**3D LUNG VOLUME CALCULATION FOR SCOLIOSIS**

**BARRIERS TO HEALTHCARE FOR THE MARSHALLESE IN NORTHWEST ARKANSAS**

An Undergraduate Thesis Portfolio
Presented to the Faculty of the
School of Engineering and Applied Science
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By

Sam Schach

May 6, 2021

**USING CONVOLUTION NEURAL NETWORKS TO MODEL LUNG VOLUMES FOR SCOLIOSIS**

**BARRIERS TO TREATING TUBERCULOSIS WITHIN NORTHWEST ARKANSAS'S MARSHALLESE POPULATION**

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By
Sam Schach

November 2, 2020

Technical Project Team Members

Tony Albini
Will Farley

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed Sam Schach Date: 11/1/20

Approved: Date:
Dr. Keith Bachmann, Department of Orthopaedic Surgery

Approved: Date:
Catherine D. Baritaud, Department of Engineering and Society

Some groups have fallen between the cracks in the US health care system. Often these groups face unique barriers to treatment, and the standard of care and health care infrastructure is not created with these groups in mind. Physicians are often put in a difficult situation when they are determining the proper standard of care for early onset scoliosis (EOS) patients. In order to determine if spinal fusion surgery should be performed, accurate measurements of the patient's total lung capacity (TLC) are needed. If spinal fusion surgery is performed before lungs have sufficiently developed, then patients can develop restrictive pulmonary disease. Currently, some patients with early onset scoliosis (EOS) have trouble complying with the current methods of measuring lung volume. These patients are either too young or may be disabled, as the large majority of neuromuscular scoliosis cases are associated with cerebral palsy (Murphy & Mooney, 2019, p. 225). Using X-ray images will provide a novel method for calculating TLC and allow physicians to better serve young children and those experiencing disability.

The STS research is loosely coupled to my technical project as it also focuses on an underserved population. The Marshallese community in Northwest Arkansas has been disproportionately affected by tuberculosis (Rothfeldt, 2016). The research will use Actor Network Theory to explore the barriers that the Marshallese face when seeking tuberculosis treatment (Law & Callon, 1988, p. 285). The Gantt chart presented in Figure 1on page two displays the projected timeline for both the STS research paper and technical project.

