

**Design of a Novel Umbilical Venous Catheter with Echogenic Distance
Markers for Increased Placement Accuracy**

(Technical Paper)

**Does Medicare Impact Mortality Rates: An Analysis of the Different
Insurance Coverages and the Impact on Neonatal Mortality Rates**

(STS Paper)

A Thesis Prospectus

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By

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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.

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Prospectus

Introduction

In 2020 the United States recorded the birth of over 3.6 million babies, and an estimated 9-13% were admitted to the neonatal intensive care unit (Pineda et al., 2023). Once admitted to the neonatal intensive care unit, commonly referred to as the NICU, the type of care that is offered to the neonate can be limited by the quality of insurance that the mother is under. This often leads to disparities in neonatal death rates, with one study citing that “uninsured neonates were 2.6 (95 percent CI: 2.4, 2.8) times as likely to die as were those with private insurance, Medicaid, Medicare or other expected primary or secondary payer.” (Morriss Jr., 2013). In addition, race often becomes a compounding factor impacting neonatal mortality rates. The health disparity seen between Black and White/Non-Hispanics for the risk of NICU admission is most evident among pregnancies covered by private insurance with more NICU admissions associated with women using public insurance than private insurance (de Jongh et al., 2012). This disparity is compounded by socioeconomic status (SES) which can be due in part to geographic location, employment status, as well as the neoliberalist economy of the United States.

Umbilical central lines are commonly used in the NICU to provide intravenous (IV) access when there is a need for resuscitation, transfusion, or other general venous access. Currently, umbilical venous catheters (UVC) are recommended for all infants delivered before 28 weeks of gestation, infants with impaired respiratory function, or those with hemodynamic instability (Lewis & Spirnak, 2024). In a 2014 study, there was a 76% incidence rate of infants born before 33 weeks, making the use of these catheters extremely high in preterm babies (Shahid et al., 2014). The current standard of care to visualize the location of the catheter is X-ray imaging, using the vertebrae as a reference point. However, this process is time

consuming and results in prolonged exposure to radiation, which is why increasing the echogenicity and using Point-of-Care Ultrasound (POCUS) is being investigated.

Technical Topic

The proper placement of the catheter within the inferior vena cava (IVC) is crucial to ensure adequate delivery of fluids; incorrect location of the catheter tip can lead to liver necrosis if placed into the portal vein, or arrhythmia and other heart issues if placed too high. Given the importance of proper placement, the location of the catheter tip must be verified before initial use and on a regular basis throughout its employment to ensure it hasn't shifted (D'Andrea et al., 2021). POCUS is a more efficient imaging method that could be used in place of X-ray to visualize catheter placement, offering more convenience and eliminating the risk of radiation exposure. However, most of the current umbilical catheters available on the market are not echogenic (visible on ultrasound scans). The primary goal of this project is to modify the currently available umbilical catheters to improve echogenicity and ultimately allow for more accurate umbilical catheter use. The modified design must be visible on ultrasound, match the standardized catheter scale, and maintain consistent flow, while adhering to standards of biocompatibility and durability. With such a large amount of neonates requiring UVCs and the importance of correct placement, increasing the ease in which they are correctly placed is imperative.

The current standard of UVC is composed of silicone, which does not effectively show up under ultrasound imaging. The echogenic catheter will have landmarks to mark specific distances from the tip of the catheter in case the tip is not in view of the ultrasound transducer. This will be achieved by a thorough inclusion of echogenic microspheres into the body of the

catheter at specific distances in order to visualize either the tip, or an accurate distance from the tip. Research on the visibility of other catheter types quantified their results using pixel intensity units (PIU) or the grayscale value. An ideal grayscale value is above 200 PIU, since it would be clearly visible and there is high contrast between the catheter and surrounding tissue. Studies regarding other catheter types showed that a grayscale value above 100 is generally classified as visible, so anything within 100-200 PIU will be considered a marginally acceptable value (Takatani et al., 2012). This will most likely be done through image analysis with the software ImageJ comparing ultrasound images of the standard catheter to the echogenic catheter.

Some of the other aspects of the original catheter that must be preserved are the size and the flow rate. Current umbilical catheters have a standardized outer diameter of either 3.5 or 5 on the French scale, which translates to 1.17 mm or 1.67 mm (Lewis & Spirnak, 2024). Therefore, the modified catheter must also have the same measurements to ensure compatibility with patient anatomy. The internal structure of the catheter needs to support the uninterrupted flow of the medicine, which will be tested through gravity flow rates. This is because the pressure and speed by which medicine is inserted into the catheter via a syringe can vary from physician to physician. The flow rate from the initial catheter should be preserved, but a flow rate 15% faster or slower will be considered acceptable, and we will compare this to the typical gravity flow rate of a 5 French catheter, 215 mL/min (*Flow Rates Through Catheters*, n.d.).

