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Stress Urinary Incontinence: A Passive Pelvis Adaptation?

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Abstract

In this theoretical paper, the concepts of elasticity are applied to the whole of the pelvic anatomy. A certaindifference in elasticity between the two sides of the vaginal cap could be the root cause of the adaptation of vesicourethral and vaginal structures under stress. Under abdominal pressure, the significant posterior elasticityof pelvis allows the bottom and the back tilt of the anterior wall of the horizontal vagina and its propulsion forward. The suspension of the anterior vaginal wall as a bridge suspension propels the vaginal cap forwardand upwards in a pendulum mode. This movement allows the sliding backwards and downwards of the bladder neck, and the creation of tension in the vertical suburethral vaginal wall by pulling it up and making it more rigid. The forward movement of the neck compresses the Retzius space, which increases the pressure therein. This increased pressure pushes back the only weak point of the walls of the Retzius space, the segment of the anterior vaginal wall located just above the pelvic diaphragm and pubourethral ligaments. This is followed by distal locking of middle urethra, the most effective mechanism of urinary continence under stress. On the whole, this theory assumes a totally passive adaptation of the urogenital system under stress which is through mechanisms that trigger each other in a descending cascade. The active role of pelvic muscles would then be only a secondary one in strengthening this passive urogenital adaptation to stress.

Keywords: Stress urine incontinence, Pathophysiology.

Introduction

In stress urinary incontinence, there is the word stress. Stress means an increase of abdominal pressure.In terms of physics, stress is a force exerted on all the tissues and structures of the pelvis, thus causing deformations and movements in them because of their viscoelastic characteristics. It is therefore appropriate to incorporate the laws of physics[1,2] into our theories in order to improve our understanding of the adaptation mechanisms of the pelvis under stress. Historically, this approach has helped to suggest shock absorption under the bladder, a selective and increasedpressure mechanism in the RETZIUS space [3]. Then the deepening of this approach helped to understand the vertical vaginal wall (VVW) and the horizontal vaginal wall (HVW),the two segments of the anterior vaginal wall on either side of the vaginal cap (VC), had different viscoelastic behaviour due to their dimensions. Later on, the difference in elasticity caused shock absorption under the bladder, which tempered and delayed the increase of pressure in the bladder in relation to the increase in abdominal pressure [4].250 milliseconds exists between the increase in recorded pressures in the urethra at the junction of the middle 1/3and the lower 1/3, and the rise in intravesical pressure [5]. The excess weight in morbid obesity acts as a competing force saturating and cancelling out this damping function, and creating a regressive functional incontinence after a weight loss [6-8]. The purpose of this article is to complete this theoretical approach by extending the study to the whole pelvis and comparing the data obtained with the existing theories, in particular the integral theory in its 3 versions [9,10].

Analysis

Theoretical effect of squashing a ball on 2 elastic structures

Theory: Let us compare the squashing of a ball by an articulated piston positioned astride 2 structures fixed at their ends on posts. The experiment is repeated successively on two identical elastic structures, then on 2 structures, one of which is elastic, the other rigid (Figure 1).

The rigid portion is defined as the front side and the elastic portion as the rear side. When the 2 structures have the same elasticity, the top ends of the 2 parts of the squashed ball remain identical, the major axis remains horizontal. However, a difference in elasticity causes the horizontal axis to tilt towards the rear, a tilt that can be presented as a similar tilt of an articulated plate with a piston. The two top ends are asymmetrical.

Applied theory in the pelvis: The observation of bladder deformation on diagnostic imaging already shows a similarity to a

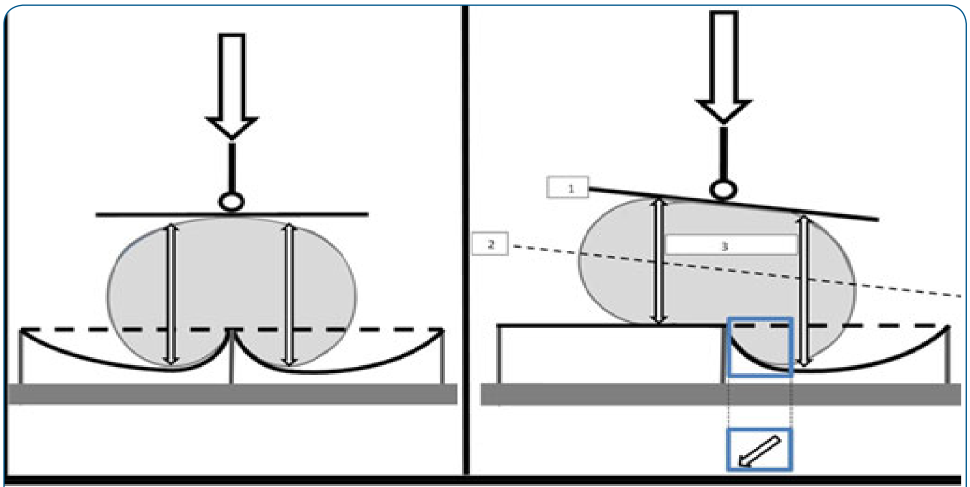

Figure 1: Comparison of the squashing of a ball by an articulated piston against two elastic structures.
1: Tilt of the articulated plate towards the more elastic rear part
2: Identical tilt of the horizontal axis of the ball towards the rear part
3: Asymmetry of heights, higher on the more elastic rear side, lower on the front side
Downward and forward movement of the portion of the elastic structure located against the central plate

