Improving Urodynamic Prediction of Non-Neurogenic Underactive Detrusor in Adult Male Patients

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Abstract

Introduction: Non-neurogenic detrusor underactivity (DU) is a common diagnosis in patients. Symptoms of DU may include urinary frequency, urinary urgency, weak stream, straining to void, urinary incontinence, infrequent urination, decreased voiding sensation, increased post-void residual volume, and chronic urinary retention. **Background:** Urinary symptoms are not specific to DU, and may be associated with a myriad of other diagnoses including benign prostate hypertrophy (BPH), bladder outlet obstruction (BOO), detrusor overactivity, and stress incontinence. (Aldamanhori et al, 2018). DU has been poorly defined in the literature with lack of evidence-based outcomes. The literature review identifies gaps in the literature regarding the predictive value of urodynamic parameters in relation to adult patients with DU, thus supporting analysis of the association of clinical diagnosis of detrusor underactivity and urodynamic parameters of detrusor pressure at max flow (Pdet@Qmax), Watts Factor (WF), bladder contractility index (BCI), and Schafer's linear passive urethral resistance relation (LinPURR) detrusor contractility nomogram for evaluation of DU identification. **Methods:** Predictive outcomes as measured by comparison of clinician diagnosis of non-neurogenic underactive detrusor pre- and post- UDS evaluation of adult male patients was performed at an outpatient urology practice in Christiansburg, VA. **Results:** Record review included all male patients with lower urinary tract symptoms (LUTS) undergoing UDS for a twelve-month timeframe of 9/2018 to 9/2019, showing a statistically significant relationship between PVR and age as well as Watts factor and DU diagnosis. **Implications:** The observed correlations support findings in the literature review. While BCI and LinPURR did not show statistically significant correlations with DU diagnosis, this analysis is limited due to small sample size.

Keywords: Urodynamic, detrusor underactivity

Introduction

The Congress of Urologic Research and Education on Aging UnderActive Bladder Series (CURE-UAB), reports underactive bladder leads to decreased quality of life due to limited options for management of the associated chronic urinary retention (CUR) including indwelling catheters, diapers, and clean intermittent catheterization (Chancellor, 2017). CUR is a significant burden for the patient, family, and the United States healthcare system as "loss of bladder control is the second most common reason for nursing home placement for the elderly" (Chancellor, 2017, para 1). According to the United States Department of Health and Human Services (USDHHS), urinary retention is more common in men than in women with incidence of urinary retention increasing with age, ranging from 100 per 1,000 men in their 70s to 300 per 1,000 men in their 80s (USDHHS, 2014). CUR is typically slow in progression and is often non-painful/asymptomatic in nature. The presenting features of CUR may include: frequency, urgency, urinary incontinence, urinary tract infection, acute urinary retention, lower abdominal pain, hydronephrosis, and acute/chronic renal failure which could lead to death. These symptoms are not specific to CUR; however, and may present a clinical picture of benign prostate hypertrophy (BPH) on AUA symptom index scoring of lower urinary tract symptoms (LUTS). The AUA symptom index score has been validated by a measurement committee of the AUA when comparing patients with BPH to control subjects, as well as sensitivity to change pre- and post- operatively with $p < 0.001$ (Barry et al, 2017). However, the AUA symptom index score cannot differentiate between BPH and DU.

CUR had been poorly defined until 2016 when the American Urological Association (AUA) Quality Improvement and Patient Safety (QIPS) Committee defined non-neurogenic CUR as "an elevated PVR [post-void residual] of >300 mL that has persisted for at least six

months documented on two or more separate occasions" (AUA, 2016, p. 6). Research and evidence-based outcomes in non-neurogenic CUR patients is limited, with focus on neurogenic and prostatic obstruction etiologies, generally excluding non-neurogenic CUR. The AUA CUR White Paper group (2016) acknowledged the lack of research in the non-neurogenic CUR realm. The group recommended utilization of UDS to determine possible association of UDS parameters and diagnosis of non-neurogenic CUR. This analysis focuses on CUR resultant from detrusor underactivity (DU), which "is a common diagnosis reported in up to 48% of men and 45% of women" who underwent urodynamic evaluation of voiding symptoms (Aldamanhori et al, 2017, p. 17).

DU shares many lower urinary tract symptoms with other voiding dysfunctions including bladder outlet obstruction, making clinical diagnosis of DU challenging. Ahmed et al, (2016) note DU is "the most poorly understood bladder dysfunction with scant research…[and] there is no clear definition and no non-invasive method" for diagnosis (p 223). The International Continence Society defines DU as "low detrusor pressure or short detrusor contraction time, usually in combination with a low urine flow rate resulting in prolonged bladder emptying and/or a failure to achieve complete bladder emptying within a normal time span measured by urodynamics" (Rademakers, 2018, para 3). This definition is limited, as it does not provide specific parameters for detrusor pressure, contraction time, flow rate, or bladder emptying. The etiology of DU may be multifactorial including: aging, neurologic disease that interrupts neuron communication with the detrusor muscle, neurologic injury during pelvic surgery, and myocyte dysfunction that inhibits detrusor contraction (Ahmed et al, 2016).

Identified gaps in the literature exist regarding predictive value of urodynamic parameters of detrusor contractility including WF, BCI, and the LinPURR nomogram in relation to

diagnosis of adult patients with non-neurogenic CUR with DU. Additionally, there are limitations in UDS. Rademakers (2018) notes disagreement exists regarding the definition of DU both symptomatically and urodynamically. UDS is the only accepted modality for diagnosing DU, relying on measurements of detrusor contractility strength in the absence of standardized diagnostic criteria (Osman, Mangera, Hillary, Inman, & Chapple, 2016). Therefore, this scholarly project evaluates predictive outcomes as measured by comparison of clinician diagnosis of non-neurogenic underactive detrusor pre- and post- UDS evaluation utilizing detrusor contractility indices of adult male patients performed at an outpatient urology clinic in Christiansburg, VA. Record review included all male patients who underwent UDS evaluation at the clinic from 9/2018 to 9/2019.

Question

Do urodynamic studies agree with clinical impression of DU in adult male patients with urinary retention?

Literature Review

In order to identify the effectiveness of UDS parameters with regards to predictive value of non-neurogenic underactive detrusor diagnosis in male patients with LUTS in the outpatient care setting, a systematic integrative review of the literature was performed in April- Sept 2019. Four serial searches were performed of electronic databases including: CINAHL, OVID Medline, PubMed, and Cochrane. Keywords "urodynamic" and "detrusor underactivity", “urodynamic” and “watts factor”, “urodynamic” and “bladder contractility index”, and “urodynamic” and “LinPURR” were used for the searches. Search of the CINAHL database yielded 75 results of which title and abstracts were scanned for relevant titles, and 5 articles were kept. OVID Medline search returned 21 results, of which 6 were kept after title and abstract

scan. PubMed search yielded 111 results of which 14 were kept after title and abstract scan. The Cochrane database returned 19 results, of which 0 were kept after title and abstract scan. Ancestry review of articles yielded 11 result, 10 of which were kept.

Inclusion criteria: any study that utilized UDS for evaluation of non-neurogenic CUR. Limitations included: research articles published in the past 10 years, English language, adult patients, and linked full text articles. Exclusion criteria were: 1) studies that did not measure non-neurogenic urinary retention/detrusor underactivity, 2) studies without an English language abstract, 3) studies with female-only patients, and 4) studies of pediatric patients. Randomized control trials, comparison cohort and quasi-experimental (non-randomized comparison cohort studies) were included in the review. After reading the articles, there were 8 studies that met inclusion criteria; however, 2 of these were duplicates, leaving 6 studies included in the literature review. Search methods are outlined below in Figure 1.

Limitation of urodynamic studies

Malik et al (2014) acknowledge while UDS is useful in determination of bladder outlet obstruction and poor bladder compliance, which places patients at risk of upper tract deterioration, there are limitations of UDS in elderly patients. Decreased mobility or cognitive impairment may limit ability to provide feedback during the test. Gray (2010) describes how mechanical, psychosocial, and psychological factors affect urodynamic outcomes. Mechanical limitations consist of accuracy of measurements including: 1. pressure variations due to the muscular contractility of the urinary tract, thus creating variability in pressure measurements and difficulty compensating for these changes using standardized equations, 2. variability in detrusor pressure measurements, as “it is a relative pressure prone to physiologic artifacts”, and 3. electromyelogram tracings which may be affected by psychosocial and psychological factors

(Gray, 2010, p 270). Gray (2010) also notes history of sexual abuse, depression, anxiety, or anxiety produced by lack of privacy during the study may induce lower urinary tract symptoms which may not be usual for the patient, thus limiting the accuracy of the UDS output.