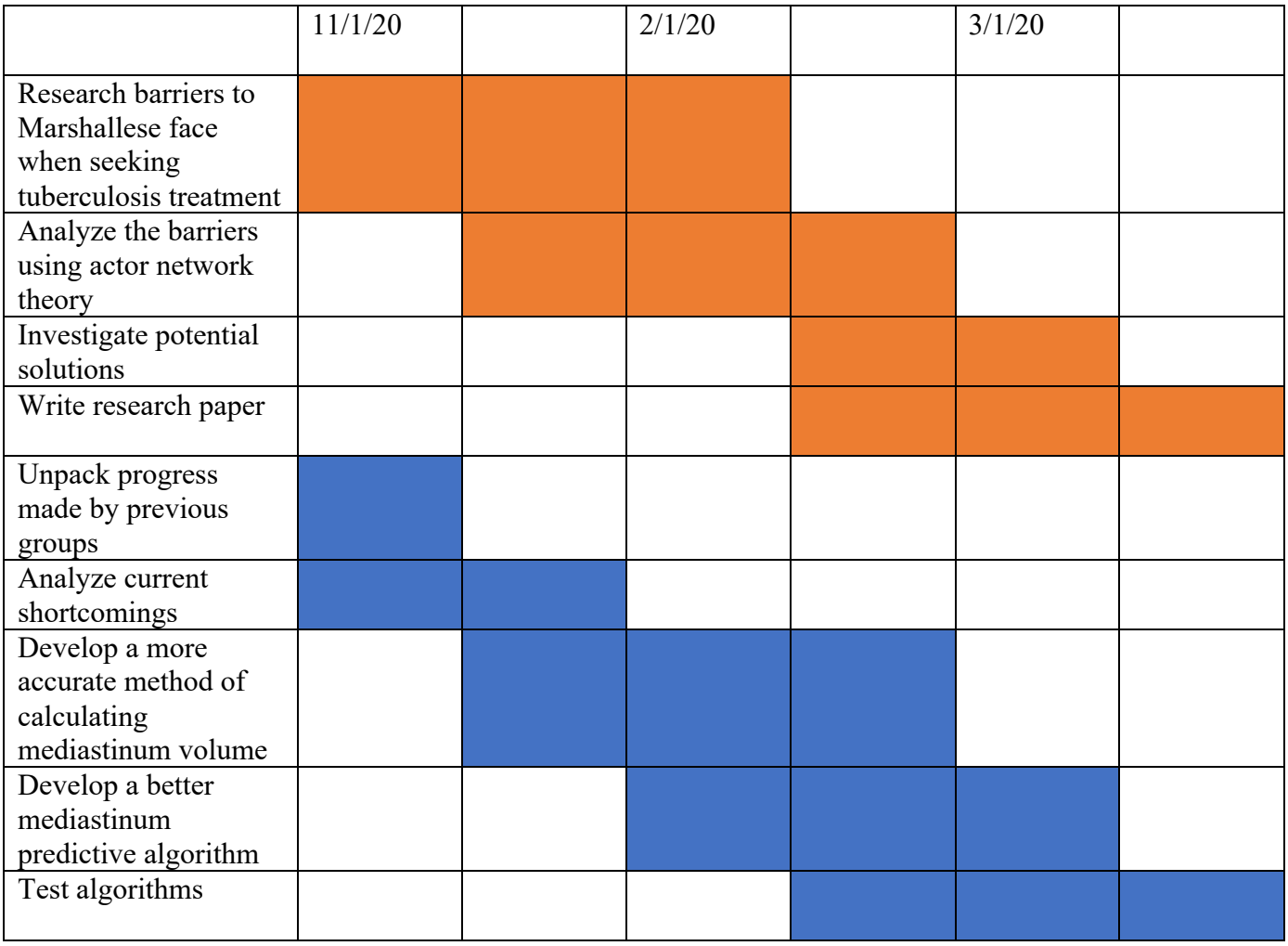


Figure 1: Timeline for STS Research and Technical Project. A rough timeline of expected progress is provided. The STS research paper timeline is shown in orange and the technical project is in blue (Schach, 2020).

## THREE-DIMENSIONAL MODELING OF LUNG VOLUME FOR SCOLIOSIS

Biomedical engineering students Tony Albini, Will Farley, and I are working under Dr. Keith Bachmann from the department of orthopedic surgery to improve health care for a currently underserved community. Specifically, patients who have early onset scoliosis (EOS) and face barriers when determining the proper standard of care. EOS is a spinal deformity that presents itself before 8-10 years of age (Skaggs et al., 2015). The four types of EOS

are idiopathic, congenital, neuromuscular, and syndromic (Blanco, 2018). Idiopathic scoliosis has no known cause. Congenital scoliosis is present at birth. Neuromuscular scoliosis is caused by a systemic condition such as cerebral palsy or muscular dystrophy. When scoliosis is part of a larger condition, such as Marfan's Syndrome, it is called syndromic scoliosis. While the overall prevalence of EOS is unknown, scoliosis has an incidence of two to three percent of the US population (Beauchamp et al., 2019, p. 291; Scoliosis – Symptoms, Diagnosis and Treatment, n.d.) Although EOS is a rare condition, a treatment plan needs to be created for each patient. If left untreated, EOS can bring about an early death due to pulmonary complications (Skaggs et al., 2015).

