clinic goals of delivery integration in 4 domains of care: access, financial cost, experience, and effectiveness.

Pre-visit Scheduling

One of the first considerations a clinic needs to make is determination of what appointment types would be eligible for a virtual visit. This can further be broken down into which patient types (new vs. return) and the reason for visit.

None of the clinicians interviewed allowed brand new patients to be seen virtually. Establishing a patient-provider relationship in person has been shown to have a positive and direct effect in online communication⁸. It is also important to consider patient demographics that are more likely to have barriers to successful use of telemedicine appointments. According to a study by Lam et al (2020)⁹ about 38% of U.S. older adults (13 million total) are deemed unready for virtual visits due to a variety of reasons. The most common barrier was technology inexperience. Other factors such as difficulty hearing or communication disabilities play a factor.

The list of “reasons for visit” that qualify must be carefully defined. A comprehensive outline of these guidelines will aid in creation of appointments and reduce the number of virtual appointments that end up being switched to virtual due to a provider’s inability to determine course of treatment via telemedicine.

From interviews with primary care physicians, appointment types that are well suited for virtual care might include: medication refills, rashes, some types of chronic or recurrent abdominal pain, post-surgical/hospital checkups, ear pain, chronic care management and some wellness visits.

Types of appointments that are not as suited for telehealth might include: acute care sick visits, chest pain, asthma, and some wellness visits (pregnancy, pap smear, immunizations) just to name a few. If patients have access to additional medical information (perhaps from lab tests, at-home monitoring technology, etc), some visits that were thought to be in-person only, could be moved into the virtual category.

Type of schedule is the next important decision. Of the five templates shown in Appendix 1, feedback from interviewers suggested that “cluster and stream scheduling” are most optimal for integrating telemedicine and face to face visits.

Cluster scheduling would entail grouping virtual visits at a particular time in the day. This structure would limit the number of transitions to connect online, move to a secure and quiet space, etc. The negative aspect of cluster schedule is less ability to provide acute care. According to Dr. Bethany Gray, “as long as

telehealth can accommodate acute care appointments this shouldn't be an issue."

Stream scheduling was the other suggested option for integration of delivery platforms. This appointment template sets a fixed time for different appointment types. An example would be 30 min for a wellness exam vs. 15 min for an acute or chronic care appointment which creates a predictable and steady flow of patients. A drawback of this method includes a higher proportion of no-shows and less ability to provide acute care. Dr. Gray noted that if a patient does not arrive for their appointment, this allows for providers to catch up on patient charting, any administrative work, or accommodating a walk in appointment.

When utilizing the stream scheduling template, it would be important to decide if telehealth and in-person visits need the same amount of time. Telehealth appointments were estimated to be 20% shorter.¹⁰ Though the exact reasons for this trend was unmentioned, interviews suggested that this might be due to less small talk or because the patient invested time into traveling to the appointment thus they tended to bring up all other maladies they could think of.

An important decision for the clinic must be to determine if this claim is true and if so how to alter the schedule. A time study in the paper "Guidelines for scheduling in primary care under different patient types and stochastic nurse and provider service times" by Oh et al 2013¹¹ provides a model for collecting wait times and service times that could be useful in assisting in the decision of appointment length.

Another problem that emerged from an interview with Dr. Braken Babula (JeffHealth) was to determine how patients make their

appointment. He attributed a lack of adoption of telehealth appointments to their clinic's inability to let patients make appointments online. It would be worth investigating whether patients who prefer telehealth appointments would also be more likely to schedule an appointment online. A post-visit survey might reveal insight into solving this problem (see section on post-visit).

The last major scheduling decision is determination of which providers should see telehealth visits. While many clinics might require all providers to offer these services, other options might include strict use of mid-level providers (such as nurse practitioners or physicians assistants., Another option would be utilizing and training certain providers to specialize in virtual visits. Finally, clinics could allow for provider preference if they'd like to offer virtual visits or not. Multiple studies have established success in increasing patient satisfaction and decreasing no shows by utilizing nurse practitioners for telehealth.^{12,13} The right combination of these options could be tailored to suit the size, makeup and needs of each clinic.

Day of Visit

The next category of strategic decisions regard workflows on the day of the visit. The first consideration is ensuring that patients are prepared for their appointment. Appointment reminder systems have been well studied. Literature reviews of these systems can be found in papers by Boksmati et al (2016)¹⁴ and McLean et al (2016).¹⁵

Given how quickly telehealth has grown, there are not many peer-reviewed papers on

connecting patients to online appointments. That being said, there are helpful tips that have been published. For example, Dr. Pete Alperin of MedCity News key tips include having patients practice using the technology before the appointment and ensure a discrete but comfortable location for the visit.¹⁰

Successful implementation of a workflow that connects patients to the online appointment is important to reduce time wasted troubleshooting technology issues and reduce telehealth “failed appointments” that need to move to an in person visit. Providing patients with information of tips for a successful telehealth visit will also make them more likely to select the appointment type in the future.¹⁶

Closely related to the issue of connectivity is troubleshooting. If the patient or provider gets disconnected, what are the protocols and who is responsible for assisting reconnection? This could be a front desk administrator, IT resource, medical assistant (MA) or others. Preventative measures such as patient practice with the online platform, creating a troubleshooting resource, and investing in IT infrastructure can help ensure “smooth sailing” in virtual visits.¹⁷

For face-to-face visits clinics already have a process of rooming the patient, taking their medical history, vitals, etc. Research suggests that use of Medical Assistants to complete these tasks decreases minutes per visit and missed screening opportunities and enhances patient-centered care.^{18,19}

An issue arises when trying to expand this medical assistant rooming workflow to virtual appointments in that currently they are only

doing in person work. This was an issue highlighted by JeffHealth as a key issue they are looking to standardize. For example, in a face-to-face Medicare annual wellness visit, the medical assistant at their clinic spends a large portion of the appointment with the patient checking up on medical history and taking vitals. When these are done via telehealth, the physician is currently completing this process which is not an efficient use of their expertise. When implementing telehealth appointments, they overlooked the importance of including the MA role in virtual visit, thinking that because there was no physical room there was no need for them to interact with the patient. This problem highlights a recommended strategy of looking to replicate whatever in-person rooming workflows for telemedicine patients. This creates a consistency for scheduling, provider workflow, and patient experience.

The last and most key part of a telehealth visit is the actual provision of care. Clinics must designate the location of providers during their telehealth visits and ensure that it is HIPAA compliant, private, and secure¹. Clinics should also consider how to alert a telehealth patient that their provider may be running late and give an accurate estimate of the appointment time. This recommendation is supported by interviews from multiple PCPs who indicated that telehealth patients often lack the context that the clinic environment provides. This can result in patients that are less understanding of delays in treatment.

Post Visit

Any new workflow implementations can benefit from a post-visit analysis. Patient satisfaction surveys are already a cornerstone of providing quality care so including telehealth patients with

expanded questions specific to their virtual experience is very important.²⁰ An example of a patient survey for telehealth patients is outlined in Polinski et al (2015).²¹

Provider support is also an important aspect of a successful telemedicine program. To put it simply, virtual care does not work if providers do not feel comfortable with the platform. Education of providers on best practices for care on virtual visits through training sessions or “office hours” are recommended by research.^{22,23} According to a Deloitte survey, most providers said “critical information and training were not available in their practice” and 90% said essential factors such as integration of technology and training in virtual visit empathy were absent in their practices.²⁴ This statistic highlights the need to collect feedback from providers to identify gaps in the process of virtual care and to work to continuously improve the entire process by incorporating feedback into meaningful change.

Conclusion

The potential of telemedicine taking a permanent foothold in healthcare delivery is both alluring and daunting from a clinic’s perspective.

Given all of the strategic decisions to make, it is pivotal that an interdisciplinary team be created to help organize efforts to implement and improve telehealth operations. Utilizing staff members with different roles (MAs, NPs, MDs, Administration, Nurses, etc) in providing care will help offer diversity in thought and

identification of problem spots. The idea of “team based” primary care is well-established as a powerful tool for achieving the quadruple aim in healthcare -- improving patient health, enhancing patient experience, reducing e costs, and improving the experience of health care staff.^{25,26} This idea should extend to telehealth implementation as well.

In order for the use of telemedicine to reach its fullest potential, more research and refinement will need to be done. In particular, application of models and algorithms for scheduling such as the work done by Oh et al (2013) should be adopted to include multiple platforms for care delivery.¹¹ More research should be performed to consider how to ensure quality of care is maintained in virtual visits as we look to achieve steady state in a post-pandemic society.

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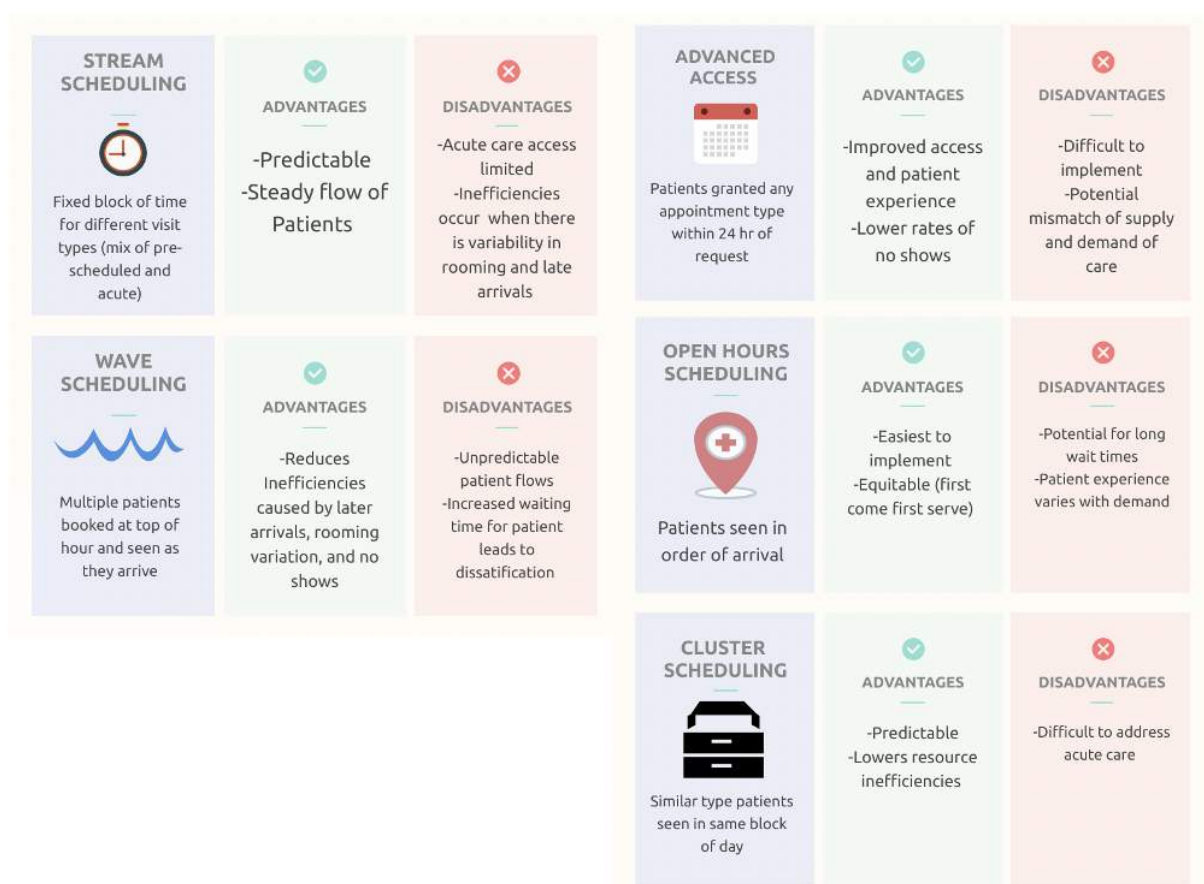
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Appendix 1.

Adapted from Matulis et al (2020). The graphic visually represents the 5 most common templates for scheduling primary care appointments. PCPs were shown this visual and asked to comment on which they currently utilize and which template would work best for virtual visits.



Appendix 2.



A visual guide of the conceptual framework presented in this document.

Appendix 3. Summary of the interviews conducted

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Dr. Alexandra Printz | Lehigh Valley Health Network | Allentown, PA | Family Medicine Provider

Dr. Beth Carevya | Lehigh Valley Health Network | Allentown, PA | Family Medicine Provider

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Optimizing Provider-Based Wholesale Pharmaceutical Purchasing

Eric Mintz | Fall 2020

Abstract. Wholesale pharmaceutical purchasing at the provider level involves a complex balancing act between need, availability, and pricing. Providers must be able to select the most cost-effective products in the correct quantities, choose reliable suppliers of high-quality drugs, establish safeguards for timely delivery, and strive to realize the lowest total cost possible. Adopting a data-driven approach is critical toward producing desired results.

Background

To understand the basis of this work, one must first become familiar with the pharmaceutical purchasing process. Providers have a choice of three general outlets from which they can purchase drugs. The first outlet, a group purchasing organization, is defined as an entity that allows hospitals to leverage their buying power through the aggregation of purchasing volume. Several hospitals in the same geographical region will often enter into this agreement together. Secondly, hospitals have the option to purchase drugs through a program called 340B. 340B, created by the US government in 1992, requires drug manufacturers to sell outpatient drugs to hospitals at a significantly lower cost. The third option, WAC, is a general term used to describe any purchase that is not made on either GPO or 340B. Since it is usually the most expensive

outlet, hospitals aim to minimize the number of purchases made on WAC. Purchasing a drug on either GPO or 340B, requires a corresponding accumulator. Accumulators are part of the split-billing process and can be thought of as a credit that allows hospitals to purchase inpatient drugs on GPO or outpatient drugs on 340B. Without an inpatient or outpatient accumulator, providers are forced to buy drugs on WAC. Beyond the outlet from which they purchase, hospitals have the ability to purchase drugs from a variety of suppliers in several different quantities. A National Drug Code is a unique identifier which describes the manufacturer, the dosage form, the specific strength, and the package size of any potential product. When purchasing a drug, hospitals can choose from several different NDCs. Attempting to optimize purchasing demands an understanding of how drugs had been selected previously.

Process

At Health System X, drugs were primarily chosen on a need-based approach. An automated medication dispensing system called Pyxis had been used to manage supply. Working in tandem with Pyxis were a group of purchasers who had been trained to strictly purchase drugs on the hospital formulary. Purchasing data from a period of one year made it clear that the lowest-cost option was not always considered. For this reason, a process had to be created that

allows identification of both the most economically viable choices along with the ratio among the three accounts by which a drug should be purchased. Three critical pieces of data were used to complete this analysis: pricing data, purchasing data, and utilization data. The volume of data associated with this project made it necessary to explore automation techniques. The first step was to orient the data in a way that allows similar NDCs to be grouped together. After exploring several identifiers, a variation of the generic code number was decided on. A generic code number is a five digit code “to uniquely identify a combination of ingredient, strength, form, and route”. This would allow all drugs of a specific dosage and primary ingredient to be compared against one another. Initially, products were evaluated on the price per NDC. This approach did not allow for proper comparison between drugs of the same dosage but different package sizes. Therefore, a price per dose metric was created. Additionally, certain products must be repackaged into individual unit dose forms before being administered to patients. Other products arrive in pre-packaged single-use doses. Taking this into account, a \$.25 unit dose factor was added onto the price per unit for each product that requires repackaging. After manipulation of pricing data to accurately reflect the cost for Health System X, the next step was to address previous purchases. Purchasing data from May 2019-May 2020 was extracted from the Health System’s reporting platform. The previous annual spend was modeled by multiplying the units purchased of a particular product by the corresponding price it would cost to purchase that product from 340B, GPO, or WAC. This figure served as the baseline to calculate projected savings. The annual quantity purchased from each purchasing outlet was then

multiplied by the equivalent price per unit for each NDC. For example, if drug Y had been purchased in a ratio of 1,500 from GPO, 300 from 340B, and 2,000 from WAC then the price to purchase that specific NDC from GPO, 340B, or WAC was multiplied by 1,500, 300, and 2,000 respectively. These three costs were added together, which led to the projected annual spend associated with purchasing any given NDC. Incorporation of utilization data involved the inpatient and outpatient percentages by which a drug had been administered. Health systems aim to purchase a drug on WAC no more than ten percent of the time. Therefore, a target WAC purchasing ratio was created by multiplying the total units purchased by ten percent. This ten percent figure was subtracted from the total units purchased and multiplied by the inpatient percentage to arrive at the suggested purchasing ratio from GPO. Likewise, the outpatient utilization percentage was used to guide the proposed purchasing ratio from 340B. For example, if drug Z had been purchased in a total quantity of 2000 units and its inpatient/outpatient use was split evenly, the proposed purchasing ratios would be as follows: 900 units from GPO, 900 units from 340B, and 200 units from WAC. Thus, each price per unit from GPO and 340B is multiplied by 900 while each price per unit from WAC is multiplied by 200. Once these figures are added together, the lowest total spend option is the suggested selection that was made. The proposed savings was determined by subtracting this theoretical value from the previous annual spend. Since drug shortages are a frequent occurrence in pharmaceutical purchasing, additional secondary and tertiary selections were made.

Results

How much money can be saved relies on three factors. First of all, the price of what had been purchased previously compared to the price of the optimal product selection is critical. If this disparity is large, there is a greater opportunity for savings.

Price variability among the three accounts is another aspect to consider. Sizable discrepancies between the three purchasing options can often impact the amount of savings. For example, one possible selection of drug Z costs \$50 from GPO and WAC but only \$2 from 340B. Savings incurred from purchasing this selection will depend on the inpatient and outpatient percentage by which that drug is used. If the drug is mostly used for outpatient designation, the savings could be significant. On the other hand, if the drug is primarily used for inpatients, this product may not even be the most viable choice.

Lastly, the volume of purchases and corresponding price associated with purchasing a particular drug will influence the amount of savings. High cost items regardless of quantity and low-cost items in high quantities present a considerable opportunity for savings.

Comparing the projected annual spend to the previous annual spend for two hundred of the most frequently used drugs at Mintz Memorial Health System produced impressive results. Low and high spend estimates were created. The low spend estimate assumes that the least expensive purchasing option is available throughout the course of the year. The high spend estimate involved the average cost among the top three purchasing selections. For the two hundred drugs in question at Mintz Memorial Health System, the previous annual cost was roughly \$8.7 million. The low spend estimate revealed an

annual savings of about \$4.3 million while the high spend estimate offered about \$2.4 million in savings. Among these two hundred drugs, there was an average savings of roughly 43%. Since these figures only apply to a subset of the annual purchases made at Mintz Memorial Health System, it can be assumed that the savings will rise proportionally as this model is expanded to all hospitals within the network.

Intuitively there is a greater opportunity for savings. Price variability among the three accounts is another aspect to consider. Sizable discrepancies between the three purchasing options available can oftentimes impact the amount of savings. For example, say one possible selection of drug Z costs \$50 from GPO and WAC but only \$2 from 340B. Savings incurred from purchasing this selection will depend on the inpatient and outpatient percentage by which that drug is used. If the drug is mostly used for outpatient designation, the savings would likely be significant. On the other hand, if the drug is primarily used for inpatient designation this selection may not even be the most viable choice. Lastly, the volume of purchases and corresponding price associated with purchasing a particular drug will influence the amount of savings. Comparing the projected annual spend to the previous annual spend for two hundred of the most frequently used drugs at Health System X produced exciting results. Low, middle, and high spend estimates were compiled based on the principle of availability in the purchasing selections that were made. The low spend estimate assumes that the top purchasing selection is available in its entirety throughout the course of the year. The middle spend estimate is the average of the top two purchasing selections, along with an additional thirty percent factor added on top. The high spend estimate involved the average of the top

three purchasing selections with the same thirty percent factor. For the two hundred drugs in question, the previous annual spend was roughly \$8.7 million. The low spend estimate revealed an annual savings of about \$4.3 million while the middle spend estimate offered about \$2.4 million in annual savings.

Future Directions

Altering established purchasing methods within a large health system is a challenging endeavor. Receiving buy-in from senior management is critical toward influencing behavior from the top down. In this case, saving money will be the catalyst for widespread adoption. Educating the purchasers is the first step toward realizing the savings tied to this model. This can be achieved by reinforcing the importance of purchasing drugs that had been identified as the lowest cost option. Secondary and tertiary purchasing selections would be made available in the case that the lowest cost option is out of stock. This information would be provided to all of the purchasers in the form of a spreadsheet containing: the type of drug, the specific dosage form, the ordering number, and the proposed annual cost.