Detrusor contractility: Pressure and flow

A detrusor contraction results in increased pressure and flow, thus maximum flow (Qmax) rates and detrusor pressure at maximum flow (Pdet@Qmax) rate have been used to diagnose DU; however, a normal range for detrusor contractility strength and duration have not been defined which complicates diagnosis of DU (Aldamanhori et al, 2017). Osman, Esperto, & Chapple (2018) recommend Qmax ≤ 15 ml/s with Pdet@Qmax of ≤ 25 cmH_2O to define DU. However, Ahmed et al, 2016, classified DU as ≤ Pdet@Qmax of 40 cmH2O and Qmax < 15 mL/s. Donkelaar et al (2017) found the average Pdet@Qmax was 42.9 cmH2O and Qmax 8.8 mL/s when utilizing LinPURR nomogram grading for diagnosis of DU. Additionally, relying solely on Qmax and Pdet@Qmax to diagnose DU "is likely to be an inaccurate method of determining the maximal pressure generated by the bladder due to the bladder outlet relation (BOR), the normal inverse correlation between detrusor pressure and urine flow during voiding…[and] the fact that the flow rate is also impacted upon by the degree of bladder outlet resistance is not considered" (Osman et al, 2016, p 3). Therefore, pressure and flow also do not allow for definitive diagnosis when a patient has both decreased contractility and obstruction present.

Watts Factor and detrusor contractility

Contractility "refers to the intrinsic property of smooth muscle to contract at a given length" (Sullivan & Yalla, 2007, p. 7). Utilizing the basics of contractility and the relationship between velocity of muscle shortening and isometric force of contraction, Watts factor (WF) "is

an estimate of the power per unit area of the bladder surface that is generated by the detrusor" (Osman et al, 2016, p 3). This is calculated by "WF = [(Pdet + *a*) (Vdet + *b*) – *ab*]/2π, where Vdet is the detrusor shortening velocity and *a* and *b* are constants (*a* = 25 cmH_2O, *b* = 6 mm/s)" (Ahmed, et al, 2016, p 226). WF measure of detrusor pressure is not influenced by bladder outlet obstruction; however, it is limited by the inability to measure the sustainability of the detrusor contraction as well as lack of general acknowledgement of a normal value. Ahmed et al (2016) utilized WF of ≤ 7 $\mu W/mm^2$ as an indicator of DU, whereas Donkelaar et al (2017) recommended a maximum WF of 10.85 $\mu W/mm^2$ to diagnose DU; however, this cut-off was established in only one center.

LinPURR and detrusor contractility

Osman et al (2016) note simple pressure flow studies do not account for urethral resistance or bladder volume when evaluating detrusor function. Therefore, in the 1970s, Griffiths responded by proposing the urethral resistance relationship which states "as bladder pressure rises, the flow rate will be zero until the intrinsic bladder pressure equals the intrinsic urethral pressure. At this point flow will start and the flow rate will rise rapidly with further increases in the intrinsic bladder pressure" (Nitti, 2005, p S16). Griffiths developed a graphical depiction simultaneously plotting the detrusor pressure (X-axis) and flow rate (Y-axis) during voiding, which produced a curve showing resistance to flow independent of detrusor function (urethral resistance relation) (Nitti, 2005).

In 1983, Schafer developed the passive urethral resistance (PURR) model to denote the relationship between pressure and flow at the time of lowest urethral resistance/complete relaxation to differentiate bladder outlet obstruction from DU (Nitti, 2005). The designation of minimal opening pressure addresses the distensible/collapsible nature of the urethra. Schafer

characterized outlet function by: 1. minimum opening pressure (urethral collapsibility) and 2. Cross-sectional area of the flow-rate controlling zone (urethral distensibility) (Nitti, 2005). The PURR curve produced depicts bladder outlet obstruction independent of detrusor strength. (Nitti, 2005).

Schafer modified the PURR to a linear model (LinPURR) to evaluate detrusor contractility independent of outlet obstruction, plotting values of flow and detrusor pressure as a linear representation of urethral resistance characterized as degree of obstruction ranging from unobstructed to obstructed and detrusor contractility strength ranging from normal to very weak (see Figure 2) (Nitti, 2005). The nomogram classifies obstruction into seven grades with grades 0-I indicative of no obstruction, grade II suggestive of mild/equivocal obstruction, and grades III-VI representing increasing obstruction (Chang et al, 2018). While the Schafer nomogram is the only tool that evaluates bladder outlet obstruction, it does not include Vdet.

Bladder contractility index and detrusor contractility

BCI evaluates bladder contraction strength utilizing detrusor pressure at maximum flow (Pdet@Qmax) and maximum flow (Qmax) indices from the Schaefer nomogram (see Figure 3). BCI is calculated "by the following formula: BCI = Pdet@Qmax + 5 Qmax. Using this formula, contractility can be divided into strong > 150, normal 100–150, and weak < 100" (Nitti, 2005, S17). BCI cannot be utilized to distinguish between bladder outlet obstruction and DU; however, "theoretically, the detrusor pressure (Pdet@Qmax) at the time of Qmax can be used to assess whether the patient has DU when voiding stops, the isovolumetric Pdet may represent bladder contractility" (Chang et al., 2018, p 180). Utilizing this approach, diagnostic criteria for DU includes BCI < 100 and Qmax ≤ 12 mL/s in men and Pdet@Qmax ≤ 10 cm H2O in women (Chang et al., 2018).

Urodynamic parameters as a predictor of detrusor underactivity

Donkelaar et al (2017) performed a retrospective analysis of 1222 men over 50 years of age who underwent UDS for evaluation of urinary symptoms. LinPURR, BCI and WF were used to evaluate bladder contractility. The LinPURR nomogram showed 622 patients had a weak detrusor and 31 patients had a very weak detrusor, the BCI classified 622 patients with a weak detrusor and 31 patients with a very weak detrusor, and WF showed 706 patients with a weak detrusor (Donkelaar et al, 2017). The study showed a 97.5% agreement in grading of detrusor contractility between LinPURR and BCI and a 80.9% agreement between LinPURR and WF, showing all three are viable measures to identify DU (Donkelaar et al, 2017).

A retrospective evaluation of UDS for 4372 patients 60 years of age or older with lower urinary tract symptoms was performed by Jeong et al (2017) showing 55.8% of men had DU by BCI criteria < 100 but only 5.4% had DU by Pdet@Qmax <30 cmH2O and Qmax < 10 mL/s. DU was diagnosed in 9.6% of women with Pdet@Qmax < 30 cmH2O and Qmax < 10 mL/s. These findings show limitations of utilization of BCI alone for diagnosis of DU. Guo et al (2017) performed a retrospective analysis of UDS in 67 men with urinary retention and average age of 68 years. This showed 73% of men had a BCI < 100, however, when bladder contractility was evaluated using isometric detrusor contraction pressure, only 29% of these men met criteria for DU (< 50 cmH2O). These findings reinforce both Jeong et al.'s (2017) findings and Chang's (2018) theoretical use of isometric contraction pressure in addition to BCI to identify DU. BCI alone may be useful in diagnosing severe DU or acontractile detrusor as noted by Jiang & Kuo (2017) who analyzed 165 men with DU, comparing those with Pdet@Qmax < 5 cmH2O and those with Pdet@Qmax ≥ 5 cmH2O, with average BCI of 5 in patients with Pdet@Qmax < 5 cmH2O compared to 26 in those with Pdet@Qmax ≥ 5 cmH2O.

Hoag & Gani (2015) performed a retrospepurpctive analysis of 79 patients (25 male, 54 female) with DU utilizing BCI < 100. The study notes 28% of the male patients had undergone transurethral resection of the prostate and 12.7% of patients were treated with anticholinergic medications, suggesting many patients with DU may be misdiagnosed and receive unnecessary surgery/medications (Hoag & Gani, 2015). However, this study is limited to utilization of BCI as the only diagnostic criteria for DU.

Liu et al (2018) reviewed UDS output for 455 men with lower urinary tract symptoms grouped by Schafer grades of very weak to weak, showed average BCI of 100 or less, average WF of 9.3 or less, and average Pdet@Qmax of 48 or less. WF and BCI were compared for each of the six groups of Schafer contractility showing both were positively correlated with Schafer contractility grade with statistically significant difference among the six groups, ($P < 0.001$) (Liu et al., 2018). These findings are supportive of using WF, BCI, and Schafer contractility grade as reliable parameters for assessing detrusor contractility.

Summary of literature review

While urodynamic evaluation is recommended for the diagnosis of DU due to lack of disorder-specific clinical symptoms, there is no standardized diagnostic criteria for DU utilizing UDS (Osman et al, 2016). One barrier to development of DU diagnostic criteria is the variability of measurements during UDS secondary to patient feedback and mechanical limitations of the study as noted by Gray (2010). Pdet@Qmax has been utilized in the past to diagnose DU; however, this is limited due to lack of an established normal range for detrusor contractility strength and duration. Furthermore, limitations of flow due to bladder outlet relation and bladder outlet obstruction do not allow differentiation between decreased contractility and obstruction

with Pdet@Qmax alone. Likewise, BCI aims to evaluate bladder contractility strength utilizing Pdet@Qmax, but cannot differentiate between bladder outlet obstruction and DU.