**CURRENT TREATMENT METHODS AND INDICATIONS**

Non-surgical options are often initially used to treat EOS to slow progression of the disease (Cunin, 2015, p. 112). A common surgical option is spinal fusion, which corrects the spinal deformity and curvature seen in scoliosis patients. An incision is made in the patient's back and their muscles are moved away so that the spine is exposed (Spinal Fusion Surgery for Scoliosis, n.d.). As seen in Figure 2, two metal rods are then placed alongside the vertebrae forcing it to straighten ("Spinal Fusion for the Treatment of Idiopathic Scoliosis in Children", 2009). If this procedure is performed too early, the patient can develop restrictive pulmonary disease (Karol, 2011, p. 1327). For this reason,

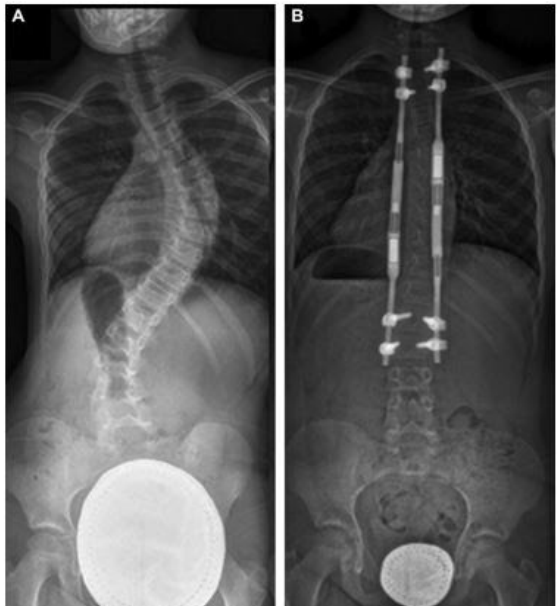

Figure 2: Spinal Fusion X-rays. A shows an X-ray before spinal fusion and B shows the results of spinal fusion surgery (Beauchamp et al., 2019, p. 299).

spinal fusion is not a routine procedure at a young age. In order to proceed with this surgery, it is crucial to

determine the total lung capacity (TLC). TLC allows the physician to determine if the patient will have proper pulmonary function after spinal fusion surgery. Two common methods for measuring TLC are spirometry or pulmonary function testing (PFT), and computed tomography (CT)(Delgado & Bajaj, 2020). However, there are drawbacks to these methods. It is difficult for young children or those experiencing disability to perform the PFT properly, due to the specific commands that have to be followed during the test. CT scans also have multiple drawbacks. They are relatively expensive, subject patients to roughly 300 times the amount of radiation of an X-ray, and children with disabilities may require a sedative to sit still for the duration of the scan (Kilbaugh et al., 2010, p. 5; Mettler et al., 2008, p. 356).

**USING CHEST AND MEDIASTINUM VOLUME TO DETERMINE TLC**

This project will investigate the hypothesis that sagittal and coronal X-ray images can be used to calculate TLC. While X-rays may not be able to identify the lungs, they do display the rib cage. If the volume of the mediastinum, the central portion of the thoracic cavity that is not the lungs, is subtracted from the volume of the chest cavity, TLC can be calculated. By comparing the similarity of our calculations of TLC from X-ray images to TLC calculated from CT scans, we will be able to explore a method for calculating TLC in a patient population that currently faces many barriers. The time needed to take an X-ray is much shorter than a CT scan, so patients with disabilities will not need to be sedated. Further, the patient's risk from radiation and their monetary costs would be limited. This would reduce burden on patients and allow physicians to better determine the potential risk before performing a spinal fusion. Determining

the TLC from X-ray images would provide a novel solution for deciding if surgical intervention is an acceptable treatment option.

## USING X-RAYS TO CREATE A 3-D MODEL OF THE RIB CAGE

Our goal is to use a convolution neural network (CNN) to determine TLC from bi-planar X-ray images. CNNs excel at identifying objects from images and classifying them. As seen in Figure 3, CNNs have been used to identify the rib cage from X-ray images in the coronal plane (Wessel et al., 2019, p. 2). We hope to also identify the rib cage from X-rays in both the sagittal and coronal plane so that a 3-D model of the rib cage can be computed. This will allow us to calculate the volume of the chest cavity. The two components within the chest cavity are the lungs and the mediastinum. The mediastinum is the area between the lungs, and it consists of the heart, thymus gland, esophagus, and trachea. We plan to create an algorithm to predict the volume of the mediastinum from patient demographics. Mediastinum volume will be subtracted from the volume of the chest cavity thereby calculating TLC. In a scholarly article, we will compare our method for calculating TLC to TLC calculated from CT scans to determine how accurate our model is.

