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Urodynamic Study in Children

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Urodynamic study (UDS) is a serial of clinical tests, like uroflowmetry, filling cystometry, pressure-flow studies and assessment of urethral closure pressure. These tests include urethral pressure uroflowmetry and also measurement of the leak-point pressure of lower urinary system. UDS is one of the essential clinical studies in children complaining of voiding dysfunction, neurogenic bladder, urine incontinence, enuresis and another lower urinary tract symptom. The aim of proper bladder management in these patients is to maintain the lower urinary tract to have good capacity, low pressure, preventing infection and incontinence. Long term goal is preventing any undue damage to the upper urinary tracts and intact kidneys function. This review article of pediatric urodynamic study provides a classified diagnostic approach to bladder dysfunctions in children.

Keywords: Lower Urinary Tract; Uroflowmetry; Urodynamic; Neurogenic bladder.

Running Title: Urodynamic Study in Children

Introduction

International Incontinence Society (ICS) defined Urodynamic Studies as the evaluation of function and malfunction of the urinary tract [1]. Urodynamic studies include any procedure that assesses how well the bladder, sphincters, and urethra store and release urine. Most urodynamic tests aim on the bladder's ability to collect urine and emptying steadily and completely. Urodynamic tests can also detect any involuntary contractions of the bladder that cause urine leakage [2]. Urodynamic tests have been used in experimental studies to determine the effect of bladder outflow obstruction on the structure and function of the developing bladder [3]. In one-third of infants with occult spinal dysraphism there is abnormal UDS irrespective of the neurological findings on clinical examination (figure 1 and 2). With increasing age, symptoms become more evident and involve bowel and bladder dysfunction and alterations in lower extremity functions.

Recently, detrusor overactivity has also been shown in all age groups with occult tethered cord syndrome [4]. Urodynamic studies assess the function of the bladder and urethra and are often useful in the assessment and diagnosis of patients presenting with lower urinary tract symptoms (LUTS). Urodynamic tests such as cystometry, uroflowmetry, pressure flow studies, electromyography and video-urodynamics tests provide objective information about the normal and abnormal functions of the urinary tract and pelvic floor, therefore there will be a better understanding of the cause of LUTS [5].
If symptoms suggest problems with the lower urinary tract UDS tests will be very helpful. The urinary tract is the body's drainage system to eliminate wastes and extra water. The objective of urodynamic testing is to find and select the appropriate treatment in each patient.

Indications for urodynamic studies in children

Most children complaining of urgency, frequency, and incontinence can be managed with behavioral therapy and anticholinergic medications. UDS is mostly useful when there is no improvement despite adequate treatments. Kaufman and colleagues find that refractory children with urinary incontinence have as high as 63% pathologic findings on UDS [6]. Baseline and periodic UDS are done in neurogenic bladder dysfunction (NBD), myelomeningocele, occult spinal dysraphism, sacral agenesis, imperforated anus, cloacal malformation, traumatic spinal cord injury, and central nervous system disorders [4].