STS Topic

Insurance companies in the United States are notorious for treating their policies as a commodity which can be used for their profit, rather than granting people the right to medical care, which would be present in an ideal society. This is often because of Neoliberalist ideals in

our economy, which advocate for free markets, but in practice, have highly organized markets which require significant bureaucratic oversight (Birch, 2020). Birch emphasizes that neoliberalism involves deliberately designing quasi-markets to achieve desired outcomes, and in the concept of automated neoliberalism, this incorporates personal data and algorithms. This concept can be applied to insurance premiums, often costing the policyholder more due to comorbidities, which further monetizes healthcare. This may lead to mother's not being able to afford insurance, or even making insurance too expensive if they have a high risk pregnancy which may lead to a stay in the NICU for the baby. In addition to this, neoliberalist societies often discourage women from working due to shifting focus onto profit rather than social and inclusion issues and even privatizing social services, often causing women to feel as though they need to fill the gaps in child and elder care. This limits the access of job opportunities, especially high paying ones in which medical coverage is included.

Despite the United States being a well developed country, there still remains a large disparity between the neonatal mortality rate based on public or private insurance coverage. For instance, in the state of Texas which has adopted a Medicaid Managed Care Plan (MMC) over a Fee-for-Service (FFS) Medicaid, the disparity between Black and Hispanic infant mortality rate increases. After the transition, it was found that there was "an increase in mortality for children born to US-born Black mothers by 15 percent," whereas "mortality rates for Hispanic infants decreased by 22 percent" (Kuziemko et al., 2018). The MMC plan incentivized plans to prioritize care for the Hispanic patients ("lower-cost clients") since they typically had lower mortality rates and better birth metrics compared to the Black infants ("higher-cost clients") which had higher mortality rates and poorer birth metrics. This was because of perceived healthcare costs which often lead to suboptimal care for Black infants because they represent a

financial loss to the capitation payment system that provides uniform rates regardless of individual costs. The implementation of this new Medicaid program increased the Black-Hispanic mortality gap by 69 percent (Kuziemko et al., 2018).

When babies are delivered with specific health defects, their insurance level can greatly impact their survival rate due to the amount of treatment that is covered. For example, babies born with a congenital heart defect (CHD) and had minimal to no insurance had a mortality rate triple that of their privately insured counterparts (Kucik et al., 2014). This shows that the decrease in insurance levels can be a barrier to life saving medical care. In addition to assessing the neonatal period, the study also looks at the post-neonatal period, which often carries a great mortality rate for publicly insured babies rather than privately insured babies. The differences between treatment for babies under Medicaid and private insurance didn't stop there though. Despite having similar rates of respiratory issues such as apnea and bronchopulmonary dysplasia, neonates that were covered under private insurance were more often sent home with supplemental oxygen or apnea monitors (Brandon et al., 2009). Preterm neonates born to mothers covered by Medicare had worse outcomes and received different post-discharge care instructions compared to neonates that had private insurance despite similar health.

For many low-income families, they cannot afford full insurance coverage, they fall into a category known as underinsured. These families have insurance plans, but lack the funds to acquire more insurance for specialized care, which was not fixed by the Affordable Care Act (ACA). The ACA decreased the number of children who lacked insurance, but overlooked those that had fallen into the category of "underinsured," and increased this number in some places (Lakshmanan et al., 2021). Low income families with children with special health needs are also more likely to be underinsured than those with public insurance, which puts a large financial

burden upon them once medical bills begin rolling in, increasing anxiety levels within the family structure. For these low-income families one of the biggest supports is the participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) for these groups and the health and safety of their children (Moss & Carver, 1998). Lower income and uninsured families have the highest incidence rates of infant mortality, but often enrollment in the WIC program can help mitigate these effects due to access to social services during and throughout pregnancy, which should be highly considered if a family is underinsured.

Research Question and Methods

How does insurance coverage levels of the mother impact a neonates' survival rate, especially when coupled with socioeconomic status and race? In order to investigate this question, first a literature review is conducted in order to identify whether or not there is a disparity between insurance levels. Following this, papers that incorporate structures of power such as race, government, and socioeconomic status are identified and bridged to help understand what truly is impacting neonatal mortality rates. Papers were chosen that highlight a variety of geographic backgrounds while focusing mainly on the United States in order to investigate how the problem manifests itself in this country, and because of the unique health care system and economy overlap in the United States. Geographic location is important because it highlights how developed the medical care system is in the area, and can also lead to other financial factors such as high out-of-network copays and even travel costs for better, more specialized medical care.

Conclusion

Through exploring how insurance coverages impact neonatal mortality rates, it can be ensured that this new catheter being produced will be covered by all insurance types, private and

public alike. The price not covered under insurance should also aim to be reasonable so that in the case of uninsured neonates, they will be able to receive comparable care at an affordable rate. This will increase equity between coverage types and hopefully in the long run help lead to a decrease in mortality rate due to a better standardization of care. This new catheter should be able to be used on all neonates regardless of insurance level and should be similar in price to the standard catheter, if not lower to decrease medical costs as a whole, which will be taken into consideration when designing the prototype. Though not explicitly related, both the technical and STS aspect of this project aim to better understand and improve the outcome of neonates, especially those that are admitted to the NICU. The production of the catheter will give medical professionals more confidence in placing a UVC, which in turn will lead to better outcomes for neonates, allowing them to thrive more frequently.

Word Count: 2010

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