distortion generated by two structures of different elasticity and, conversely, is not compatible with the notion of identical elasticity in the front and in the back of the pelvis.

Comparatively to a trampoline system, uterine downward movement is allowed by a support and suspension system due to the high elasticity of the rear portion of the vagina. Anatomically, this difference in elasticity between the anterior and posterior portions of the pelvis is mainly due to the difference in measurements. In fact, a structure stretched between two fixed attachments has a more elastic behaviour the greater the distance between the attachments is. The distance between the sacrum and VC is far greater than between the VC and the symphysis. The distance between the two ischial spines is far greater than the distance between the 2 arcustendinous fasciae pelvis(ATFP) in the portion located forward of the VC. Similarly, the vagina is separated from the rectum by the fibrous fascia, which is thick and fibrous in front, while at the rear the rectovaginal septum is thin, more elastic. Therefore, many anatomical factors combined explain this difference of viscoelastic behaviour between the anterior and the posterior portion of the pelvis.

As shown in Figure 1, there's a tilting down and backward associated with a downward and forward motion of the portion of the most elastic rear part located next to the central plate. Anatomically the tilt forward of the HVW, corresponding to the elastic portion against the central plate, is confirmed by radiographic observation of the movements of the anterior vaginal wall during voiding and during the stress after opacification of different cavities (bladder, vagina, rectum) and the placement of clips at different parts of the anterior vaginal wall [11].

The VVW moves downwards and forwards during the stress, while the HVW and the rectum move down and backwards during the stress and the bladder neck is also drawn back and down. The theoretical proposal of the integral theory[8] is these movements are linked to the action of the pelvic muscles that, in this way, pull the vagina.However, the vagina is an organ suspended by the pelvic fascia from the ATFP. The ATFP acts like the catenary-shaped cable of a suspension bridge [12], a proposition taken up by the integral theory. If we include the "technical" characteristics of the suspension bridge, it becomes possible to understand better how it works, and to change the meaning of the movements described above.

The first feature is that the ATFP moves from the symphysis up to the ischiatic spine.In a woman standing up they move back and forth, from within outwards, and especially from the bottom up. The pillars of the suspension bridge are therefore not at the same height.The one located at the rear is higher. The second feature is that the bridge is directlyattached to the front pillar, the vagina being attached to the pubis by the pubourethral ligaments (PUL). At the rear, the bridge is not attached to a fixed but to a movable part (the cervix). The third feature is that the bridge is composed of 2 segments, the VVW and the HVW united by a VC junction. The 2 segments have different lengths, the VVW being much shorter than the HVW. If we draw this suspension bridge with these characteristics and apply the down and forward movement of the HVW caused by the difference in elasticity, we realize easily that the difference in elasticity of both sides of the VC causes movements of the vagina in a passive manner as described in radiological studies[13].

In conclusion, the action of abdominal pressure combined with the difference in elasticity of both sides of the VC propels the uterine body backwards and downwards, which tilts the HVW downward and forward, thus propelling the VC forward and up in a pendulum motion like a swing.

Impact of VC on continence

The thrust of the VC upward and forward associated with the backward propulsion of the uterus and the movement of the bladder will loop the bladder neck just ahead, causing the bladder neck to slide backwards and downwards. According to the first version of the integral theory[9], it also has a structural function and prevents urgency by supporting the hypothesised stretch receptors at the proximal urethra and bladder neck. These receptors physiologically initiate detrusor contraction during urination once the urine enters the bladder neck.

Anterior vaginal relaxations are associated with symptoms of urgency, frequency, nocturia and urge incontinence. This aspect of the integral theory is however subject to controversy [14]. The vertical push of the VC pulls the VVW, fixed firmly at its lower part to the pelvic diaphragm on one hand and to the symphysis pubis on the other, by the action of the PUL. Thusaccordingto the theory of the hammock [15], the urethra can be compressed more efficiently on a vagina made more rigid by stretching. This upward movement is also at the origin of the theory of the pressure vessel, a theory now completely refuted [16]. Given its vertical direction, the VVW can be likened to a tent held by two pegs, the ridge of this tent corresponding to the VC. At this level, the anatomical connection (pegs) to the ATFP through the EPF (EndoPelvic fascia) is particularly strong [17] and the tearing of the EPF at this level is correlated with vaginal hypermobility and Stress Urinary Incontinence (SUI).

