389

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RELIABILITY OF ELECTRICAL IMPEDANCE TOMOGRAPHY (EIT) AS A NOVEL NON-INVASIVE CYSTOVOLUMETRIC TECHNIQUE FOR SELF MONITORING– A COMPARATIVE STUDY TO STANDARD ULTRASOUND METHODS

Hypothesis / aims of study

Electrical Impedance Tomography (EIT) is proposed as an unobtrusive cystovolumetric technique to determine bladder volume continuously and a possible integration into a portable device which would enable self monitoring to patients with bladder dysfunction. For this technique, a set of electrodes are placed around the lower abdomen. A small AC current (5 mA at 50 KHz) is injected into the body and the generated surface voltages are measured between the remaining pairs of electrodes. These measurements contain information about the cross-sectional impedance distribution in the lower abdominal region. Previously, it has been shown that the measured impedance correlates linearly to bladder volume [1]. In this study, the feasibility of this promising method is analyzed by comparison to standard ultrasound (US) and bladder scan (BS) measurements, which are the gold standard for non-invasive bladder volumetry.

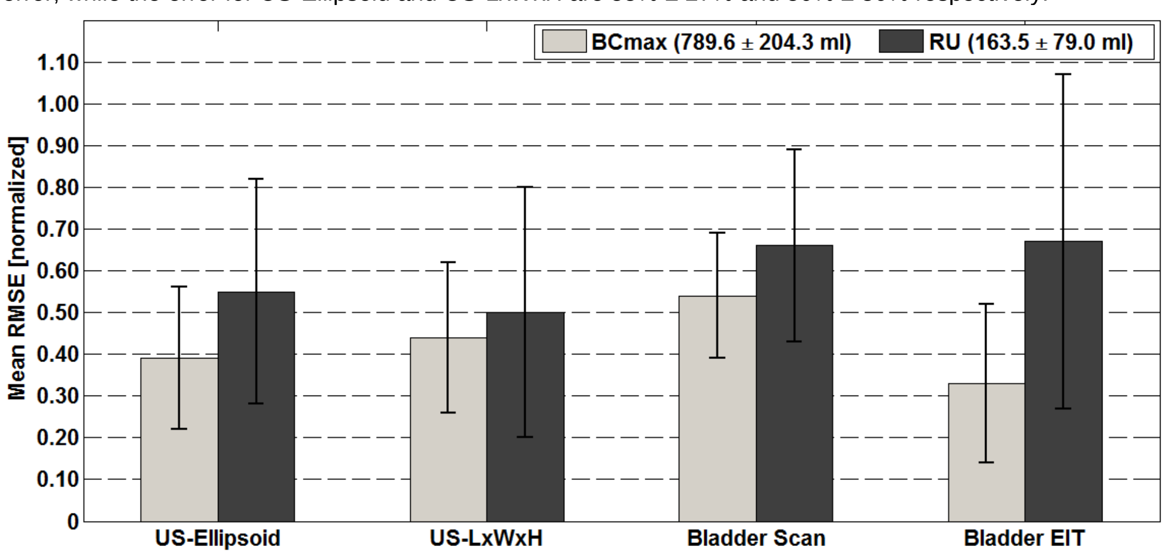
Study design, materials and methods

The study was conducted on ten healthy volunteers, ages between 28 and 34. For the EIT measurement, 16 standard ECG electrodes were placed on the test subjects' lower abdomen, in different arrangements. After liquid ingestion and at the time point of urgency, the test subjects underwent consecutively volumetries for maximum bladder capacity (BCmax) by US (Voluson 730) and BS (CUBEscan Biocon 500) measurements performed by a professional clinician. For the US measurements, two different software estimation formulas were applied: the ellipsoidal method (US-Ellipsoid) and the Length x Width x Height x 0.62 method (US-LxWxH). The test subjects then emptied their bladder into a measuring pitcher while simultaneous recordings of flowmetry and EIT measurements were conducted. Residual urine (RU) volume was recorded via US-Ellipsoid, US-LxWxH, BS method and collection in the measuring pitcher. For the EIT volume estimation, one of the voiding measurements was used as calibration for the subsequent estimation of BCmax and RU. Volume validation was carried out by flowmetry and collection in the pitcher. The urine mass measured on the electric scale of the flowmetry system was converted from grams to milliliter by a conversion factor of 1.015 g/ml. BCmax was calculated as voided volume (VV) plus RU as collected in the measuring pitcher.

Results

Fig. 1 indicates the mean error for US-Ellipsoid, US-LxWxH, BS and EIT in the estimation of BCmax and RU. The mean error is normalized with respect to BCmax (789.6 ± 204.3 ml) and RU (163.5 ± 79.0 ml) as measured with the pitcher. For the estimation of BCmax, US-Ellipsoid (39% ± 17 %) and US-LxWxH (44% ± 18%) perform comparably to each other, while BS (54% ± 15%) has the higher average error. In contrast EIT (33% ± 19) shows better performance than the standard sonographic measurement techniques.

On the other hand, for the estimation of RU, both EIT (67% ± 40%) and BS (66% ± 23%) show comparable but also the highest error, while the error for US-Ellipsoid and US-LxWxH are 55% ± 27% and 50% ± 30% respectively.



Interpretation of results

Standard US and BS methods show a considerable error for both BCmax and RU estimation. In comparison, Bladder EIT shows superior performance than US and BS for BCmax estimation. For RU, all methods have decreased performance compared to BCmax, and EIT shows higher error than the standard US and BS methods. This might be explained by the fact that the EIT electrode positions are fixed on the body, and, at lower volumes, the bladder falls underneath the electrode plane, which has a negative effect on the sensitivity of the EIT system to bladder volume changes.

Concluding message

EIT shows a good promise for a continuous bladder volumetry system. The accuracy of the system may be improved by compensating the negative effects of variable urine conductivity and movement artefacts, as well as optimizing the electrode arrangement to achieve higher sensitivity to bladder volume.

References

1. Leonhardt et al. Electric impedance tomography for monitoring volume and size of the urinary bladder. Biomed Tech 2011; 56:301–307

Disclosures

Funding: BMBF Grant Number: 13EZ1128A **Clinical Trial:** Yes **Registration Number:** Clinical Trial Center Aachen (CTC-A), Uniklinik RWTH Aachen, Pauwelsstraße 30, 52074 Aachen Registration Number: 13-042; BlasenEIT **RCT:** No **Subjects:** HUMAN **Ethics Committee:** Ethik-Kommission an der Medizinischen Fakultät der RWTH Aachen, Uniklinik RWTH Aachen, Pauwelsstraße 30, 52074 Aachen **Helsinki:** Yes **Informed Consent:** Yes