A Review on Modeling of the Lower Urinary Tract

Nazlar Ghassemzadeh[1], Majid Pouladian [*2], Sahar Shirafkan[3]
[1]Department of Biomedical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran, stu.nghasemzadeh@iaut.ac.ir
[2] Department of Biomedical Engineering,Science and Research Branch, Islamic Azad University, Tehran, Iran pouladian@srbiau.ac.ir
[3] Department of Biomedical Engineering,Science and Research Branch, Islamic Azad University, Tehran, Iran saharshrfkn@gmail.com

Abstract

This paper presents a review on modeling of bladder and the Lower Urinary Tract. A biomechanical model of the lower urinary tract which is able to respond to input signals from a neural network is presented. The neural input is the starting point in the description of the relationships between the various physical parameters in the mechanical model of the bladder and the urethra. The cybernetics of the lower urinary tract are described on the basis of the muscle dynamics of simple models of both the detrusor in the bladder wall and the urethral sphincter. . Parameters like the bladder volume, the flow rate and the pressure in the bladder can be compared with clinical data of urodynamic measurements. bladder model includes detrusor and sphincter dynamics. The model focuses on artificially controlled bladder contractions under Electrical Stimulation. outputs in these models are (pressure, volume and urine flux). A sensitivity analysis of various parameters in the model leads to a better understanding of the biomechanics of the lower urinary tract ad bladder.
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Keywords: Bladder Modeling , Lower Urinary Tract Modeling, Bladder artificial control.

Introduction

The bladder is the organ that collects urine excreted by the kidneys prior to disposal by micturition. Urine enters the bladder via the ureters and exits via the urethra (Figure 1). The bladder system is composed of two muscle types: 1) the detrusor muscle which is a layer of the bladder wall made of smooth muscle fibers and 2) the sphincter muscles (smooth and striated ones). For the urine to exit the bladder, both the autonomically controlled internal sphincter (smooth muscle) and the voluntarily controlled external sphincter (striated muscle) must be opened. In normal conditions, the bladder is supposed to empty by a synergistic contraction of the detrusor and relaxation of both sphincters during micturition. By contrast, supra-sacral spinal cord injured (SCI) patients may loss this synergy, as well as detrusor contraction efficiency. [1]
The mechanical aspects of the bladder have been described in several models [2][3][4][5][6][7]. In this paper we have reviewed ES controlled bladder modeling and a myocybernetic model of the lower urinary tract. Bladder modeling is most often considered under two aspects: 1) in terms of the biochemistry involved in smooth muscle contraction [8][9][10]) . 2) in terms of the neural mechanisms of urination [11] [12] [13]. ES has been used for approximately 30 years to restore bladder function especially in SCI individuals [14].
To study the neural regulation of the lower urinary tract, a control model has been developed, which consists of a combination of a neural network model and a biomechanical model of the lower urinary tract (LUT model)[7]. To investigate neurological disorders, the activation of the muscle fibers of both the bladder and the urethra by the nervous system should be the starting point in the description of the mechanical behavior of the lower urinary tract.[7]

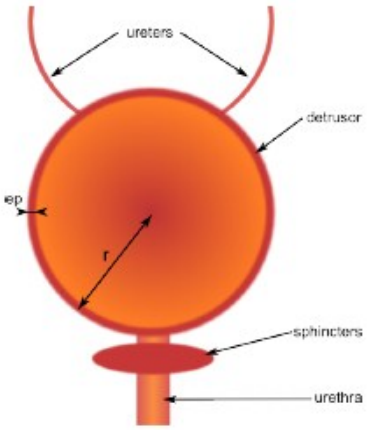

Figure 1. Lower urinary tract description[1]

Lower Urinary Tract (LUT) Model

A schematic overview of the LUT model, as part of the neural control model of the lower urinary tract, is given in Fig. 2. The excitatory and inhibitory neural inputs to the detrusor and the excitatory neural input to the sphincter[15] are the input signals for the LUT model [Fig.2(a)]. In the LUT model, the dynamics of the lower urinary tract is described as a function of the input signals and the state of the bladder and the urethra. The fire frequencies of the stretch receptors in the bladder wall and in the urethral wall are output signals of