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Ensuring Delivery of COVID-19 Vaccines to Underserved Communities

Ardelle Persad | Fall 2020

Abstract. The state of the healthcare system has left underserved communities at a higher risk of contracting and dying from the coronavirus. As members of these communities are disproportionately affected by this disease it is imperative that they are deemed a high priority in the delivery of the COVID-19 vaccine (5).

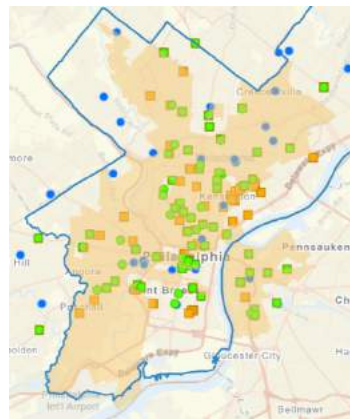
Introduction

The rapid spread of the coronavirus disease (COVID-19) throughout the United States has been unprecedented (1). Since the confirmation of the first reportable U.S. case in January 2020 (2), the number of people infected with COVID-19 has skyrocketed to 14.9 million with 282,900 deaths in just under a year (3).

Of the cities hit hard by COVID, Philadelphia, PA has an infection rate that ranks 68th out of more than 3,000 U.S. counties tracked by Johns Hopkins University (4). Furthermore, of those individuals contracting or dying from COVID-19, there is evidence emerging showing the great toll the virus has had on racial and minority groups, underserved communities and impoverished people.

The poverty rate in Philadelphia is 24.9% which is strikingly high compared to the rate of the state of Pennsylvania at 12% and the national average of 10.5%. (10) (11) There are many different regions of the city that are designated

as Medically Underserved Areas (MUAs) as per the Health Resources and Services Administration. Figure 1 displays the regions of Philadelphia that have been deemed MUAs.



Medically underserved populations (MUP) are defined as specific sub-groups of people living in a defined geographic area with a shortage of primary care health services. (6) These populations lacking healthcare include members of Black, Indigenous and People of Color (BIPOC), homeless people, the elderly, low-income workers as well as migrant workers. In the city of Philadelphia, African Americans and Latin-X community members have had the highest rates of COVID infections, hospitalizations, and deaths of any racial/ethnic groups (22). This is primarily due to the continued disparities observed in this city that appears diverse by the population demographics but remains the fourth most segregated city in the country (14). The impact this segregation

has on the healthcare of BIPOC in this community is large and requires special attention from public health officials during this pandemic.

Frontline Worker Demographics and Risks

COVID-19 is primarily spread through close contact with an infected person, but it can also be spread through airborne transmission. (7) This puts essential workers – frontline workers specifically – at a greater risk of contracting the disease due to the lack of the ability to social distance without work from home options available. In Philadelphia, the demographic breakdown of the individuals working frontline worker jobs, making up 60% of essential workforce, vary in type of work and pay as per Figure 2. Blau et. al state that frontline workers reportedly make lower wages than average (12).

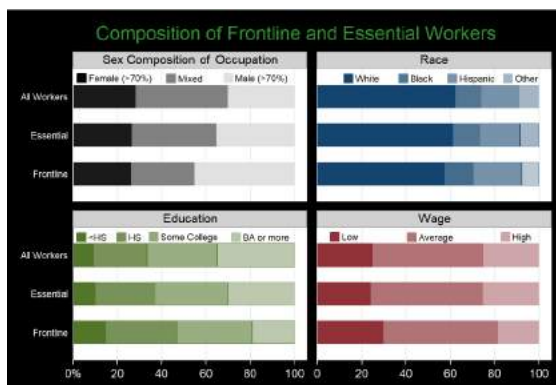


Figure 2: Composition of frontline and essential workers by sex, race, education and wages. (12)

For example, grocery store workers are considered frontline workers. According to Glassdoor, the average hourly pay for a Philadelphia grocery store cashier is \$9.48 (24). While this is above the minimum wage and poverty wage in Philadelphia, \$7.25/hour and \$6.00/hour respectively, it is still almost \$3/hour short of the Philadelphia living wage of \$12.45/hour (26). Furthermore, the workers in

these low-paying jobs are also more likely to not have employer-provided insurance or, if it is available, it is often too expensive to afford (25). They are also unlikely to have paid sick time off and often forego taking a sick day to ensure their income remains steady (13).

Each graph in Figure 2 can be summarized to state that frontline workers primarily come from backgrounds that have less education, more minorities, have more men and earn lower wages (12). With lower wages comes the inability to be selective with housing. This often leads to workers earning lower wages living in poorer regions of the city.

Race and COVID in Philadelphia

The pandemic has had a disproportionate impact on BIPOC due to the jobs and ongoing systemic issues in the healthcare system in Philadelphia. Roe et. al. states that BIPOC are overrepresented within frontline industries (27). Previous studies show that as a city, Philadelphia has ten times as many primary care physicians within a short drive in the best-served neighborhoods when compared with underserved ones (14). In this study it was determined that the underserved census tracts with fewer providers are located within the Northeast and Southwest regions of the city which has a higher Black population. Additionally, a study performed by Penn Medicine showed that another underserved region of Philadelphia, the West and Northwest areas of the city, have the highest Black populations as well as low access to healthcare. (16) This is primarily due to the continued disparities observed in this city that appears diverse by the population demographics but is notably the fourth most segregated city in the country (15). The Centers for Disease Control

states that discrimination exists in our system and that the social and economic factors impacted by that discrimination can lead to racial and ethnic minorities having a higher risk of contracting COVID. (7) The organization also states that many of the inequities observed among racial and ethnic minorities in terms of social determinants of health (i.e. – discrimination, access to healthcare, occupation, housing and income) are cause for an increase in risk of contracting COVID-19 (23). Many of these issues with social determinants of health are rooted in systemic failures by the government.

store clerks and bus drivers, which are both predominantly worked by BIPOC, have a higher frequency of contact with strangers putting individuals near one another and creating a higher risk of transferring the virus to customers or coworkers (9). This furthers the idea that the onus of providing care to these groups falls on the government and health officials in charge due to the systemic and former negligence of the past. These individuals are in roles that create a higher chance of passing the virus to someone privileged to work from home during the pandemic during an essentials run to the store.

Figure 3 below shows how disproportionately this virus has impacted BIPOC in the Philadelphia. The city of Philadelphia is reporting two times as many COVID cases with Black residents as White residents.

Vaccination and Barriers to Entry

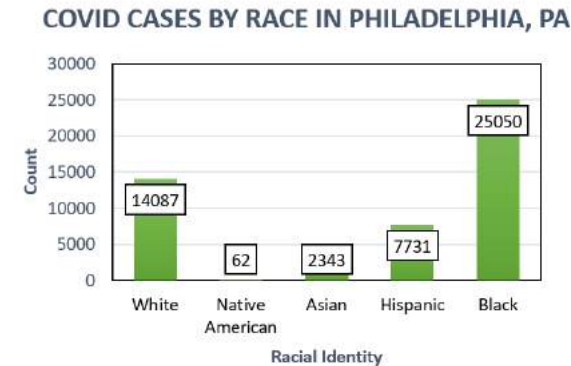


Figure 3: COVID Cases by Racial Identity in Philadelphia, PA as of 26Nov2020 (8).

With at least two vaccine candidates showing around 94% efficacy (17), discussion surrounding the distribution and prioritization of immunizing the population has become the next obstacle to face. The CDC is recommending that the following groups are vaccinated first if there is a shortage of vaccines available: healthcare personnel, essential and frontline workers, persons with pre-existing conditions and the elderly. (18)

Further compounding the issue is how densely packed the city is in poorer communities (9) as well as the reliance on public transportation. These settings do not allow social distancing nor reduce the possibility of airborne transmission. To further support the need for more emphasis of the delivery of COVID vaccines to the underserved communities, it is important to note the role occupation plays. Jobs like grocery

The Advisory Committee on Immunization Practices (ACIP) is a committee of medical and public health experts who determine recommendations on vaccination in America. This organization has suggested that minority groups should be included in the initial rollout as to not create new disparities in healthcare. Their four cornerstones of their ethical plan for vaccine allocation of maximize benefits and minimize harms; promote justice; mitigate health inequities and promote transparency (19). All aim to ensure the members discussed in this paper are included.

However, years of inequities in care allowed by the U.S. government has left BIPOC wary and untrusting of the healthcare system. In an interview with Yolette Bonnet, CEO of FoundCare Inc., a Federally Qualified Health Center in Palm Beach, Florida, the damage of these years of negligence was made evident: minority and Latin-X patients are not interested in receiving the vaccine first. Their fears of being experimented on and general mistrust of the government from instances of mishandlings – specifically citing the Flint, Michigan water crisis – outweigh their interest in “getting back to normal.” This sentiment was echoed by the Deputy Commissioner for Public Health Service at the New Jersey Department of Health (NJDH), Dr. David Adinaro. He reported almost identical reports from community leaders in the state of New Jersey. He also made the argument that there will have to be far more community outreach and education provided to these communities on the safety and efficacy of the vaccine. He went on to add that while they want to reach minority groups and ensure they are getting vaccinated they don’t want to explicitly state that they are specifically trying to vaccinate these groups first as it would not bode well with community members. This again supports the idea that members of these communities are wary to trust a new vaccine without providing proof of safety.

Dr. Adinaro stated that their department has spoken with over 3,000 community leaders and stakeholders to ensure minority groups are given the access to vaccination they need. Additionally, for the case of the homeless population, mobile testing clinics were used to diagnose those populations. The NJDH will be considering leveraging those outposts to proceed with vaccinating these hard to reach groups. He noted that due to the means of transmission the

NJDH has had to pivot from the routine methods of vaccination.

Conclusion

Due to the complexity in planning for vaccination and caring for individuals infected by this virus, there has been need for innovation. Several healthcare providers had to adopt new methods of conducting appointments with telemedicine. Hospitals have rushed to convert isolated sectors of their network of buildings to mitigate the spread of infection and maintain throughput (20).

With that, there is also a great need to revisit vaccination for this disease due to how contagious it is. Major drugstores and retailers are planning on delivering COVID vaccines directly to the public in conjunction with typical healthcare providers as well as mobile vaccine clinics. (21) All of these new methods of vaccinating the general population will be critical in ensuring underserved communities participate in getting vaccinated. Due to the scarcity of primary care providers and health clinics in the MUAs shown in Figure 1, having chain retailers and mobile clinics that can directly go into these communities are crucial.

Even more useful would be the full deployment of mobile vaccination clinics into underserved communities. Experts have seen that mobile health clinics can have a far larger reach. Clinics can partner with community leaders and organizations to earn the trust of individuals. (5) This would be imperative to vaccinating some individuals in the most at-risk groups for infection and death from COVID as many do not trust the government due to the pace of

vaccine development and hesitation from past government failures. vaccination is safe and important.

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A Strategy for Effective ICU Nurse Scheduling:

Part 1

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Abstract. Scheduling ICU nurses is challenging due to cyclical variations in patient admissions and discharges. Understaffing leads to increased work loads which impacts patient safety, throughput, and job satisfaction. Overstaffing results in increased labor costs. Understanding the variation of inflow and outflow of patients is critical for developing nurse scheduling models.

Background

Nurse scheduling and nurse staffing are often used interchangeably, but they are fundamentally different. Nurse scheduling refers to the process of determining a set number of nurses required to care for patients in a future time period based on factors such as historical census, time of the year, and anticipated surgical volumes (Hanoski). The American Nurses Association defines nurse staffing as a match of registered nurse expertise with the needs of the patient within the context of the practice setting (American Nurses Association). There is a federal regulation (42CFR 482.23(b)) which requires hospitals certified to treat Medicare patients to employ adequate staff to safely care for their patient population. This has led to fourteen states creating their own laws and regulations surrounding nurse staffing in hospitals.

Often, ICU nurse scheduling does not meet the day to day staffing requirements of care units resulting in either overstaffing or understaffing. Overstaffing leads to increased labor costs and understaffing leads to over burdened nurses, the trauma intensive care unit (TICU).

ICU nurse tripling (one nurse to care for three critically ill patients), burnout, patient safety issues, and throughput problems (Thoms).

Objective

Utilizing system engineering tools, the goal of this project is to optimize a nurse schedule that minimizes overstaffing, understaffing, and nurse tripling.

Part 1, described within this text, will explain the process of evaluating the patient inflow and outflow of three different ICUs followed by an analysis of the current nurse scheduling model. Part 2 will describe how to use the analysis of Part 1 to create a discrete-event simulation for optimization and testing of various nurse scheduling models.

Introduction

Three ICUs were evaluated within an urban academic Level I trauma center. The surgical intensive care unit (SICU) is an eleven bed unit that treats critically ill surgical patients including postoperative cardiac, neurosurgical, and emergency general surgery patients. The unit is staffed with a 30 nurse team consisting of full and part-time nurses. The average midnight census (number of patients in the unit at midnight each day) is seven patients. The unit utilizes a standard one nurse to two patients ICU ratio for scheduling and staffing. The SICU also treats overflow patients from

The TICU is a ten bed unit specialized to treat critically ill polytrauma patients. It shares a 35

member nursing team with the Step-Down Unit (SDU). The SDU is a 6 bed unit which treats a combination of both trauma and surgical patients at a nurse to patient staffing ratio of 1:3. With this ratio, the patients are less ill compared to those in the SICU and TICU. Similar to the SICU, the TICU adheres to a standard ICU 1:2 nurse to patient ratio for scheduling and staffing. The TICU has an average midnight census of eight patients. The SDU average is five patients. See the appendix for a detailed description of the current nurse scheduling methodology for the units.

Often, the TICU and SICU care for extremely ill patients who require a 1:1 nurse to patient ratio. These patients drastically impact staffing needs and must be included in the scheduling analysis.

Methods

Twenty-four consecutive months of hourly data which included the number of patient admissions, discharges, and unit census was collected for each of the three units. Admission variability for each unit was determined utilizing analysis of variance techniques (ANOVA). Admission differences by quarter of the year, month of the year, and day of the week were explored. An ANOVA p-value < 0.05 was used to determine statistical difference. Based on the admission variability identified, hourly admission histograms were created to determine probability distributions of admissions to the SICU, TICU, and SDU. An identical process was used to determine discharge variability for each of the three units.

The hourly census data in conjunction with daily nurse scheduling information, staffing information, and 1:1 nurse-to-patient hours were used to determine the number of hours the unit was understaffed, overstaffed, or at the correct staffing level.

Results - Admission Variability

A total of 17,538 consecutive hours of data was collected for each ICU in this evaluation. ANOVA demonstrated that SICU admission variability was statistically significant for days of the week only. Specifically weekday admissions were different from weekends. Goodness of fit tests showed hourly admissions to the SICU best fit a 3-parameter Weibull distribution.

TICU variability was found to vary by quarter of the year. Quarters one and four had similar hourly admission variability. Quarters two and three also had similar variability, but differed from quarters one and four. Goodness of fit tests revealed TICU hourly admissions best followed a 3-parameter Weibull distribution.

Similar to SICU, SDU admission variability was apparent between days of the week only. Significant differences were found between weekday and weekend admissions. Hourly admissions also best fit a 3-parameter Weibull distribution. See figure 1 for a summary of hourly admission variability.

Results - Discharge Variability

The identical 17,538 consecutive hours of data used in the admission variability analysis was used for the patient discharge analysis. SICU hourly discharges were statistically significant between weekdays and weekends only. These data best fit a 3-parameter Weibull distribution.

TICU hourly discharges were variable by quarters of the year only. Similar to admissions, discharges during quarters one and four were significantly different than quarters two and three. These discharges best fit a Johnson Transformation.

SDU hourly discharges were significantly different by day of the week only. Data from Sunday and Monday were similar, and was statistically different from that obtained for Tuesday through Saturday. Goodness of fit testing showed this data best fit a Johnson

Transformation distribution. See figure 2 for a summary of discharge variability.

Results - Current Nurse Scheduling & Staffing

Correct staffing was achieved 32% of the time in the SICU. This led to the SICU being overstaffed 39% and understaffed 29% of the time. Of the 29% of hours that were understaffed, 8% was covered with tripling.

Similarly, the TICU schedule appropriately covered staffing needs 30% of the time. However, 52% of the hours were understaffed and 18% were overstaffed. Six percent of the understaffed hours resulted in nurses being assigned to care for three critically ill patients (tripling).

Since all patients in the SDU are treated on a one nurse to three patients ratio, only the nursing schedule is needed to determine if staffing needs were met (there are no 1:1 nursing needs in the SDU). Also, based on the current scheduling methodology, the SDU gets two nurses for every shift which means understaffing is not possible (unless nurses are floated or called off, see appendix). SDU data showed the schedule covered the staffing needs 70% of the time with the remaining 30% of time the unit was overstaffed. See figure 3 for a summary of these findings.

Discussion and Conclusions

For hospitals within the United States, the midnight census is considered to be the standard indicator of nursing workload (Beswick). There are many researchers who condemn the midnight census' ability to predict nursing staffing for the entire day. The midnight census does not capture patient acuity (Welton), nor does it account for admission and discharge workload (Beswick), and unit-level workload (Hughes).

The goal for this project is to develop an evidence-based nurse scheduling methodology within a busy, academic, Level 1 trauma center's SICU, TICU and SDU. This goal will be accomplished in two parts. Part one, described in this manuscript, details the process for determining the impact of ICU admission/discharge variability and patient acuity (one to one nursing needs) on nurse scheduling and staffing. Using this data, part two will create a discrete event-simulation model which can be used to test various scheduling methodologies to decrease over- and under-staffing.

The SICU, TICU, and SDU currently only use the midnight census averaged over one year to define the number of nurses which can be scheduled for each shift. Evaluating admission and discharge variability is critical to developing nurse schedules. This project demonstrated significant variability in census based on admissions and discharges to the unit.

Admissions and discharges to the TICU depend on the quarter of the year, but not month of the year or day of the week. This makes clinical sense since it is logical that the TICU would see more admissions in the spring and summer months ("trauma season") due to the known increase use of motorcycles, outside activities, and violence (Pape-Kohler).

The SICU and SDU unit showed admission and discharge variability based on day of the week and not month or quarter of the year. This also makes clinical sense since many SICU and SDU admissions come directly from the operating room which is much busier during the week compared to weekends. Also the operating room has a predictable and steady volume because of operating room planning.

Evaluating patient acuity through the surrogate of 1:1 nursing requirements is also critical to determine scheduling and staffing needs. Using the current nurse scheduling methodology with the addition of one to one nursing hours, the

TICU and SICU were understaffed 52% and 29% of the time respectively. The TICU, SICU and SDU were overstaffed 18%, 39% and 30% of the time respectively.

In conclusion, this data analysis demonstrates the impact of cyclical patient volumes and patient acuity on nurse scheduling and staffing. This robust and granular data set can be used to create a discrete-event simulation model which will include the admission/discharge and nurse one to one variability. This simulation can then be used to test various scheduling methodologies to determine their impact on staffing and tripling hours.

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Current Nurse Scheduling Methodology

Nursing administration uses the average midnight census over the previous year to calculate the number of nurses scheduled each shift in the three units. The midnight census is defined as the number of patients in the unit at 12AM. This daily number is averaged over the year and a one nurse to two patients ratio is used to calculate the number of nurses scheduled for each shift in the SICU and TICU. A one nurse to three patients ratio is utilized for scheduling in the SDU.

Based on this midnight census evaluation, the TICU is scheduled to have four nurses for every shift every day. Similarly, the SDU is scheduled to have two nurses each shift every day. The SICU permits five nurses per shift from Monday 3pm through Thursday 7pm and four nurses per shift from 7pm Thursday through 3pm on Monday. Nurse staffing is evaluated every 4 hours to ensure adequate coverage. If units are overstaffed, extra nurses are moved to understaffed units (floated). If units are understaffed, nursing leadership uses the following methodology to provide adequate nursing coverage. Vacancies are filled first with float nurses from other critical care units. Next, if a need for additional nurses persists, a search is made for available part-time nurses to fill in. If there are no part-time nurses, extratime followed by overtime nurses are utilized. If vacancies remain, a one nurse to three patient ratio (tripling) is utilized- or the empty critical care bed goes unstaffed, requiring the patient to be cared for elsewhere in a suboptimal location.