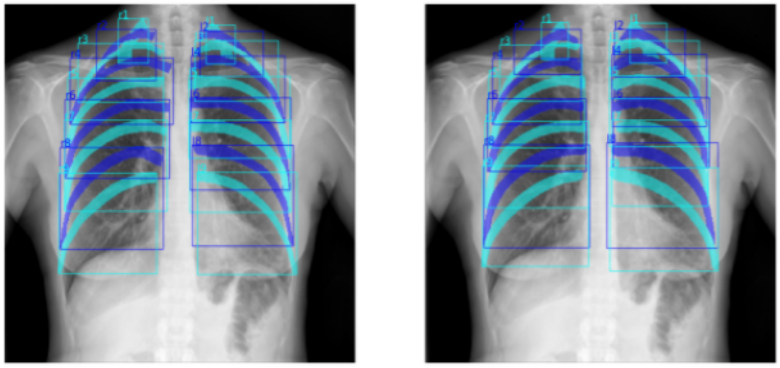

Figure 3: CNN Identification of Ribs. Ground truth rib labeling is shown on the left and the results of the CNN network are on the left (Wessel et al., 2019, p. 3).

## BARRIERS TO DISTRIBUTING TUBERCULOSIS MEDICATION TO THE MARSHALLESE IN NORTHWEST ARKANSAS

Healthcare inaccessibility is often looked at through the lens of medical deserts. Medical deserts are analogous to food deserts, and they are characterized by a lack of access to medical care. The level of access a population has to medical care is measured by the number hospitals, physicians, or some other tangible aspect of medical care within a specified radius from the patient (Carr et al., 2017, p. 335; Saslow, 2019; Tung et al., 2019, p. 3). Often these areas are rural, and there could be only one doctor within 11,000 square miles (Saslow, 2019). Urban areas can also be deemed as medical deserts and may disproportionally affect minorities. Tung et al. (2019) found that urban medical deserts in Chicago and Los Angeles were more likely to happen in majority black census tracts than majority white census tracts (p. 10).

Medical deserts provide a narrow lens to view the accessibility of healthcare. By focusing solely on the existence of medical care within a specified radius of the patient, the concept of a accessibility is severely narrowed. A population may reside in area with nearby hospitals or physicians, but the presence of medical services alone does not make them accessible. A population can experience a medical desert even with nearby hospitals and physicians. This will be illustrated by examining the spread of tuberculosis within the Marshallese population of Northwest Arkansas (NWA).

## TUBERCULOSIS IN NORTHWEST ARKANSAS

Springdale Arkansas is home to the largest population of Marshallese islanders in the continental United States (Pearl A. McElfish et al., 2019, p. 3). Many of the Marshallese live within Washington County in Springdale, Arkansas (A. Brown, n.d.). Pacific islanders, including the Marshallese, are estimated to make up 2.8% of Washington County's population (U.S. Census Bureau QuickFacts, n.d.). Although the Marshallese account for a very small amount of the population, they made up 79% of all tuberculosis cases in Washington County in a 2016

study (Rothfeldt, 2016). Furthermore, a survey found that only 46% of Marshallese had a primary care physician which is much lower than the national average of 75% (Pearl Anna McElfish et al., 2016, p.3; Norton, 2019). A map of the Washington County's Marshallese population was generated using data from the US Census Bureau, and it showed that the majority of Marshallese within Washington County live within a five-mile radius of a medical center (https://rb.gy/ywnpny). Despite close proximity to medical centers, the Marshallese are still an underserved community. As shown in Figure 4, other factors could influence the Marshallese population's access to health care. By expanding on the concepts of a medical desert, gaps in accessibility can better understood.

