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A Non-Invasive Diagnostic Technique to Diagnose Bladder Outlet Obstruction Using IoT

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Abstract : Patients underwent the International Prostate Symptom Score (IPSS) questionnaire and had their prostate size assessed through transrectal ultrasonography (US). Additionally, pressure-flow studies were conducted to ascertain the urodynamic diagnosis. Bladder wall thickness (BWT) was measured at 250-mL bladder filling using transabdominal US. A statistical technique known as Recursive Partition Analysis (RPA) was employed to analyze the combined dataset of BWT, maximum urinary flow rate (Qmax), post-void residual urine volume (PVR), IPSS, and prostate size, with the aim of predicting bladder outlet obstruction (BOO). RPA methodically divides the data into subsets based on various parameters to identify the most effective predictors of BOO.

***Keywords*- Bladder Outlet Obstruction, Uroflowmetry, Lower Urinary Tract Symptoms, Proteus simulator, Non-invasive method**

I. INTRODUCTION

Lower Urinary Tract Symptoms (LUTS) represent a constellation of clinical manifestations that encompass various urinary dysfunctions affecting both men and women across different age groups. These symptoms, ranging from urinary frequency and urgency to hesitancy and incontinence, significantly impact an individual's quality of life and pose considerable burdens on healthcare systems globally. Despite their prevalence and clinical significance, the underlying etiology and optimal management of LUTS remain complex and multifactorial, often requiring a comprehensive understanding of both physiological and pathological mechanisms.

LUTS encompass a spectrum of urinary symptoms, often categorized into storage (irritative), voiding (obstructive), and post-micturition symptoms. Storage symptoms include urinary urgency, frequency, nocturia, and urgency incontinence, which are suggestive of overactivity of the detrusor muscle or altered sensory thresholds within the bladder. Voiding symptoms, such as hesitancy, weak stream, intermittency, and straining, typically indicate obstruction or impaired bladder emptying, commonly associated with benign prostatic hyperplasia (BPH) in men or pelvic floor dysfunction in women. Post-micturition symptoms, including incomplete emptying and post-void dribbling, reflect abnormalities in the bladder or urethra after urination.

The prevalence of LUTS increases with age, with studies suggesting a substantial impact on individuals over 40 years old. However, LUTS can also affect younger populations, often associated with specific risk factors such as obesity, sedentary lifestyle, hormonal changes, neurological disorders, and certain medications. Furthermore, the socioeconomic implications of LUTS are noteworthy, as they can lead to decreased productivity, increased healthcare utilization, and diminished quality of life

Lower urinary tract symptoms (LUTS) can significantly impact the quality of life for both men and women, often prompting individuals to seek medical assistance, particularly when symptoms indicate the presence of bladder outlet obstruction (BOO), which can lead to significant urinary difficulties. BOO, typically stemming from benign prostatic hyperplasia (BPH), often necessitates surgical intervention, highlighting the importance of accurately diagnosing its presence to optimize patient care. Traditionally, pressure-flow studies (PFS) or urodynamic studies (UDS) have been considered the gold standard for diagnosing BOO, despite their drawbacks, including invasiveness, discomfort, and expense. Recognizing these limitations, various non-invasive diagnostic methods have emerged, aiming to provide earlier detection and treatment of LUTS/BPH while improving patient comfort. Although these alternative methods offer promise, there remains inconsistency in their clinical effectiveness. While previous studies have evaluated these non-invasive approaches, a quantitative meta-analysis to compare their diagnostic accuracy has been lacking. Therefore, the objective of this meta-analysis is to comprehensively assess the diagnostic performance of non-invasive methods in detecting BOO among men with LUTS, focusing on sensitivity, specificity, diagnostic odds ratio, and area under the curve. This study represents the first attempt to quantitatively evaluate and compare the diagnostic efficacy of these alternative approaches for BOO diagnosis.

II. OBJECTIVE

We conducted a pioneering meta-analysis to assess the diagnostic efficacy of non-invasive techniques for detecting bladder outlet obstruction (BOO) among men experiencing lower urinary tract symptoms (LUTS). The primary objective of this prospective study was to compare the accuracy of various tests, including detrusor wall thickness (DWT), free uroflowmetry, postvoid residual urine, and prostate volume, against pressure-flow studies, which serve as the reference standard for diagnosing BOO in men. Given the diversity of methods proposed for diagnosing BOO, our review aimed to comprehensively examine the literature on non-invasive diagnostic approaches, facilitating a comparative analysis.