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Figure 1: Admission variability frequency distributions. Variability was identified in the TICU between quarters of the year and in the SICU and SDU based on day of the week.

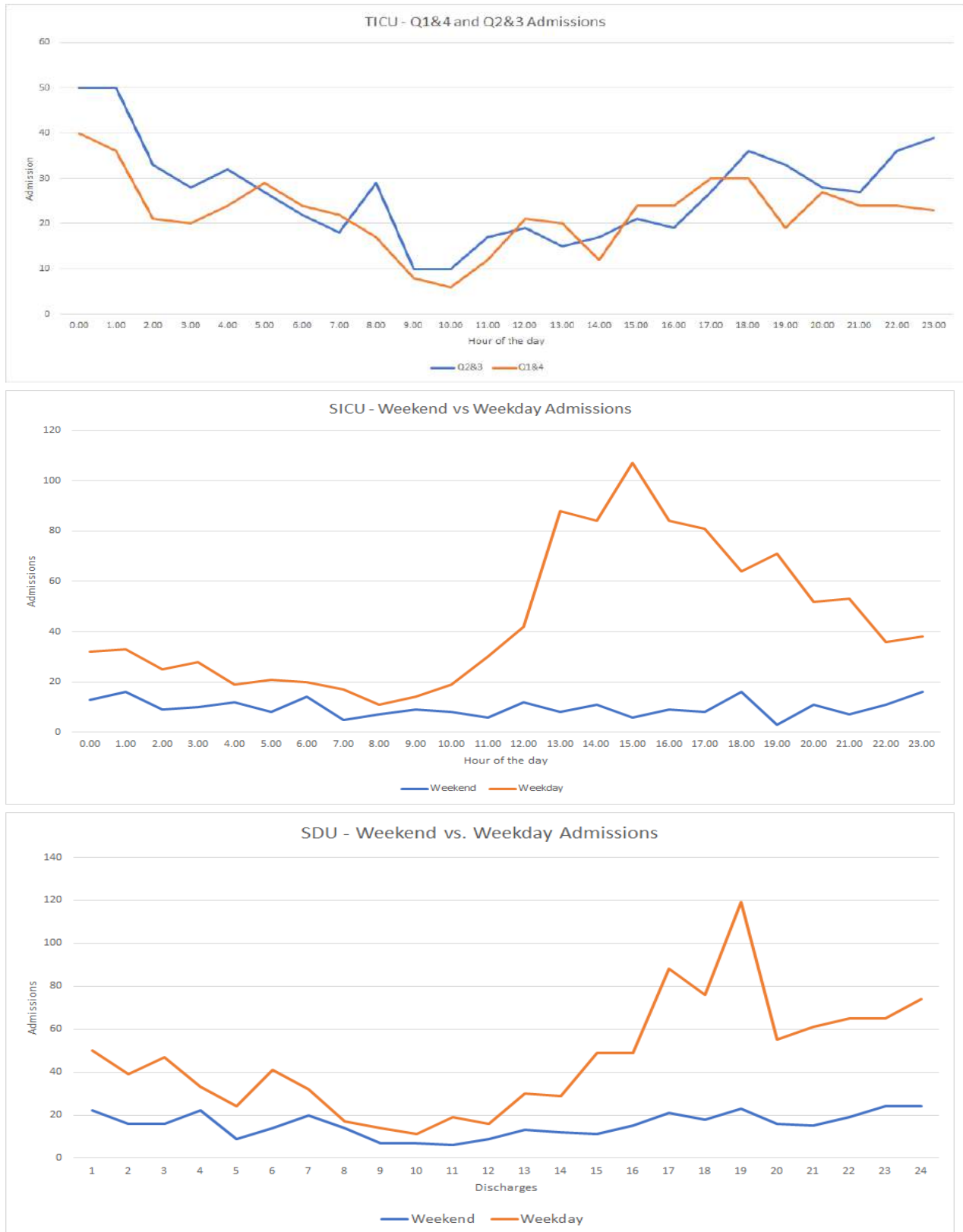


Figure 2: Discharge variability frequency distributions. Variability was identified in the TICU between quarters of the year and in the SICU and SDU based on day of the week

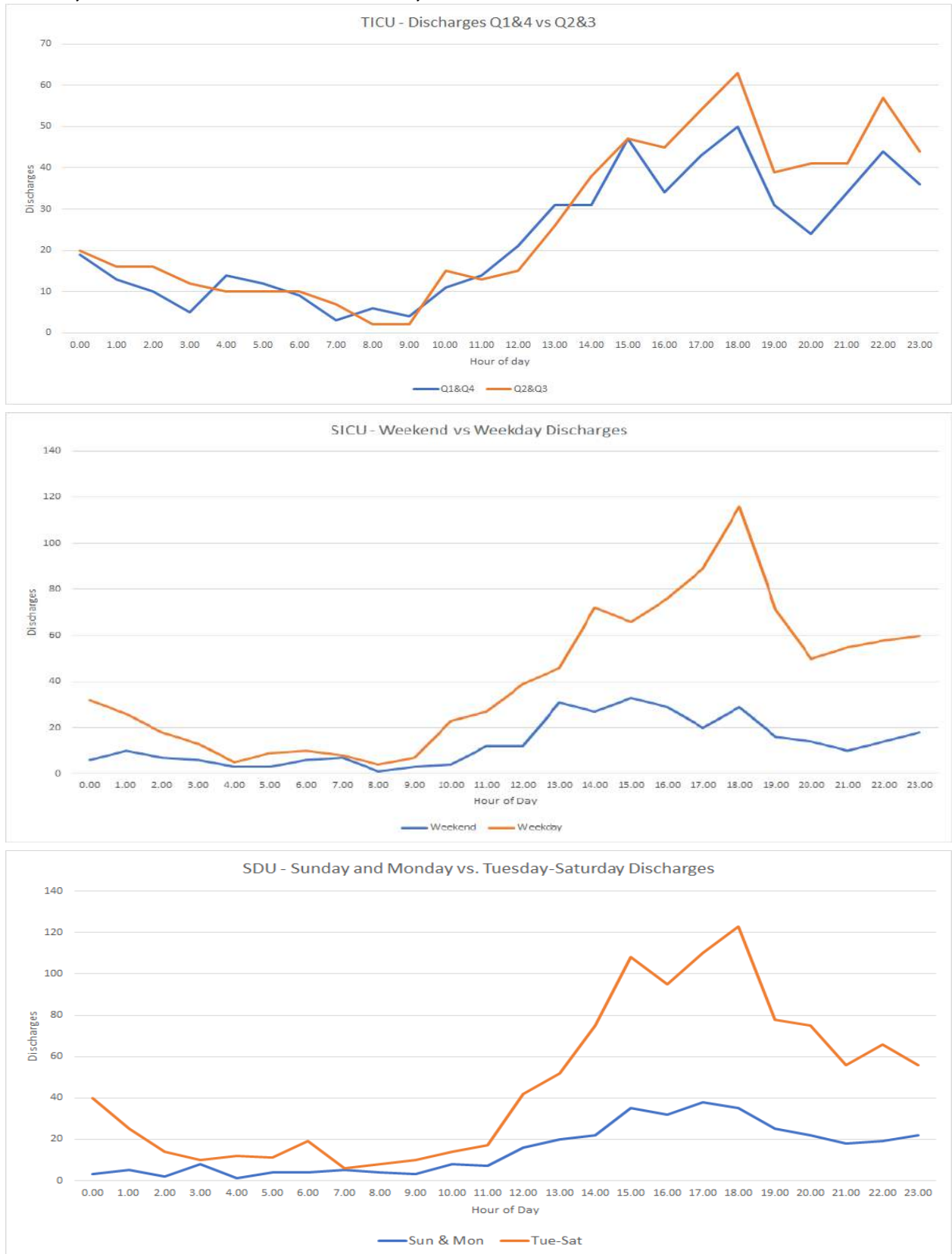
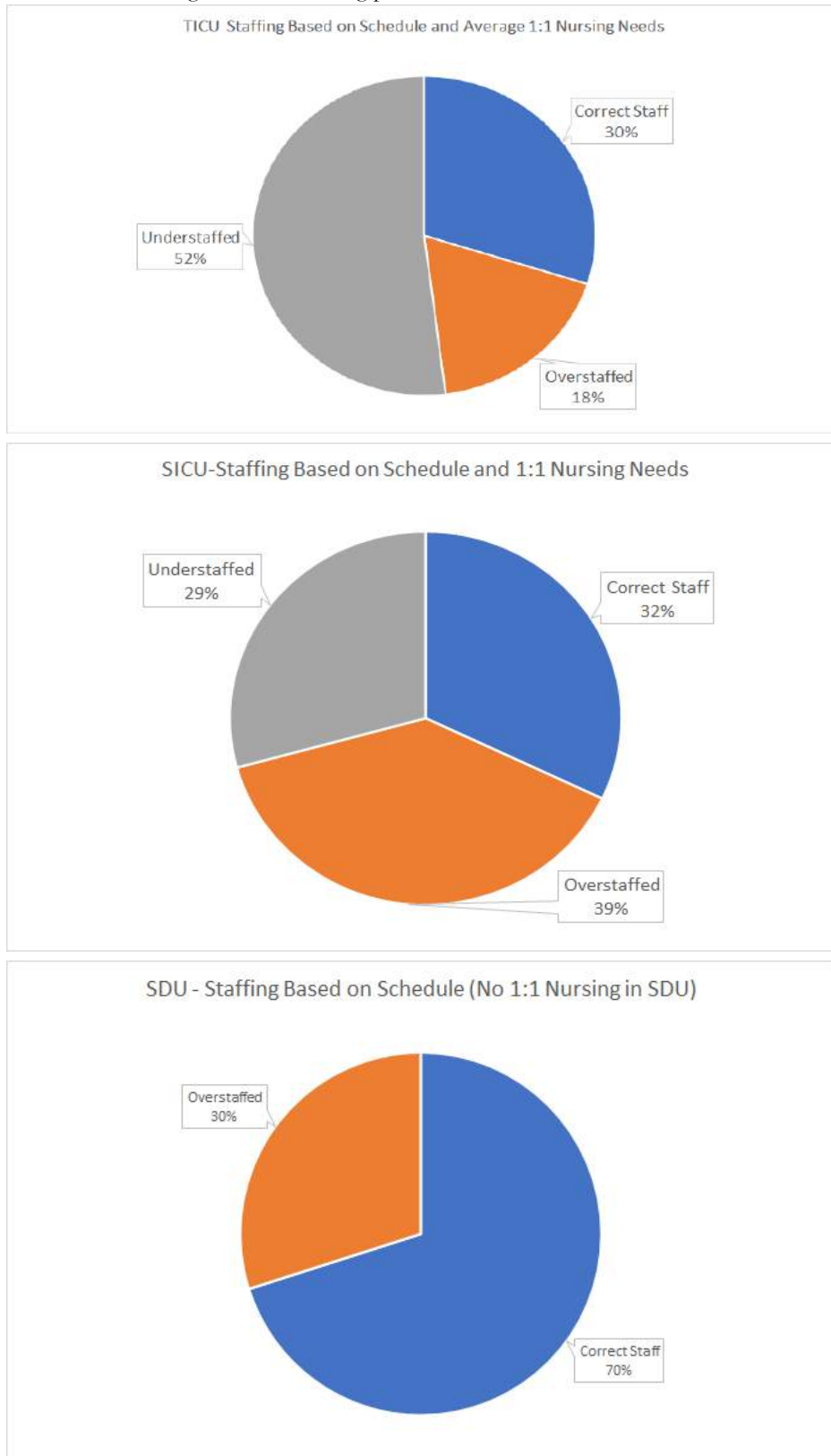


Figure 3: Based on the current scheduling methodology and 1:1 nurse to patient ratio requirements there are both overstaffing and understaffing periods in the units.



A Strategy for Effective ICU Nurse Scheduling:

Part 2

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Abstract. Scheduling nurses to meet the patient demand in ICUs can be challenging. This project aims to use discrete-event simulation to create optimal nursing schedules that take into consideration the patient admission and discharge variabilities, acuity and daily census, thereby minimizing understaffing, and reducing risk to patient safety and nurse burnout.

Background

Scheduling nurses to meet the staffing needs of hospital Intensive Care Units (ICUs) is a challenging endeavor. As previously reported in Part 1 of this project that was performed at an urban, academic, Level 1 trauma center in Ohio, nurse scheduling often falls short of the requirements needed to care for the ICU patients. This has been found to result in the Surgical ICU (SICU) and Trauma ICU (TICU) units being understaffed for over 50% of the time during a continuous two year period (May 2018 through April 2020). This extent of understaffing can lead to patient safety issues such as delays in care, as well as patients being forced to be admitted into inappropriate locations within the hospital. Understaffing also plays a large part in nurse burnout and turnover¹.

Objective

Utilizing discrete-event simulation modeling, this project aims to create models for the different ICU units, and evaluate the hourly ICU nurse staffing conditions, namely, the percentage of correctly staffed, understaffed, and overstaffed hours. These key performance

indicators (KPIs) are calculated based on various nursing schedules that will be created and optimized to factor in the variabilities in seasonal admissions and discharges, daily patient census, and patient acuity in the ICU units.

Introduction

Many hospitals utilize the well known midnight census approach to determine the number of nurses to be scheduled in the ICUs and regular nursing wards^{2,3}. This methodology counts the number of patients in the ICUs at midnight, for every day of the previous year. The average census per day over the year is then calculated, to arrive at the midnight census value. For ICUs, the national standard for nurse to patient care ratios is 1:2. This means that one nurse can care for up to two critically ill patients. Using the average midnight census and a 1:2 nurse to patient ratio, the number of nurses required to care for the midnight census patients is calculated. This is the number of nurses that are budgeted and scheduled to care for patients in the ICUs for the upcoming year. For example, the midnight census of the TICU was 7.2 patients over the time period studied. This number was rounded up to eight patients. At a 1:2 nurse to patient ratio, four nurses are required to care for this average midnight census. Therefore, the TICU scheduled four nurses for each 12-hour shift, every day of the year.

The midnight census is the most common methodology used across the United States for

nurse scheduling. Unfortunately, this methodology does not consider admission and discharge variability or patient acuity. For example, patient acuity has a large impact on ICU staffing. The sickest patients in the unit often require a 1:1 nurse to patient ratio. These patients alter the standard staffing ratios, and often require additional nursing resources to meet the patient demands. Admission variability can also impact staffing needs. For example, the summer months are often referred to as the “trauma season” due to increased admissions in June, July, and August in comparison to the winter months. Part 1 of this project demonstrated that the TICU, for instance, has significantly more admissions and discharges during quarters 2 and 3 compared to quarters 1 and 4. We hypothesized that adding admission/discharge variability and patient acuity to ICU nurse scheduling methodologies will enable the creation of optimal nursing schedules that will effectively decrease understaffing in the SICU, TICU, step down unit (SDU), and an experimental combined ICU with a unified nurse pool.

The combined ICU model will merge the SICU, SDU, and TICU beds, and will also share the same nurse pool. This kind of model will allow for a bigger nurse staffing for the overall patients, thereby eliminating the need for nurses to be floated from one unit to the other, in case of increased patient demand. In addition, having a unified nurse pool will also allow for the SDU nurses to care for ICU patients, if need be, consequently, reducing scrambling for additional resources.

Methods

Model Creation and Validation

Discrete-event simulation models were created for the TICU, SICU, SDU and Combined ICU units, utilizing Rockwell Automation’s Arena® software, by following the standard approach to a simulation study as described by Dr.

Averill M. Law⁴ (Figure 1). This approach starts with evaluating the scheduling and staffing policies in the units being modeled. The next step involves identifying all the assumptions that need to be built within the models. The models are then created, ensuring that they are verified with all the aforementioned assumptions and policies. Next the models will be validated with the real data obtained from the past two years. Finally, these validated models are utilized to conduct relevant analyses.

The data utilized for this analysis included consecutive hourly admission, discharge, and census data from May 2018 to April 2020 for the SICU, TICU and SDU. This equated to 17,544 consecutive hours of data for each intensive care unit. Patient acuity (1:1 nurse to patient ratios) data included the average number of hours per day of 1:1 patient care by month of the year, for the TICU and the SICU. The SDU does not offer 1:1 patient care, therefore its model does not include the patient acuity analysis. This data is termed as the ‘real data’ for the remainder of this paper.

The models were created, verified and validated in two stages. The first step involved evaluating the staffing KPIs for each model using the arrival, discharge and patient acuity information from the real data for the period of two years. The same KPIs were then manually calculated from the real data using Microsoft Excel®. The KPIs from the model were then compared to those obtained from the Excel® calculations, thereby ensuring that the logic in the coding of the models was valid. The experimental combined ICU had no such data with which to calculate the KPIs, and hence, this stage was only used to evaluate the performance of such a model with the real data.

The second step of the model involved the addition of randomness to admissions, discharges, and patient acuity. Utilizing patterns identified in the real data for hourly

admissions, hourly discharges, and monthly patient acuity, distributions were introduced within the models to mimic randomness. The average monthly census of each unit calculated from the real data was then compared to the average monthly census generated by the randomized models that were run with twenty 1-year replications (since nurse budgeting and scheduling is done at the end of every year) using a student T-test after conducting an F-test to evaluate if the sample variances were the same or different. The average census in each unit has a direct impact on the KPIs, and hence testing the average census for each randomized unit with respect to the real data would help prove that the randomized models fit the reality.

Creation of Staffing Schedules

The last step in the project was to create a variety of nursing schedules to test changes in the hourly staffing patterns, in order to find the optimal fit for each unit. The first nurse schedules tested were those which are currently being used in the SICU, TICU, SDU and the experimental combined unit (SICU = 4 nurses every shift from 7PM Thursday to 3PM Monday and 5 nurses from Monday 3PM until Thursday 7PM. TICU = 4 nurses every shift. SDU = 2 nurses every shift. Combined unit = sum of the nurses used in the SICU, TICU and SDU for each shift). Utilizing these schedules, twenty replications were run for a period of 1 year, and the staffing KPIs were each calculated with their 95% confidence intervals. These results were termed as the 'Current Schedule'. The average number of nurses required each month for each model were also calculated.

Using the average monthly nurses required with a 95% confidence interval, an 'Average Schedule', a 'Low Schedule', and a 'High Schedule' were created for each model. [Refer Appendix 1 for these schedules.] The 'Average Schedule' was calculated by taking the average monthly nurses required and rounding them up

to the next whole number to constitute whole nurses. The 'Low Schedule' was created by subtracting the 95% confidence interval from the average number of monthly nurses required, and rounding up to the nearest whole number, thereby creating a schedule for the lowest possible number of nurses required on average. Similarly, the 'High Schedule' was created by adding the 95% confidence interval to the average number of nurses required each month, and then rounding up to the nearest whole number, creating a schedule for the most nurses required on average.

Using each of the schedules, twenty replications were run for a period of one year, and the staffing KPIs were obtained for each of the 4 models, TICU, SICU, SDU, and the combined ICU, and the most optimal schedules were determined for each of them.

Results

Validation of Models Using Real Data

For the first stage of the validation of the models, the KPIs from the various models that were created from the current scheduling methods for the first 4 months can be found in Table 1. The results from the TICU, for example, showed that the unit was correctly staffed 25% of the time, understaffed 66.8% of the time, and overstaffed 8.2% of the time. These values, when compared to the KPIs calculated from Excel® using the real data obtained over the past 2 years, showed exactly identical numbers. Similarly, the KPIs for the SICU and SDU models were also calculated and compared, to show identical values. These results proved the validity in the logic of the created models.

For the second stage of validation, t-tests conducted between the average monthly census data obtained from the created models with the inclusion of randomization, and the average monthly census calculated from the

real data showed no significant differences. For example, the t-tests performed assuming unequal variance for the TICU generated a p-value of 0.6, showing that the means between the two sets of data are the same (Figure 2). Similar tests were conducted for the SICU, SDU and Combined ICU models after the inclusion of randomization, and the same results held true. This proved the validity of the randomized models, thereby alluding to the conclusion that the scenarios in the randomized models fit the reality.