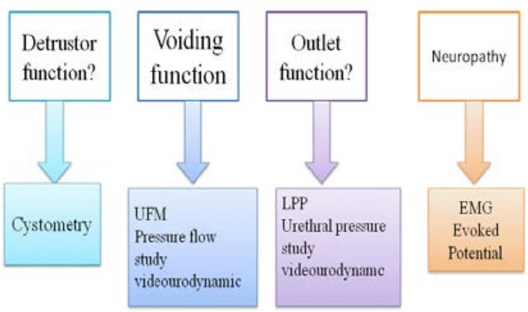

Figure 1. Approach to children with urinary incontinence according to history

The more specific application of pediatric urodynamics is understand the evolving natural history of lower urinary tract function in specific pathological conditions such as posterior urethral valves and vesicoureteric reflux (VUR) (figure 3).
Urodynamic tests are very useful to assess the efficacy of treatment as well as determining any refinements necessary to improve the outcome of such treatments. Examples of this role of urodynamics can be found in: Evaluating the success of procedures to increase outlet resistance in patients with classic bladder exstrophy - Kelly repair, assessing the effect of botulinum toxin injection in neuropathic detrusor overactivity, and the impact of correction of VUR with bulking agents in early life on long-term outcome of bladder function [3].
UDS for neurogenic bladder is repeated following any change in medical or surgical therapy, new onset of incontinence or hydroureteronephrosis, or recurrent symptomatic infections. Because deterioration in bladder function may occur silently, changes in the orthopedic or neurological examination warrant reassessment with UDS [7].
Urodynamics have also been used in experimental studies in order to find the effect of bladder outflow obstruction on the structure and function of the developing bladder.
Finally, with an improved understanding of the causal factors in a urodynamic abnormality, urodynamic aids might be employed to direct treatment options e.g. Biofeedback in the treatment of dysfunctional voiding disorders [4].

Figure 2. Dimple and hair tuff in a 2.5-year-old child with urinary incontinence

Figure 3. VCUG of a child with neurogenic bladder

Urinary bladder function

Normal urinary bladder has two major functions, storage of the urine to an adequate level, and complete emptying of the urine in periodic times (figure 4). During the filling phase the bladder remains relaxed and during the voiding phase the muscle of the urinary bladder contracts to increase the bladder pressure and thereby make it possible to empty the bladder. At the same time the urethral sphincters must be relaxed so the urine can be excreted out. Thus perfect co-ordination of bladder and urethral muscles (including the pelvic floor, in which the neural system also plays an important role) is the basis for continence and normal voiding function [5].

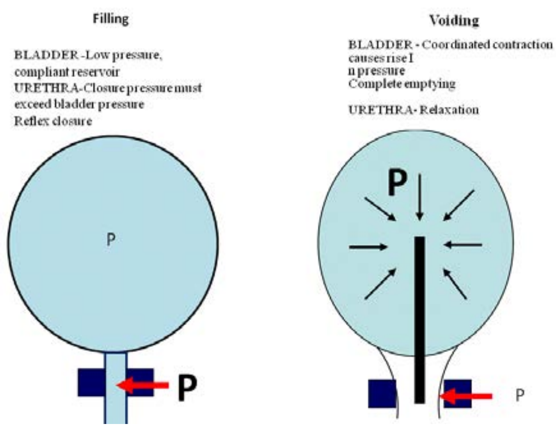

Figure 4. Filling and voiding phases in normal bladder

Preparation before UDS

Bowel or rectum preparation should be done [1].

Complete history including detailed voiding chart, physical and laboratory examination should be taken. Last three days voiding record that include fluid intake through the day, presence of UTI, bowel elimination pattern, and current voiding habits including how urine is eliminated (voluntarily, spontaneously with Crede's maneuver or via a catheter). Validated Persian questionnaire is available for taking voiding history [2,3].

Ultrasonic evaluation of the upper urinary tract that detect anatomical malformations (duplicated systems, dilatation or scarring) [4].

Flowmetry (for the children capable to void into the flowmeter) provides indications for further invasive UDS if necessary. The nomogram of uroflometry for Iranian children is available.

The well experienced and knowledgeable staff and explanation patiently to patients is very important. Explaining of the procedure and aim of urodynamic study to the child and parents, and if possible trying to create as friendly as possible environment for children to cooperate is mandatory [7].

There may be need to administrate adequate sedative (not anesthetics), and recording in the report if the child too afraid [8].

Following the voiding on the flowmeter the bladder is catheterized by a multi-lumen or microtransducer urodynamic catheter. Prior application of 1% lidocaine jelly or a liquid solution instilled into the urethra as a topical anesthetic may be helpful in catheter insertion.

The urodynamic evaluation approach should start as gently as possible ending up in the majority of the cases with more invasive investigations.

Following these initial assessments some children will go on to have an invasive urodynamics studies. Ambulatory urodynamic monitoring (AUM) also is a functional urodynamic study that uses such a system that does not interfere with normal daily activities of the subject. So the AUM has many advantages and shows natural bladder filling, longer observation period and a relatively normal study environment. It is therefore more physiological than conventional UDS. AUM can detect detrusor over-activity more accurately than conventional urodynamics, and there is a more strong correlation of symptoms with AUM findings [9].