Unlike Pdet@Qmax and BCI, WF does measure detrusor pressure without being influenced by bladder outlet obstruction by utilizing maximum velocity of shortening and isometric force. Unfortunately, WF also has its limitations including lack of standardized normal value and lack of ability to measure sustainability of detrusor contraction. Schafer's LinPURR also evaluates detrusor contractility independent of outlet obstruction by plotting flow and pressure to represent both degree of obstruction and detrusor contractility. LinPURR does not; however, evaluate velocity shortening. Table 1 depicts a comparison of the various UDS measure capabilities and limitations.

All three measures of detrusor contractility have proven effective for CUR diagnostic purposes: Donkelaar et al (2017) showed 97.5% agreement in grading of detrusor contractility between LinPURR and BCI and 80.9% agreement between LinPURR and WF. Utilizing a combination of measures for diagnosis of DU was proven more effective by Guo et al (2017), who noted a 44% difference in diagnosis of DU utilizing BCI and Pdet@Qmax. Liu et al (2018) also showed a statistical significance of positive correlation between WF and BCI with Schafer contractility grades.

Implementation Framework

Graham et al. (2009) developed the Knowledge-to-Action (KTA) Process Framework (see Figure 4) which guides the use of research to apply existing knowledge to clinical practice, improving care delivery through evidence-based practice. It is "estimated that 30%-45% of patients are not receiving care according to scientific evidence and that 20%-25% of the care provided is not needed or is potentially harmful" (Graham et al., 2009, p. 13). Clinicians often

use subjective data, simple uroflowmetry studies, and post-void residual volumes for diagnosis of voiding dysfunctions, which can be poor diagnostic indicators leading to misdiagnosis and unnecessary/ineffective medication utilization and even unnecessary surgical intervention. The lack of expert consensus regarding definition of DU symptomatically and urodynamically, lack of standardized diagnostic criteria for DU, and underutilization of UDS parameters for diagnosis of voiding dysfunction may increase risk of misdiagnosis and ineffective therapies. Therefore, the KTA process was utilized to identify the lack of evidence-based knowledge surrounding diagnostic criteria for DU (see Figure 5). Literature review was utilized to review/synthesize existing knowledge and barriers to DU diagnosis. A focused population consisting of patients with non-neurogenic DU was selected and UDS parameters specific to that patient population were identified for process improvement implementation.

The KTA process framework also acknowledges collaboration between knowledge production and utilization, as these processes may be performed by different individuals or teams. UDS parameters have continued to evolve, with development of numerous tools including LinPURR, BCI, and WF. Unfortunately, each of these measures has proven diagnostic limitations, so applying the KTA Process Framework for continued knowledge inquiry/adaptation and tailored interventions is imperative to improve diagnostic accuracy of DU. Consequently, the study utilized all three urodynamic output measures collaboratively with subsequent evaluation to determine if there is resultant improvement in diagnostic accuracy of DU outcomes.

Purpose

The purpose of this study was to analyze and compare a practice site data with the review of literature to assess evidence for practice improvement in determining diagnostic accuracy of

non-neurogenic DU in adult male patients. The analysis aims to determine if a relationship exists between urodynamic study parameters and diagnostic accuracy of DU when compared to clinical diagnosis of same in adult patients with non-neurogenic CUR. Baseline diagnosis will be noted. Review of data on age, AUA symptom index score, Qmax, PVR, Pdet@Qmax, WF, BCI, and Schafer contractility grade will be noted to determine if there is a statistically significant, defined as probability value (p-value) ≤ 0.05, improvement in diagnosis of DU utilizing UDS compared to clinical suspicion. Identification of relationships may not only determine if UDS parameters improve diagnosis of DU, but also help identify risk stratification and guide treatment algorithms in the future.

Analysis Questions

The analysis of this study seeks to answer the following question regarding adult male patients with lower urinary symptoms at an outpatient urologic clinic in Christiansburg, VA:

1. What is the percentage of agreement between clinical impression of non-neurogenic DU and urodynamic diagnosis of DU utilizing Pdet@Qmax?
2. What is the percentage of agreement using additional UDS parameters of PVR, Watts factor, bladder contractility index, and Schafer LinPURR stratification of detrusor contractility/bladder outlet obstruction with diagnosis of DU based on Pdet@Qmax?
3. Is there a relationship between AUA symptom index score and the diagnosis of DU utilizing Pdet@Qmax?

Methods

The analysis consisted of a retrospective chart review of all adult male patients presenting to the urology clinic for urodynamic evaluation over a one year period, with comparison outcome of pre-UDS diagnosis and post-UDS diagnosis starting after approval by the following:

the hospital's IRB, the hospital's Research and Development Department, and the hospital's Urology Surgery Chair/Department Head. Urodynamics parameters including Watts factor, bladder contractility index, Shaffer LinPURR nomogram grades of obstruction and detrusor contractility, and voiding pressure flow study parameters of Pdet@Qmax, voiding duration in seconds, and ability to generate a stream were analyzed to determine if any relationship exists between these measures and clinical diagnosis of DU pre-UDS.

Setting/Sample

This is a single-site analysis of patient records in a non-academic, for-profit, outpatient clinic at urology clinic in the mid-Atlantic region of the United States employing three medical doctors and four advanced practice providers. Inclusion criteria include: male patients age 18+ years who underwent urodynamic evaluation. The pre-UDS diagnosis for all adult male patients undergoing UDS was noted. The numerical representation WF max and BCI, LinPURR degree of obstruction from O-VI, LinPURR flow strength from "normal+" to "very weak", Pdet@Qmax in cmH2O, flow time in seconds, and ability to generate a stream represented as "yes" or "no" was noted. The independent variables in the analysis are UDS parameters with dependent variable of medical diagnosis pre- and post- UDS evaluation. Extraneous variables include but are not limited to: age, gender, co-morbid disease processes, and accessibility to the Christiansburg clinic.

Procedures

Urodynamics tests were conducted by the same nurse practitioner utilizing the same Laborie Medical Technology Aquarius urodynamic machine. An air charged single sensor urethral catheter was utilized to measure intravesical pressure and for bladder infusion. An air charged abdominal sensor was placed in the rectum to measure abdominal pressures. Neotrode

II electrodes were placed on either side of the anus and a ground electrode on the bony hip prominence to record electromyelogram (EMG) tracings of pelvic floor muscle function. Sensors were zeroed and pressure lines equalized to achieve a baseline detrusor pressure of 0 cm/H2O. Sensor and EMG placement was verified by asking the patient to cough. Bladder infusion was performed, requesting cough test intermittently during infusion to assess for leak and verify sensor placement. The patient was asked to notify examiner of bladder filling sensations: first sensation, first desire, strong desire, and maximum capacity. The patient was then given permission to void. The results of urodynamic studies were prepared by the same nurse practitioner utilizing a standardized report. Clinical measures include pre-UDS diagnoses, WF max, BCI, LinPURR degree of obstruction and flow, Pdet@Qmax, flow time, ability to generate a stream, PVR, and post-UDS diagnoses. Demographic data of patient age were collected.

Measures

The community-based hospital's research electronic data capture (REDCap) software was used as the central location for data collection, providing a secure, web-based application design to support data management and collection for research/quality assurance/quality improvement studies. The hospital's REDCap servers are securely housed onsite in a limited access data center, and all data are stored on the hospital's firewall protected network. The Health Analytics Research Team (HART) supports the proper development of projects and surveys in REDCap, observing appropriate change control and enforcing appropriate security controls. Data collection projects are built with a study-specified data dictionary, enforcing intuitive, accurate, consistent and complete data entry. REDCap also provides a survey tool for building and managing online surveys. HART restricts user access to the IRB-approved project research team utilizing the approved processes and standards of technology services group

(TSG). REDCap is Health Insurance Portability and Accountability Act (HIPAA) compliant and provides audit trails. Data can be easily exported in several formats to a secure network directory for combination with extracted data, if appropriate, and analysis is with common statistical packages.

Patient data collected included: patient age in years, pre-UDS diagnosis, post-UDS diagnosis, and urodynamic parameters as outlined in Setting/Sample section. The data was de-identified to protect patient privacy, utilizing age in years to replace date of birth. Descriptive statistics were computed using SPSS software for the patient age. These results are presented below following IRB-approved protocol and utilization of ethical considerations for the protection of dignity of subjects and the publication of the information in the research.