KPIs for Various Staffing Schedules

Applying the various low, average, and high staffing schedules to the various created models generated KPIs that can be referred to in Tables 2.1, 2.2, 2.3 and 2.4 for the TICU, SICU, SDU and the Combined ICU models respectively. The results of the TICU, for instance, showed that the lower model was able to reduce understaffing from about $49.66 \pm 4.35\%$ to $37.59 \pm 4.23\%$. Similarly, the average model reduced understaffing to $33.48 \pm 3.66\%$, while the higher model showed understaffed hours as low as $28.78 \pm 3.25\%$. Consequently, there was an increase in the percentage of hour overstaffed, with the higher model increasing the overstaffed hours from $33.46 \pm 4.48\%$ to $53.37 \pm 4.1\%$, while the lower and average models showed overstaffed hours of $44.65 \pm 4.12\%$ and $48.85 \pm 4.37\%$ respectively. The correctly staffed hours, as expected, stayed in a uniform range around 17%, similar to the current schedule.

Similarly, the results for the SICU, SDU and combined ICU models showed comparable results, with the higher schedule proving to produce the least understaffing hours and the most overstaffing hours, while the correctly staffed hours remained approximately constant.

Discussion

Staffing Conditions

One of the biggest impacts of understaffing in the ICU is that it could have adverse implications with respect to patient safety. The main aim of this project was to decrease the risk to the patient associated with understaffing. Other impacts of understaffing may include possibly overworked nurses causing nurse dissatisfaction, that could lead to nurse burnout, and consequently a high nurse turnover rate. An understaffed ICU may also require overtime nurses to be called in to meet the patient demand, and hence would require a higher hourly salary for those overtime nurses, which could potentially lead to expenses that are higher than having additional nurses on schedule. Understaffing could also imply that the ICU has a lack of ability to flex up during situations that have higher admissions or increased patient acuties, and would have to resort to scrambling for resources in order to meet the demand.

On the other hand, having an overstaffed unit could mean unnecessary expenses for underutilized nurse resources. However, in most scenarios, if the nurse schedule is higher than the patient demand, the additional nurses can be floated to other units that require resources in order to meet their patient demands. There is also the concept of a free charge nurse, who is a nurse kept on staff to handle the administrative activities of the nursing units. However, if need be, this free charge nurse could also handle patients, in order to satisfy the patient demands. The same could hold true for an overstaffed ICU. The additional nurse could serve as a free charge nurse, and take care of the administrative duties until they are required to handle patients again. Overstaffing also provides the ICU with the ability to flex up with ease in order to treat higher admissions or increased patient acuity conditions.

As evident from the results, maintaining a unit at correct staff is very challenging. This is

because patients' conditions and their severities can be extremely volatile, and can change quickly. A unit that is correctly staffed for one hour could quickly become understaffed, if a patient with a 1:2 nurse to patient ratio has a complication and needs 1:1 nursing care. To be correctly staffed for a particular hour, the scheduled number of nurses have to match the admissions and discharge variabilities and patient acuity perfectly, which is highly improbable and impossible to predict.

These analyses are essential in order to make a decision on which staffing schedule would be the most optimal fit for the ICUs. Since one of the most important aims of this project was to decrease risk to the patient, as well as nurse burnout, minimizing understaffing as much as possible would be the best approach, and hence staffing schedules that have the lowest understaffing, the high schedules, would be the best solution, with respect to patient safety and nurse satisfaction.

Cost Impacts

However, another factor that needs attention is the cost associated with the various nurse schedules. Modifying the nursing schedules in the ICUs could have different cost implications for the hospital. Tables 3.1, 3.2, 3.3 and 3.4 show the change in nurse wages per year for the hospital for each schedule in every unit, with respect to the current schedule. For instance, the high schedule in the TICU would mean a 22.6% increase in nurse wages per year, while the low and average schedules show a 6.0% and 18.6% increase in nurse wages respectively. Similar comparisons can be made for the other units as well, with the higher staffing models showing the most increase in nurse wages, while the other two models have comparatively lower changes in nurse wages.

The most increase in cost with respect to the current schedule is observed for the combined ICU model's high schedule, with an increase in nurse wages of about \$660,000 (Table 3.4),

calculated using the average hourly nurse wages of \$33.48 for the state of Ohio. However, these increases in costs can be justified, since having an adequate staffing schedule could result in minimizing other exorbitant costs that the hospital can incur as a result of inadequate or poor staffing. To put things into perspective, the average cost for one malpractice claim in the state of Ohio can amount to about \$309,908⁵. Negative consequences of patient safety issues can cost the hospital up to \$200,000 per patient in additional services and procedures⁶. Nursing turnover can cost hospitals anywhere between \$40,300 and \$64,000 to replace a single nurse. Hospitals, on average, spend about \$4.4M to \$6.9M per year in nursing turnover⁷. In addition, it is impossible to put a price on a patient's life that is lost as a consequence of delays in care due to poor staffing. Having adequate nurses on staff, similar to the high schedules from the models, can significantly help reduce these scenarios, that are a direct result of patient safety instances and nurse dissatisfaction, from occurring.

Conclusions

The addition of patient admission and discharge variabilities, and patient acuity to the midnight census while deciding the nurse schedules is an effective approach that can help create nurse schedules which effectively minimize understaffing. Using discrete-event simulation models to simulate the various ICUs and test the staffing conditions can help determine the optimal scheduling methodologies for each ICU model. Based on the results and inferences obtained from this project, utilizing the high nursing schedules created for each of the ICUs would be the best solution to minimize understaffing, and consequently reduce patient safety risks and nurse dissatisfaction.

Acknowledgements

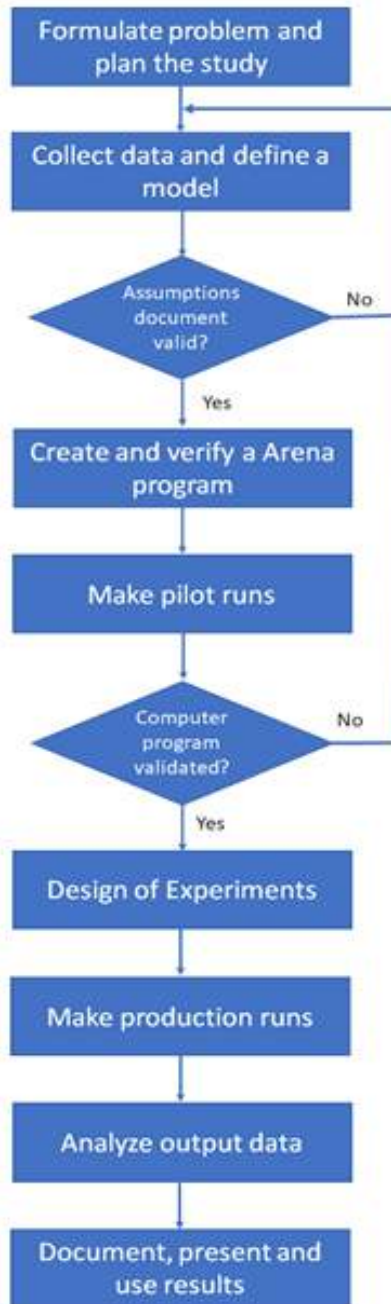
From Lehigh University, we would like to thank Professor Ana Alexandrescu and Dr. Terry Theman for their tireless efforts and mentorship with this project. We would also like to thank Professor Karmel Shehadeh and Professor Robert Storer for their inputs and guidance with the project. From MetroHealth, we would like to thank Catherine Sagi RN for the hours of work put in to obtain the robust data set used in this analysis. We would also like to thank the efforts and guidance of Stacey Gianakis RN and Mary Barns RN, who serve as the nurse managers of the units analyzed.

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Figures



Steps in a Simulation Study
Adopted from: Simulation Modeling and Analysis
by Law (5th edition pp. 67)

Figure 1: Steps in a Simulation

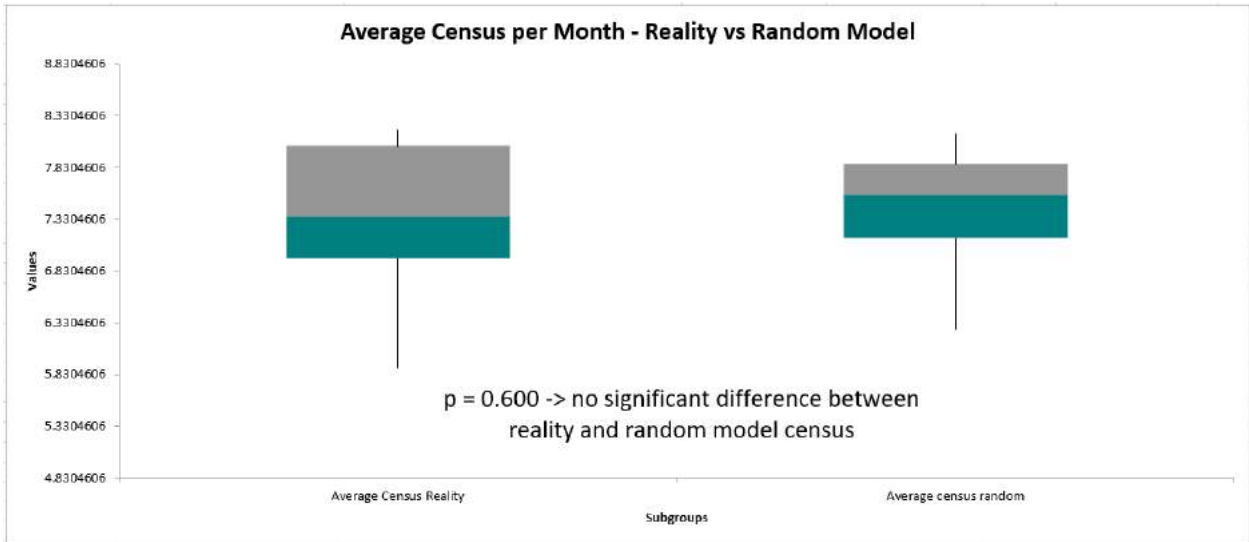


Figure 2: t-test for Average Census per Month - Reality vs Random for TICU

Tables

	TICU		SICU		SDU	
	Model	Data	Model	Data	Model	Data
Correct staff (Hours)	25.00%	25.00%	30.10%	30.10%	68.00%	68.00%
Understaff (Hours)	66.80%	66.80%	58.80%	58.80%	NA	NA
Overstaff (Hours)	8.20%	8.20%	11.00%	11.00%	32.00%	32.00%

Table 1: Validation of Models with Real Data

KPI	Correct Staffing (% hours ± 95% CI)	Understaffing (% hours ± 95% CI)	Overstaffing (% hours ± 95% CI)
Current	16.9 ± 1.2	49.7 ± 4.3	33.5 ± 4.5
Average	17.7 ± 1.7	33.5 ± 3.7	48.9 ± 4.4
Low	17.8 ± 1.3	37.6 ± 4.2	44.6 ± 4.1
High	17.8 ± 1.8	28.8 ± 3.2	53.4 ± 4.1

Table 2a: TICU Staffing KPIs

KPI	Correct Staffing (% hours ± 95% CI)	Understaffing (% hours ± 95% CI)	Overstaffing (% hours ± 95% CI)
Current	15.9 ± 1.0	45.5 ± 4.0	38.6 ± 3.9
Average	16.1 ± 1.1	35.5 ± 4.9	48.3 ± 4.2
Low	16.0 ± 1.1	47.6 ± 4.2	46.4 ± 3.7
High	16.3 ± 1.3	30.2 ± 3.9	53.6 ± 4.2

Table 2b: SICU Staffing KPIs

KPI	Correct Staffing (% hours ± 95% CI)	Understaffing (% hours ± 95% CI)	Overstaffing (% hours ± 95% CI)
Current (High)	41.9 ± 1.9	0	58.1 ± 1.9
Average	47.6 ± 2.1	18.2 ± 1.6	34.1 ± 1.7
Low	46.1 ± 1.5	37.2 ± 1.9	16.6 ± 1.2

Table 2c: SDU Staffing KPIs

KPI	Correct Staffing (% hours ± 95% CI)	Understaffing (% hours ± 95% CI)	Overstaffing (% hours ± 95% CI)
Current	8.3 ± 0.6	25.4 ± 3.2	66.3 ± 3.2
Average	9.0 ± 0.8	24.4 ± 3.2	66.6 ± 3.3
Low	8.6 ± 0.8	34.5 ± 3.7	56.9 ± 3.6
High	9.1 ± 0.8	13.8 ± 2.1	77.0 ± 2.7

Table 2d: Combined ICU Staffing KPIs

KPI	Nurse Wages (Millions \$)	% diff in Wages from Current Schedule
Current	1.17	--
Average	1.44	18.60%
Low	1.25	6.00%
High	1.53	22.60%

Table 3a: TICU Nurse Wages

KPI	Nurse Wages (Millions \$)	% diff in Wages from Current Schedule
Current	1.31	--
Average	1.49	12.30%
Low	1.27	-2.80%
High	1.59	17.70%

Table 3b: SICU Nurse Wages

KPI	Nurse Wages (\$)	% diff in Wages from Current Schedule
Current (High)	291,535	--
Average	439,525	33.70%
Low	318,193	8.40%

Table 3c: SDU Nurse Wages

KPI	Nurse Wages (Millions \$)	% diff in Wages from Current Schedule
Current	2.71	--
Average	3.05	11.30%
Low	2.76	1.90%
High	3.37	19.60%

Table 3d: Combined ICU Nurse Wages

TICU Staffing Schedules

Month	Average Nurses Required per Hour	95% CI	Low Schedule	Average Schedule	High Schedule
January	4.44	0.42	5	5	5
February	4.24	0.51	4	5	5
March	4.56	0.54	5	5	6
April	4.37	0.41	4	5	5
May	4.29	0.53	4	5	5
June	4.22	0.53	4	5	5
July	4.50	0.58	4	5	6
August	4.42	0.39	5	5	5
September	4.04	0.57	4	5	5
October	4.07	0.50	4	5	5
November	4.01	0.54	4	5	5
December	3.62	0.58	4	4	5

SICU Staffing Schedules

Month	Average Nurses Required per Hour	95% CI	Low Schedule	Average Schedule	High Schedule
January	4.28	0.47	4	5	5
February	4.47	0.52	4	5	5
March	4.01	0.55	4	5	5
April	4.72	0.63	5	5	6
May	4.44	0.59	4	5	6
June	4.32	0.53	4	5	5
July	4.35	0.65	4	5	5
August	5.03	0.62	5	6	6
September	4.89	0.55	5	5	6
October	4.55	0.46	5	5	6
November	4.01	0.57	4	5	5
December	4.46	0.47	4	5	5

SDU Staffing Schedules

Month	Average Nurses Required per Hour	95% CI	Low Schedule	Average Schedule	High Schedule
January	1.19	0.11	2	2	2
February	1.06	0.14	1	2	2
March	0.91	0.11	1	1	2
April	0.81	0.10	1	1	2
May	0.86	0.08	1	1	2
June	0.98	0.13	1	1	2
July	1.02	0.14	1	2	2
August	0.96	0.11	1	1	2
September	0.96	0.14	1	1	2
October	1.05	0.11	1	2	2
November	1.05	0.11	1	2	2
December	1.08	0.10	1	2	2

Combined ICU Staffing Schedules

Month	Average Nurses Required per Hour for ICU	95% CI	Average Nurses Required per Hour for SDU	95% CI	Low Schedule (ICU+SDU)	Average Schedule (ICU+SDU)	High Schedule (ICU+SDU)
January	9.18	0.92	1.24	0.19	11	12	13
February	8.16	1.01	1.25	0.20	10	11	12
March	7.79	1.08	1.19	0.18	9	10	11
April	7.47	0.90	1.23	0.19	9	10	11
May	7.99	1.16	1.30	0.17	9	10	12
June	8.81	0.98	1.25	0.21	10	11	12
July	8.41	0.81	1.40	0.22	10	11	12
August	7.95	0.96	1.16	0.15	9	10	11
September	8.36	0.94	1.14	0.27	9	11	12
October	6.87	0.78	1.26	0.22	9	9	10
November	7.33	0.88	1.26	0.15	9	10	11
December	7.60	0.91	1.31	0.18	9	10	11

Evaluating the Hospital Discharge Process

Christina Vikingstad | Spring 2021

Abstract. Managing capacity and improving throughput is often a significant challenge faced by hospitals around the world. Ensuring timely patient discharge is key in order to improve patient flow. Inefficiencies and delays in the discharge of patients can lead to bottlenecks in hospital operations. The current discharge planning process in hospitals is very complex and involves coordination between a variety of team members. Based on interviews with subject matter experts, observations, and literature review, the discharge process was evaluated and recommendations for improvement were formulated.

Background

The Hospital of the University of Pennsylvania (HUP) has 806 beds and discharges approximately 37,508 patients per year. The average length of stay (LOS) is 7.8 days.¹ Throughout the past several years, HUP has implemented various strategies in an attempt to improve the overall discharge process. From the moment of admission, the hospital focuses on planning the patients' discharge.

Based on data analysis completed by the process improvement team, in 2020 the average discharge time was 3:01 pm, and over 50% of discharges occurred after 3 pm. In January, the team implemented Project JEDI (Joint Effective Discharge Initiative), which consists of an interdisciplinary standardized discharge checklist in CareAlign (an application in PennChart that helps facilitate communication between members of the care team). The goal is of this initiative is to increase the number of discharges that occur before 12 pm. Despite this initiative,

they continue to experience delays in the discharge process, resulting in longer wait times for patients awaiting admission, transfer, and elective surgeries and procedures.

Delays within the discharge process can have negative impacts on the health of patients as well as the hospital's operations. A delayed discharge is defined as a period of continued stay at a hospital when a patient is clinically ready to leave the hospital, but is unable to do so for non-medical reasons.² As a result, such delays are often associated with a decrease in patient satisfaction. Delayed discharges can also contribute to bed shortages, as well as boarding and crowding in the emergency department. Furthermore, delays in the process can lead to inefficient resource utilization, admission bottlenecks, and increased length of stay.³ Discharge delays ultimately have an impact on the hospital's ability to deliver care effectively and efficiently.

Approach

In order to complete the project, the following steps were taken:

1. Identify problem
2. Complete background research
3. Conduct interviews and observations
4. Create a flowchart of discharge process
5. Identify sources of delay
6. Formulate recommendations

After the problem was identified and literature sources were reviewed, the discharge process was explored through conducting interviews with subject matter experts and observing

resident team rounds as well as discharge meetings. The project specifically focused on identifying different sources of discharge delays from various perspectives, such as delays relating to pharmacy, nursing, and patient transport, in order to develop recommendations to improve the overall discharge process.

Findings

The discharge process currently requires input from a variety of members within the healthcare team, including residents, physicians, pharmacists, clinical resource coordinators, transporters, physical/occupational therapists, schedulers, nurses, social workers, and pharmacists (See *Figure I* for the players involved in the process). From the moment a patient is admitted, the team begins planning for his or her discharge. In order to do this, they prioritize evaluating the medical history of each patient and scheduling necessary consults with providers. Based on the initial evaluation, an estimated discharge date is communicated to the patient.

In preparation for discharge, teams conduct virtual discharge meetings every morning. Participants in the discharge meetings include the unit's social worker, clinical resource coordinator, and the chief resident. During these rounds, each patient's expected discharge date is mentioned and any potential barriers to discharge are discussed. The purpose of these meetings is to make sure that problems that could potentially lead to discharge delays are addressed early on in the process. However, there are unanswered questions often remain after these meetings occur. For instance, physicians may experience challenges predicting the exact discharge date of patients due to the complexity of their conditions and the nature of patient care. In addition, the care team members frequently report difficulty scheduling meetings with the family members of patients in order to discuss their condition and the next steps in the care plan. As a result, a lack of communication

between the care team and the patient's family often exists.

Resident team rounds also occur daily on each floor. These teams consist of the attending physician, residents, interns, and medical students. Due to the fact that HUP is a teaching hospital, the rounds serve as a critical part of the learning experience for residents, interns, and students. The team meetings begin at 7:30 am with an educational experience. Most teams do not begin to visit the patients' rooms until around 11 am, making it difficult to achieve the noon discharge target.

It is important to note that interdisciplinary rounds do not occur on the majority of the units. Instead, many care team members meet with patients at their own convenience due to their busy schedules, making it difficult to directly communicate with the other providers regarding the patient's health status and care plan. As a result, much of the communication occurs asynchronously through messaging and phone calls, which often results in information not being recorded within the system, making it difficult for other team members to stay completely updated regarding the patient's information.

