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A MOTION-TRACKING ALGORITHM TO QUANTIFY KINEMATIC PARAMETERS OF THE URETHRA AND PELVIC FLOOR ON 2D TRANSPERINEAL US

Hypothesis / aims of study: Urethral hypermobility and the loss of pelvic-floor muscle support are the primary causes of female stress urinary incontinence [1]. New technologies, such as 2D ultrasound imaging, provide important information regarding the mobility of the urethra, the support and dynamic activity of the pelvic floor muscles (PFM) during an active contraction and, potentially, incontinence-producing stress, such as the stress experienced during a Valsalva maneuver and a cough. In order to quantify the kinematic parameters of the urethra and the pelvic floor muscles (PFM) during contraction and effort, this study explored the possibility of developing an automatic motion-tracking algorithm based on optical flow techniques.

Study design, materials and methods:
This was an observational study that characterized the morphology and function of the female pelvic floor in urinary incontinent older women. Women 60 years and older were recruited and included in the study, if they were independently ambulatory, were incontinent and reported, at least, weekly symptoms of stress urinary incontinence. Women were excluded if they reported other conditions or were taking medications likely to interfere with the study. An experienced pelvic floor physiotherapist taught the women to perform PFM contractions correctly; their technique was confirmed by digital palpation. Imaging used an Acuson Antares TM ultrasound machine (Siemens, USA Inc) with a 5-3 MHz curvilinear probe. Transperineal 2D ultrasound was used to study the kinematics of the urethra and the PFM in three conditions. During the imaging, the women were positioned in the supine position with their knees bent. They were asked to perform: 1) two PFM maximal voluntary contractions separated by a one-minute rest, 2) two coughs separated by a one-minute rest, and then 3) a Valsalva maneuver. This sequence was repeated twice.

The motion tracking algorithm for the urethro-vesical junction and the ano-rectal angle (ARA) was based on optical flow techniques. Optical flow measures the velocity of the apparent motion that results from projecting the real motion of 3D anatomical structures onto the 2D image plane. The main advantage of optical flow techniques is that the segmentation of the moving structures is not required for their tracking. This is relevant for the analysis of pelvic transperineal 2D US videos, where the boundaries of the moving structures are ill-defined, with a high variability in contrast and brightness. An optical flow technique based on block matching was implemented due to its robustness to noise [2]. Block matching defines the velocity $\vec{v}(x,y)$ as the displacement $\vec{d}=(d_x,d_y)$ that yields the best fit between rectangular image regions located in the current frame and in the frame of reference. Finding the best match is equivalent to maximizing a similarity measure over $\vec{d}$ in the search space. This study uses the normalized cross-correlation as similarity measure. The reference frame had been chosen to be the first frame of the video sequence, in order to: 1) remove cumulative errors in the motion estimation, who results in a shift of the tracked structure overtime [3] and 2) enable a fast recovery of tracking when the tracked structure disappeared over a short subsequence of frames. Motion estimation via optical flow is a computationally expensive process. To limit the computation time, only the pubis, the urethro-vesical junction and the ano-rectal angle (ARA) were tracked by the algorithm. These structures were manually initialized by a series of points on the first frame of each video sequence.

Results:
The tracking algorithm has been successfully tested on 17 US videos containing PFM contraction, Valsalva maneuver and cough. The pubis, the ARA were successfully tracked on all frames of all videos. The urethro-vesical junction was successfully tracked as well, when the structure was visible in the video. In all cases when the structure disappeared temporarily, the algorithm was able to automatically resume tracking once the structure became visible again.

(a) (b) (c)
Figure 2: Tracking results: (a) PFM Contraction, (b) Cough and (c) Valsalva maneuver.

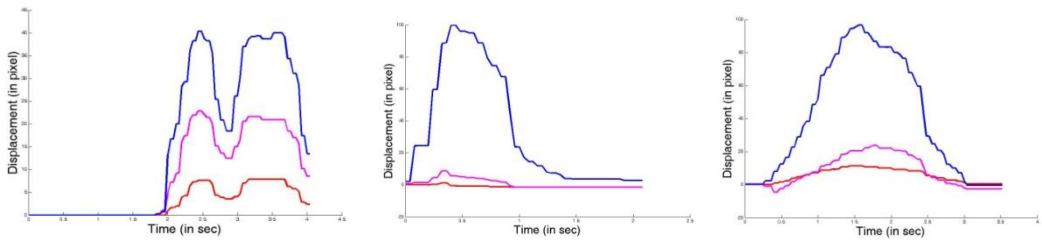

Figure 3: Displacement for the pubic bone (in red), the ARA (in pink) and the urethra (in blue): (a) PFM Contraction, (b) Cough and (c) Valsalva manoeuvre.

Interpretation of results:

Figure 2 shows typical examples of tracking results for 3 videos acquired during one PFM contraction, one cough and one valsalva maneuver respectively. The positions of all structures of interest (pubic bone, urethro-vesical junction, ARA) are indicated at regular time intervals on each image in using a gradient colour code (yellow for the first frame, evolving to red for the last frame). For clarity, the time interval is manually adjusted for each video in order to represent the entire displacement of this structure. Figure 3 shows the displacement graph for each type of motion. Large magnitudes for the local slope of the graph correspond to large motion velocities, while small magnitudes for the local slope correspond to low velocities. The results in Figures 2-b and 3-b show the capability of the motion tracking algorithm to accurately capture information about very fast structure motions caused by cough. Information captured in the displacement graphs will be very useful for the estimation of kinematic parameters of the urethra and the pelvic floor muscle.

Concluding message:

This study reports explored the potential of automatic motion tracking algorithms based on image processing techniques. The optical flow tracking based on block matching has been very successful in this stage. Further studies are needed.

References

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Was this study approved by an ethics committee?	**Yes**
Specify Name of Ethics Committee	**Comité mixte d'éthique et de la recherche -Regroupement neuroimagerie Québec**
Was the Declaration of Helsinki followed?	**Yes**
Was informed consent obtained from the patients?	**Yes**