Data Analysis

Due to the rarity of UDS studies in men in this region, a review of all male patients that meet the requirements of the study protocol over the 12-month period between 9/2018-9/2019 were included in the record review/analysis. A comparison of the pre-diagnosis of DU and the post-diagnosis of DU by Pdet@Qmax was conducted by looking at the percentage of matching diagnoses. Similarly, a comparison of the diagnosis of DU by Pdet@Qmax and each of the other UDS parameters including Watts Factor, BCI, LinPURR and CUR defined as >300 mL PVR was studied by looking at the percentage of matching DU test results. Descriptive statistics were used to analyze the various variables. Due to the small sample size, additional statistical testing was not possible.

Results

A review of all male patients that met the inclusion criteria of the study protocol over the 12-month period between 9/2018-9/2019 was performed during 2/2020 with a total of 66

included in the record review/analysis. The youngest patient was 23 and the oldest was 87 years of age with range of 64 years, mean of 69.6 years, median of 73 years, and modes of 77 and 78 years. A total of 30 patients (45.4%) were not able to void and were not included in the final analysis. The remaining 36 patients (54.5%) were able to void and were included in the final analysis. The mean age of the patients who were unable to void was 72.9 years while the mean age of patients who were able to void was 66.8 years (Figure 6). Wilcoxon two-sample test yielded statistically significant difference (p-value = 0.0239) in the age of patients based on ability to void, with those who could not void being statistically significantly older than those who could void.

The agreement between clinical impression of non-neurogenic DU and urodynamic diagnosis of DU utilizing Pdet@Qmax was evaluated utilizing Fisher's exact test and was found not to be statistically significant with p-value = 0.0876 (Figure 7). Next, agreement between UDS parameters and diagnosis of DU based on Pdet@Qmax was evaluated for:

1. PVR using Fisher's exact test showing PVR values are dependent on Pdet@Qmax. Those not diagnosed with DU by the Pdet@Qmax were statistically significantly (p-value = 0.0056) more likely to be identified as < 300 by PVR (Figure 8).
2. Schafer LinPURR stratification of detrusor contractility with Fisher's exact test showing LinPURR values are independent of the Pdet@Qmax values (p-value – 0.4429). There does not seem to be a connection between these two tests; however, this could be secondary to the small sample size (Figure 9).
3. Bladder contractility index showing BCI is independent of the Pdet@Qmax values with no statistical significance using Fisher's exact test with p-value = 1.0000 (Figure

10). There does not seem to be a connection between these two tests, but this could be due to the small sample size.

4. Watts factor showing a statistically significant dependence on Pdet@Qmax values using Fisher's exact test with p-value=0.0062 (Figure 11). Those not diagnosed with DU by Pdet@Qmax > 40 cmH2O were more likely to be identified as normal by WF. DU was defined as ≤ 7 $\mu W/mm^2$ for this study, as Ahmed et al, (2016) utilized a systematic review of literature from January 1972 to January 2016 to establish this value while Donkelaar et al's (2017) recommendations were based on data from a single site.

The data were reviewed to determine if a relationship exists between AUA symptom index score and the diagnosis of DU utilizing Pdet@Qmax; however, this is limited as only 13 of the 36 patients included in the analysis had an AUA score documented with 10 being in the severe symptom range, 2 in the moderate range, and 1 in the mild range. Only 3 of these patients were diagnosed with DU utilizing Pdet@Qmax with AUA scores of 4, 12, and 24, which ranges from mild to severe.

Discussion

There is no uniformly agreed upon definition of DU including either symptom presentation or urodynamic outcomes. In male patients, age proved to be statistically significant in voiding ability with the average age of those able to void 66.8 years and those unable to void 72.9 years. However, those diagnosed with DU averaged 66 years of age while those not diagnosed with DU averaged 67 years of age. There was no statistical significance in clinical diagnosis of DU and urodynamic diagnosis of DU when utilizing Pdet@Qmax for diagnosis. The analysis utilized Pdet@Qmax of < 40 cmH2O based on the findings of Donkelaar et al

(2017) and Ahmed et al, (2016). There was a statistical significance in PVR with those not diagnosed with DU more likely not to have CUR.

Utilizing Pdet@Qmax for comparative diagnosis, showed no statistical significance in diagnosis of DU with Schafer LinPURR stratification of detrusor contractility or BCI; however, this may be secondary to small sample size. Those not diagnosed with DU by Pdet@Qmax showed there was a statistically significant likelihood of being identified as normal by WF. DU was defined as ≤ 7 $\mu W/mm^2$ for this study, as Ahmed et al, (2016) utilized a systematic review of literature from January 1972 to January 2016 to establish this value while Donkelaar et al's (2017) recommendations were based on data from a single site. The lack of relationship between AUA symptom index score and diagnosis of DU utilizing Pdet@Qmax supports the AUA measurement committee findings that AUA score cannot be utilized to differentiate DU from BPH.

The study design is limited by a small sample size of male patients at a single site urology clinic. When compared to Donkelaar at al's (2017) analysis which utilized Schafer LinPURR as the basis for diagnosis of DU, the current analysis utilizing the longstanding standard of care, Pdet@Qmax, for urodynamic diagnosis of DU, did not find BCI or Schafer LinPURR degree of contractility statistically significant in diagnosis. This may be due to small sample size; however, WF did prove to be statistically significant in identifying patients without DU as well as patients without CUR.

This analysis demonstrates CUR and WF prove to be statistically significant in distinguishing patients with and without DU. Combining Pdet@Qmax with WF and presence of CUR may improve detection of DU and become useful in tracking outcome in the future. While LinPURR and BCI did not prove statistically significant in this small study, further evaluation

utilizing a larger sample is warranted given Donkelaar et al's (2017) findings. Additionally, further evaluation of PVR volume may help identify possible interventions before patients develop CUR, as the ability to void in relation to PVR volume did prove to be statistically significant.

Implications for Practice & Research

- The hospital's philosophy is based on the three pillars of patient care, education, and research (Carilion Clinic, 2015). These pillars are strengthened by utilizing evidence-based practice to promote quality care. The recommendation to further investigate if UDS parameters improve diagnostic accuracy of DU is based on:
    - the limited research available for the subset of patients with non-neurogenic detrusor underactivity including the small sample size utilized in this analysis.
    - the inability to utilize BCI to distinguish between bladder outlet obstruction and DU with use of applied theory to interpret results of bladder contractility with limited evaluation in this analysis due to small sample size but promising correlation in Donkelaar et al's (2017) study warrants further analysis.
    - data showing WF is limited by the inability to measure sustainability of detrusor contraction and lack of accepted normal value with three studies offering different normal values for WF. Future analysis on a larger scale may help development of an accepted normal value and increase WF utilization in the diagnosis of DU.
    - limitations of LinPURR for evaluation of detrusor shortening velocity. Further analysis on a larger scale is warranted to determine if LinPURR contractility grade utilization improves the diagnosis of DU.

- The correlation between voiding ability and age suggests potential for urologic deterioration in those aged 65 and older. Further evaluation should be considered as to the effectiveness of annual voiding symptoms screenings to identify patients with deterioration in urological function.
- The correlation between DU and PVR warrants further evaluation in patients with LUTS to determine the effectiveness of PVR screenings in identification and prioritization of patients with deterioration in detrusor function.

Conclusion

DU may present concomitantly with obstructive, irritative, or neurogenic problems thereby necessitating identification of the etiology utilizing best methods practices for initiation of patient-specific treatment. Unfortunately, DU cannot be accurately distinguished from other etiologies of LUTS based on clinical judgement, rather, UDS evaluation is necessary to improve diagnostic accuracy of DU; however, this approach is also limited as there are no widely accepted parameters for the diagnosis of DU utilizing UDS. This retrospective analysis utilizing standard of care, Pdet@Qmax, for urodynamic diagnosis of DU, demonstrates WF and the absence of CUR to both be statistically significant in identifying the absence of DU. Findings agreed with both Jeong et al (2017) and Guo et al (2017)'s studies, showing BCI alone was not statistically significant in diagnosis of DU. Additionally, LinPURR degree of contractility alone was not statistically significant in diagnosis of DU. Donkelaar et al (2017) showed Pdet@Qmax was higher in the "normal" compared to the "weak" contractility group; however, utilization of LinPURR contractility alone for diagnosis of DU was not undertaken. This lack of research accompanied with the limited sample size in this analysis, necessitates further evaluation of utilization of LinPURR degree of contractility for diagnosis of DU.

Products of the DNP Scholarly Project

Collaboration with the hospital's Health Analytics Team, Nursing Research, and Urology Departments facilitated the project's contribution to improve gaps in the literature regarding DU diagnosis. The resultant scholarly project, author guidelines, and draft manuscript will be submitted to the School of Nursing. Study findings will be presented at the University of Virginia on 4/17/2020. Abstract submissions to Urologic Nursing Journal after approval is obtained from the University of Virginia and the hospital.