Numerous non-invasive methods have emerged as alternatives to invasive urodynamic studies for diagnosing BOO in men, aiming to alleviate the burden and complications associated with invasive procedures. Despite the development of these tests, uncertainty persists regarding their diagnostic accuracy. Our objective was to systematically evaluate the existing evidence on the diagnostic performance of non-invasive tests in identifying BOO among men with LUTS, utilizing pressure-flow studies as the benchmark for comparison.

III. LITERATURE SURVEY

Mohammed et al. (2021) investigated the statistical analysis of urodynamic parameters in relation to various presentations of stress urinary incontinence (SUI). While the paper contributes to understanding SUI pathophysiology, the lack of a detailed discussion on methodological limitations and potential biases hinders the robustness of their statistical analyses.

Takahashi et al. (2021) examine symptoms and non-invasive test parameters to differentiate detrusor underactivity (DU) from bladder outlet obstruction (BOO) in men with lower urinary tract symptoms (LUTS). While the study sheds light on clinical differentiation, the lack of a pressure-flow-based diagnosis limits the comprehensive understanding of DU and BOO in this population.

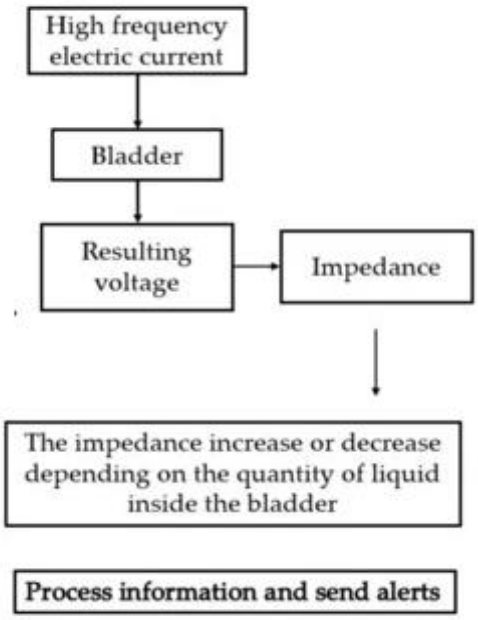
Perrin and Corcos (2023) investigate conservative and medical management approaches for nonneurogenic female bladder outlet obstruction (BOO). Despite providing insights into treatment strategies, the paper may lack comprehensive discussion on the effectiveness and long-term outcomes of conservative and medical interventions for nonneurogenic BOO in females.

Tan et al. (2022) conduct a systematic review and meta-analysis on transabdominal intravesical prostatic protrusion (IPP) assessment in diagnosing bladder outlet obstruction (BOO) and unsuccessful trial without catheter (UTUC). While offering valuable insights, the study's drawback may lie in potential heterogeneity across included studies, affecting the robustness and generalizability of the meta-analytic findings.

Krukowski et al. (2021) evaluate non-invasive tests for assessing bladder outlet obstruction (BOO) severity in men with anterior urethral stricture. Despite contributing to diagnostic strategies, the study may be limited by a small sample size or lack of comparison with gold standard diagnostic methods, potentially affecting the reliability and generalizability of the findings.

IV. METHODOLOGY

Benign prostatic hyperplasia (BPH) is a prevalent condition among men, characterized by benign enlargement of the prostate gland, which can lead to lower urinary tract symptoms (LUTS) and potential bladder outlet obstruction (BOO). Notably, a substantial portion of men with BPH experience bothersome LUTS and may seek medical assistance. BOO has been detected in a significant percentage of symptomatic and asymptomatic men with BPH. However, the relationship between LUTS, prostate enlargement, and BOO remains unclear, necessitating separate evaluation of each aspect of the disease.



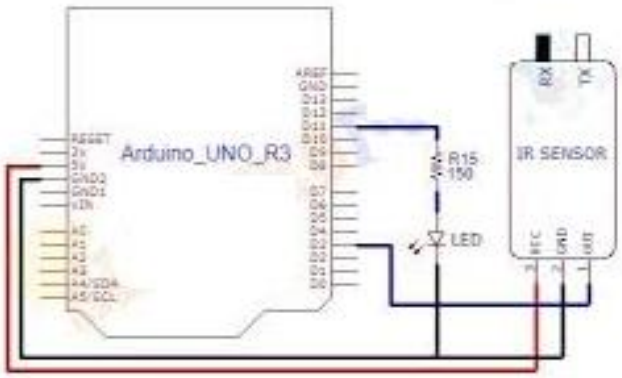
While assessing prostate size and LUTS can be done relatively easily through digital rectal examination, ultrasound measurement, and history or questionnaire, respectively, determining BOO poses greater challenges. Pressure-flow studies have traditionally been