The main observation criteria for stating that a tent is badly stretched are:

- excessive mobility during mobilisation of the tissue with the hand, more marked at the ridge
- excessive downward curvature of the ridge line visible especially in the middle, which is lowered,
- a more open angle between the two sides of the tent

The same three criteria are found among the paraclinical criteria for the assessment of SUI: excessive mobility of the urethrovesical junction (UVJ or bladder neck), its high position relative to the bone reference points (pubis), and the opening of the posterior vesicoureteral angle and the vaginal angle.

Mobility of the UVJ: Mobility measurements by ultrasound [18] show a mobility above 1 centimetre corresponds to urinary leakage. An analysis of the literature [19] clarifies this mobility must be measured in the cerebrospinal-caudal direction and not in the ventral-dorsal direction. Similarly, the mobility of a badly stretched tent is visible mainly along the ridge. Since the "bladder-neck" is located just abovethe VC, the"bladder-neck mobility" is therefore a clearlyidentified sign of SUI which physically reflects the failure in the tensioning and excessive elasticity of the VVW.

The height of the UVJ: It can be measured by its distance from the symphysis[20]. We should also takeinto account the crossing of the symphysis plumb line [21]. In MRI, an important criteria is the distance from the UVJ relative to the pubococcygeal line (PCL) [22].

The posterior vesicoureteral angle (VUA) and the vaginal angle (VA): Measuring VA and especially the VUA wasradiologically studiedin the 50's [23] and with ultrasound in the late70's [24]. Observations are consistent and confirm this angle is more closed in continent women both at rest andunder stress. The threshold value for VUA is 140°[25]. The opening of these 2 angles only reflects the lowering of the VC and the UVJ in relation to the ATFP.

Forward thrust of the VC and the Retzius space

Although described in the integral theory [1], the forward thrust of the VC appears to have no role. It may even seem contrary to the principle of the same theory.Indeed it hypothesizes distal locking is the most important factor of continence which requires a backward VVW thrust.To resolve this paradox, we must again focus onthe laws of physics and their application to anatomy.The anatomical target of the forward displacement of the VC and the upper part of the VVW is the Retzius space. Anatomically, this is a space of small volume closed in the front and at the sides by the totally nondeformable pelvic bone. This forward movement of the VC and a part of VVW compresses the Retzius space, which decreases in volume. In its upper part, the action of the abdominal pressure prevents the lifting of the bladder base. This results in an increased pressure which is related to this decrease of volume, according to the physical formula: $\Delta P/P = \Delta V/V$ = constant α [26]. Thus, the pressure registered in the Retzius space may be temporarily and transiently greater than the intra-abdominal pressure. The concept of a pressure gradient between the 2 spaces is comparable to the intra-abdominal pressure gradient in the pelvis, which dependson the location of measurement and the ventilation [27]. However, whereas the pressure in the Retzius space has already been measured directly [28], no study has been attempted to measure the existence at stress of a gradient related to abdominal pressure. This selective increase in pressure in the Retzius space seems to be the mechanism of the action of two procedures: the Burch procedure [29] and Retzioplasty [30]. The Burch procedure consists of attaching the anterior vaginal wall to Cooper's ligaments. The success of the operation is in the increase of intraurethral pressures [31], a better fixing of the UVJand an increase in the length of the urethral canal, but not in a decrease in the mobility of the vagina. The mechanism of action may be a decrease in the volume of the Retzius space, which increases its internal pressure and thus increases the pressure in the urethra (located anatomically speaking in the Retzius space). Retzioplasty reduces the volume of the Retzius space by injecting surgical glue into it, and induces fibrosis[32]. Moreover, increased pressure in the Retzius space is incorrectly correlated to the increase in urethral pressure in the case of pathological rigidity thereof (sclerosis, post-radiation urethra), which is also a factor in SUI [32].

Distal locking

As shown in Figure 2 increased pressure in the Retzius space can cause a passive, induced motion at only one point of its walls: the area just above the insertion of the PUL. In fact, the osseous wall is nondeformable, the bottom of the pelvic diaphragm is only slightly deformable, and the upper part of the VVW is drawn forward with the bladder neck. Under stress, the hyper pressure in the Retzius space creates at this level a backward movement so that the globalmotion of VVW is then a winding around the symphysis [33]. Anatomically, at this level, there is a small α anglemeasuring 16 degrees between the VVW and the extrapelvic portion of the vaginal wall (EPVW) [34]. At this level, ultrasound finds a urethral knee between a movable and a fixed intraperitoneal portion [35], the knee measured by a β angle. An ultrasound assessment of this β angle both at rest and under stress [36] con-