Uroflowmetry is totally noninvasive and can be used in patients who void spontaneously. The flow pattern is accurate as long as the volume is > 50% of maximum voiding volume. The shape of the flow curve denotes the detrusor muscle function, outlet resistance, and external sphincter dysfunction during urination. Voiding patterns include bell-shaped (normal), tower (OAB), plateau (outlet obstruction), staccato (sphincter activity during voiding), and interrupted curve (acontractile or underactive bladder).

Perineal patch electromyography (EMG) can be used as an adjunct in determining the etiology of an abnormal flow pattern or postvoiding residual urine. Postvoiding residual study (PVRs) using bladder scanning should show residuals of ≤ 20 cc or abnormal emptying in suspected children. PVR is useful in patients on anticholinergic therapy to assess the efficacy of treatments [10].

Uroflowmetry

Uroflowmetry is generally used in any children suffering from bladder dysfunction but can void voluntarily. Children less than 2-year-old and those with NBD are unable to void spontaneously. It is usually recommended to calculate the residual urine at the beginning of UDS, or just before with a catheter is inserted to drain the bladder. The most frequent voiding patterns of children are shown in Table 1. Not all of children show a smooth urine flow curve.

Table 1. Voiding patterns on uroflowmetry

Voiding Pattern	Suspected Pathology
Bell-shaped curve	Normal sustained detrusor contraction
Tower	Overactive bladder
Plateau	Outlet obstruction
Staccato	Sphincteric overactivity during voiding
Interrupted	Acontractile/underactive bladder

Uroflowmetry is generally valuable in the assessment of voiding function for a wide range of urological conditions. The measured flow is affected by a number of factors including:

A. strength of detrusor contractility
B. presence of bladder outlet obstruction
C. adequacy of relaxation of the sphincter mechanisms
D. patency of the urethra
E. compensatory mechanisms such as abdominal straining

However, the maximum urine flow is accurate only when the volume is greater than 50% of maximum voided volume. Detrusor in children can exert a strong contraction to overcome any outflow resistance so the flow pattern in children is far more informative than the actual flow rate. The shape of the curve shows detrusor function, degree of bladder outlet resistance and external urethral sphincter activity during voiding. Ideally uroflowmetry should be repeated 2 or more times to ensure that a consistent voiding pattern is recorded. Simultaneous perineal patch EMG gives quite enough information about the cause of the abnormal flow pattern and the post-voiding residual urine, and prevents further unnecessary invasive tests [11].

Voiding volume and post voiding residual

Children bladder capacity can be estimated by equation 'age + 2'ounces. In 1988, Hjalmas presented another equation that has been adopted by ICCS till now (expected bladder capacity [ml] = 30 + [age in years X 30]). There are no formulas used in newborn to predict the bladder capacity or voiding volume although voiding volume is a good parameter to evaluate neonate bladder function. Voiding volumes increases significantly with age and reach a maximum at day 4 and day 28 in full-term newborns. In contrast, although pre-term neonates show similar increase as full-terms during 28 days after birth, they have only one single surge at day 28. Full-term newborns have higher voiding volume than pre-term, while the former has less intermittent voiding. In term newborns the voiding volume (19.8±10.9) is significantly higher than that of preterm newborns.

PVR (postvoiding residue) measurements are performed routinely by using formal ultrasonography which calculates the volume and generate a number without providing anatomical visualization of the bladder. Children with PVR equal to 5 to 20 ml should be re-examined. Successive values of greater than 20 ml indicate abnormal emptying of the bladder. Voided volumes and interval duration between the voidings and PVR should be recorded. Attention to detail is necessary in children with hydroureteronephrosis or VUR in whom urine in the upper urinary tract might drain back into the bladder soon after voiding is complete. Changes in PVR may indicate a need for further invasive studies, especially in those who do not or cannot do CIC [12].

Invasive methods

Cystometry, an invasive procedure determines bladder capacity, contractility, compliance, emptying ability and degree of continence. Video UDS also allows real-time viewing of the change of bladder function assisting to the diagnosis as well as accurate interpretation of the findings. Passing an urodynamic catheter transurethrally also allows accurate assessment of the PVR as well as intravesical pressure at that volume of natural filling. In children with prior urethral surgery may require catheter placement by cystoscopy under sedation before the beginning of the study. A suprapubic catheter can also be inserted. Increased invasiveness of this maneuver is acceptable because of the more physiological nature of voiding records without placing a catheter in the urethra. If required, a 6Fr double lumen catheter is placed with the child under sedation 6 to 24 hours before the study. Children can be in the supine or sitting position. Previous studies have proved that there were no significant changes in measurement outcomes according to variability of position.