Before a patient can leave the hospital, several actions must be taken by members of the interdisciplinary care team in order to adequately prepare for the discharge. First, discharge planning must occur, which is completed by various members of the healthcare team, including the physicians, residents, social worker, clinical resource coordinator, bedside nurse, PT/OT and pharmacist. During the planning phase, team members have specific tasks they are responsible for completing depending on their unique area of expertise. Throughout the process, the team members focus on identifying and addressing the patient's anticipated healthcare needs following the hospital stay in order to ensure a smooth transition from one level of care to the next.⁴ (See *Figure II* for complete list of discharge considerations). All of

these considerations are incorporated into the comprehensive discharge summary, which is provided to the patient upon his or her discharge.

Next, the physician must sign a discharge order, which signifies that the patient is medically ready to leave the hospital. Many times, the physician is waiting to receive lab results indicating that the patient's condition is stable, and it is safe for him or her to be discharged. A medication reconciliation also must be completed by the attending physician and pharmacist, and the necessary medications are delivered to the patient's room by the pharmacy team prior to the discharge. In addition, the social worker is responsible for contacting the family of the patient and coordinating a pickup time and location with them.

After the nurse receives notice that the patient is ready to be discharged, he or she is responsible for providing the patient with a discharge teaching regarding instructions for managing their condition. The nurse is also responsible for explaining how to use any medical equipment and providing information about any new prescriptions. Any upcoming follow-up appointments that have been scheduled for the patient are also discussed.

In order to help improve the organization of the overall discharge process and increase coordination among providers, HUP implemented a standardized discharge checklist as part of project JEDI throughout the hospital units. However, the list is frequently not updated due to the fact that teams often find it difficult to navigate and many of the tasks are not assigned to specific roles, making it challenging to delegate responsibilities to each member of the care team in an efficient manner. In addition, each unit approaches the discharge process slightly differently depending on the floor's specialty, making it difficult to develop a useful, standardized checklist that fulfills the unique needs of each patient.

Sources of Delay

Through shadowing various medical teams, interviewing doctors, pharmacists, nurses, residents, and performance improvement advisors, and reading literature, the complex steps involved within the discharge process were evaluated. The process includes many steps due to the fact that most of the work completed by the care team throughout the hospital stay is performed in an attempt to prepare the patient for a safe and timely discharge.

After evaluating the overall process, a root cause analysis was conducted through creating a fishbone diagram in order to identify the major sources of discharge delays. The main categories of delays include the physicians, nurses, overall unit management, patients, pharmacy, and patient transport (See *Figure III* for more details regarding major sources of delays). After evaluating each of these categories, it was discovered that healthcare workers often work in their own silos and many times electronic health records (EHRs) do not fully support clinical workflows.

Based on the observations and research, it is evident that one of the most significant themes present within sources of delay during the discharge process is related to a lack of communication and coordination among the care team. Medical team members have variable schedules, and they rotate throughout the hospital, so it is often difficult for them to acquire unit-specific knowledge to improve the efficiency of discharges.⁵

Discussion

In order to optimize care delivery and improve the discharge process, timely, efficient, and accurate communication among numerous providers is necessary. Perhaps implementing care coordination meetings among all members of the care team as well as the family on a more regular basis could help facilitate communication between them in order to

increase the focus on discharge transitions. Furthermore, because differing opinions regarding patient care approaching the discharge often exists, such meetings could help ensure a more collaborative, patient-centered approach to care.⁶

Patients often report dissatisfaction about insufficient communication regarding their expected discharge date and time, making it difficult to ensure that the family will be available to pick them up at the proper time.⁷ In order to prevent uncertainty and improve communication with patients and their families, it would be beneficial to provide them with more frequent updates. In order to do this, electronic reminders could potentially be sent to the patient's family in the days leading up to the discharge to make sure that any questions regarding providing care at home are addressed and transportation is arranged in advance, ultimately preventing delays. In addition, implementing the concept of a confirmed discharge time (CDT) in the EHR could help facilitate improved discharge coordination efforts. Working to identify patients who are expected to be ready for discharge a day ahead of time would help the care team members be more prepared to accomplish the tasks earlier on. Other hospitals, such as Stanford Hospital and The American Family Children's Hospital, have established a CDT as a clear and inclusive way of facilitating communication not only among the care team, but also with the family to increase planning and coordination, allowing for earlier discharges.⁷

Furthermore, several distinct tasks must be completed once it is established that the patient is clinically ready for discharge. In order to maximize efficiency and prevent overlap in responsibilities, each task should be clearly assigned to a specific team member, promoting a greater sense of accountability. (*Figure IV* illustrates the different tasks that must be completed by various members of the team as the day of discharge is approached.) Establishing a standardized checklist outlining the specific

sequence in which tasks should ideally be completed could assist the care team in their efforts to discharge more patients earlier in the day.

To further improve communication among the care team, there is also potential to consider health information technology redesign. Although HUP currently uses CareAlign and EPIC, communication and coordination could potentially be enhanced through implementing more innovative technology to help restructure the overall workflow. For instance, a more specific and structured discharge checklist could be developed within the system. The checklist could be personalized based on the specific needs of patients on each unit in order to maximize its usefulness.

In the future, working on improving estimates of LOS in order to ensure accuracy in the planning of discharges would also be beneficial, as it would help enhance the planning process as well as hospital capacity management. It would also be useful to consider the importance of resource allocation through conducting research from a capacity standpoint, specifically focusing on evaluating data relating to admissions and discharges.

Recommendations

Overall, in order to identify and address the root causes of delay within the discharge process, several actions are recommended:

- Modifying the structure of daily rounds
 - Having a more interdisciplinary approach that incorporates additional members of care team
 - Prioritizing visiting patients who are ready to be discharged
- Refining discharge checklist to promote a greater sense of accountability
- Prioritizing lab results for patients with pending discharges
- Prioritizing tasks such as medication reconciliation and filling discharge

prescriptions based on which patients have upcoming discharges

- Incentivizing nurses/residents to discharge patients before noon
- Collecting/ analyzing data on factors related to discharge
 - Provide insight regarding root causes of delays
 - Examples: medication delivery timing, transportation timing, timing of rounds, bed request/ admission timing
- Establishing a discharge committee
 - Creating a Chief Discharge Officer position to reduce the number of decentralized responsibilities involved within the process
- Implementation of Six Sigma DMAIC methodology to identify causes of delay and reduce discharge process cycle time

It is important to identify the most significant sources of delays accurately in order to prioritize certain issues and ultimately make a significant impact on the system. Taking these actions would help the team members understand and address the root causes of the process delays in an effective manner.

Conclusion

Patient discharge from the hospital involves both medical and non-medical teams working collaboratively to accomplish multiple key tasks in a timely manner. Both patient-level and system-level factors contribute to delayed discharges. Focusing on restructuring the discharge process in order to prevent delays is important in order to improve the overall operations of a hospital. Refining the discharge process can help reduce readmissions, ensure patient safety, decrease the occurrence of hospital-related adverse events, and improve patient outcomes.⁸ In addition, preventing delays can result in significant financial savings by decreasing administrative costs and improving capacity management. Effective teamwork and

multidisciplinary coordination within hospitals is necessary in order to effectively address the root causes of the delays.

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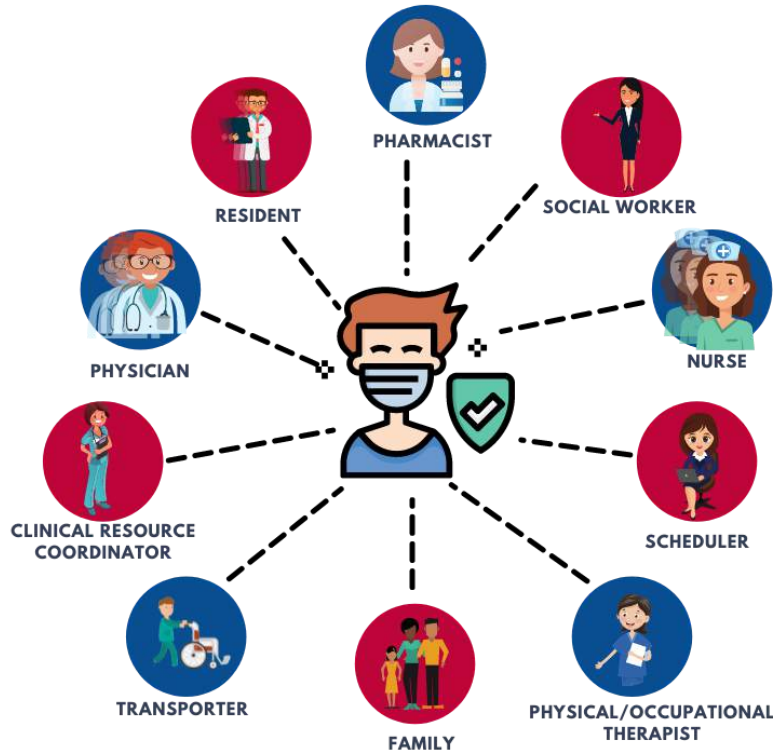
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Appendix

Figure I: Team Members Involved in Discharge Process



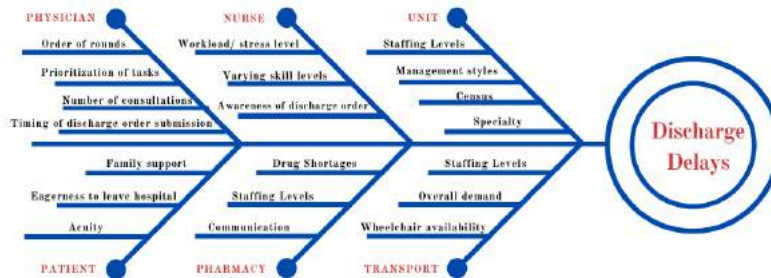
The various team members involved within the discharge process are highlighted.

Figure II: Patient Discharge Considerations



The unique aspects involved in the discharge process are highlighted and the specific team members responsible for each task are identified.

Figure III: Discharge Delay Fishbone Diagram



The fishbone diagram illustrates the major sources of delay present within the current discharge process.

Figure IV: Coordination Approaching Discharge Date

Coordination Approaching Discharge Date							
TASKS	MEMBERS INVOLVED	5 DAYS	4 DAYS	3 DAYS	2 DAYS	1 DAY	0 DAYS
Hold family meeting discussing home healthcare needs/ expected discharge date		█					
Arrange necessary caregiving/ home health services			█				
Confirm necessary follow up appointment(s)				█			
Confirm patient has necessary DME				█			
Coordinate transportation home/ pick up time					█		
Prepare discharge summary/ medication reconciliation						█	
Ensure lab results meet standards							█
Sign off on discharge order							█
Deliver medications to patient's room							█
Provide discharge teaching to patient (and family)							█
Schedule patient transport to lobby							█

The tasks that must be performed in order to adequately prepare for the discharge are highlighted, and the team members who are responsible for each task are identified.

Pediatric Telehealth: Establishing Rapport and Building Trust between Providers and Patients for Improved Quality of Care

Teresa Carotenuto, Elizabeth Kim, Croidy Veliz | Spring 2021

Abstract. Telehealth visits have drastically increased within the past year due to the Covid-19 pandemic. Virtual visits can be a challenging feat for children. In this study, a combination of expert interviews, research findings, and systems thinking are used to create recommendations that can positively impact the future of pediatric telehealth.

Background

Telehealth is an important tool in our modern day healthcare system. Telehealth virtual visits have been a vital tool for many who live in rural areas as a means for continuous care, while also providing accessibility.

A study was conducted in July of 2020 by Academic Pediatrics, the official journal of the Academic Pediatric Association, which looked at pediatricians' experiences, views, and attitudes towards telehealth. Their study found that 12.9% of pediatricians indicated the use of telehealth services in the past 12 months, and 6.4% reported they had referred patients for telehealth during that time. Overall, 15.2% of respondents reported any telehealth usage during the past year.¹

The lack of telehealth usage prior to the COVID-19 pandemic left a lot of opportunities for its future utilization in healthcare. Prior to the

COVID-19 pandemic, most insurances did not reimburse or cover the costs of virtual visits. After the pandemic began, there was a need for telehealth services in order to follow mandates and restrictions. Due to these changes, insurances began to cover and reimburse the costs of telehealth, making the utilization more feasible for patients. Policy changes by insurance companies due to the pandemic led to expanded coverage of telehealth services. The COVID-19 pandemic allowed providers to seize the opportunity to deliver care through a virtual platform. This shift has led to an increase in access to care, but has also led to the uncovering of many issues in the virtual healthcare space.

Although telehealth appears to be efficient and to provide access to more individuals, it can actually be quite challenging for all parties involved. One of the populations that can be significantly impacted by telehealth is the pediatric population. The American Academy of Pediatrics (AAP) believes the best place for children to receive medical care is at a pediatrician's office.² Children can be more difficult to care for, as they often have a harder time describing their symptoms and what they are feeling. Pediatricians have tactics and specific training they use for in-person pediatric visits to combat some of the challenges of providing care to children. Now forced to use a virtual platform, these tactics need

to be adjusted in order to properly provide quality care for pediatric patients.

Issues

Telehealth can offer many benefits to providers and patients, however, it does come with many underlying issues. Many of these issues can be overcome, but it will take planning, coordination, communication, and teamwork.

When conducting our interviews, there were issues that kept resurfacing. There seemed to be patterns of problems that providers, parents, and patients were all facing when utilizing telehealth.

Patients

The age range of the pediatric patients is between the ages of 7-15. The main concern of the children regarding telehealth was understanding the providers. Many of the children explained “not understanding the big words” used by the provider. There seemed to be a disconnect between the providers and themselves. The other main concern was the issue of technology. When technological issues such as glitching, audio/visual problems, and freezing occurred, it made the visit a lot more difficult for the patients to communicate and to stay engaged.

Parents

The similar issues were about provider language and technological issues. These two problems can be worked through with proper communication, systems, and education. The parents did offer a different perspective on other issues and concerns. The main concerns of the parents interviewed were their child’s ability to communicate with the provider and a quiet

environment for the appointment. In communicating, it seemed that the parents were concerned about their child’s ability to properly advocate for themselves during a telehealth visit. The reason behind this can be due to the lack of comfortability and familiarity with the provider. Oftentimes, the patient is seeing an unfamiliar mid-level provider or a specialist. This can cause a sense of anxiety, bashfulness, and a lack of trust from the pediatric patient. The environment concerns were alluding to the lack of privacy and trying to find a quiet, non-distracting location in the home to conduct the visit. This can be different depending on a family’s home environment

Providers

Physicians, PAs, NPs, Nurses

Although similar, the provider’s perspective was much more detailed. The providers raised many more concerns than those of the parents and patients. The main concerns are technology issues, environment issues, lack of connection with the patient, and inequity of access to technology.

In establishing a connection with the patient, the providers encountered the challenge of providing a welcoming, distraction-free environment for their pediatric patients. The providers recommended attempting to have a colorful background or conducting a virtual visit from the pediatric office in order to catch the patient’s attention, however, they still found it difficult to foster a welcoming environment through a screen. The lack of connection with the child was often caused by things such as lack of body language, attention, and comfortability from the patient. These concerns were similar to those of the patient in being nervous when speaking with

a provider through a screen. Providers also mentioned the lack of vitals and patient information being ready prior to the appointment. If a parent obtains their child's vitals (height, weight, temperature, etc.) prior to the visit, the visit will be more efficient and effective overall.

In inequities and disparities occurring in the telehealth space, it was mentioned that “not all families have access to technology or strong wifi” in order to complete a virtual visit. Providers mentioned the need for expanded telehealth access and coverage for many populations of people, especially those in low socioeconomic status, inner-city communities, and rural populations.

Support Tools

Through our research and interviews with pediatricians in the Lehigh Valley, we did not find many support tools available that were children-specific in solving the issues related to lack of trust, maintaining engagement, and lack of communication. Many telehealth platforms have the ability to change one's background to something more lively or “warm-feeling,” but our research and interviews unfortunately have not produced any tools, but rather tips and recommendations on how to provide a more empathetic virtual visit.

The increase in telemedicine utilization has also resulted in a shift to a new standard of care. As a result, the traditional in-person model in many subsectors of healthcare, such as pediatric wellness visits or cardiac outpatient care sectors, have been replaced with a hybrid model using in-person visits when necessary. In addition to the hybrid model, there has been an addition of

synchronous video visits, asynchronous symptom checks, and at-home vital sign monitoring with medical-grade digital devices and consumer wearables. These tools are used as a means to get diagnostic data or manage certain diseases such as diabetes or hypertension, but rarely do the researchers speak on the willingness of the patient to be more open or trusting about their problems through a virtual visit. The cardiovascular team at Massachusetts General Hospital administered surveys that only gauged the patients' overall satisfaction with the telehealth virtual care system rather than gauging their comfort, trust, and satisfaction of the visit itself.⁴

Education

Providers

The shift to telehealth during COVID-19 left many healthcare organizations scrambling to not only gather the necessary technology, but also train their providers and staff. Only 24% of healthcare organizations in the USA had existing telehealth programs as of January 2020. Training is an important part of telehealth because there is a lot more than just being present during the videoconference itself. According to Cornell's telehealth physician training course, training also encompasses demonstrating effective communication, creating action plans for troubleshooting technical challenges, identifying how to modify the medical decision-making process in a virtual space, etc.⁵ “Webside manner” is vital in ensuring quality care as well, especially amongst the pediatric population.

A standardized training approach to empathizing with the patient should be of importance in order to build rapport and trust with the child-patient since clinicians don't receive mandated training for telemedicine on the national level. It is also

necessary for the provider to inform the parent and child-patient what to expect during the telehealth visit as well as what information needs to be gathered in preparation for the telehealth visit.

Patients/Parents

It is equally important for pediatric patients and their guardians to educate themselves before a telehealth visit. There are many ways for parents and patients to educate themselves to help to alleviate some of the technical burden associated with telehealth visits. Videoconferencing applications like Zoom or Webex have educational videos and step-by-step instructions on their websites to help guide you through the process. By going through this information, patients will have a much easier time when it comes to the actual visit in regard to navigating the technical platform. With an informative approach from the provider, parent, and child-patient side, we can hope to see smoother virtual visits that result in lessened technical issues and a more trusting provider-patient relationship.

Guidelines and Recommendations

According to the American Academy of Pediatrics (AAP), there are several guidelines that should be followed when deciding if telehealth is the best option for a child. Below is a list of guidelines recommended for pediatric telehealth from the AAP, as well as our recommendations.

1. Telehealth should not replace your pediatrician.² Oftentimes, the child's pediatrician will be the provider during the telehealth visit, however, it is not

uncommon for the primary provider to refer the child to a pediatric specialist or a midlevel provider. It is important to understand that the child's primary pediatrician is the provider who truly knows the child the best.

2. Telehealth providers should be trained to treat children.² It is important that the specialist you seek out is *specifically* trained in pediatric services. The AAP mentions that "children are not small adults"; they require specific and specialized care.
3. An adult should be present at all times during the virtual visit.² It is important to provide a sense of security to the child when enduring a visit with a pediatrician. If the child is an adolescent or of consenting age, the AAP recommends that it may be a good idea to step out of the room when the doctor suggests so your child can practice taking more responsibility for their healthcare.²
4. Telehealth tools should work well for children.² The devices involved in the appointment should be prepared and should work effectively. The AAP states that by being prepared, it will allow a detailed examination of your children from a variety of settings -- including the home -- with proper training and practice.² The virtual tools should be specific to children and should be easy to use.
5. The telehealth visit should include all needed examinations and tests.² Even though the visit is virtual, it does not mean that tests and examinations cannot be performed. It is crucial that the provider gets vital information about the child in order to prescribe certain

medications and order further tests. Parents should collect their child's vitals (height, weight, temperature, etc.) prior to the visit.

6. The providers should know when to convert virtual services to face-to-face visits.² During a visit, a provider may decide that it would be more beneficial for the child to receive a more thorough examination, which would most likely be in-person. The provider should know when and how to refer your child to the most appropriate healthcare facility.²
7. The provider should provide a warm and welcoming environment to the patient through a virtual setting. This may require the use of colored backgrounds, games, sounds, etc.
8. All parties involved (provider, parent, and patient) should be actively engaged and attentive. Providers should tailor their conversation based on the age of the child. Parents should prepare questions prior to the visit and use a non-distracting environment. Patients should openly communicate with the provider, as well as ask questions for further explanation when confused.

