Autonomic Neuroscience: Basic and Clinical 200 (2016) 11–20

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

journal homepage: www.elsevier.com/locate/autneu

Review

# The use of imaging techniques in understanding lower urinary tract (dys)function

Yves Deruyver [a], Lukman Hakim [a,b], Jan Franken [a], Dirk De Ridder [a,*]

[a] Laboratory of Experimental Urology, Department of Development and Regeneration, KU Leuven, Leuven, Belgium
[b] Airlangga University School of Medicine and Dr. Soetomo General Hospital, Department of Urology, Surabaya, Indonesia

ARTICLE INFO

*Article history:*
Received 1 December 2014
Received in revised form 22 December 2015
Accepted 23 May 2016

*Keywords:*
Urinary bladder
Lower urinary tract dysfunction
Brain bladder control
fMRI
Pet
Ultrasound
Magnetic resonance imaging
Cystography

ABSTRACT

The ability to store urine in the bladder and to void at an appropriate time depends on several complex mechanisms in the lower urinary tract (LUT) and its neural control. Normal LUT function requires coordination of the urinary bladder, urethra, pelvic floor, efferent and afferent neurons and specific spinal cord and brain areas. These structures can be visualised using different imaging modalities, such as ultrasound, X-ray and magnetic resonance imaging. The supraspinal neural control of the LUT can be studied using functional brain imaging. During the last two decades, the many technological improvements of these imaging techniques have increased our knowledge of voiding dysfunction.

Here, we review the different imaging modalities of the LUT and its neural control and discuss their importance for diagnosing and understanding voiding dysfunction.



**Contents**



* Corresponding author at: Herestraat 49, 3000 Leuven, Belgium.
*E-mail address:* dirk.deridder@uzleuven.be (D. De Ridder).

http://dx.doi.org/10.1016/j.autneu.2016.05.008
1566-0702/

## 1. Introduction

The lower urinary tract (LUT) requires coordination of the urinary bladder, urethra, prostate, pelvic floor and specific spinal cord and brain areas. Different imaging modalities can be used to visualize these structures and are used to diagnose voiding dysfunction and study its pathophysiology.

Imaging modalities such as ultrasound (US), cystourethrography, computed tomography (CT) and magnetic resonance (MR) imaging are used to visualize the different structures of the LUT. In daily practice, US and cystourethrography are commonly used techniques to assess LUT dysfunction (LUTd). Although the use of MR imaging for voiding dysfunction remains limited, several clinical studies have already proven its potential in the diagnosis of stress urinary incontinence and benign prostatic hyperplasia (BPH). Imaging modalities of the LUT (i.e. bladder and urethra), prostate and pelvic floor and their application for diagnosing and understanding LUTd are discussed in the first part of this review (Table 1).

The LUT is also subjected to a complex neural control mechanism. In the last two decades it has become possible to study this supraspinal control of the LUT by means of positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) of the brain. Although the number of studies investigating brain control of the LUT remains limited, they have already provided new insights into LUTd. Specific supraspinal changes are seen in women with detrusor overactivity, raising the question if this is more a dysfunction of the brain than of the bladder. Imaging of the supraspinal control mechanisms of the LUT and its importance for voiding dysfunction are reviewed in the second part of this article.

## 2. Imaging of the lower urinary tract to assess lower urinary tract dysfunction

### 2.1. Lower urinary tract

Although they are anatomically distinct structures, the bladder and urethra are functionally closely interrelated. Imaging of the bladder is often necessary to confirm clinical examination. Transabdominal US is an easy and cheap modality to assess structural abnormalities of the bladder, post-void residual urine (PVR), stone disease of the bladder or vesico-ureteral junction, inflammatory conditions and neoplasms. Retrograde and voiding cystography provide useful information to assess urogenital traumata and neurogenic bladder dysfunction. In the last two decades CT and MR imaging have proven their usefulness to assess voiding dysfunction, although their application in daily life practice for LUTd remains limited.

Clinical assessment of urethral symptoms is difficult and often requires further evaluation with imaging. Several urethral imaging modalities are currently available. Retrograde and voiding (cysto)urethrography provide information about luminal abnormalities of the urethra and are the most commonly used imaging modalities for patients with urethral abnormalities such as trauma, inflammation and strictures (Kim et al., 2007). In the last decade, cross-sectional imaging techniques such as US and MR have also shown their potential to study voiding dysfunction, congenital abnormalities, urethral diverticula, urethral carcinomas and periurethral cysts. Also endovaginal MR imaging of the female urethra offers reliable high resolution diagnostic imaging of these urethral abnormalities (Elsayes et al., 2006).

#### 2.1.1. Ultrasound

In daily practice, US is frequently used to accurately measure the PVR that indicates how completely a patient empties his bladder. Elevated PVR occurs in patients with bladder outlet obstruction (BOO) and/or detrusor underactivity (Abrams and Griffiths, 1979). However, it is important to realize that elevated PVR is a poor predictor of urodynamically diagnosed BOO (Kranse and van Mastrigt, 2003).

Bladder wall thickness (BWT), measured by transabdominal US, might also be used as a diagnostic tool for BOO. It is important to note that BWT is dependent on bladder filling. BWT rapidly decreases during the first 250 ml of bladder filling but, thereafter, remains more or less stable (Oelke et al., 2006). At a filling volume of 150 ml, a cut-off value of 5 mm appeared to be characteristic for the presence of obstruction (Manieri et al., 1998). Other studies showed similar results, although with other threshold values (Kessler et al., 2006). Another study by Blatt et al. could not demonstrate any differences in BWT in patients with BOO (Blatt et al., 2008). Detrusor wall thickness (DWT, bladder wall without the mucosal and subserosal layer) might be a more accurate measure for BOO. A DWT > 2 mm was reported in 94% of

**Table 1**
Overview of imaging modalities used to assess the different structures of the lower urinary tract and the possible diagnostic findings in patients with LUTd.

| | Imaging of | | | |
|---|---|---|---|---|
| Imaging modality | Bladder | Urethra | Prostate | Pelvic floor |
| Cystourethrography | Bladder capacity, vesico-ureteral reflux, contour, emptying capability, detrusor sphincter dyssynergia, tumor, calculi | Detrusor sphincter dyssynergia, stricture, fistula, trauma | – | – |
| Cystocolpodefaecography | Cystocele | – | – | Enterocele, rectocele, pelvic floor descent |
| Ultrasound | PVR, bladder wall thickness, detrusor strain, bladder weight | Diverticulum, neoplasm, urethral hypermobility | Size, structure, resistive index of capsular artery, presumed circle area ratio, prostatic urethral angle, intravesical prostatic protrusion | Urethral hypermobility, pelvic organ prolapse, post-surgical evaluation |
| MR imaging | Congenital abnormality, tumor | Diverticulum, neoplasm, urethral hypermobility, urethral muscle volume, bladder neck funneling, vesico-urethral angle | BPH, prostate cancer, prostate cyst | Pelvic organ prolapse, disruption of urethral support ligaments, asymmetric pubococcygeus muscle |
| CT imaging | Tumor | – | – | – |
| NIRS | Oxygenation level of detrusor | – | – | – |