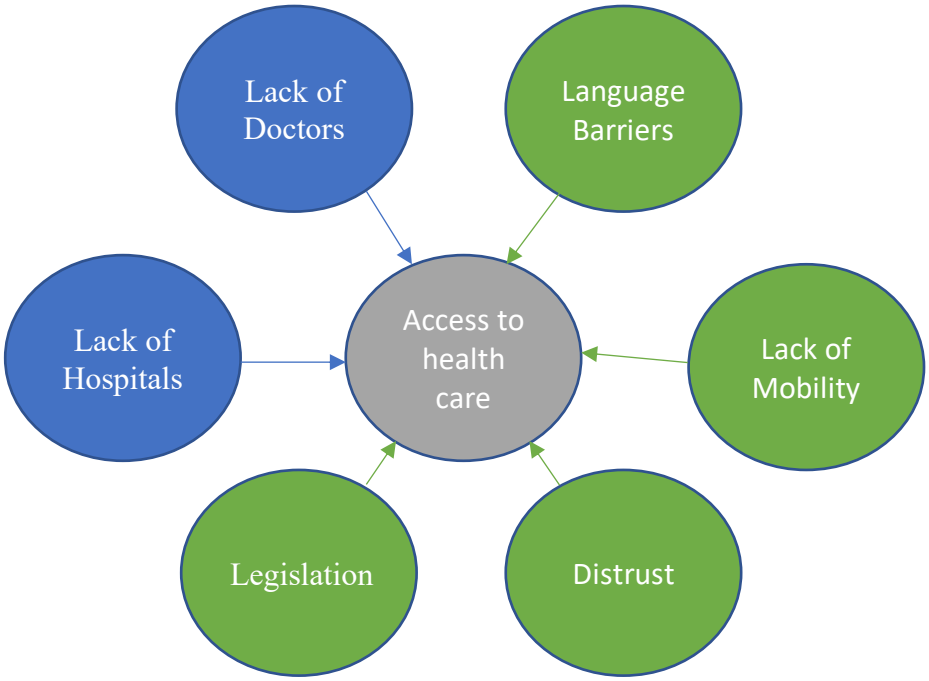


Figure 4: Factors That Can Negatively Affect Quality of Healthcare. The blue circles represent conventional causes of a medical desert, while the green circles represent other factors that could contribute to a lower quality of healthcare (Schach, 2020).

## USING ACTOR NETWORK THEORY TO BETTER SERVE THE MARSHALLESE

The STS project will examine the barriers to treating tuberculosis in the Marshallese community. As shown in Figure 5, actor network theory will be used to examine the challenges in distributing tuberculosis medication to the Marshallese.