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Figure 1

Flow of Systematic Review Database Search Results

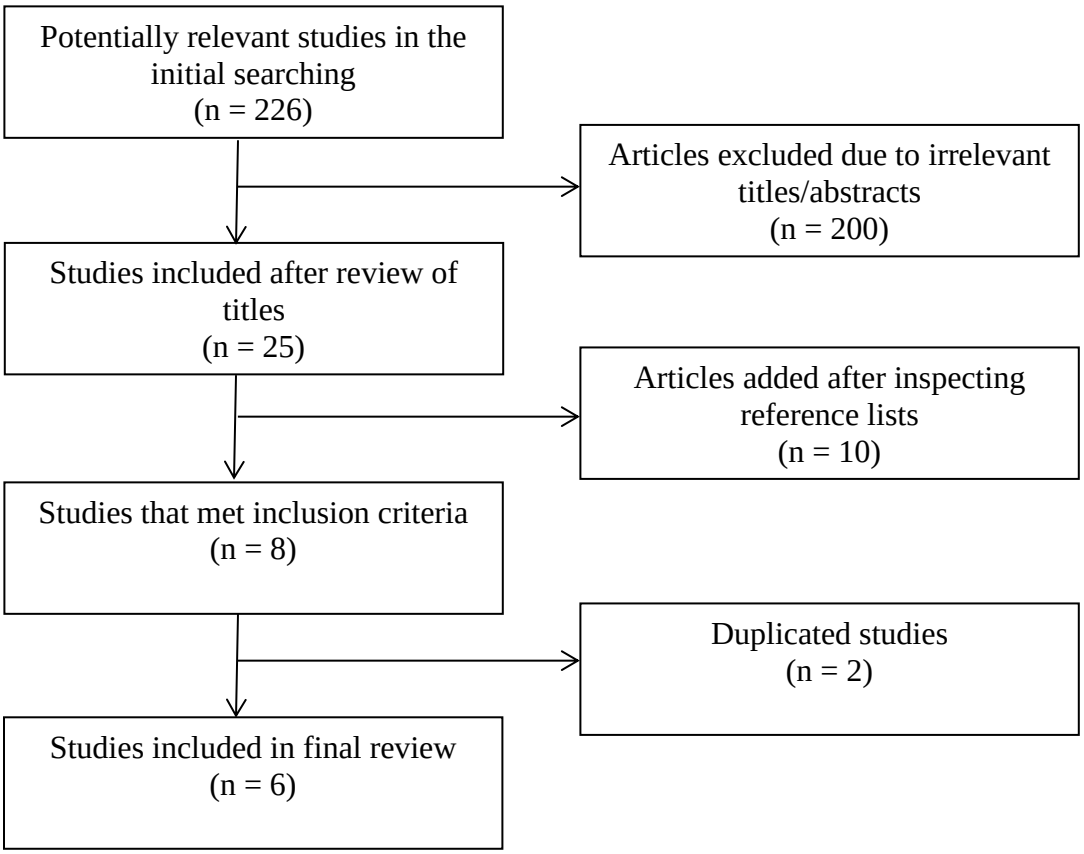


Figure 2

Shafer LinPURR Nomogram utilizing Pdet (detrusor pressure) and Flow to Classify Obstruction Severity (0-VI) and Detrusor Contractility Strength (very weak-strong)

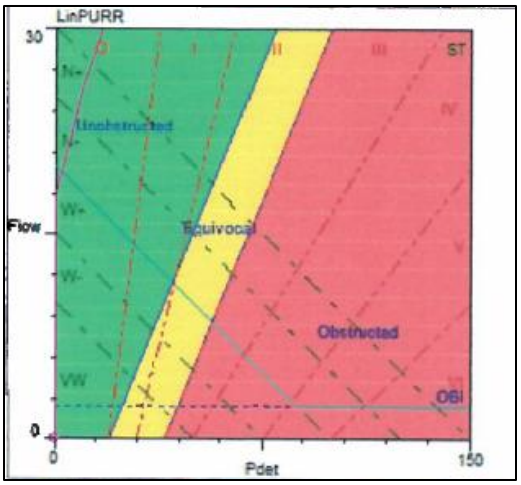
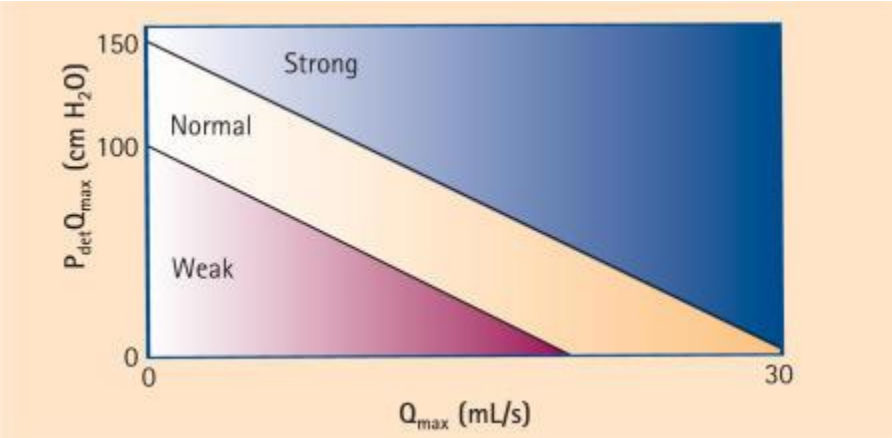


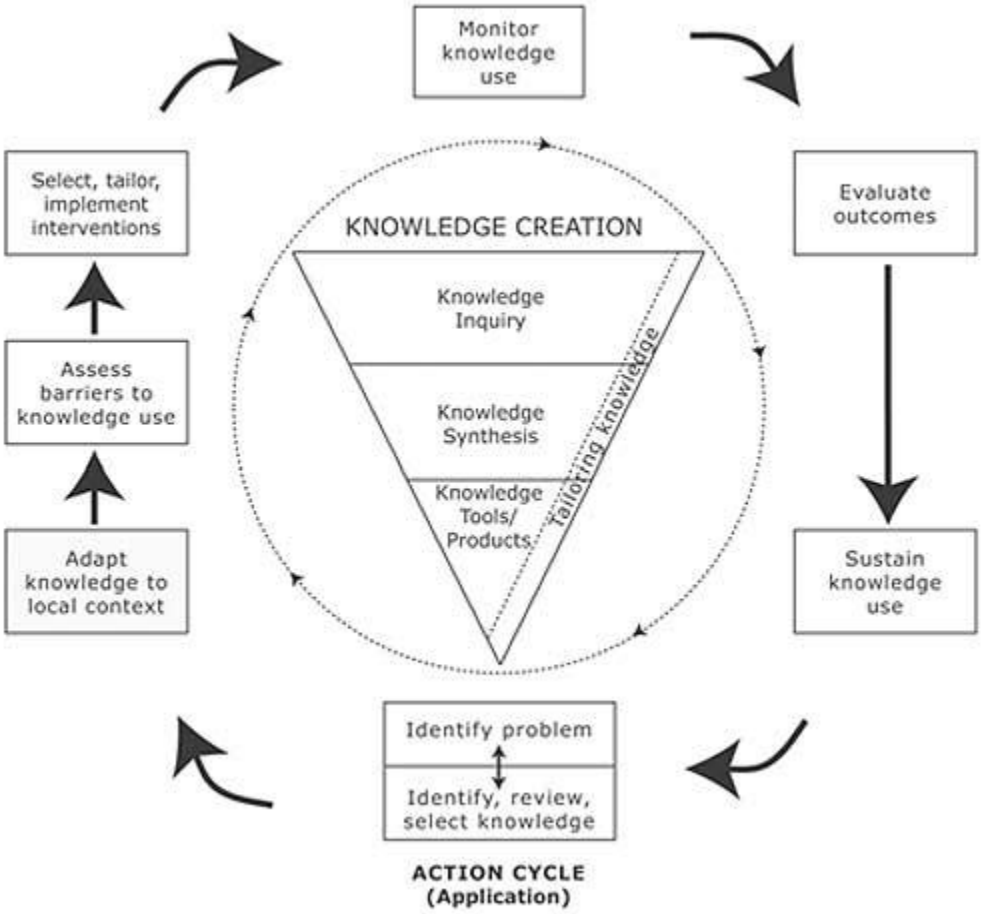
Figure 3

Bladder Contractility Nomogram utilizing Pdet@Qmax (detrusor pressure at max flow) and Qmax (max flow) to Classify Contractility Strength according to the Bladder Contractility Index