After putting the catheter in the bladder, the children can get away from the examination room for a while to reduce anxiety and agitation until him or her become quite.

(1) The toys could make child forget the examination;

(2) Eating or drinking is allowed during the examination.

(3) Sedation, such as diazepam, or local anesthesia, such as lidocaine glue, might be considered if the child feels painful on catheterization.

(4) Two cycles of cystometry is necessary for children to make sure the result is repeatable.

(5) Older children, especially girls should respect their privacy as much as possible [13].

Invasive UDS can be done in sitting or supine positions. Rectal and urethral catheters provide intraabdominal and intravesical pressures (figure 5). The difference in these pressures is the detrusor pressure. A PVR is obtained in a non-CIC patient and patch EMG electrodes are positioned perineally in boys or paraurethrally in girls [14]. EMG provides information on individual motor units at rest in response to sacral reflexes and during bladder filling and emptying with suspected or previously diagnosed NBD [15].

During bladder filling, saline infusion at a temperature of 21°; to 37°C is done at a rate of 5% to 10% of the expected bladder capacity/minute. Bladder capacity for children is determined from the Hjälmås equation: expected bladder capacity (mL) 5 × 1 (age in year × 30). For children with MM, the formula 24.5 × age (years) + 62 should be used. Children on CIC use the largest catheterized volume during the test. At least two cycles of filling are required unless the child has no sensation or if there is NBD. The bladder has been sufficiently filled when the child has a strong urge to urinate and is uncomfortable. When voiding starts, bladder pressures are > 40 cm of water, or the volume infused is > 150% of the expected capacity. The fluoroscopic video portion of the test permits determining correlation of detrusor pressures and urinary incontinence or reflux and also provides information on the bladder shape and the state of the sphincter during filling and emptying. Intrinsic or bladder neck dysfunction can also be assessed [16]. The pressure profile along the length of the urethra can be measured by slowly infusing a fluid through a catheter while withdrawing it through the urethra. Catheter tip transducers can also be used for this purpose with high reliability. The urethral pressure profile can also be recorded during micturation with the potential advantage of localizing the site of an obstruction [17].

Traditionally, the study is done by a double channel catheter introducing a saline solution into the bladder with a flow that mimics the normal filling phase of the bladder and then evaluating the patient´s micturation. The catheter can be passed through the urethra or via the suprapubic route. The advantage of the suprapubic route is that urethra and bladder emptying is not interfered by a foreign body. Using urethral catheter prevents the need for the child to have a general anesthesia for suprapubic catheter insertion. The choice of which route to introduce the dual lumen catheter depends on which of the filling, storage and emptying phases is primarily considered. If the leak point pressures are being studied a suprapubic approach would be ideal [1].

If the bladder pressure is under study, we must know the intra-abdominal pressure. The intra-abdominal pressure is measured with a balloon inserted into the rectum or when available through a distal enterostomy. This balloon sends the changes of pressure to a transducer that, through a software, records a second curve. The same software permanently calculates differences between bladder and abdominal pressure to create a third curve that records the detrusor muscle strength or pressure. **det P° = blad P° – abd P°**

