Original Article

An investigation into the sensitivity of shear wave ultrasound elastography to measure the anterior bladder wall pressure in patients with neurogenic bladder

Alireza Ghorbani Bavani[1], Mohammad Ghasem Hanafi[1], Mohsen Sarkarian[2]

[1]*Department of Radiology, Golestan Hospital, Ahvaz Jundishapur University of Medical Sciences,*
[2]*Department of Urology, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*

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/H_2O. 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 ± 0.88 m/s vs. 0.94 ± 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 urorodynamic testing in the evaluation of NB (bladder dysfunction) in children.

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

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.[1] 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.[2]

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.[3]

Address for correspondence: Asst Prof. Mohammad Ghasem Hanafi, Department of Radiology, Golestan Hospital, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
E-mail: gasemhanafi@yahoo.co

Access this article online

Quick Response Code:

Website: www.jfmpc.com

DOI: 10.4103/jfmpc.jfmpc_84_19

How to cite this article: Bavani AG, Hanafi MG, Sarkarian M. An investigation into the sensitivity of shear wave ultrasound elastography to measure the anterior bladder wall pressure in patients with neurogenic bladder. J Family Med Prim Care 2019;8:1342-6.

Timely diagnosis and appropriate management of bladder dysfunction requires several tests and can help prevent and minimize its effects on renal function over time.[4,5] At present, urodynamic tests are commonly used for the diagnosis of these dysfunctions and high detrusor compliance.[5-7] 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 urorodynamic evaluations.[8] In other words, factors such as capacity, compiliance, and bladder-specific compliance are associated with structural diseases. On the other hand, catheterization of patients through urorodynamic studies causes rare complications and is therefore considered a disadvantage for these invasive methods.[6,9] Therefore, a simple and noninvasive methodology can be a valuable and cost-effective tool for evaluating bladder dysfunction.[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.[11] In this method, tissue characteristics are determined indirectly based on shear wave speed (SWS).[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.[15-17] In cases of liver failure, SWE identifies tissue damage and the effect of treatment to improve the disease.[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.[18] In a similar study, the urorodynamic findings were compared with the shear wave elastography findings on the bladder tissue.[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 urorodynamic testing. In this study, the bladder urorodynamic 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 wavepassing 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 bandwidh 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: (age + 2) ×30 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).

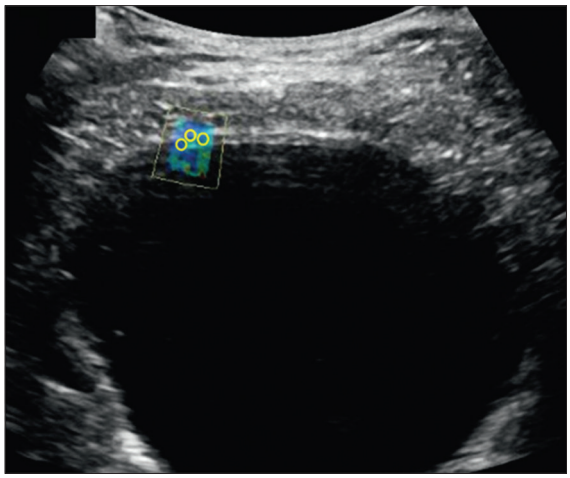

Figure 1: SWE ultrasound image

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]

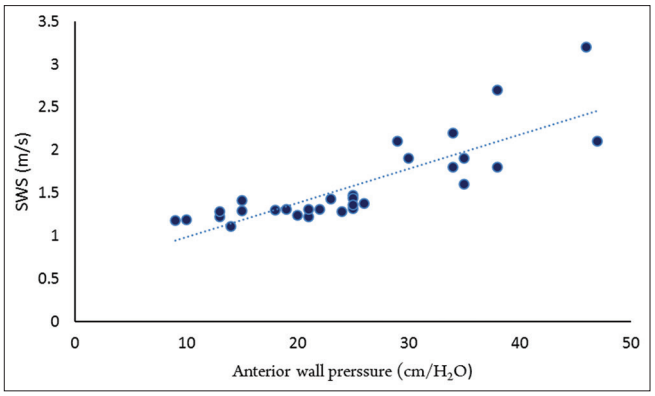

Figure 2: Relationship between detrusor compliance (in the urodynamic testing) and shear wave speed (in elastography)