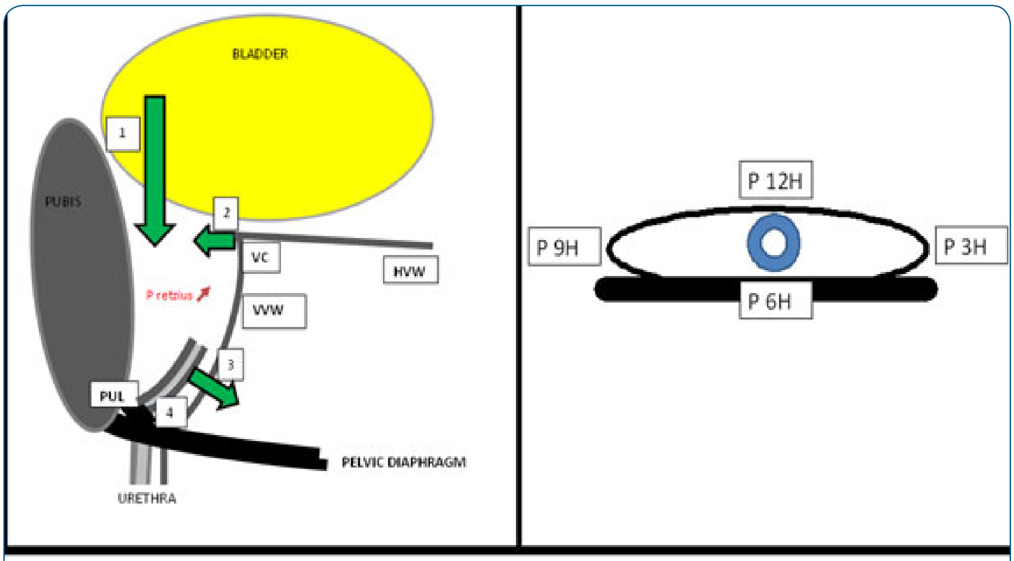

Figure 2: Distal Locking
1: Movement of the base of the bladder as a result of abdominal pressure
2: VC pendulum movement
3:Backward movement of the urethra and the VVW in its lower portion
4: Distal locking by constriction of the urethra against the PD (pelvic diaphragm)

P retzius ↗ : Increase of pressure in the Retzius space

firms a significant role of the urethral knee in maintaining female urinary continence.

Increased pressure in the Retzius space causes the movement of the rear portion of the VVW located just above the PUL, the EPVW remaining relatively stationary. This movement increases the α and β angles, indicating a constriction between the fixed part and the movable part of the urethra at this level. This constriction presses the urethra onto the posterior edge of the hole created by its passage through the pelvic diaphragm.A French study showed functional length varied only slightly according to the position of the probe[37]. Therefore the deformation of the urethra is oval in shape, which may correspond to the constriction effect. Thus, the distal locking mechanism complies with both the integral theory[9] and the experience with urethral support slings. Indeed, the mechanism of action of TVT urethral support slings was studied by ultrasound and dynamic MRI[38]. The width of the slings has no influence on their effectiveness, which seems to be associated with the constriction and pressing of the urethra on their posterior edge. In theory, the distal locking mechanism is related either to a faulty pressurization of the Retzius space or to an anatomical defect of the pelvic diaphragm (or to its fixing by the PUL) which is translated clinically by a thrust of the meatus on coughing, objectified by Q-Tip test [39].

Overall Synthesis

On the whole, thanks to physics we can demonstrate that the main cause of urogenital adaptation to stress is the overall difference in elasticity of the pelvis, on either side of the VC. This difference in elasticity creates a downward succession of mechanisms that trigger each other in a cascading fashion. This sequence of events creates pressure gradients. The rise in pressure is delayed and regulated in the bladder by a subvesical shock cushion. Then the pressure in the Retzius space is selectively increased. In this physiological hypothesis the role of different pelvic muscles would be both secondary in accompanying and strengthening the voluntary or reflex adaptation mechanisms, and in their participation in this elasticity difference within the pelvis by their thickness, firmness and their own viscoelastic characteristics at rest. As there are several mechanisms at work in this adaptation to stress, each individual criterion is only partially associated with SUI and clinical observation allows the identification of SUI only in 57% of cases [40]. Some mechanisms may more or less compensate some others, such as moderated cystocele, which is a protective factor [41]. Finally, the effectiveness of the overall adaptation to stress also depends on bladder filling [42].

Conflictof Interest

Filings of industrial patents and partnership with the B Braun Medical SAS laboratory, 204 Avenue du Maréchal JUIN, BP 331, 92107 BOULOGNE CEDEX for the purpose of development of a preventive intravaginal device for female urinary incontinence.

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