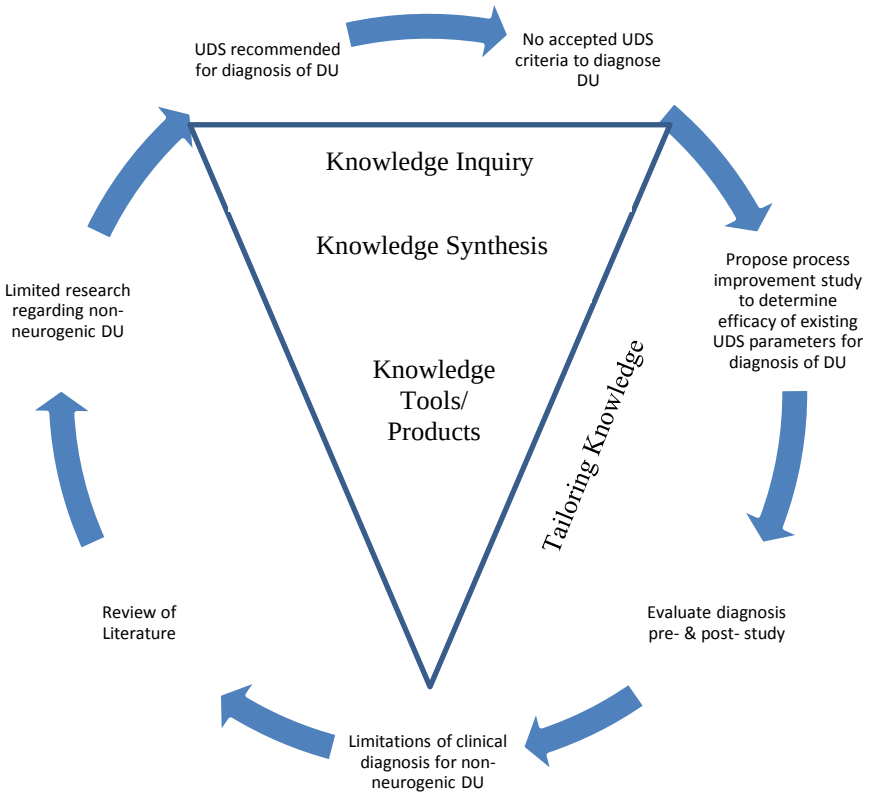
Note. Adapted from "Pressure flow urodynamic studies: The gold standard for diagnosing bladder outlet obstruction" by V. Nitti, 2005, *Reviews in Urology(7)*6, S14-S21.

Figure 4
Conceptual Model of Knowledge to Action Implementation Framework



Note. Adapted from "Lost in knowledge translation: Time for a map?" by I. Graham, J. Logan, M. Harrison, S. Straus, J. Tetroe, W. Caswell, & N. Robinson, 2006, *The Journal of Continuing Education in the Health Professions*, 26(1), p. 19.

Figure 5
Conceptual Model of Knowledge to Action Implementation Framework applied to Scholarly Project



Note. DU = detrusor underactivity. UDS = urodynamic study.

Figure 6
Age Distribution in Years of Patients Based on Ability to Void

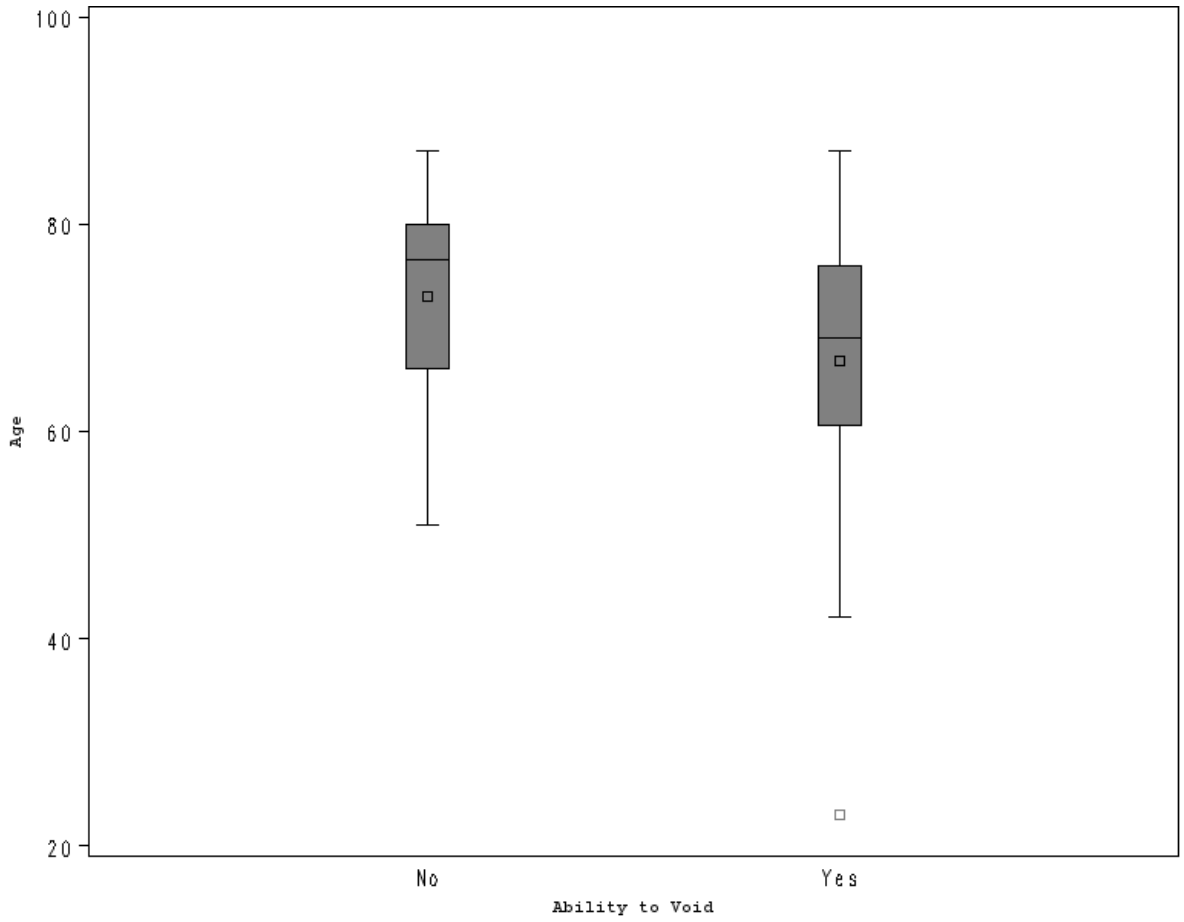


Figure 7

Agreement Between Clinical Impression of Non-Neurogenic Detrusor Underactivity and Urodynamic Diagnosis of Detrusor Underactivity Utilizing Detrusor Pressure at Max Flow

	Post Diagnosis by Pdet@Qmax	
Pre-Diagnosis	Yes DU	No DU
Yes DU	3	2
No DU	6	25

Note. Fisher's Exact Test: p-value=0.0876. DU = detrusor underactivity. Pdet@Qmax = detrusor pressure at max flow

Figure 8

Agreement Between Post-Void Residual Volume and Urodynamic Diagnosis of Detrusor Underactivity Utilizing Detrusor Pressure at Max Flow

	Post Diagnosis by Pdet@Qmax	
PVR	No DU	Yes DU
< 300	25	4
>= 300	2	5

Note. DU = detrusor underactivity. Pdet@Qmax = detrusor pressure at max flow. PVR = post-void residual volume in mL. PVR values are dependent on Pdet@Qmax values. Fisher's Exact Test: p-value=0.0056. Those not diagnosed with DU by the Pdet@Qmax were more likely to be identified as < 300 mL by PVR.

Figure 9

Agreement Between Shafer's LinPURR Stratification of Detrusor Contractility Strength and Urodynamic Diagnosis of Detrusor Underactivity Utilizing Detrusor Pressure at Max Flow

	Post Diagnosis by Pdet@Qmax	
LinPURR	No DU	Yes DU
Underactive	26	8
Normal	1	1

Note. DU = detrusor underactivity. Pdet@Qmax = detrusor pressure at max flow. LinPURR = linear passive urethral resistance relation. The LinPURR values are independent of the Pdet@Qmax values, with no obvious connection between these two tests; however, this could be due to small sample size. Fisher's Exact Test: p-value=0.4429.

Figure 10

Agreement Between Bladder Contractility and Urodynamic Diagnosis of Detrusor Underactivity Utilizing Detrusor Pressure at Max Flow

	Post Diagnosis by Pdet@Qmax	
BCI	No DU	Yes DU
Underactive	21	7
Normal	6	2

Note. DU = detrusor underactivity. Pdet@Qmax = detrusor pressure at max flow. BCI = bladder contractility index. The BCI values are independent of the Pdet@Qmax values, with no obvious connection between these two tests; however, this could be due to small sample size. Fisher's Exact Test: p-value=1.0000.

