Introduction

Neurogenic bladder (NB) is a lower Urinary tract infection (UTI) which involves the bladder and urethra. It may be caused by damage to or diseases of the central nervous system. It is one of the most challenging problems in urology. Various neurological disorders can cause chronic bladder dysfunction, including stroke, Parkinson’s disease (PD), multiple sclerosis (MS), spinal cord injury (SCI), and spina bifida. These disorders can damage the central nervous system. As a result, the bladder may experience decreased activity (no complete discharge) or excessive activity (fast discharge), which leads to urinary retention or frequent urination. Children with NB are at higher risk for lower UTI and kidney damage. Neurogenic lower urinary tract dysfunction (NLUTD) is attributed to various diseases and events affecting the lower urinary tract. NLUTD depends on the location and severity of the neurological lesion. Both congenital and acquired NLUTDs require rapid diagnosis and treatment. Accordingly, irreversible changes may occur, especially in children with Myelomeningocele (MMC), as well as people with traumatic SCI, even if the neuropathological symptoms are normal.

Abstract

Introduction and Objective: Urodynamic testing (urodynamics) is widely used for evaluating bladder function as a result of high detrusor compliance. This aggressive and uncomfortable test is especially difficult for children. This study aimed to determine the sensitivity of shear wave ultrasound elastography (SWE) as a new method for evaluating the biomechanical characteristics of bladder to measure the anterior bladder wall pressure in children with neurogenic bladder (NB). Materials and Methods: The present prospective clinical study was carried out on 30 children with allegedly NB and 20 healthy children as control group. These children referred to Ahwaz Golestan Hospital in 2018. After clinical evaluations, urodynamics was performed for children with NB and detrusor compliance was measured in cm/H₂O. The ultrasonography of the SWE was performed on the anterior wall of the bladder (Estimated bladder capacity (EBC) 50%) for the two groups. The relationship between shear wave speed (SWS) and detrusor compliance was estimated using Pearson’s correlation coefficient. Independent t-test was used to compare SWS between two groups. Results: In patients with NB, there was a significant relationship between the mean SWS of the anterior bladder wall and detrusor compliance \( (R = 0.89, P = 0.0001) \). The comparison between normal and NB groups showed that the mean SWS of the anterior bladder wall in the patients was significantly higher than the healthy group \( (1.88 \pm 0.88 \text{ m/s} \text{ vs. } 0.94 \pm 0.15; P = 0.0001) \). There was also no significant relationship between SWS, gender, age, weight, and body mass index of patients \( (P > 0.05) \). Conclusion: The results showed that SWE can be used as a useful alternative for urodynamic testing in the evaluation of NB (bladder dysfunction) in children.

Keywords: Bladder, neurogenic, shear wave elastography, ultrasound, urorodynamics

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Timely diagnosis and appropriate management of bladder dysfunction requires several tests and can help prevent and minimize its effects on renal function over time.\textsuperscript{[4,5]} At present, urodynamic tests are commonly used for the diagnosis of these dysfunctions and high detrusor compliance.\textsuperscript{[6‑7]} These invasive tests may require special equipment.

Studies show that there is a relationship between the rate of tissue damage (caused by various factors and diseases) and urodynamic evaluations.\textsuperscript{[8]} In other words, factors such as capacity, compliance, and bladder-specific compliance are associated with structural diseases. On the other hand, catheterization of patients through urodynamic studies causes rare complications and is therefore considered a disadvantage for these invasive methods.\textsuperscript{[6,9]} Therefore, a simple and noninvasive methodology can be a valuable and cost-effective tool for evaluating bladder dysfunction.\textsuperscript{[10]}

Several researches have been conducted with the advancement of imaging technologies to remove and reduce aggressive tests as much as possible. One of these new findings is known as shear wave elastography. Shear wave ultrasound elastography (SWE) is one of the latest technological advances in ultrasound that measures tissue consistency, especially in soft tissues.\textsuperscript{[11]} In this method, tissue characteristics are determined indirectly based on shear wave speed (SWS).\textsuperscript{[12‑14]}

SWE is currently used to examine cases of cancer and monitor fibrotic tissue changes in other organs such as liver, breast, prostate, and thyroid.\textsuperscript{[15‑17]} In cases of liver failure, SWE identifies tissue damage and the effect of treatment to improve the disease.\textsuperscript{[15,16]} In other studies, there was a strong relationship between histological and pathological findings with shear wave elastography in prostate tissue infected with malignancy in an animal sample.\textsuperscript{[14]} In a similar study, the urodynamic findings were compared with the shear wave elastography findings on the bladder tissue.\textsuperscript{[6]}

This study aimed to evaluate the efficacy of shear wave elastography for measuring bladder compliance in patients with NB. It is assumed that the increase in SWE (m/s) is associated with an increase in bladder compliance during the urodynamic testing. In this study, the bladder urodynamic findings (bladder capacity) were compared with SWE findings.