Table 1: Relationship between quantitative variables and bladder pressure evaluated by urodynamics and SW elastography

Variable	Method	Correlation
Age	SWS (m/s)	*R*=0.124 Sig=0.513
	Urodynamics (cm/H_2O)	*R*=0.117 Sig=0.365
Weight	SWS	*R*=0.124 Sig=0.513
	Urodynamics	*R*=0.117 Sig=0.365
BMI	SWS	*R*=0.352 Sig=0.641
	Urodynamics	*R*=0.278 Sig=0.486

SW: shear wave; SWS: shear wave speed; BMI: body mass index

Table 2: Relationship between children's sex (gender) and bladder pressure evaluated by urodynamics and SW elastography

Method	Girl SD±mean	Boy SD±mean	*P*
SWS (m/s)	1.54±0.57	1.60±0.41	0.723
Urodynamics (cm/H_2O)	23.23±10.38	26.23±9.71	0.422

SW: shear wave; SD: standard deviation; SWS: shear wave speed

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

	SD±mean	*P*
SWS (m/s)	(3.20-1.11) 1.58±0.48 Median=1.37	*R*=0.829 Sig=0.0001
Urodynamics (cm/H_2O)	(47.0-9.0) 24.96±10.02 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) 1.58±0.48 Median=1.37	0.0001
Normal (20)	(0.7-1.2) 0.94±0.15 Median=0.9	

SWS: shear wave speed; 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 hydronephrosis and vesicoureteral reflux. Moreover, renal dysfunction in children is associated with NB.[6-8] 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 urorodynamic testing.

Unlike urodynamic testing, SWE is an imaging technique, specifically developed to evaluate the stiffness of the tissue.[19,20] The SW technology directs high-intensity sound waves in soft tissue, generating micron-level displacement and propagates shear wave.[21-23] SWS represents the local histology and pressure on the wall during filling.[24-26]

This interaction between tissue and volume characteristics is shown in this study (EBC 50%). Sturm *et al*.[7] 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.[16] 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.[27] 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.[17]

In contrast, Shepard *et al*. (2016) investigated the relationship between ARFI and urorodynamic 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 urorodynamic parameters in children.[28]

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 urorodynamic testing. However, further studies are needed to confirm the efficacy of this technique.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Ginsberg D. The epidemiology and pathophysiology of neurogenic bladder. Am J Manag Care 2013;19:191-6.
2. Przydacz M, Denys P, Corcos J. What do we know about neurogenic bladder prevalence and management in developing countries and emerging regions of the world? Ann Phys Rehabil Med 2017;60:341-6. doi: 10.1016/j.rehab.2017.02.008.
3. Roshanzamir F, Rouzrokh M, Mirshemirani A, Khaleghnejad A, Mohajerzadeh L, Dalirani R. Treatment outcome of neurogenic bladder dysfunction in children: A five-year experience. Iran J Pediatr 2014;24:323-6.
4. Snow-Lisy DC, Yerkes EB, Cheng EY. Update on urological management of spina bifida from prenatal diagnosis to adulthood. J Urol 2015;194:288.
5. Sturm RM, Cheng EY. The management of the pediatric neurogenic bladder. Curr Bladder Dysfunct Rep 2016;11:225-33.