Conclusions

Although telehealth services have expanded with increased access, the pandemic has influenced an increase in its utilization. When virtual visits first started, it was a new feat for all parties involved. Now, individuals are more accustomed to technology. The main problems with telehealth visits are becoming clear. Building rapport with and gaining the trust of the pediatric patients is one of the hardest problems to solve. From our research, interviews, and systems thinking, we

were able to create a set of recommendations that we believe will make pediatric telehealth a more robust and valuable service in the future, as well as strengthen the provider-child relationship.

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Analysis of COVID-19 Vaccine Distribution Inequities

Leigh Friedman, Liz Turi, Neha Mandhyani | Spring 2021

Abstract. This dashboard is a Proof of Concept tool for visualizing equity in COVID-19 vaccine distributions. It combines a context-setting index as a background layer with point reference layers that indicate variance between expected and actual vaccine doses by racial and ethnic groups in order to look at vaccination from a systems perspective. If we want to understand better ways to increase accessibility and equity, vaccination needs to be viewed in the setting of social determinants of health and health disparities. While we focused on race/ethnicity for this project, the methods used can be applied for other groups to determine the variance between expected and actual outcomes. In addition, the methods used can be applied to other healthcare topics, such as childhood vaccination rates, diabetes management programs, and others.

Background

Coronavirus disease 2019 (COVID-19), an infectious disease caused by a newly discovered novel coronavirus, SARS-CoV-2, has disrupted all aspects of daily life. In order to return to any semblance of “normal”, we will need to reach herd immunity. Initial estimates suggested natural or vaccine-mediated immunity to reach herd immunity would need to be within about 60-70% (McNeil, 2020) of the population. As the virus as well as our understanding of transmissibility, morbidity, and mortality have evolved, those estimates have been revised upwards to around 75-80%. The most equitable and efficient means to achieve herd immunity is through vaccination (D’Souza & Dowdy, 2021). Through a tremendous global effort in

sequencing, identifying, and compiling existing research on SARS and mRNA vaccines, Pfizer-BioNTech and Moderna have reached a historic milestone in developing an mRNA vaccine with 94-95% efficacy in less than a year. The Food and Drug Administration (FDA) issued an Emergency Use Authorization (EUA) for the mRNA vaccines on December 12, 2020, and December 18, 2020, respectively. In addition, the Janssen/Johnson and Johnson vaccine received EUA effective February 27, 2021 (ACIP COVID-19 Vaccine Recommendations, 2020), and more vaccines are in development; thus, our collective ability to meet the demand for herd immunity increases. However, vaccine rollout in the United States has been plagued by several obstacles ranging from manufacturing to government response (Wilcox, 2021) to vaccine hesitancy. In the absence of a federal vaccine rollout plan initially, states were left to individually define their vaccination rollout plans (Hennigan et al., 2021). This patchwork of state-level rollout plans, we find inequitable vaccine distribution across age, racial/ethnic groups, and medical risk groups leading to exacerbating existing health disparities.

Per conversation with Dr. David Adinaro at the NJ Department of Health, it helps to think of vaccination in terms of phases:

1. Protect the workforce (December 2019/January 2020)
2. Protect the vulnerable
3. Address vaccine hesitancy (once supply outstrips demand either due to

manufacturing capacity or vaccine hesitancy)

4. Outreach to remaining populations

With this framework in mind, policymakers need to understand where gaps are, where vulnerable populations live, where COVID-19 is still high risk, and where gaps in vaccination are occurring. As needs change based on phase, the ability to have real-time information is critical.

Health Disparities are differences that exist among specific population groups in the United States in the attainment of full health potential that can be measured by differences in incidence, prevalence, mortality, the burden of disease, and other adverse health conditions (NIH, 2014). Within the context of COVID-19, we found health disparities in disproportionate rates observed of COVID-19 infections, hospitalizations, and deaths in African American, Native American, and Hispanic communities compared to White communities (CDC, 2021). In response, public health officials began to push for an equitable distribution of COVID-19 vaccines by providing recommendations that promote vaccine equity (preferential access and administration to those who have been most affected by COVID-19), noting the latter should be prioritized (AJMC, 2021). The intersection of the population's risk and vulnerability to COVID-19 should be viewed in conjunction with vaccination data in order to understand whether or not COVID-19 vaccine distribution is equitable at the county level. Specifically, we can expose the variance, or difference, between expected distribution based on population demographics and the actual distribution. Seeing this variance provides more information in getting target groups vaccinated than a straight rate comparison. This then highlights inequities and unequal distribution of vaccinations, helping policymakers make decisions and take action in order to boost vaccination rates.

Per John Kingdon's "Multiple Streams Framework" (De Wals et al., 2019), it is essential

to move gradually in three streams for a new immunization program to be developed and be effective:

1. the problem stream, which focuses on a particular vaccine-preventable disease and its perception by stakeholders;
2. the policy stream, which is centered on expert views on the optimal use of available vaccines; and
3. the politics stream, which consists of socio-political factors, including budgetary constraints.

Under scenarios where haste is important, these three streams can be accelerated via a policy entrepreneur, who progressively shapes the ideas generated across these streams into a proposal with concrete implementation strategies. This project works in a policy entrepreneur capacity by creating a decision support tool via an interactive dashboard that incorporates the intersections mentioned above.

Methods

Our project went through 5 phases:

1. Review vaccination rollout policies across the US
2. Interview subject matter experts
3. Analyze data source options; select focus state
4. Data cleansing and normalization
5. ArcGIS modeling and dashboard creation

Review vaccination rollout policies. We started collecting data on vaccination policies across the US in early February. When vaccination rollouts were widely varied at that point in time, the data made accessible was often in dashboard form only, and stage definitions varied even more. It was impossible to track which states changed the comorbidities and prioritized them on a real-time basis because it was changing so rapidly. This emphasized the need for coordinated data to support rapid policy

changes, and convinced us that we needed to build a model for evaluating vaccine distribution that was resilient to frequent changes.

Interview subject matter experts. We looked for subject matter experts who understood the dynamics of public health policy - both the political science and the implementation of policies. Also necessary were subject matter experts that would be able to expand our understanding of healthcare disparities, health equity, social determinants of health, and how COVID-19 impacted vulnerable communities. Our panel of experts included those in epidemiology, biostatistics, health equity, public health, political science, and legislation.

Analyze data source options and choose focus state. In reviewing our data from vaccine rollouts, we determined the following data criteria were required:

- Must be downloadable
- Must be script accessible (i.e., not a PDF)
- Must have race/ethnicity data by county

The only state that met all of these criteria in early March was Pennsylvania.

Data cleansing and normalization. The data available through Pennsylvania are accessible through their OpenData portal at <https://data.pa.gov>. There are datasets that cover both actual vaccination rates (by demographic slice) as well as vaccine allocation data. There were three data sources for vaccine allocation data: doses allocated for first doses, doses allocated for second doses, and doses allocated through the federal direct to pharmacy program where first/second dose was not differentiated. This meant that we couldn't look at discrepancies between first/final doses, but rather needed to look at cumulative vaccine doses administered

Normalization was handled along two vectors:

1. Updating the Pandemic Vulnerability Index from the National Institute of Environmental Health Sciences (NIEHS) to include the Hispanic population under Population Demographic risk factors.
2. Compiling data from census sources and PA sources to calculate Expected (Forecast) Rates, aggregate Actual Rates, and variance.

Pandemic Vulnerability Index (PVI) presents a visual synthesis of county-level vulnerability indicators. It covers 12 domains of vulnerability. The table in the Appendix displays the domains and their definitions. Briefly, these domains are infection rate, population concentration, intervention, and health and environment. It can be represented as a spider diagram and will be explained further in the dashboard section.

To get the total number of doses allocated per county, we had to combine three datasets from PA's OpenData Portal - First Doses to Providers, Second doses to Providers, and Federal Direct to Pharmacy doses allocated. Because of this, our expected doses are a cumulative number encompassing first and second doses.

We then calculated the expected number of vaccine doses by group by county using 2018 census data (congruent with the census data that was used in PVI calculations) to calculate each group's percentage and then multiplied that by the total number of vaccines allocated to each county.

Because allocated doses could not be split into first and second doses, we needed to ensure that the actual number of vaccine doses administered also reflected first and second doses. We calculated the actual number of doses per subgroup per county by aggregating first and second doses administered by subgroup by county.

Once allocated and expected doses per subgroup per county were calculated, we may then calculate variance:

$$Variance(\%) = \left(\frac{Actual}{Expected} - 1 \right) * 100$$

By calculating a variance from expected doses per group per county, we can develop a good understanding of where there are gaps in vaccine administration between each group.

Dashboard

For the dashboard, we wanted to create a spatial view of data that shared both the risk/vulnerability context and the variance in vaccine administration between racial and ethnic groups. *Figure 1* shows the base layer - a map of counties in Pennsylvania filled in with gradient colors based on the modified PVI score we calculated.

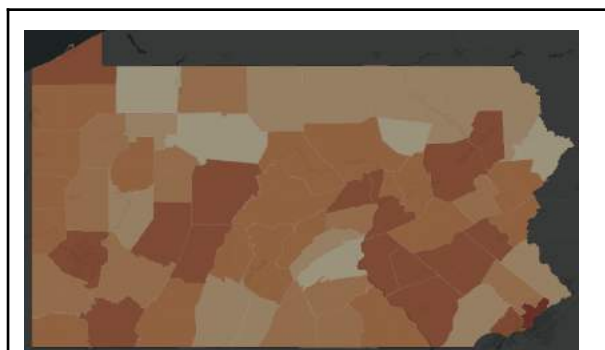


Figure 1. Map of counties in Pennsylvania color coded by modified PVI. Darker shades represent higher scores. Lighter shades represent lower scores.

As you can see in *Figure 2*, darker pigments are associated with a county's higher vulnerability and risk for COVID-19. The lighter pigments are associated with lower vulnerability and risk for COVID-19.

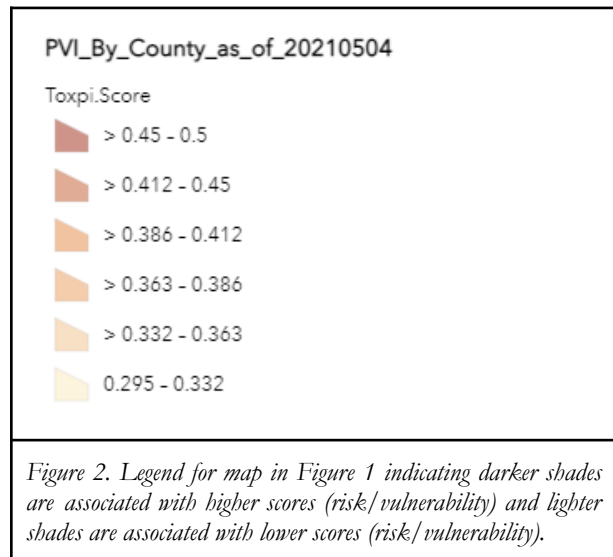


Figure 2. Legend for map in Figure 1 indicating darker shades are associated with higher scores (risk/vulnerability) and lighter shades are associated with lower scores (risk/vulnerability).

This layer also contains popup references to more detailed information for each county (The PVI spider diagram, Expected doses, Actual doses, and Variance - by race and by ethnicity). While not required, it is assumed this layer remains visible at all times. This is shown in *Figure 3*.

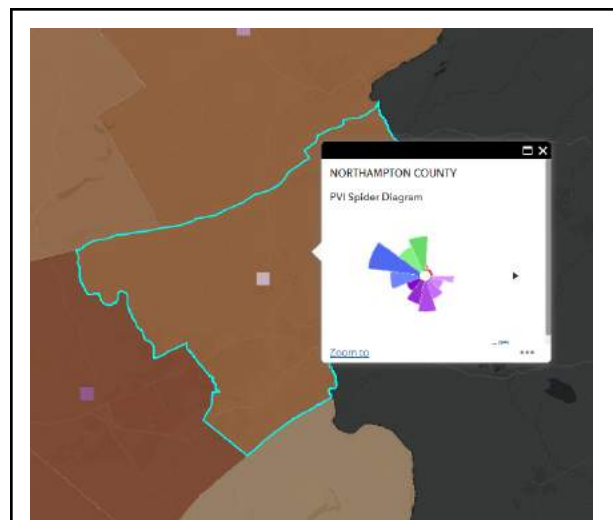


Figure 3. Zoomed in map of Northampton county displaying its spider diagram in popup.

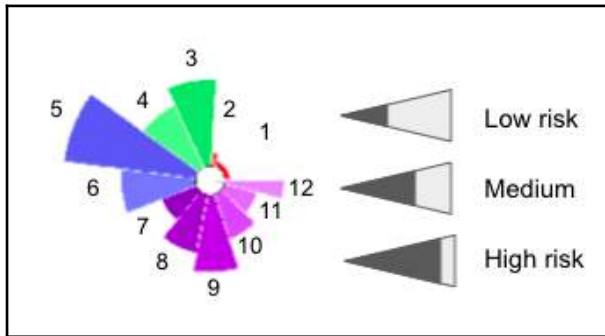


Figure 4. Spider diagram for Northampton County with numbers identifying the PVI slice, and indicators to determine size of slice relative to risk.

Each slice in the PVI spider diagram represents a different risk/vulnerability domain. Figure 4 shows where in Northampton County, the biggest drivers of overall risk are the slices numbered 3, 5, and 9. This means higher residential density, less social distancing, and an older skewed population, which aggregates to greater risk for the county. Greater risk to the county translates to an increased PVI score.

By clicking on the arrow to the right of the PVI spider diagram graphic, the user can click through to see charts representing the expected doses, actual doses, and variance by race and by ethnicity for that county.

In order to visualize specific subgroup data at the county level, the user can select layers. Each layer, when selected, shows an icon on each county in the state. This icon is colored according to a gradient regarding if the county meets or does not meet the expected rate of vaccination for the subgroup. Figure 8 shows what a user would see if they selected the % Variance-Hispanic layer.

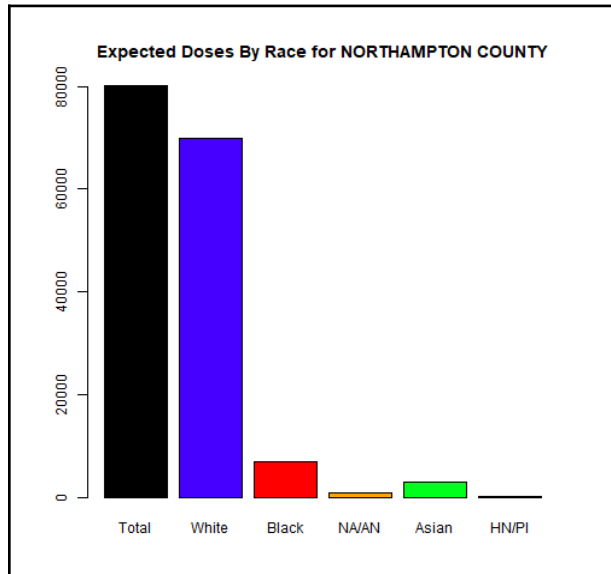


Figure 5. Expected Doses by Race for Northampton County taken from the popup in Figure 3.

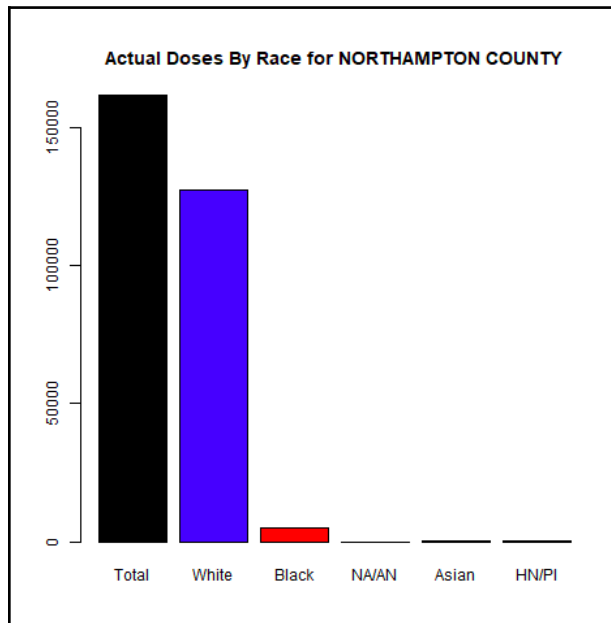


Figure 6. Chart indicating actual doses by race for Northampton county, taken from the popup in Figure 3.

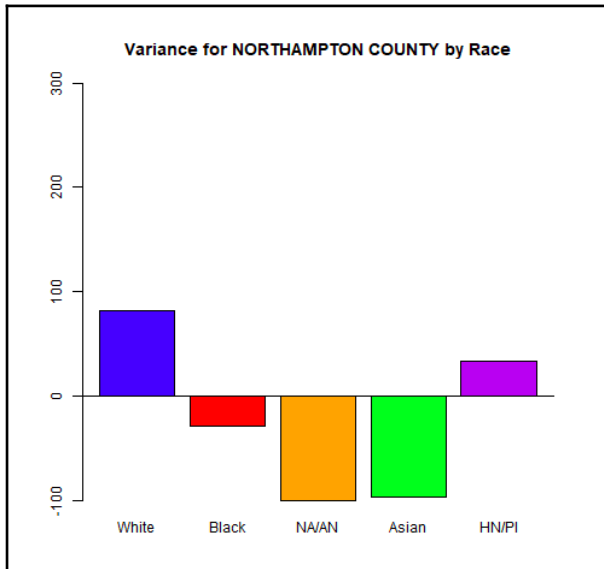


Figure 7. Chart indicating variance by race for Northampton County, taken from the popup in Figure 3.

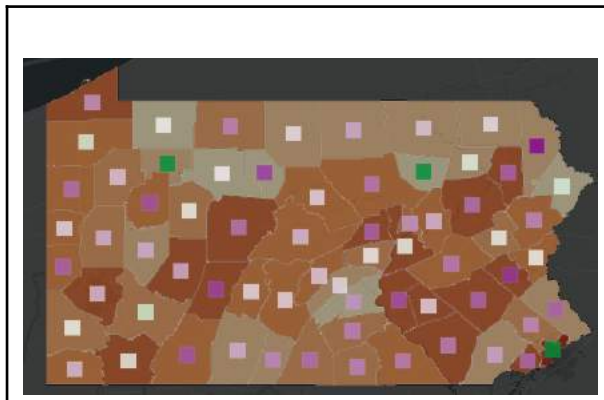


Figure 8. The % Variance - Hispanic layer displayed over the map from Figure 3 showing color coded symbols associated with variance based on data from May 4, 2021.

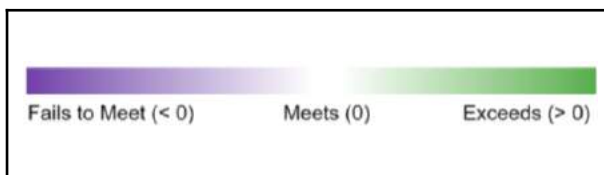


Figure 9. The color code chart indicates how to interpret the maps in Figure 8.

The gradient in *Figure 9* displays the legend for the icons on the map. The darker the purple, the farther the county is from meeting expected vaccination rates.

Outcomes

The goal of this project was to create a tool that equipped policy makers with necessary information regarding COVID-19 vaccination to make better data-driven decisions regarding equitable distribution. In creating a dashboard, we are able to facilitate visualization of subgroup vaccination statistics and vulnerability indices. To effectively demonstrate equity, we focused on describing and calculating variance. To understand the gaps, it is important to compare the number of doses allocated to each county. To measure equitable distribution, when this value is compared to the actual number of doses, they should be the same. In other words, variance should be 0.

Within the dashboard, we were able to display the above information by applying a color coded scale to variance, and set it in spatial context. What makes our dashboard transformational is that the user can also see the county’s risk and vulnerability via the PVI in the background. In doing this, our dashboard effectively demonstrates complex information in a comprehensible and interactive map with multiple layers of granularity. This allows policymakers to visualize equitable vaccine distribution.