the gold standard for diagnosing BOO, but their invasiveness, cost, and time-consuming nature limit their widespread use. In clinical practice, non-invasive methods such as free uroflowmetry, postvoid residual urine measurement, and prostate volume assessment are commonly employed to estimate BOO in men with BPH. Experimental studies on obstructed bladders in animals have shown significant changes in the detrusor wall, which can be visualized effectively through ultrasound technology. As a result, recent focus has shifted to measuring detrusor wall thickness (DWT) as a potential non-invasive method for diagnosing BOO in men with BPH. A meta-analysis has highlighted DWT measurements, along with bladder weight, as promising approaches with a solid evidence base for clinical adoption pending further evaluation. However, no previous study has prospectively investigated the diagnostic accuracy of DWT measurements in conjunction with other routine clinical tests within a single patient group, nor has any study adhered to the recommendations of the STARD initiative. Therefore, our study aims to prospectively assess the diagnostic accuracy of DWT measurements, along with free uroflowmetry, postvoid residual urine, and prostate volume, in diagnosing BOO as defined by pressure-flow analysis in patients with clinical BPH.

V. MATERIALS AND USAGES

a) ARDUNIO UNO:The Arduino Uno integrates a microcontroller, digital and analog input/output pins, voltage regulator, and USB interface, facilitating versatile electronic prototyping. Its functions include reading sensor data, controlling actuators, and executing programmed tasks, making it ideal for a wide range of projects in robotics, automation, and IoT applications.

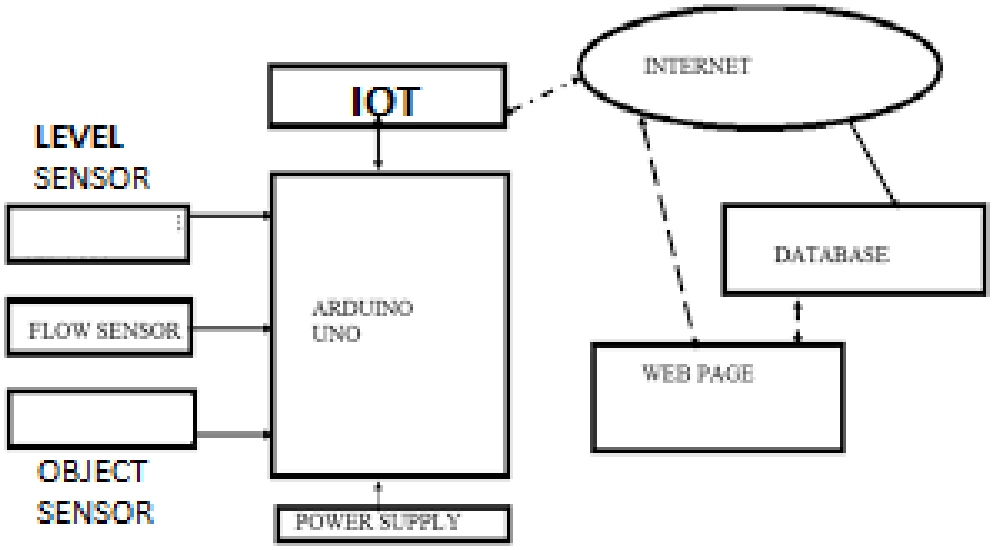
b) LEVEL SENSOR:A level sensor is a device used to detect and measure the level of liquids, solids, or powders in a container or tank, providing real-time data for monitoring and control applications. It employs various technologies such as ultrasonic, capacitive, or optical principles to accurately determine the level of the substance being measured.



c) LCD (Liquid Crystal Display) :LCD is a flat-panel display technology commonly used in electronic devices for visual output. It utilizes liquid crystal molecules to modulate light transmission, enabling the display of text, images, and graphics with low power consumption and high contrast.

d) PHOTODIODE:A photodiode is a semiconductor device that converts light into electrical current or voltage, commonly used in various applications such as light sensing, communication systems, and optical detection. It operates based on the principle of the photovoltaic effect, where incident photons generate electron-hole pairs within the semiconductor, resulting in a flow of current proportional to the incident light intensity.