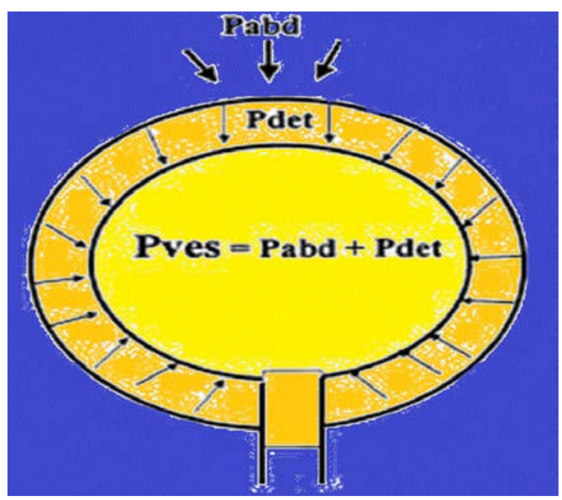

Figure 5. Vesical pressure and detrusor pressure

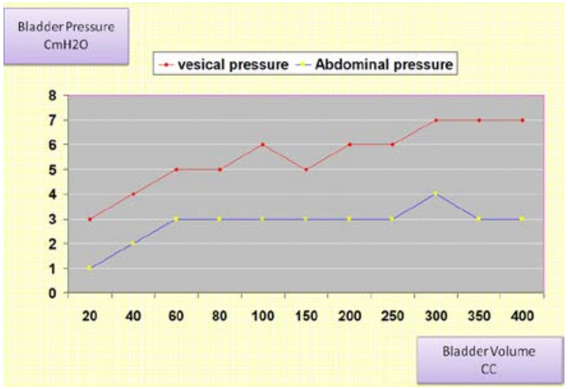

Figure 6. Bladder pressure related to bladder volume

In normal conditions the detrusor pressure remains low during the filling of the bladder, with values under 10 cm H_20. Bladder accommodates by the viscoelastic properties of its wall and then, even when volume grows, pressure remains constant inside it (figure 6).

At some point during the filling process, patient will have bladder fullness sensation, with voiding desire, that will increase progressively until having an imminent voiding desire. At this time the pump must be stopped and the patient allowed to urinate.

During voiding the child must be observed if there is some degree of hesitancy or Valsalva´s maneuvers applied to start micturition.

Usually the patients start spontaneous voiding with a detrusor contraction that is recorded as an increased and supported value of 35 a 45 cm H_20, associated to a bell shape voiding curve with decreased electromyographic activity (figure 7).

At the end of voiding, we measure post-voiding volume that must not exceed 10% of total bladder capacity [18].

Detrusor Overactivity or Overactive Bladder (OAB)

Presence of Phasic Contractions or uninhibited contractions, characterized by a sudden increase of detrusor pressure over 15 cm H_20.

It´s the most common urodynamic alteration in children without any neurological disease. This causes urge and urge-incontinence symptoms. Overactive contractions are considered to be normal when there is a strong desire to void. This voluntary maturation achievement usually reaches by 4_{th} year of age [19].

Compliance alterations

This is referred to the inability to maintain a low intravesical pressure during the filling stage. It is as a progressive increase of detrusor pressure that may alter or even damage the upper urinary tract. It may be due to the high intravesical pressure preventing urine passage to the bladder or secondary a vesicoureteral reflux (figure 8).

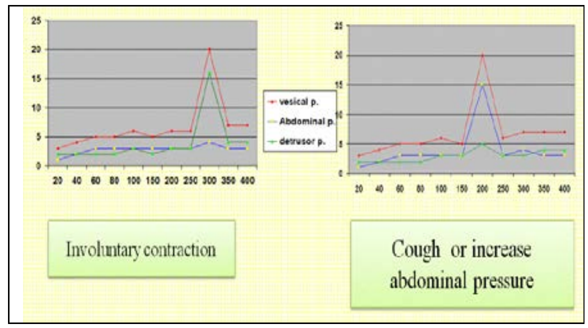

Figure 7. Artifacts in vesical, detrusor, and abdominal pressure

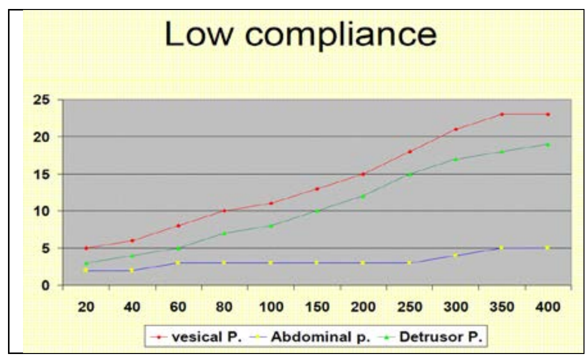

Figure 8. Low bladder compliance

Lower urinary tract obstructions

This condition refers to anatomical or functional disorders that increase the resistance to urinary flow. In late stage, it is characterized by a plateau curve, associated a prolonged contraction of the detrusor muscle, that is trying to overcome the obstruction with or without an elevation in intra-abdominal pressure. When dealing with a functional obstruction this will show sphincter over activity during voiding. These patients usually have increased post voiding residual volumes (figure 9).