6. Sturm RM, Yerkes EB, Nicholas JL, Snow-Lisy D, Diaz Saldano D, Gandor PL, *et al.* Ultrasound shear wave elastography: A novel method to evaluate bladder pressure. J Urol 2017;198:422-9. doi: 10.1016/j.juro. 2017.03.127.
7. Farhat W, Bägli DJ, Capolicchio G, O'Reilly S, Merguerian PA, Khoury A, *et al.* The dysfunctional voiding scoring system: Quantitative standardization of dysfunctional voiding symptoms. J Urol 2000;164 (3 Pt 2):1011-5.
8. Landau EH, Jayanthi VR, Churchill BM, Shapiro E, Gilmour RF, Khoury AE *et al.* Loss of elasticity in dysfunctional bladders: Urodynamic and histochemical correlation. J Urol 1994;152 (2 Pt 2):702-5.
9. Scarpero HM, Padmanabhan P, Xue X, Nitti VW. Patient perception of video urodynamic testing: A questionnaire based study. J Urol 2005;173:555-9.
10. Nenadic I, Mynderse L, Husmann D, Mehrmohammadi M, Bayat M, Singh A, *et al.* Noninvasive evaluation of bladder wall mechanical properties as a function of filling volume: Potential application in bladder compliance assessment. PloS One 2016;11:e0157818. doi: 10.1371/journal.pone. 0157818.
11. Wells PN, Liang HD. Medical ultrasound: Imaging of soft tissue strain and elasticity. J R Soc Interface 2011;8:1521-49.
12. Denis M, Mehrmohammadi M, Song P, Meixner DD, Fazzio RT, Pruthi S, *et al.* Comb-push ultrasound shear elastography of breast masses: Initial results show promise. PloS One 2015;10:e0119398.
13. Gennisson J-L, Deffieux T, Fink M, Tanter M. Ultrasound elastography: Principles and techniques. Diagnostic and interventional imaging. 2013;94:487-95. doi: 10.1016/j.diii. 2013.01.022.
14. Mehrmohammadi M, Song P, Meixner DD, Fazzio RT, Chen S, Greenleaf J, *et al.* Comb-push ultrasound shear elastography (CUSE) for evaluation of thyroid nodules: Preliminary *in vivo* results. IEEE Trans Med Imaging 2015;34:97-106.
15. Piscaglia F, Salvatore V, Mulazzani L, Cantisani V, Schiavone C, *et al.* Ultrasound shear wave elastography for liver disease. A critical appraisal of the many actors on the stage. Ultraschall Med 2016;37:1-5.
16. Naqvi NF, Saldera K, Mahmood T, *et al.* Shear wave elastography; Assessment of liver fibrosis in a patient of chronic liver disease associated infected by hepatitis B and C. Professional Med J 2016;23.
17. Wei C, Li C, Szewczyk-Bieda M, Upreti D, Lang S, Huang Z, *et al.* Performance characteristics of transrectal shear wave elastography imaging in the evaluation of clinically localized prostate cancer: A prospective study. J Urol 2018;200:549-58.
18. Wang Y, Yao B, Li H, Zhang Y, Gao H, Gao Y, *et al.* Assessment of tumor stiffness with shear wave elastography in a human prostate cancer xenograft implantation model. J Ultrasound Med 2017;36:955-63.
19. Brandenburg JE, Eby SF, Song P, Zhao H, Brault JS, Chen S, *et al.* Ultrasound elastography: The new frontier in direct measurement of muscle stiffness. Arch Phys Med Rehabil 2014;95:2207.
20. Chernak LA, DeWall RJ, Lee KS, Thelen DG. Length and activation dependent variations in muscle shear wave speed. Physiol Meas 2013;34:713.
21. Nightingale K, McAleavey S, Trahey G. Shear-wave generation using acoustic radiation force: *In vivo* and *ex vivo* results. Ultrasound Med Biol 2003;29:1715.
22. Stenzel M, Mentzel HJ. Ultrasound elastography and contrast-enhanced ultrasound in infants, children and adolescents. Eur J Radiol 2014;83:1560.
23. Zaleska-Dorobisz U, Kaczorowski K, Pawlus A, *et al.* Ultrasound elastography –Review of techniques and its clinical applications. Adv Clin Exp Med 2014;23:645-55.
24. Frulio N, Trillaud H. Ultrasound elastography in liver. Diagn Interv Imaging 2013;94:515.
25. Li C, Guan G, Zhang F, Song S, Wang RK, Huang Z, *et al.* Quantitative elasticity measurement of urinary bladder wall using laser-induced surface acoustic waves. Biomed Opt Express 2014;5:4313.
26. Nenadic IZ, Qiang B, Urban MW, de Araujo Vasconcelo LH, Nabavizadeh A, Alizad A *et al.* Ultrasound bladder vibrometry method for measuring viscoelasticity of the bladder wall. Phys Med Biol 2013;58:2675.
27. Du LJ, He W, Cheng LG, Li S, Pan YS, Gao J. Ultrasound shear wave elastography in assessment of muscle stiffness in patients with Parkinson's disease: A primary observation. Clin Imaging 2016;40:1075-80. doi: 10.1016/j.clinimag. 2016.05.008.
28. Shepard CL, Smith EA, Dillman JR, Kraft KH. Acoustic radiation force imaging (ARFI) does not predict abnormal urodynamic parameters in children. Presented at Pediatric Urology Fall Congress, Dallas, TX, USA, September 9-11, 2016.