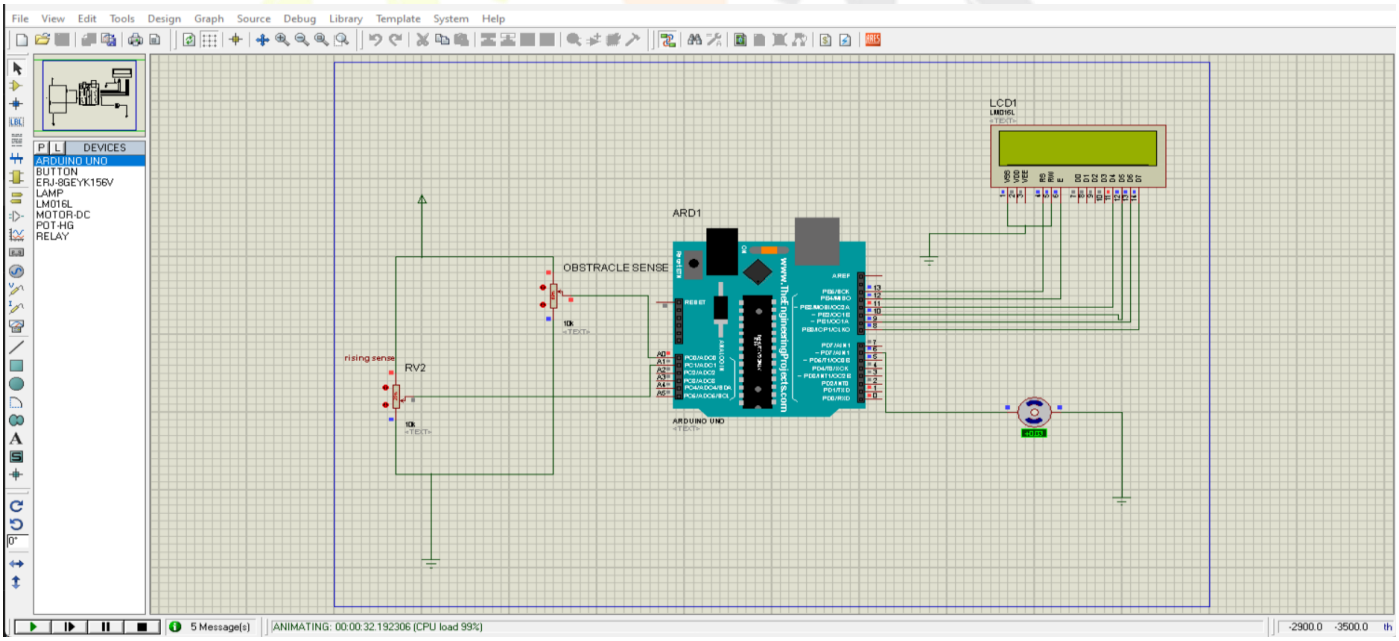
VI. BLOCK DIAGRAM



VII. SIMULATION

The Proteus Design Suite offers comprehensive support for the Arduino ecosystem, encompassing both STM32 Arduino with the Blue Pill board and traditional AVR-based Arduino boards. It provides hardware and firmware design capabilities, advanced system-level simulation and debugging features, as well as hardware programming functionalities.

Proteus Design is used for a software tool suite used primarily for electronic automation . The software is used mainly by electronic design engineers and technicians to create schematics.



VIII. RESULT

In this study, 160 men aged between 40 and 89 years (with a median age of 62 years) took part. Among them, 8.1% (13 men) exhibited benign prostatic enlargement (BPE) with prostate volumes exceeding 25 ml but did not report lower urinary tract symptoms (LUTS) according to the International Prostate Symptom Score (IPSS) threshold of 7. Additionally, 21.3% (34 men) reported LUTS with IPSS scores exceeding 7 but did not have BPE. The majority, comprising 70.6% (113 men), presented with both BPE and LUTS. According to pressure-flow analysis, 46.9% (75 out of 160) of the study population exhibited bladder outlet obstruction (BOO). Detrusor wall thickness (DWT), maximum urinary flow rate (Qmax), average urinary flow rate (Qave), postvoid residual urine volume, and prostate volume showed significant differences between bladders classified as non-obstructed and obstructed.

IX. CONCLUSION

The effectiveness of Recursive Partition Analysis (RPA) in predicting Bladder Outlet Obstruction (BOO) has been established through its analysis of combined data. In a study involving 45 patients, high-frequency sequential ultrasound images captured during voiding proved successful. The correlation between successive ultrasound images decreased more significantly in patients with bladder outlet obstruction compared to those without obstruction and healthy individuals. Analysis using Receiver Operating Characteristic (ROC) curves yielded an Area Under the Curve (AUC) of 0.96, with 95% specificity and 88% sensitivity. Additionally, a linear correlation was established between the decorrelation values and the degree of obstruction, quantified by the bladder outlet obstruction index obtained from separate pressure-flow studies.

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