Policymakers can now see which counties carry risk/vulnerability for COVID-19 and how well vaccination is going across subgroups. With this information, they are empowered to take specific action to increase equity. In addition, policymakers can begin to answer questions such as:

- Are there enough Federally Qualified Health Centers in a region with poor vaccination rates of vulnerable groups?

- Are there clusters of counties that have relatively “simple” problems to fix, like supply chain management?
- Are there spatial relationships between counties, risk factors, and vaccination variances that might highlight patterns to investigate?

For example, when a policymaker identifies a county with negative variance in Hispanic populations, they can now investigate the current state in that county and identify future steps:

- Are there enough Public Service Announcements available in appropriate languages
- Are there community based organizations available to help
- Are there other reasons people aren’t getting vaccinated?

Limitations

Dashboards are only as good as the data available, and there were significant challenges.

First, because census data as well as vaccination demographic attribute data rely on self-identification, we cannot measure what does not get reported. This means that true rates may be under reported, and some groups may not be visible at all. Any expansion work to cover other vulnerable populations may likewise go unseen.

Next, 2018 census data was used. While we calculated differences between 2018 and the current data provided by Pennsylvania’s OpenData platform, and found only minor changes in county populations, it still may have a mild impact on overall calculations.

Lastly, using variance adds excess weight to significant outliers which may skew results inappropriately - inadvertently overemphasizing gains or deficits. For example, in one case, we saw that one county indicated an 800% positive

variance for the Native Hawaiian/Pacific Islander population. Variance doesn’t tell us root causes, but it does show up as an outlier that would need further investigation.

Future Endeavors

This dashboard has the potential to be expanded upon.

More data points are needed. While this project focused on race and ethnicity, there are other groups for which it would be significantly harder to complete this work for (for example, LGBTQIA+ data are missing entirely in PA data, and in many other states (Kramer, 2021)). In Massachusetts, there is an effort to do exactly this through the legislative process, where they are looking to add data elements to be collected at the time of vaccination. Per Senator Rausch in the Massachusetts State Legislature, in developing the proposed Community Immunity Act (An Act promoting community immunity, S.1517), stakeholders working with vulnerable populations were engaged in order to define a set of elements that would not negate trust. This would address some of the self-identification issues noted above, and expand visibility into vulnerable populations.

While we worked on vaccination rate and vulnerability/risk, this tool can also be modified to display hospitals, prisons, or other artifacts that could assist in understanding and visualizing equity in vaccination. Themes encountered in COVID-19 vaccination, are also found in childhood vaccinations and can be modified to help communicate childhood vaccination data. Though this project focused on the Commonwealth of Pennsylvania, the methods and strategies used here may also be applied to other states or regions, or may be applied to help prepare for future pandemics, or evaluate other public and population health initiatives.

This dashboard works well to highlight areas to develop action plans at the county, multi-county region, or state level, however, more work can

be done at the local level to help enact local policies to support vaccination campaigns that reflect the individual characteristics of local communities. Having data available at the census tract level would be key for that work.

Finally, in looking at the metrics used, the pandemic vulnerability index is not truly comprehensive, so what other data may be relevant to understanding risk and vulnerability? Is the PVI the best measurement to use to understand risk and vulnerability or are there others that may reflect it better? These are some important questions to ask as future work is done on this project.

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Appendix

Table 1: Pandemic Vulnerability Index Legend (Modified) (NIEHS, n.d.)

Infection Rate; Transmissible Cases	<i>Population size divided by cases from the last 14 days.</i> This time period was chosen because of the 14 day incubation period. This metric is the number of contagious individuals relative to the population. A greater number indicates more likely continued spread.
Infection Rate; Disease Spread	<i>Fraction of total cases that are from the last 14 days.</i> This metric is always between 0 and 1, with values near 1 during exponential growth phase, and declining linearly to zero over 14 days if there are no new infections.
Population Concentration; Population Mobility	<i>Estimated daytime population.</i> Greater daytime population density is expected to increase the spread of infection because more people are in closer proximity to each other. This also includes baseline traffic, which is the average traffic volume per meter of major roadways in the county.
Population Concentration; Residential Density	<i>Integrates data from the 2014-2018 ACS on families in multi-unit structures, mobile homes, overcrowding (more people than rooms), being without a vehicle, and persons in institutionalized group quarters.</i> All of these variables are associated with greater residential density, which is expected to increase the spread of infection because more people are in closer proximity to each other.
Intervention; Social Distancing	<i>Unacast social distancing scoreboard grade is assigned by looking at the change in overall distance travelled and the change in nonessential visits relative to baseline (previous year), based on cell phone mobility data.</i> The grade is converted to a numerical score, with higher values being less social distancing (worse score) is expected to increase the spread of infection because more people are interacting with others.
Intervention; Testing	<i>Population divided by tests performed (currently only state-wide statistics are available).</i> This is the inverse of the tests per population, so greater numbers indicate less testing. Lower testing rates mean it is more likely that infections are undetected, so would be expected to increase the spread of infection.
Health & Environment; Population Demographics	<i>Percentage of population who self-identify as either Black, African American, American Indian, Alaska Native, or Hispanic.</i>
Health & Environment; Air Pollution	<i>Average daily density of fine particulate matter in micrograms per cubic meter (PM2.5) from 2014 Environmental Public Health Tracking Network.</i> Air pollution has been associated with more severe outcomes from COVID-19 infection.
Health & Environment; Age Distribution	<i>Aged 65 or Older from 2014-2018 ACS.</i> Older ages have been associated with more severe outcomes from COVID-19 infection.
Health & Environment; Comorbidities	<i>Premature Death: Years of potential life lost before age 75 per 100,000 population (age-adjusted).</i> This is a broad measure of health, and a proxy for cardiovascular and pulmonary diseases that have been associated with

	<p>more severe outcomes from COVID-19 infection. <i>Smoking</i>: Percentage of adults who are current smokers from 2017 Behavioral Risk Factor Surveillance System. <i>Diabetes</i>: Percentage of adults aged 20 and above with diagnosed diabetes from 2016 United States Diabetes Surveillance System. <i>Obesity</i>: Percentage of the adult population (age 20 and older) that reports a body mass index (BMI) greater than or equal to 30 kg/m². Obesity, smoking, and diabetes have been associated with more severe outcomes from COVID-19 infection.</p>
<p>Health & Environment; Health Disparities</p>	<p><i>Uninsured</i>: Percentage uninsured in the total civilian noninstitutionalized population estimate, 2014- 2018 ACS. <i>SVI Socioeconomic Status</i>: integrates data from 2014-2018 ACS on percent below poverty, percent unemployed (historical), income, and percent without a high school diploma. Individuals without insurance and lower SES are more likely to be undercounted in infection statistics, and may have more severe outcomes due to lack of treatment.</p>
<p>Health & Environment; Hospital Beds</p>	<p>Summation of hospital beds for hospitals with “OPEN” status and “GENERAL MEDICAL AND SURGICAL” description.</p>

How Much Will A Total Knee Replacement Surgery Cost You?

Nico Lastauskas and Jake Levine (Spring Semester 2021)

Abstract. Total knee replacement surgeries are conducted all over the world on a daily basis. Specifically, these procedures have a wide range of costs associated with variability, location, and materials used. Through research done in the United States by various sources, we found that the price of the surgery is variable based on four main factors: price of material, salaries of the various employees, length of stay in the inpatient facility, and type of insurance. For the purpose of this project, we focused on strictly inpatient cases from Medicare patients to eliminate further variables including: price differential between inpatient and outpatient, price discrepancies based on insurance coverage, differences in state regulations, etc.

Background

In 2014, approximately 684,000 total knee replacement surgeries were conducted in the United States (American Academy of Orthopedic Surgeons, 2014). This number is estimated to grow roughly 189% by 2030 to 1.29 million annually (Projected, 2018). The increase in the number of surgeries proves there is a great need for total knee replacement surgeries and with a continuous effort to limit cost. This demand could further increase as the population continues to age and increase.

An analysis conducted by the Wall Street Journal demonstrated that although the average charge for a total knee replacement surgery approached \$50,000 the cost incurred by the institution was only \$10,500 (Evans, 2018). The latter includes the salaries of the physicians and nurses as well as the material used. Therefore, this illustrates the massive gap in price versus cost.

We found further discrepancies in the cost to the provider for different aspects of the surgery. Depending on the “buying power” of the health system, the price of the middle-tier prosthesis for a patient that is of average athleticism (walks daily, minimal excessive running) would range anywhere from \$2,100 to \$8,000. This number reaches the lower end of the range when higher amounts are ordered from the distributors.

Additionally, the cost of the cement can vary from \$20 to \$120 for the amount needed for the surgery. The \$20 is the cement arriving separately from the biomes, whereas the \$120 comes with everything pre-mixed. The time value analysis of mixing the cement as compared to just purchasing the pre-loaded mixture was minimal in regards to the cost of the procedure with the non pre-loaded cement.

Methodology

In order to determine the “true cost” of a total knee replacement surgery, we analyzed the procedure from the initial evaluation through the operative procedure up until the rehabilitation. Following these steps eliminates variability that could occur in the manufacturing, post-operative, and rehabilitation settings. These findings were conducted through extensive research from healthcare journals and peer reviewed journals. Additionally, interviews were conducted with surgeons and other accredited healthcare professionals on the subject matter.

To narrow our focus, we used an article from the Wall Street Journal, in which they followed the total knee replacement surgery at Gundersen Health System in La Crosse, Wisconsin to uncover the costs that go into a total knee

replacement. During the study, they were able to locate two main points in which cost could be mitigated further including the type of cement as well as the time it takes to conduct the surgery.

They further found variability with how the surgeons were conducting the surgery. By creating more consistency across the surgical process, as well as mixing the biomes into the cement rather than purchasing the pre-loaded cement, Gundersen Health System was able to save 18% on their operational costs for the procedure. This translated to a 7% decrease to the cost of care for the patients (Wall Street Journal, 2016).

To further understand the costs going into the procedure, we interviewed accredited healthcare professionals to complete the cost analysis of a total knee replacement surgery. For consistency across these interviews we outlined a model patient referred to as patient “A” who is a 67 year old, female, Medicare patient residing in New York. Both participants completed a cost analysis of patient “A”. The number each participant came up with is cost specific to the model patient. Both answers were remotely similar in that one of our interviewees estimated the cost to the patient be \$11,000 and the other estimated the cost to be \$12,500. Due to the consistent payment structure of Medicare, it was interesting to see how the hospital in which the cost will be \$11,000 will generate more profit than the hospital charging \$12,500. This raises further questions for future studies including why don’t all hospitals decrease their costs in order to generate more profit?

Based on the results, it seems as if the data that we received from our first interviewee varied from the other interviewee, located in the Northeast. This is partially due to the buying power associated with their respective hospital system. It is evident that there is a major pull for hospital systems conducting more total knee replacements when purchasing the prosthetics from the respective companies.

The scope of our project is to analyze the cost of a total knee replacement surgery from the lens of the provider which can be focused around evaluating the inputs and cost variances associated with those that occur in a total knee replacement operating room.

Results

The cost of inputs was determined through extensive literature research. The cost of the knee itself ranged from \$2,100-\$8,000. The cement used in a total knee replacement surgery ranged from \$20-\$120. Based on annual salary, we gathered statistics from Forbes and Glassdoor regarding the salaries of the essential healthcare workers in a TKR procedure. A surgeon is paid \$294,110 - \$776,231/year, a nurse is paid \$48,690 - \$104,100/year, an anesthesiologist is paid \$180,630 - \$281,070/year, and a physician assistant is paid \$48,000 - \$140,000/year. In addition, medication prices range from \$250- \$300 and physical therapy costs approximately \$2,200 for twelve visits.

After analyzing the patient and comparing their circumstances to past patients at Coordinated Health, our team and our interviewee from the hospital system determined that patient “A” would be required to pay \$11,000 for a total knee replacement surgery. On the other hand, the Orthopedic Oncologist determined that the patient “A” would be required to pay \$12,500 for her procedure. As depicted above, both accredited professionals had a similar analysis of our model patient.

Limitations

Some of the limitations included the number of available sources, the time available in conducting the research, limiting our scope only to the continental United States, and our sample size and timing of the data collection. By having more time, a larger sample size in the number of interviewees, and having more relevant data, we would be able to conclude more reliable

information and build on the given information further.

Conclusion

Overall, the objective of this project was to display the “true cost” of replacing a damaged knee joint with a prosthesis from the lens of the provider. Based on the research conducted, it is evident that there is availability for the providers to save money on total knee replacement surgeries. The motivation in doing so would not only minimize the waste associated, but also maximize profit for the hospital system.

Although the Medicare bundled payment is a specific amount, by lowering the cost of the materials, the provider can maximize their profit for better returns. In the future, it would be valuable to look into further studies such as the incentives for hospital systems to implement further studies into limiting waste, the effect of insurance and the cost of care for the patient, the actual statistics of the “buying power” and how much money could actually be saved for the provider with exact statistical figures and how providers decide which knee to give their patient and the role that the patient plays in their care.

Key Takeaways

- There is cost variability in the cost of total knee replacements from and within different hospital systems.
- There is a significant price differential depending on the different inputs involved in a total knee replacement including but not limited to: cement, prosthetics, and salaries of the staff involved.
- It seems that buying power plays a role in determining the cost of the total knee replacement from the lens of the provider.

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Improving Operation Scheduling with Surgical Case Length Prediction

Jeff Dicker, Spencer Leuba, Ryan Seth | Spring 2021

At more than \$100/minute, the operating room (OR) is a very costly area for a hospital, but it is also one of the highest revenue-generating assets. Correctly predicting the duration of a surgery is crucial for any hospital looking to maximize an OR's utilization while also valuing the time of its patients and employees. Like many researchers before us, we approached this problem from a data analytics standpoint. Through conversations with surgeons, surgical schedulers, and other researchers, we learned this data analytics problem is just one component of a larger challenge. This broader challenge, the institutional challenge, involves process re-engineering and cultural transformation. The institutional challenge encompasses hospital-specific obstacles and is the reason why there is currently no general solution for improving and implementing predictive analytics for surgical case duration. We have distilled the conclusions of our project into a methodological approach for improving and implementing case duration predictive analytics. This article details this methodology which is also attached as a project road-map in the appendix.

Applying a machine learning algorithm is a unique process and dependent on the sample data set. The first step in using machine learning to build a predictive model of case duration is identifying which factors should be

included in the desired data set. After performing a literature review, we identified around 25 features to include from a patient's medical record as well as a factor that incorporates the surgeon performing the operation. After identifying the minimum features required for a viable dataset, the next step is to acquire a de-identified medical dataset, assuming the data is not readily available or in-house. This was the greatest obstacle in our data analytics efforts. With the correct data set acquired, different machine learning algorithms can be used to make predictions of case duration, and accuracy of the model can be calculated. Following our literature review, we decided to use multiple linear regressions because of its simplicity and minimal mean-squared-error value when applied to our dataset.

We acquired a dataset from Dr. Joseph Golob of MetroHealth which contained 150 datapoints of Coronary Artery Bypass Graft (CABG) procedures. After further examination, we discarded 50 of these data points because they contained additional procedures beyond CABG. Using this set of ~100 recent CABG procedures we first transformed all of our variables into numeric values so they could be used in a mathematical model. We encoded our categorical features using "dummy" variables which is a fairly common practice. The idea of

this is to use binary variables to represent each unique value present in a feature. For example, our Smoker feature contained 3 values, “No”, “Past”, and “Current”, so we engineered this feature as three separate features - Smoker_No, Smoker_Past, and Smoker_Current, and used a 1 to represent if that was true of the patient and 0 if not. Additionally, we normalized our numerical values on a 0-1 scale so no numeric value was weighted more heavily than another. After our data processing and feature engineering was complete, we used the Multiple Linear Regression algorithm from the MLLib python library to train a model. We then applied feature selection to determine which features of our dataset were most predictive of surgical case duration. Using our test set, we tested the accuracy of our model and calculated the mean squared error (MSE) and R^2 value. Unfortunately, our model was not highly predictive of surgical case duration because it did not contain the Surgeon feature, which is known to be the second most predictive feature of case duration behind Procedure. The results of machine learning work is included in the appendix.

A team looking to improve surgical case duration predictions must also develop an understanding of what institutional challenges are present at the partner hospital. These institutional challenges, which can be separated into process issues and buy-in issues, are specific to the hospital and affect the accuracy and eventual efficacy of the model. Data collection is a common process challenge. Specifically, a communication barrier between clinical and administrative staff may exist and cause the erroneous input of incorrect CPT codes. Other times, relevant information, such as if an additional surgeon or time-intensive equipment is required, may be omitted from the sample

dataset. These errors may compromise the integrity of the sample dataset and the accuracy of the model. Buy-in issues can also affect implementation of the algorithm, even if the ideal processes for model utilization have been identified. For instance, if administrative leadership does not set the incentives needed to ensure all team members embrace and utilize the model, the model will not return the desired results. It is also essential to achieve buy-in from clinical leadership. With some surgeons having significant influence at a hospital, it may not be possible to use a new schedule unless key surgeons are bought into the hospital’s mission of improving schedules with predictive analytics. Acquiring physician and administrative buy-in early in the process of implementing a new model is essential. These issues are also represented in the “process map” and “collective buy-in” branches of the project map (see appendix).

Appendix I

Feature engineering results:

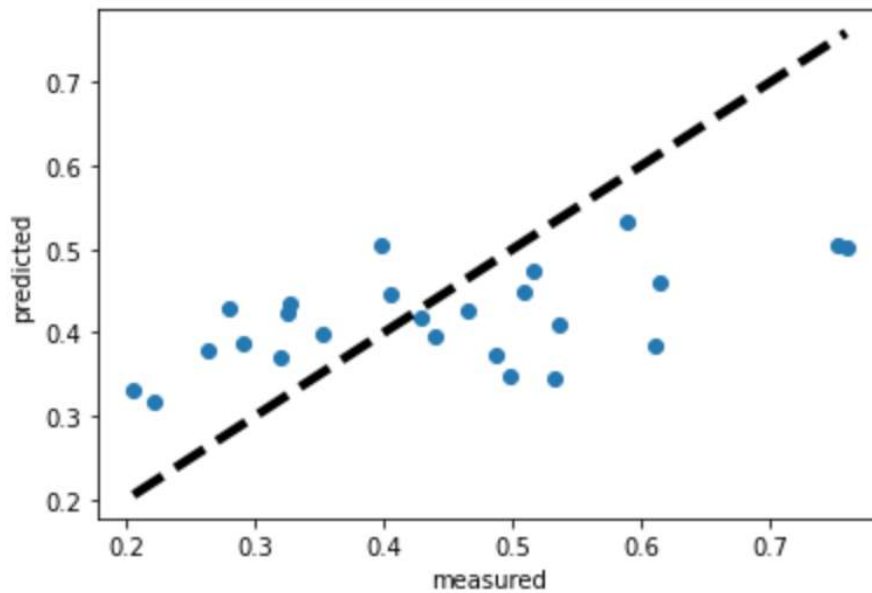
	Specs	Score
	Weight_(kg)	5.821647
	Alcohol_>= 8 drinks/week	5.056479
	Alcohol_2-7 drinks/week	4.119328
	Entry_Hour	3.602874
Chronic_Lung_Disease_Lung disease documented, ...		3.469041
	BMI	3.352550
	Tobacco_Use_Never smoker	3.070256
	Diabetes	2.756282
	Tobacco_Use_Former smoker	2.392849
	Family_History_Premature_CAD	2.365852

Appendix II

Model Accuracy:

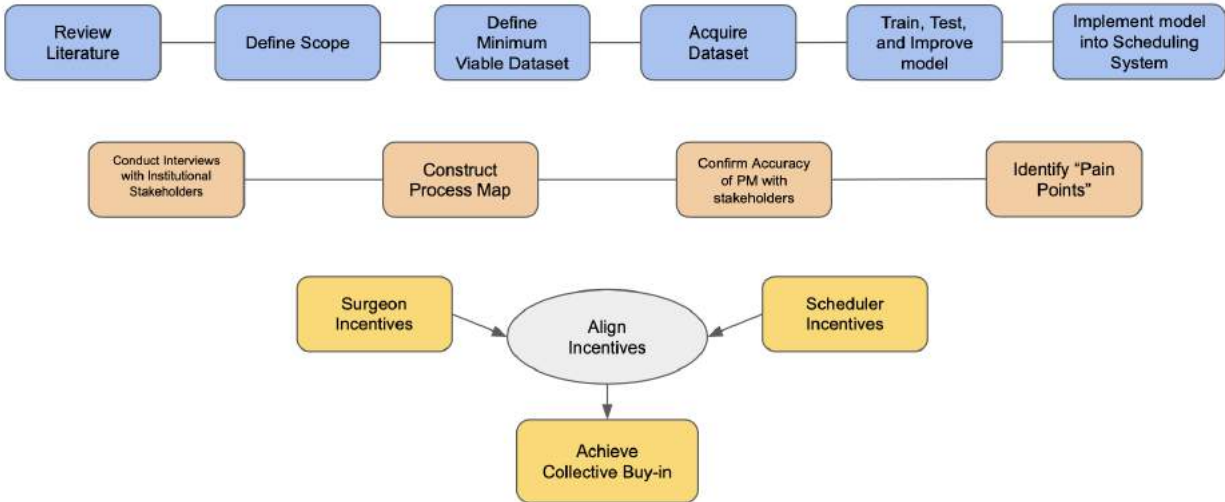
Mean squared error: 0.02

R²: 0.25



Appendix III

Project Road Map:



Analysis of the Operational Failures to Address Covid-19

Namya Elsa Thupili | Spring 2021

Abstract. This paper discusses the failures of the existing healthcare system to respond to corona virus from an operational standpoint. The failures were detected and represented using a root cause analysis and these failures are further broken down into a granular level and are further analyzed and the respective recommendations are provided for every failure. Assessing the risk for all the failures helped identify the major failures that require utmost attention. They are staffing shortages, long order fulfilment times of the equipment, Insufficient supply of equipment, healthcare personnel reusing PPE, unable to handle overwhelming patient numbers and the staff's fear of contracting the virus. The recommendations section in the paper highlights what steps are needed to be taken to mitigate these failures.

