Differences in non-invasive Estimation of the Bladder Volume during Urodynamics by Electric Impedance Tomography and Ultrasound

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Introduction

Most individuals with spinal cord injury (SCI) make use of intermittent catheterization to empty their bladder. Moving from a fixed number and fixed time interval of catheterizations to a more natural, need-based catheterization scheme is medically and economically desirable. Thus, a method that continuously and unobtrusively monitors fluid volume in the bladder would be a valuable asset for these patients.
The aim of this pilot study conducted in the framework of the BMBF-funded project UroWatch (grant no. 13EZ1128) is to quantify the differences between the absolute bladder volume estimated on the basis of non-invasive Electric Impedance Tomography (EIT) and ultrasound measurements in individuals with SCI during a standardized urodynamic examination.

Methods

All measurements took place at the Spinal Cord Injury Center of Heidelberg University Hospital during routine urodynamic examinations. The study was approved by the ethics committee of Heidelberg University Hospital (vote no. S-485/2007).
Before the urodynamic examination started, 16 ECG-electrodes (red dot, 3M Poland Sp.z.o.o.) were attached equally spaced around the pelvis of each participant. The correct location of the belt was verified by x-ray. The electrodes were connected to a commercial EIT amplifier (Goe MF II, Cardinal Health, USA). Raw EIT data were multiplied with a reconstruction matrix resulting in 1024 equally distributed impedance values over the lower body cross section that were summed up to one global impedance value every 73 ms.
With the patient in supine position an urodynamic catheter was inserted into the bladder, which was then emptied. Afterwards, the bladder was slowly filled with a contrast fluid (Peritrast infusion 31 %, Dr. Franz Koehler Chemie GmbH, Germany) with a conductivity of 13.35 mS/cm. The filling of the bladder was performed in 100 ml steps and between two infusion episodes an EIT image was acquired together with two ultrasonic measurements (Acuson X300, Siemens Healthcare, Germany). When the individual maximal bladder capacity (determined by first signs of renal reflux) or the maximum injection volume of 500 ml was reached, the infusion trial stopped. Afterwards, an evacuation measurement was performed to link impedance values of the infusion trials and volume data.
By application of in-built algorithms of the ultrasound device, the bladder volume was determined from ultrasound images. Accuracy is measured via Root Mean Squared Error (RMSE).
Nine subjects were included in the calculation of the EIT accuracy. The subjects were stratified into three groups according to their weight and urine conductivity. For every group, four measurement electrode pairs were chosen via a brute-force optimization algorithm. The voltages of these electrode pairs were linearly combined and used to define calibration data from the micturition curve of each patient.

Results

Eleven patients (8 male, 3 female with a mean age of 53 years and 6.6 years mean time after injury) participated in the study. Their mean maximum bladder volume was 491 ml with a range of 284 to 559 ml.
In all study participants, the EIT global impedance decreased with increasing fluid volume within the bladder. The Pearson correlation coefficient between the evacuated volume and smoothed EIT data is -0.96.
The average RMSE for ultrasonic measurements is 15,0 % (referred to the individual bladder volume) and 13,2 % for EIT.

Conclusion

In this pilot study, an increase in overall impedance with decreasing bladder volume during standardized urodynamic examinations was verified in all eleven study participants.
The mean errors of bladder volume estimation derived from ultrasonic measurements are in the same range than those derived from EIT data. Further research is necessary to systematically examine all issues that affect the accuracy of the EIT system during everyday life conditions of individuals with SCI.

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