Detrusor Underactivity

In this condition the detrusor is weak, absent or has too short contraction that is inefficient to complete bladder emptying. Patients use Valsalva maneuvers to assist bladder emptying, recorded as increased abdominal pressure, and may present with increased post voiding residual volume. It can be due to a bladder outlet obstruction, with an exhausted detrusor, or due to neurological problems [20].

According to non-invasive tests and where appropriate, other procedures to complete the urodynaimc study are Computed Axial tomography, Magnetic Nuclear and Whitaker test or urodynamic test of upper urinary tract. The image studies (MNR and CT scan) exceed the objectives of this review and the Whitaker test has lost its popularity over time and is replaced by new less invasive studies [1].

Table 2. Classification of urinary tract dysfunction (ICS 2002)

	Filling phase	Voiding phase
Detrusor function	DO	UAD, ACD
Bladder sensation	Increased (hypersensitive)	
	Reduced (hyposensitive)	
Urethral function	Incompetent	Obstructive: BOO Dysfunctional voiding DSD Non-relaxing

DO- detrusor overactivity
UAD - underactive detrusor
ACD - acontractile detrusor
BOO-bladder outlet obstruction
DSD -detrusor sphincter dyssynergia

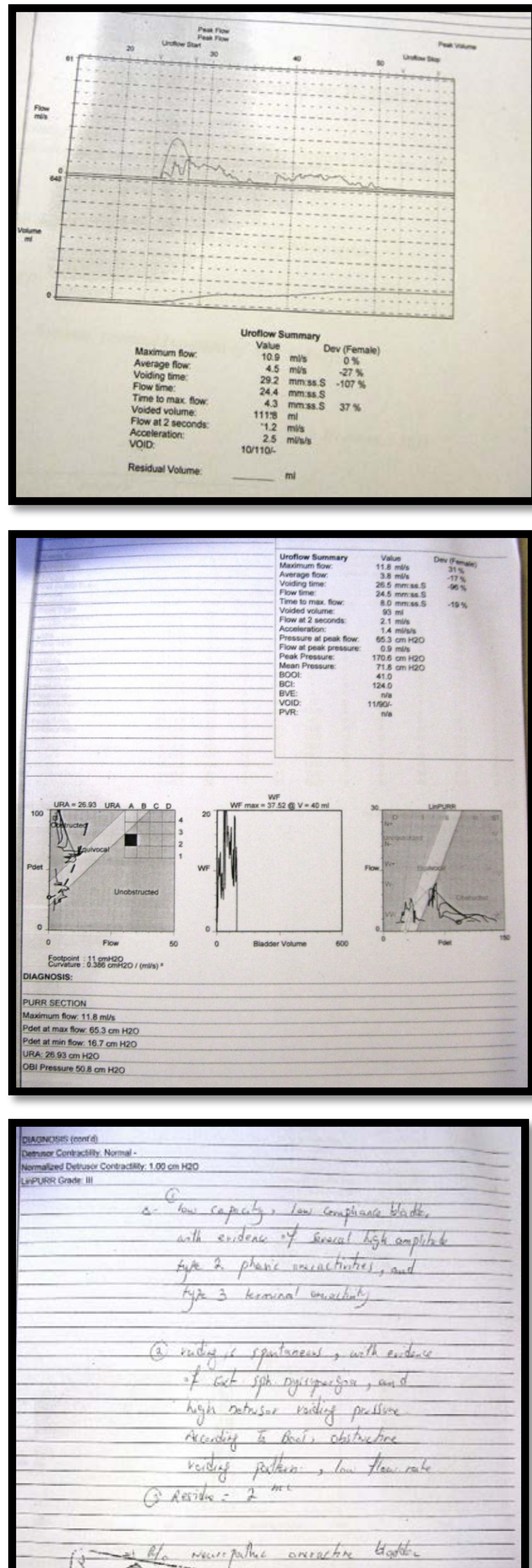

Figure 9. UDS study in a 6-year old girl with recurrent urinary tract infection with report (three successive photos)

Conflict of Interest

None declared

Financial Support

None declared

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