Figure 11

Agreement Between Watts Factor and Urodynamic Diagnosis of Detrusor Underactivity Utilizing Detrusor Pressure at Max Flow

	Post Diagnosis by Pdet@Qmax	
WF	No DU	Yes DU
Underactive	4	6
Normal	23	3

Note. DU = detrusor underactivity. Pdet@Qmax = detrusor pressure at max flow. WF = Watts factor. The WF values are dependent on the Pdet@Qmax values, with those not diagnosed with DU by Pdet@Qmax more likely to be identified as normal also by WF. Fisher's Exact Test: p-value=0.0062.

Figure 12
Carilion Clinic Institutional Review Board Exemption Determination

CARILION CLINIC
Institutional Review Board

January 27, 2020

To: Kimberly F Carter, Ph.D., R.N., NEA-BC

Re: Exemption Determination for IRB Protocol # IRB-19-663, Improving Urodynamic Prediction of Non-Neurogenic Underactive Detrusor in Adult Male Patients

Exempt Determination Date: **01/27/2020**

The Carilion Clinic Institutional Review Board (IRB) determined the above-referenced study is exempt from IRB review under DHHS regulatory **Category 4(iii): Secondary Research Without Consent: Secondary research uses of identifiable private information or identifiable biospecimens**. This approval is limited to the activities described in the approved IRB Application **and may include the retrospective review of medical charts up to 12/23/2020.** This study may proceed without further oversight by the IRB. In conducting this study, you are required to follow the requirements described in INVESTIGATOR GUIDANCE: Investigator Obligations (HRP-800), located on the IRB website at https://www.carilionclinic.org/irb/policies.

Please note:

- Changes that may significantly change the study may not be implemented without submission of a Modification and further review by the IRB prior to implementation of the changes. Significant changes include:
  - Change in PI;
  - Procedures or new information that may alter the benefits or risks to participants;
  - Types of personal health information (PHI) or private identifiable information (PII) to be accessed;
  - Addition of new research tools that collect sensitive or potentially stigmatizing information;
  - **Addition of external collaborators (including VT personnel or VTCSOM medical students) are not permitted under this Exemption category and would require the study to be upgraded to an Expedited review;**
  - Addition of new study populations
- Research team member changes (other than changes to the PI) do not need to be submitted to the IRB for studies that have been determined to be exempt.
  - The PI is responsible for ensuring every team member has completed the Biomedical Researchers CITI training and any other necessary training before the new members become engaged in the study.
  - If the study is externally funded or receives external support, it is the PI?s responsibility to ensure every new team member files a study-specific COI disclosure form with the Office of Integrity and Compliance through COISmart by contacting Compliance@carilionclinic.org.
- Consent is not required for this retrospective study.
- The IRB has determined that a **full** HIPAA waiver of research subject authorization is justified under 45 CFR 46 164.512.

This letter conveys IRB approval only and does not grant institutional approval. If your research involves any Carilion facilities, then separate arrangements must be made with the appropriate hospital or medical staff, department or committees, along with the Carilion Department of Research and Development. The Carilion Clinic Institutional Review Board would like to thank you for the opportunity to review this protocol.

If you have any questions, please do not hesitate to contact the IRB at bblevins@carilionclinic.org or 540-224-5882.

Figure 13
University of Virginia Institutional Review Board Determination of Agency

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UNIVERSITY of VIRGINIA IRB-HSR **Institutional Review Board for Health Sciences Research**

DETERMINATION OF UVA AGENT FORM

INFORMATION ABOUT THIS FORM

- This form is to determine if UVA personnel are or are not considered to be working as an Agent* for UVA on this project.
- If it is determined that UVA personnel are considered to be working as an Agent* for UVA the study, then your team will be required to provide an additional submission to the IRB-HSR, unless the project is determined to not involve human subject research. See Determination of Human Subject Research Form

***Agent-** all individuals (including students) performing institutionally designated activities or exercising institutionally delegated authority or responsibility.*

Enter responses electronically. Email the completed form to IRBHSR@virginia.edu for pre-review.

An IRB staff member will reply with any changes to be made.

Name of Individual to be Working on Project:	Dana Garnand
UVA Email:	dg3uf@virginia.edu
Phone:	540-230-3634
UVA Messenger Mail Box #	
Project/Protocol Title if Known:	☐ Unknown or Title: Improving Urodynamic Prediction of Non-Neurogenic Underactive Detrusor in Adult Male Patients
List your UVA School or Department affiliation *(e.g. Nursing, Medicine, etc.)*	Nursing, Graduate
Name of the Division *(if applicable)* *(e.g. Anesthesia, Graduate Studies etc.)*	
Explain your role in the project: (200 words or less)	Researcher, data collection, data analysis, and author of resultant research documents
Explain the reason for traveling to the outside institution.	I work at Carilion Clinic Urology, thus making this an accessible location for the research project

INSTRUCTIONS: Complete the applicable option below:

Option A: Typically used by UVA personnel who are asked to assist with a research study after arriving at the non- UVA institution. (e.g., resident doing rotation at another institution)

Answer the following questions:

☐ **Yes** ☐ **No** I was involved in the design of this research project.
☐ **Yes** ☐ **No** A UVA IRB has approved this research. IRB-HSR/UVA Study Tracking #
☐ **Yes** ☐ **No** Funding to conduct this research will come from or through UVA.
☐ **Yes** ☐ **No** Working on this research is required for my degree program.

I confirm that:

☐ **Yes** ☐ **No** I am a student, employee or faculty member of the University of Virginia.
☐ **Yes** ☐ **No** My work on this project will be overseen by the Principal Investigator and the IRB at the outside institution. This includes completing any training in human subject research protection or other training as required by the outside IRB.
☐ **Yes** ☐ **No** I will communicate with the UVA IRB and UVA Contracts Office for my school, to determine what approvals may be needed, prior to receiving any data from the outside institution

Option B: Typically used by graduate students conducting their research outside of UVA.

I confirm that:

☒ Yes ☐ No I designed this research.
☒ Yes ☐ No I am a student, employee or faculty member of UVA but am employed by another institution.
☒ Yes ☐ No All subjects will be enrolled at this outside institution.
☒ Yes ☐ No Only de-identified data may be brought to UVA. If data is brought to UVA it will be protected according to UVA Data Security Policies.
☒ Yes ☐ No The research will be overseen by their IRB and, if applicable, their HIPAA Privacy Board. This includes completing any training in human subject research protections or other training as required by the outside IRB.
☒ Yes ☐ No There is no funding for this study or if there is funding, it will be handled by the non-UVA institution at which I am employed.
☒ Yes ☐ No I have notified the outside IRB that a UVA IRB will not be overseeing my work. ATTACH COPY OF THE OUTSIDE IRB APPROVAL/DETERMINATION.

Option C: Typically used by a person who will continue working on their research at their previous institution after transferring to UVA. No research protocol will be opened to enroll additional subjects at UVA.

I confirm that:

☐Yes ☐No I am a student, employee or faculty member of UVA but I was employed by another institution when the research was begun.

☐Yes ☐No All subjects were or will be enrolled at the outside institution & all data will remain there.

☐Yes ☐No The research will be overseen by a non-UVA IRB and, if applicable, the HIPAA Privacy Board of my previous institution. This includes completing training in human subject research protections or other training as required by the outside institution.

☐Yes ☐No There is no funding for this study or if there is funding, it will be handled by my previous institution.

☐Yes ☐No I have notified the IRB of Record that I have transferred to UVA and that a UVA IRB will not be overseeing my work on this research protocol.
ATTACH COPY OF THE OUTSIDE IRB APPROVAL/DETERMINATION.

Option D: Typically used by a UVA Faculty member who has an appointment or clinical privileges at another institution. Research to be conducted at outside institution. Research protocol will not be opened to enroll subjects at UVA facilities.

I confirm that:

☐Yes ☐No I am a faculty member of UVA and I have an appointment or clinical privileges at another institution.

☐Yes ☐No All subjects will be enrolled at the other institution and all data will remain there.

☐Yes ☐No The research will be overseen by a non-UVA IRB and, if applicable, the HIPAA Privacy Board of the other institution. This includes completing any training in human subject research protections or other training as required by the other institution.

☐Yes ☐No There is no funding for this study or if there is funding, it will be handled by the other institution.

☐Yes ☐No I have notified the IRB of Record that a UVA IRB will not be overseeing my work on this research protocol.
ATTACH COPY OF THE OUTSIDE IRB APPROVAL/DETERMINATION for this protocol.

FOR IRB-HSR OFFICE USE ONLY

☒ UVA personnel are not considered to be conducting research as an Agent for UVA on this project.
No approvals from the UVA IRB-HSR are required.
No data may be brought back to UVA for any purpose except as described above.
If you wish to collect and use data from the original study for an additional research project you must obtain IRB approval/determination from the IRB-HSR before taking data outside of the non-UVA institution.