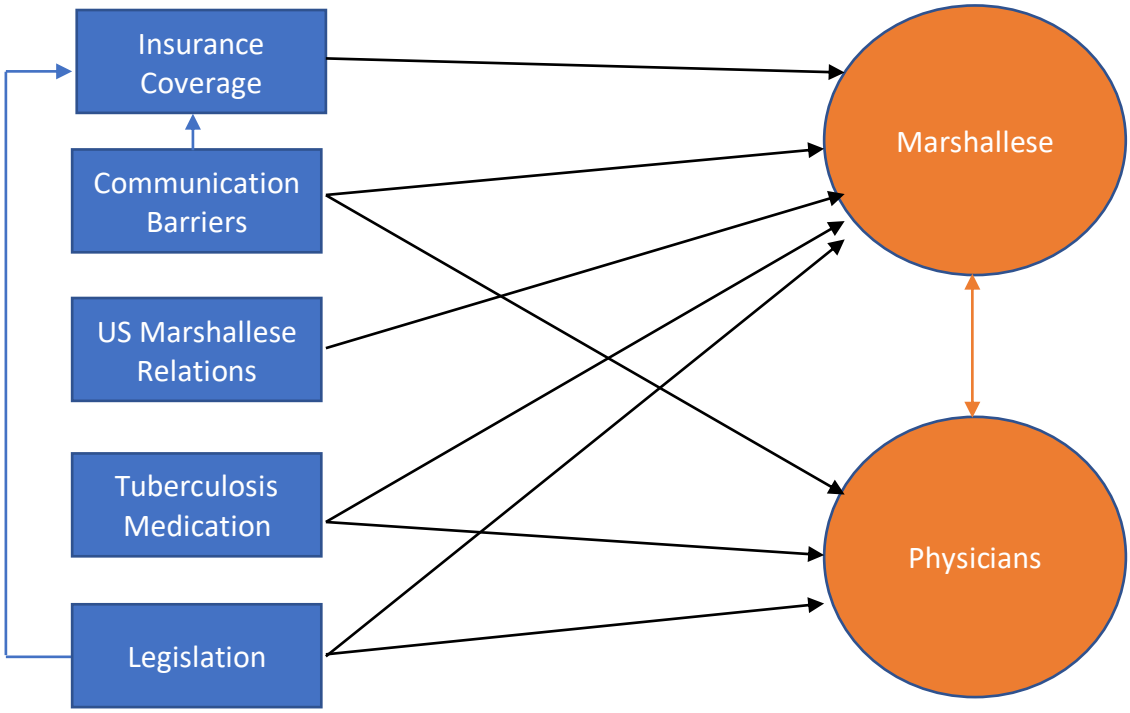


Figure 5: Actor Network Theory Applied to the Distribution of Tuberculosis Medication to the Marshallese Community. The blue rectangles represent actants, and the orange circles represent the actors. Blue lines represent the impact actions of actants have on other actants. Black lines represent impacts between actants and actors, and orange lines represent interactions between actors (Schach,2020).

A lack of healthcare coverage is a major barrier that stops many of the Marshallese from getting sufficient health care or tuberculosis treatment. A survey of the 394 Marshallese in Northwest Arkansas found 46% did not have any health care coverage (Pearl Anna McElfish et al., 2017, p. 1045). Many Marshallese are uncomfortable speaking English in a clinical setting and some medical terms have no direct translation into Marshallese (Williams & Hampton, 2005, p. 323). Marshallese were interviewed in focus groups organized by Ayers et al. (2019) and the

Marshallese vocalized the challenges they faced due to the language barrier: “We might know how to speak English, but the medical terms being used to explain the conditions by the doctors is like a puzzle waiting to be solved, but we are afraid to ask what the meaning of their terms are” (p. 150). Both the complex medical language and the Marshallese’s unease around doctors makes it difficult to foster trust and a strong doctor-patient relationship so that tuberculosis medication can be effectively administered.

Historic relations between the Republic of the Marshall Islands (RMI) and the United States have contributed to Marshallese distrust in the US government and medical system. From 1946 to 1958 the US detonated over 50 nuclear weapons over the RMI (A. L. Brown, 2014, p. 40). The US failed to educate the Marshallese on the dangers of nuclear fallout, and when ash began raining down from the sky, children tasted it and women used the ash as shampoo (Schwartz, 2012, p. 6). Because of this, the Marshallese were exposed to large amounts of radiation, and in response the US government began using the Marshallese to study radiation’s effects on humans and began treatment measures. (A. L. Brown, 2014, p. 41). However, the Marshallese were never asked to consent to the studies, and due to a lack of translators they were ill informed about the medication they were receiving. These negative interactions with the US and western medicine created the foundations of distrust that would later prove difficult to shake.

McElfish (2019) notes that in 1986, well after nuclear testing was completed, the RMI “became ostensibly sovereign” and entered a Compact of Free Association (COFA) with the United States (p. 2) . When the COFA was signed, the Marshallese were eligible for federal benefits such as Medicaid (Pearl Anna McElfish et al., 2016, p . 2). However, in 1996 the Personal Responsibility and Work Opportunity Reconciliation Act was passed and to this day COFA migrants are excluded from receiving Medicaid benefits (*Korab v. Fink*, 2012, p. 2; Pearl

Anna McElfish et al., 2016, p . 2).

This STS research project will be in the form of a research paper, and it will further explore the barriers to treating tuberculosis within NWA's Marshallese. The goal is to determine if the addition of a new actant or changes to communications between actors and actants could improve the Marshallese's accessibility to tuberculosis treatment.

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