**Materials and Methods**

This study also aimed to investigate the use of SWE. This method can be used to identify NB in children. For this purpose, 30 children between 5 and 14 years of age with NB referring to Golestan Hospital of Ahwaz were first examined through urodynamic testing which is mainly used to measure changes in bladder compliance. Then, the children underwent shear wave elastography to measure the speed of the wave passing through the bladder tissue. Furthermore, 20 healthy children (normal bladder) were selected as control group who underwent SWE. Finally, the results of the two groups were compared.

**Inclusion criteria**

- Consent to participate in the study
- Children age 5–14 years
- Children with NB (patient group)
- Healthy children with normal bladder (control group).

**Exclusion criteria**

- Children with frequent urinary tract infections
- History of bladder augmentation
- Diabetes, spina bifida, cerebral tumors, cerebral palsy, lupus, MS, HIV
- History of radiotherapy in the pelvic area
- SCI, history of spinal cord surgery
- History of abdominoperitoneal surgery
- History of drug administration: ouroculin, betancole, prostaglandin E2 and F2, phenoxybenzamines
- Increased thickness of the bladder wall.

**Evaluation and imaging**

**Urodynamic testing**

Urodynamic testing was performed using the MMS device, and systometrograms were completed under the supervision of a pediatric urologist. A urine catheter (6–9 Fr) and a rectal catheter (8 Fr) were used for monitoring bladder compliance and abdominal pressure, respectively. The compliance inside the bladder and, more precisely, the capacity detrusor pressure was measured by the urodynamics. Detrusor pressure was calculated by subtracting the abdominal pressure from the bladder compliance.

**Shear wave ultrasound elastography**

All children were examined by an experienced radiologist using SWE. For this purpose, supersonic device equipped with SWE and 1- to 6-MHz bandwidth probe were used. During the imaging process, ultrasound compliance was manually minimized. All images were taken in noncontractile mode. The regions of interest (ROI) were confirmed by an experienced radiologist. The speed of the wave passing through the bladder tissue was measured using shear wave elastography images. This speed was measured in various views [Figure 1].

Bladder volume was calculated by the following formula:

Bladder volume formula for children: \((\text{age} + 2) \times 30 \text{ cc}\)

Bladder volume in adults: 400–500 cc

Yellow circles represent ROIs on the SWS map. Blue section represents a low SWS in the bladder (1.2 m/s on average).

**Data analysis**

Data were analyzed using SPSS (SPSS Inc., Chicago, IL, USA; version 22).
Results

Fifty children (age 5–14 years) participated in this study. There was no significant difference between the two groups [Tables 1 and 2] in terms of age, sex, height, weight, and body mass index (BMI) ($P > 0.05$).

The results of urodynamic testing and SW elastography

Comparison of the results of the anterior bladder wall pressure through urodynamic testing and SWS in children with NB is presented in Table 3 and Figure 2. There is a positive and significant relationship between detrusor compliance and the mean SWS of the anterior wall of the bladder ($P = 0.0001$).

Comparison of the SWS of the anterior bladder wall in children with NB and normal bladder is presented in Table 4. Obviously, SWS in NB group was significantly higher than normal group ($P < 0.0001$).

Relationship between anterior bladder wall pressure and different variables

The results of the relationship between quantitative and qualitative variables and bladder pressure by urodynamic testing and SW elastography in children with NB are presented in Tables 3 and 4, respectively.

As shown in Table 1, there was no significant relationship between age, weight, and BMI of patients with bladder wall pressure in either of the two methods of urodynamic testing and SW elastography.

According to Table 2, there was no significant relationship between the sexes of children and bladder pressure evaluated by urodynamics and SW elastography.

Discussion

The application of the SWE technique to detect lesions in some organs, especially breast and thyroid, has showed promising results.[12,14] In this regard, this controlled clinical trial also examined the ability of shear wave elastography for detecting bladder pressure changes in children with NB.