UVA Study Tracking # 22149

.

☐ UVA personnel are considered to be conducting research as an Agent for UVA on this project.
Submit a research application to the UVA IRB-HSR.

Karen Mills _____ 02-04-20 _____

Name of IRB Chair, Director or Designee Date

Figure 14
Instruction for Authors from Urologic Nursing

Urologic Nursing, the official journal of the Society of Urologic Nurses and Associates, Inc. (SUNA), is a peer-reviewed journal that welcomes the submission of original manuscripts pertinent to the practice of urologic health care professionals. Unless clearly specified, the views expressed in articles, editorials, and letters published in *Urologic Nursing* represent the opinions of the authors and do not reflect the official policies of SUNA.

The journal accepts original articles: case study, clinical practice, continuing education, patient education, systematic review of the literature, quality/performance improvement, and research. Specific templates for many types of manuscripts are available online (www.suna.org/unj). Query letters are welcomed, but not required. Material must be original and never published before. Material is submitted for review with the understanding that it is not being submitted to any other journal simultaneously. An electronic copy of the manuscript should be submitted to the editorial office.

Urologic Nursing is a refereed journal. All manuscripts submitted undergo review by the editor and blind review by members of the manuscript review panel and/or editorial board. Each manuscript is evaluated on its timeliness, importance, accuracy, clarity, and applicability to urologic nursing. Upon acceptance of the manuscript, the author will yield copyright to *Urologic Nursing*. Manuscripts accepted are subject to copy editing. The author will receive proofs for review prior to publication.

Manuscript Preparation

Manuscripts must be typed and double-spaced. Style should follow the *Publication Manual of the American Psychological Association* (6th ed.). As a general rule, manuscripts should be saved as MS Word documents. Use the author-date method of citation within the text, e.g., (Doe, 2017) or "Doe (2017) states...." With multiple authors, the first citation must list all authors, and subsequent citations should list only the last name of the first author and et al. (Doe et al., 2017).

Acquiring permission to reprint previously published materials is the responsibility of the author.

Format of Manuscript

Title Page: Include the manuscript title, authors' names, credentials, and job titles and affiliations. Also include a brief abstract of 40 words or less along with an address for correspondence, day and evening phone numbers, fax number, and email address.

Text: Double-space all typing, using 1-inch margins. Include the title or a short descriptor on top of each page, but do not include the author's name. Use Times Roman and avoid complex font attributes such as outline.

Subheadings: Include subheadings in the manuscript where possible. The first three levels use bold font. Italics are not used unless there are more than 3 levels of headings:

Level 1 Example
Centered, Boldface, Uppercase and Lowercase Heading

Level 2 Example
Flush Left, Boldface, Uppercase and Lowercase Heading

Level 3 example.
Flush left, boldface, lowercase heading ending with a period.

Level 4 example.
Flush left, italicized, lowercase heading ending with a period.

Figures: These include line drawings, photographs, diagrams, and graphs. Each figure should be numbered, and the number must correspond to a statement in the manuscript directing the reader to see such figure (see Figure 1). Include a separate legend sheet with captions. When using figures reprinted or adapted from another source, the author must obtain written permission for *both* print and electronic use from the original publisher.

Tables: Construct tables using the "Draw Table" tool in MS Word or create tables in an Excel spreadsheet. Do NOT place tables inside a separate text box, and do not use tabs to create columns of text.

Photographs: Camera-ready photographs may be black and white or color. Photos should be glossy, 5 x 7 inches. Electronic files (JPGs) must be in high resolution, 300 dpi.

Please note: Images found on Google, Bing, or other Internet search engines are not public domain; permission from the original source must be provided.

References

List all references (only those cited within the text) in alphabetical order. All citations should reference primary sources. The use of secondary sources (material analyzed or interpreted from the primary source) is discouraged. If necessary, locate a copy of the original work and credit it as such. Authors are encouraged to provide the digital object identifier (DOI) number for all references when possible directly after the citation. Manuscripts must NOT contain reference software codes.

Citing Multiple Authors: In-text citations with six or more authors should include the first author followed by et al., even in the first citation.

In the list of References, if there are eight authors or more, list the first six, then an ellipsis, then the last author. If there are seven authors, list all seven.

Websites: It is not necessary to include the date a site was accessed, unless the material will change over time.

Samples

Periodical:
Lamb, B., Jalil, R., Shah, S., Brown, K., Allchorne, P., Vincent, C., ... Sevdalis, N. (2014). Cancer patients' perspectives on multidisciplinary team working: An exploratory focus group study. *Urologic Nursing, 34*(2), 83-91, 102.

Book:
American Psychological Association (APA). (2010). *Publication manual of the American Psychological Association* (6th ed.). Washington, DC: Author.

Chapter in a Book:
Gray, M. (2009). Management of men with reproductive disorders. In J. Black, & J. Hawks (Eds.), *Medical-surgical nursing: Clinical management for positive outcomes* (8th ed., pp. 873-911). Philadelphia: Elsevier.

Conflict of Interest

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Table 1
Comparison of Urodynamics Study Measures of Pdet@Qmax (detrusor pressure at max flow), Schafer nomogram, Watts Factor, and BCI (Bladder Contractility Index) formulas

	Pdet	Qmax	Vdet	BOO
Pdet@Qmax	+	+	-	-
Schafer nomogram	+	+	-	+
Watts factor	+	-	+	-
BCI	+	+	-	-

Note. Pdet = detrusor pressure. Qmax = max flow. Vdet = detrusor shortening velocity. BOO = bladder outlet obstruction.

Table 2
Study Table

Author/Year	Subjects/Setting	Design	Intervention and Comparison Intervention	Bias/Limits	Applicability to Study
Donkelaar, Rosier & Kort, 2017	Adult males aged 50+ years; quantitative, n = 1222	Retrospective analysis of detrusor contraction using LinPURR, BCI, and max WF	Comparison of agreement of LinPURR, BCI, and WF in grading detrusor contractility	Limited to adult males at one clinical site	Shows 80% agreement between LinPURR and WF and 97% agreement between LinPURR and BCI in grading detrusor contractility
Guo, Comiter & Elliott, 2017	Adult males with median age 68 years; quantitative, n = 67	Retrospective review of males with urinary retention	Comparison of BCI and isometric detrusor contraction pressure for diagnosis of DU	Limited to adult males at one clinical site	73% of men had a BCI < 100, however, when bladder contractility was evaluated using isometric detrusor contraction pressure, only 29% of these men met criteria for DU (< 50 cmH2O). These findings reinforce Chang's (2018) theoretical use of isometric contraction pressure in addition to BCI to identify DU.
Hoag & Gani, 2015	Adult patients with DU	Retrospective analysis of 79 patients (25 male, 54 female) with DU utilizing BCI < 100	Utilization of UDS to identify patients with DU and comparison with prior diagnosis/treatments	Limited to BCI for diagnosis of DU. Does not consider coexistence of bladder outlet obstruction	Utilization of BCI to identify DU. Many patients underwent unnecessary surgery/medication trials due to misdiagnosis
Jeong et al., 2017	Adult patients with DU, quantitative, n = 4,372	Retrospective analysis of 3,357 men and 1,105 women ages 60+ years	Utilization of UDS to compare methods of diagnosing DU	Limited to single site, data may not be generalizable. Lack of consensus on optimal for diagnosis of DU. BCI does not consider coexistence of bladder outlet obstruction	55.8% of men had DU by BCI alone but only 5.4% had DU when incorporating Pdet@Qmax into diagnostic criteria. 9.6% of women were diagnosed with DU using Pdet@Qmax criteria. BCI alone is limited as diagnostic tool for DU
Jiang & Kuo 2017	Adult male patients with LUTS, average age71 years for those with DU, quantitative, n = 1329	Retrospective analysis of 1329 men with lower urinary tract symptoms who had failed initial treatment	Utilization of UDS to identify parameters associated with DU	Limited to single site, hospitalized patients. Limited to male patients.	165 men had DU with average Pdet@Qmax of 9.74 cmH2O, Qmax 1 mL/s, and PVR 348 mL. Average for: BCI was 19, Pdet 9, and Qmax 1.9.Those with acontractile bladders had statistically significant lower BCI
Liu et al., 2018	Adult males ages 18-87 with lower urinary tract symptoms, quantitative, n = 455	Retrospective analysis of UDS to determine if WF is a reliable measure of detrusor contractility	Comparison of correlation of WF and BCI with Schafer contractility grades	Limited to male patients at a single site. BCI does not consider coexistence of bladder outlet obstruction	WF and BCI showed positive correlation with Schafer contractility grades, showing these are reliable indicators of contractility (P <0.001)