Background

When the pandemic was at its peak in April 2020, I volunteered to help retrofit Laurel Regional Hospital one of the hospitals ordered by the state of Maryland to reopen. My experience at Laurel led me to think about addressing some of the failures that hospitals faced during the pandemic. There were many problems in the limelight at that time so I decided to explore the problems and study them. I began to analyze what caused these failures, what are the potential impacts, and what measures can detect these failures. I chose to develop a fishbone analysis that could help me list out the failures and analyze them using a tool called Failure Modes and Effects analysis.

Methodology

The Ishikawa diagram was developed to list out the failures that would be used to analyze and provide recommendations. This diagram depicts the causes and effects of the failures and using the FMEA tool every failure is analyzed. It is concluded that using the fishbone and the FMEA tool is a way to analyze the issues that contribute to the fish head and formulate recommendations. The different categories of the fishbone that represent these failures are as follows.

Process

- Failure to enforce quarantining for patients at the hospital (Jewett, 2020)
- Delays in inter/intra hospital transfers (Ali, 2020)
- Nurses are not being tested on a regular basis (National Nurses United, 2020)
- Delays in information exchange (Schaye et al., 2020)
- Reusing PPE and putting healthcare workers at risk (Castellucci, 2020), (The Guardian, 2020)

Organizational failures

- Lack of working as teams and following accepted protocols (Schaye et al., 2020)
- Lack of resources to tackle Covid-19 patients (Abelson, 2020)
- Unable to handle overwhelming numbers of patients (Weber & Rankin, 2020)

- Overburden on telehealth (Farr, 2020) Environment
- Failure to sanitize all surfaces leading to spread (Caserta, 2019)
- Insufficient negative pressure rooms contributing to spread (Schaye et al., 2020)
- Failure to combat cross contamination (Gold & Evans, 2020)

Staff

- Not having enough staff to provide care (Goldhill, 2020)
- Physical and emotional drain of healthcare workers (Kulkarni et al., 2020)
- Unable to train new staff quickly (Nestor Harper, 2012)

- Strain on ICU Staff (Al Thobaity & Alshammari, 2020), (Teriakridis et al., 2021)
- Staff afraid to contract the virus (Modern Healthcare, 2020)

Equipment

- Insufficient supply of equipment (Ventilators & PPE) (Ranney et al., 2020)
- Damaged equipment received from stockpile (Sanger et al., 2020)
- Long order fulfilment times (Health Industry Distributors Association, 2020)

The fishbone used for the analysis is depicted below:



The fishbone is a cause and an effect diagram, and it helps list out all the failures with the help of brainstorming or evidence from researching the published content that contributes to the fish head. The Five Whys logic has been used and every branch is supported by published evidence that contributes to the failures. A general fishbone has several divisions called as the limbs of the fishbone which have been supported by published literature.

The limbs that were considered are Equipment, Staff, Organizational, Process, and the

Environment. The regulations have not been dealt with for the purposes of this project and are treated as out of scope, but if studied one could include the limb develop an analysis for the same. It is logical to identify the different failures using a fishbone and develop the analysis for those failures using a tool called FMEA. The sequence used to tackle the failures (which is the fishbone first and then the FMEA) is important and follows a logic that enables us to comprehend every failure at a

granular level and provide recommendations for every failure.

There are three pieces to this project. The first one is the identification of the failures or listing out the failures which is done using the fishbone and the second part is analyzing the failures which is done using the FMEA tool. This tool not just helps in providing the analysis and recommendation but also helps to assess the priority that needs to be followed while addressing every failure. The intensity of a failure could be judged using the scoring system in the tool.

This project is targeted for hospitals and the main audience is the hospital's COO. Every audience that sees this paper looks for it with a need. It could be staffing issues, it could be equipment issues, how to deal with increase in hospitalizations and how to address technology issues when there are overwhelming numbers and how best to respond and how the United States has been responding. The RPN or the risk priority number helps in giving an assessment of how severe, frequent and detection of the failure has been. This enables the reader to understand and gauge for what situations and on what conditions are these numbers reliable and useful.

Results

With the help of a detailed analysis in the FMEA tool every failure scored a unique RPN (risk priority number). A high score of risk (≥ 100) implies that attention is needed to be given to the failure with a high risk and it helps in prioritizing the sequence of tasks to be followed. In the analysis it is inferred that by populating the FMEA and assessing the severity, occurrence, and detection.

- Insufficient supply of equipment-128
- Reusing PPE and putting healthcare workers at risk - 128
- Not having enough staff to provide care-

112 Long order fulfilment times- 112

- Unable to handle overwhelming numbers - 112
- Fear of contracting the virus (Staff)- 100

The lowest score is the delay in information exchange. These are the scores without the intervention and once the intervention was in place the RPN changed but not to a very large extent. The initial RPN computed without the intervention or the mitigation steps is taken into consideration.

Discussion

The FMEA helped to list the failures, helped analyze the impact, causes and detection, and consequently recommend the potential solutions for the failures and assess where the country is with implementing actions that mitigates the failures. The thought process involved to guess the impact is what has happened after encountering the failure. Contrastingly, the cause of the failure is what is the reason behind the occurrence of the failure. After rigorous brainstorming and assessing ways that can help with the detection of the failure, a consensus was reached via discussion that the detection of a failure is an alert or a metric that helps identify what could help us measure the failure.

There could be various viewpoints for the score, considering the failure physical and emotional drain of healthcare workers when a healthcare worker is stretched beyond his/her capabilities (See Appendix) there is a likelihood of a medical/medication error to occur this might not be very prevalent during the normal scenario but during the pandemic there were significant amount of staff shortages, so the regular working staff had to work overtime due to the increase in the number of patients. The cause of this failure to occur is working

overtime and seeing a number of patients dying and a constant fear of contracting the virus.

The metric used to detect the failure could be the rate of medical errors increasing and the number of patients dying. I scored an 8 for severity and a 5 for occurrence and 2 for detection. The 8 for severity is due to the likelihood of death involved when such errors occur and due to the lack of a proven treatment for covid-19. The 5 for occurrence is because it is not very prevalent that the deaths are caused by medical/medication errors. The detection is a 2 because the number of deaths is easy to detect. A successful doctor might score low for both severity and occurrence because there might not be a likelihood of death when the staff is burned out. The scoring of the FMEA is highly subjective and this is a known limitation of the tool. One might achieve a consensus with the help of discussion or computing the average of the scores. This paper has the scoring of a subject matter expert who with the help of his experience in the industry has scored the failures (See Appendix)

Recommendations

There are separate recommendations for every row of the FMEA.

Under the staff limb the recommendations are as follows:

- Not having enough staff to provide care- Understand the staffing needs, be in communication with local health coalitions in federal, state, local public health partners to identify additional HCP, recruiting retired HCP, protect existing staff members from the virus by providing adequate PPE, reassign staff that are not occupied (Elective Surgery staff) (CDC, 2020a)
- Physical & emotional drain of healthcare workers- Communicate with co-workers

about the stress, recognize that the staff is playing a crucial role with the available resources, keeping a consistent daily routine, exercising & breathing exercise, Spending time outdoors, taking a break from watching and listening to the news (CDC, 2020b)

- Strain on the ICU staff- Creation of staffing pools, taking help from external agencies to increase the staff available, construction of teams to ensure sufficient expertise within a team (Schaye et al., 2020)
- Unable to train new staff quickly- Implement crisis standards of care plans as to determine who gets care when the resources are scarce (Miceli, 2020)
- Fear of contracting the virus - Redeploy perioperative services staff to provide front line care, remind employees about the available benefits and roster them in flexible shifts (SHRM,2020)

Under the equipment limb the recommendations are as follows:

- Insufficient Supply- Understand current inventory and supply chain, understand the current utilization rate and be in communication with local health coalitions, federal, state and local health partners to identify supplies (CDC, 2020c)
- Damaged equipment received from the stockpile- Tending to order supplies from local vendors to compensate for the shortage (Mehrotra et al., 2020)
- Long order fulfilment times - Tending to curbside pickup for local orders and shipping orders from stores, keeping more inventory on hand, nearshoring manufacturing, deploy flexible order picking strategies (Korosec, 2020).

Under the environment limb the recommendations are as follows

- Failure to combat cross-contamination- Using hand sanitizer frequently, wearing

adequate PPE, laundry of soiled linens should be done separately, using disinfectant sprays and wipes (Memic, 2020)

- Insufficient negative pressure rooms contributing to the spread - Collaborate with other hospitals that can help with contributing to the lack of negative pressure rooms and transform rooms to accommodate negative pressure and continuous oxygen monitoring needs. (Schaye et al., 2020)
- Failure to sanitize all surfaces leading to spread- Perform intensive environmental cleaning, implement a color code system for cleaning the surfaces such as high risk, medium risk and low risk areas, determine what needs to be cleaned and how areas will be disinfected, consider the resources needed and implement the cleaning protocols (Higgins & Dunn, 2020)

Under the organizational limb the recommendations are as follows

- Unable to handle overwhelming patient numbers- Diverting the patients to other facilities that have opened especially for the covid patients (Adinaro, 2020)
- Lack of working as teams and following accepted protocols - Working as teams and following accepted protocols and collaborating and working as teams is needed.
- Overburden on telehealth - Engineers could work to make the platform more resilient and perform constant health checks to make the platform able to handle high volumes of calls (ASPA, 2020)

Under the process limb the recommendations are as follows

- Reusing PPE and putting healthcare workers at risk- providing adequate PPE for healthcare workers and keep them from reusing PPE.

- Nurses are not being tested on a regular basis- Testing HCP with and without signs and symptoms of the virus should be done. Even the HCP that has not been in close contact or not exposed to the virus should be tested (CDC, 2020d).
- Delays in inter/intra hospital transfers- Systems should be in place for identification of transfers and handoffs & there should be dedicated respiratory and non-respiratory areas of the ED (Schaye et al., 2020)
- Failure to enforce quarantining for covid patients at the hospitals- Give detailed instructions to the positive cases at the hospital to follow the quarantining rules and ensure that they are enforced and followed by the patients and staff (Moroti, 2020)
- Delays in information exchange Develop multimodal communication strategies and tailor strategies to the needs of the staff; Communicate within affiliated hospital systems and colleagues at other institutions (Schaye et al., 2020)

Conclusion

I picked the pandemic as a reference for building this project. We might not face a similar pandemic, we could face something worse or something different. The logic and the approach used for this project will apply to even such pressing emergency situations. A fishbone could be developed which has all the failures incorporated in it and consequently a FMEA could be done to analyze the failure as to why it occurred, what are the controls we have over it and how can the problem be addressed at a granular level and how can the problem be handled. It is possible to formulate new recommendations or incorporate some of the existing recommendations from rows like insufficient supply of equipment. This is a common issue that was faced by most industries due to the international restrictions

in place. I dealt with the healthcare (particularly hospital) aspect of the issue. This could be applied universally to all industries and not just healthcare. This paper succeeds in highlighting the key failures involved in making a hospital to become a competent player to combat a national public health emergency and the recommendations consequently. One could assess the order of priority given to address these failures using the FMEA tool and become better equipped to deal with such biological disasters.

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Appendix 1

The FMEA tool

Column A talks about what is the process/step or feature under investigation- The first column contains the specific branch of the fishbone under investigation which is the mode under examination. The main title of the limb is depicted as the process or the feature under investigation.

Column B consists of in what ways could a step change or the feature to go wrong- The way a step could go wrong is in other words called the failure which is the name of the sub-branch in the fishbone that is under investigation.

Column C talks about what is the impact on the customer if the failure is not prevented or corrected? The impact of the failure (in column B) is identified and listed.

Column D talks about the severity which is rated on a 1-10 scale (1- low severity & 10- highly severe)

Column E talks about what causes the step to change or the feature to go wrong? (how could the failure occur)- the cause of the failure in column B is listed.

Column F talks about the occurrence which is rated on a 1-10 scale (1-least frequent & 10- most frequent)

Column G talks about what controls exist that prevent or detect the failure- The controls that are stated are the metrics or the alerts that detect the failure.

Column H talks about the detection which is rated on a 1-10 scale (1- easiest to detect & 10- toughest to detect)

Column I talk about the RPN or the risk priority number which is the multiplication of the three columns which is the severity, occurrence, and detection ($I=Severity*Occurrence*Detection$)

Column J talks about the what are the recommended actions for reducing the occurrence of the cause or improving detection around the world and in the US- The recommendations that are recommended to combat the failure and keep the failure from occurring or what needs to be done when such a failure is encountered is listed.

Column K talks about who is responsible to make sure the actions are completed? - The concerned stakeholders who are responsible to ensure the actions are completed are listed below.

Column L talks about what actions are completed with respect to the RPN in the US? The concerned actions that were taken in the US are listed below.

Appendix-2 : FMEA

Process description	Potential failure mode	Potential Failure Effects	Severity (1-10)	Potential causes	Consequence (1-10)	Control controls	Residual risk (1-10)	Risk Assessment	Plan	When complete	When	When	When	When	When	When	When	When	When	
Staff	Not having enough staff to provide care	If this failure is not prevented or corrected there would be no staff to care for the patients admitted to the hospital when they arrive or the staff would be unable to care for the patients to die	6	The staff available are not sufficient for the number of patients coming to the hospital. In other words, there could be an imbalance in the supply and demand. The staff could be stretched for time or there could be fear of contracting the virus that keeps them from showing up at work	7	Expected demand of the staff is greater than the available demand of staff. Decrease in available staff due to production staff requesting for sick leaves and vacation breaks	1	11	Understand the staffing needs, be in communication with local health facilities to inform, state, local or public health partners to identify additional HCP, recruiting retired HCP. Prohibit visiting staff members from the vicinity providing adequate PPE. Assign staff that are not occupied (in the surgery staff)	Hospital Management, IT recruitment is done at a national state or local level for the federal, state or local decision. Nurses would be involved	1	2	3	4	5	6	7	8	9	10
Organizational constraints	Unavailability health care services	Patient wait times increased and hospitals runs at full capacity	8	The virus spreading at a rapid exponential rate	9	The number of patients waiting to be seen by the doctor at a hospital	2	11	Directing the patients to other facilities that have opened up essentially for the covid patients	Hospital management staff	1	2	3	4	5	6	7	8	9	10
Organizational weaknesses	Overstressing on the system	The system experienced occasional crashes	7	High volume of patients using telehealth	8	The number of overstuffed computers and the number of customers that have long wait times	3	10	Engineers could work to make the platform more resilient and perform constant health checks to make the platform able to handle high volumes of calls		1	2	3	4	5	6	7	8	9	10
Process	Not having PPE and putting healthcare workers at risk	Healthcare workers could contract the virus with not adequate PPE or reusing them	8	Lack of enough supplies of PPE	9	Limited supply (the number of PPE available) and the number of positive cases increasing everyday. Demanding PPE to be used on a daily basis	3	10	Provide adequate PPE for the healthcare workers and keep them from reusing PPE	Hospital management	1	2	3	4	5	6	7	8	9	10
Process	Nurses are not being tested on a regular basis	Nurses could be potential carriers of the virus and spread it to the patients they treat and their co-workers	8	The hospital busy with patients and nurses having to work overtime	9	The number of nurses that test positive, tracking the number of nurses that haven't been tested and testing	3	10	Testing nurses on a regular basis	Hospital management	1	2	3	4	5	6	7	8	9	10
Process	Delays in lab/testing hospital transfers	This delay could delay testing up to a day for a critical patient and could cause them to die	8	Backlog of computational staff	9	Number of cancelled transfers due to lack of beds, increased wait times (duration of the request transfer is more than normal)	3	11	Systems should be in place for identification of transfers and hospital staff	Hospital Management	1	2	3	4	5	6	7	8	9	10
Process	Failure to enforce quarantining for covid patients at the hospital	The patients that are positive could spread the virus to the hospital staff by not following the rules	7	The patients not following the rules or are unaware of the rules	8	The HCP being cases of the covid patients had a positive	4	10	Give detailed instructions to the positive cases at the hospital to follow the quarantining rules and ensure that they are enforced and followed by the patients and staff	Hospital staff and individual self	1	2	3	4	5	6	7	8	9	10
Process	Delays in information exchange	The right treatment would be delayed leaving the patient to lose his life	8	The pace of changing information	9	The number of wrong cases	2	10	Develop multilateral communication strategies and follow these strategies to the needs of the staff. Communicate within different hospital systems and delegates at other facilities	Hospital Management	1	2	3	4	5	6	7	8	9	10

Appendix-3 : FMEA (Subject Matter Expert)

Prevention	Control	Response/Recovery	Severity (S)	Prevalence (P)	Detection (D)	Control (C)	Residual (R)	Overall Risk	Control Measure	When	When Done	Severity (S)	Prevalence (P)	Residual (R)	Overall Risk		
When the critical step change happens, what happens?	Is there any backup plan in place for this step?	What is the impact on the patient if this step is not completed as intended?	1	1	1	1	1	1	What are the resources available to ensure the recovery after a step change?	When resources are being used to ensure the recovery?	What actions are completed and when will resources be used?	1	1	1	1		
Staff	Not having enough staff to provide care	If this failure to full protected there would be no staff to care for the patients admitted to the hospital which might cause delay in care or no care causing the patients to die	1	1	1	1	1	1	<p>Identified demand of the staff is greater than the available staff due to positive test results staff reporting for sick leave, and vacation breaks</p> <p>Understand the staffing needs, be in communication with local health conditions in federal, state, local public health partners to identify additional staff, recruiting retired NCP</p> <p>Protest asking staff members from the city by providing alternate PPE</p> <p>Recruit staff that are not associated (Director Surgery staff)</p>	Hospital Management	Staffing staff have been secured by expanding traveling nurse contracts, paying extra shift bonuses, canceling planned time off	1	1	1	1	1	1
Staff	Physical & Emotional State of Healthcare workers	Medical/Infectious services more likely to occur	1	1	1	1	1	1	<p>Working overtime, being the failure of treatment, being high number of patients dying</p> <p>Risk of Medical Errors, Number of patients dying increases</p> <p>Communicate with (colleagues) about the times</p> <p>Recognize that the staff is playing a crucial role with the available resources</p> <p>Having a consistent daily routine</p> <p>Exercising & breathing exercises</p> <p>Opening time outdoors, taking a break from walking and listening</p>	Individual Staff members and also the Hospital management in a certain	Providing adequate amount of PPE, Rest, nutrition and catering flexible staff and providing mental health support	1	1	1	1	1	