The results showed a positive and significant relationship between detrusor compliance and the mean SWS of the anterior wall of the bladder. In addition, the SWS of the anterior wall in full bladder was significantly higher in NBs than normal bladders. Therefore, SWE is a promising clinical method for detecting high bladder pressure.

These results are in good agreement with the findings of Sturm et al. (2017). They showed that SWS of the anterior and posterior wall of the bladder is significantly related to detrusor compliance of the bladder.[6]


Table 3: Results of anterior bladder wall pressure through urodynamic testing and SW elastography

|                      | SD±mean        | P             |
|----------------------|----------------|---------------|
| SW (m/s)             | (3.20±1.11)    | R=0.829       |
|                      | Median=1.37    |               |
| Urodynamics (cm/H₂O) | (47.0±9.0)     | Sig=0.0001    |
|                      | Median=24.5    |               |

SW: shear wave; SD: standard deviation; SWS: shear wave speed. *Pearson’s correlation test

Table 4: Comparison of SWS among children with neurogenic bladder and normal bladder

| Group             | SD±mean        | P             |
|-------------------|----------------|---------------|
| Patient (30)      | (3.20±1.11)    | 0.0001        |
|                   | Median=1.37    |               |
| Normal (20)       | (0.7±1.2)      |               |
|                   | Median=0.9     |               |

SD: standard deviation. *Independent t-test

Urologists are looking for a reliable evaluation method to measure detrusor compliance since increased bladder pressure is recognized histologically as a key factor in the pathogenesis of hydroureter and vesico-ureteral reflux. Moreover, renal dysfunction in children is associated with NB. One of the strengths of this study is the comparison of new SWE technology with urodynamic testing, which is commonly used for the diagnosis of bladder dysfunction. The ultimate goal of this study is to use this noninvasive method to avoid catheterization. Given the fact that in this study SWS of the anterior bladder wall was significantly different between the two groups with neurogenic and healthy bladder, SWE is expected to be most commonly used as a noninvasive method for diagnosing bladders that put kidneys at risk of dysfunction. There was also a significant relationship between SWS results and the pressure measured by urodynamic testing.

Unlike urodynamic testing, SWE is an imaging technique, specifically developed to evaluate the stiffness of the tissue. The SW technology directs high-intensity sound waves in soft tissue, generating micron-level displacement and propagates shear wave. SWS represents the local histology and pressure on the wall during filling.

This interaction between tissue and volume characteristics is shown in this study (EBC 50%). Sturm et al. reported that there was a significant difference between the SWS of the compliance and the noncompliance bladder (EBC 25% or more). However, no significant difference was found in the empty bladder. Therefore, SWE has the potential for bladder diagnosis by changing the biomechanical properties associated with increased storage pressure.

A previous study showed a positive and significant relationship between SWS using acoustic radiation force imaging (ARFI) and tissue fibrosis in the liver. In addition, Du et al. (2007) studied the use of this method in PD in the United States in 2016. They showed that this method can help measure the stiffness of the tissue (Young’s modulus of the biceps brachii) in patients with PD. Wei et al. (2018) also reported that SWE can accurately detect prostate cancer foci. There was a significant difference between cancerous tissue and healthy tissue.

In contrast, Shepard et al. (2016) investigated the relationship between ARFI and urodynamic parameters in children at risk of neuropathic bladder. According to the results, there was no significant relationship between SWS using ARFI and reduced bladder compliance. However, researchers argued that further studies are required to determine the role of ADFI to predict the urodynamic parameters in children.

The exact cause of the difference in the results is unclear and requires further investigation. However, there were some differences in the methods of the two studies, including different devices, bladder wall measurement, and SWS measurements. Furthermore, participants’ characteristics were different in the two studies. Sturm et al. showed that there was a significant relationship between SWS and the anterior bladder wall pressure. Accordingly, SEW technology can help diagnose the NB.

**Conclusion**

The results showed that there was a significant relationship between the mean shear wave propagation speed in the anterior bladder wall and bladder pressure in children with NB. Shear wave elastography can be used as a noninvasive method for evaluating the biomechanical changes in the bladder wall. Moreover, SW elastography is an important alternative to urodynamic testing. However, further studies are needed to confirm the efficacy of this technique.

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**Conflicts of interest**

There are no conflicts of interest.

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