Gynaecol Perinatol 2006;15(3):131–141

Department of Obstetrics & Gynecology, Faculty of Medicine,
University »Sv. Kiril i Metodij«, Skopje, Macedonia

BIOMECHANICS OF THE SUPPORT OF PELVIC ORGANS
Pelvimetric study of the suspension system in genital prolapses

BIOMEHANIKA STATIKE ZDJELIČNIH ORGANA
Pelvimetrijska studija suspenzionog sistema kod genitalnih prolapsa

Momčilo B. Lazarevski

Original paper

Key words: genital prolapse, endopelvic fascia, suspension system of genital organs, support of pelvic organs

SUMMARY. ***Aim.*** The mechanisms of the support of pelvic organs are still debatable. There are three major concepts regarding the role of the suspension and sustention systems: »suspensionistic«, »sustentionistic« and »dualistic«. The aim of this paper is to elucidate the role of the suspension system in these phenomena. ***Material and method.*** The study involves 441 patients (340 genital prolapses and 101 control cases). All patients are submitted to a standard colpocystography (pelvigraphy during maximal contraction of pelvic diaphragm and during maximal bearing down). The suspension system is simplified as a chain composed of three links and the pelvimetric measurements are made between the well defined points: lower edge of pubic symphysis, bladder neck, external uterine orifice and middle point of anterior surface of third sacral vertebra. Biomechanical study of changes of these parameters is carried out through analysis of elastic oscillations and plastic deformation indices. ***Results.*** The index of *elastic oscillation* within *control group* of the whole suspension system is 7.8%, however, all part of the system do not comport uniformly. The most important oscillations are registered at genito-sacral (15.3%), and much smaller at pubo-urinary distance (3.3%). However, the index of uro-genital part is negative (–1.5%), demonstrating that this part of suspension, where the ureter is located, is maximally protected from distension. With *hysteroprolapses*, the elastic oscillation indices of whole system increase proportionally to the degree of descent, reaching maximum of 45%. Analyzed separately, all elements of suspension do not comport uniformly, as well. Genito-sacral portion indices are always highest, reaching maximum of 49.5%, pubo-urinary portion presents smaller indices (max. 29.5%). However, the indices of uro-genital segment increase very slowly with intravaginal hysteroprolapses, but they show a sharp increase after uterine exteriorization (max. 42.7%). The analysis of *plastic deformation* indices of hysteroprolapses demonstrates that the whole suspension system changes parallel prolapse progression (15.4%, 28.0%, 68.0% and 73.3%). The highest deteriorations are registered at genito-sacral part (max. 105.3%). The indices of pubo-urinary part run at a somewhat lower level (max. 53.4%). However, the indices of uro-genital portion are very interesting: with intravaginal hysteroprolapses, they are even negative, but after uterine exteriorization, they increase sharply, reaching maximum value of 32.3%. Within sliding bladder prolapses, uro-genital portion is six times more deteriorated than with concomitant ones. ***Conclusion.*** The biomechanical analysis implies that genital prolapse is primarily connected with deteriorations of the suspension system. Consequently, genital prolapse surgery should be primarily directed towards realization of adequate correction of deteriorations of the suspension system. The correction could be done by shortening of respective elements of suspension system (resection, plication or duplication), or by their substitution with heterogeneous material. Due to high resistance of heterogeneous material, substitution gives better and more durable results.

Izvorni članak

Ključne riječi: genitalni prolaps, endopelvina fascija, suspenzioni sustav genitalnih organa, podrška zdjeličnih organa

SAŽETAK. ***Cilj istraživanja.*** Mehanizam fiksacije zdjeličnih organa je još diskutabilan. Postoje tri glavne koncepcije u odnosu na ulogu suspenzionog i sustenzionog sistema: »suspenzionistička«, »sustenzionistička« i »dulistička« koncepcija. Cilj ove publikacije je da baci novu svjetlost na ulogu suspenzionog sustava kod ovih zbivanja. ***Materijal i metode.*** Studija obuhvata 441 pacijenticu (340 genitalnih prolapsa i 101 kontrolnih slučajeva). Sve pacijentice su podvrgnute standardnoj kolpocistografiji (pri maksimalnoj kontrakciji zdjelične dijafragme i tijekom maksimalnog tiskanja). Pelvimetrijska mjerenja su vršena između dobro definiranih točki zdjeličnih struktura: donji rub simfize pubične kosti, vrat mjehura, vanjsko ušće maternice i sredina prednje površine trećeg sakralnog kralješka. Na taj način, dobivaju se tri distancije koje karakteriziraju suspenzioni sistem: pubo-urinarna, uro-genitalna i genito-sakralna. Biomehanička ispitivanja promjena ovih parametara vršena su na bazi analize indeksa elastičnih oscilacija i plastičnih deformacija, koji se klasično koriste u mehanici za izučavanje sistema građenih od elastičnih struktura. ***Rezultati.*** Elastične oscilacije u kontrolnim slučajevima indeks cijele suspenzije iznosi 7,8%, pri čemu svi dijelovi ovog sistema ne ponašaju se uniformno. Najveće promjene su na nivou genito-sakralnog dijela suspenzije (15,3%). Mnogo manji indeks je na nivou pubo-urinarne distancije (3,3%). Međutim, najinteresantniji nalaz je negativan indeks elastičnih oscilacija uro-genitalnog dijela (–1,5%). Kod različnih stupnjeva prolapsa maternice indeksi elastičnosti cijelog supenzionog sistema povećavaju se proporcionalno težini spada, dostižući maksimalne vrijednosti od 45%. Pri tome, najveći indeksi su na nivou

genito-sakralne partije, dostižući maksimum od 49,5%, a manji na nivou pubo-urinarne distancije, dostižući maksimum od 29,5%. Kod intravaginalnih histeroprolapsa, indeksi elastičnih oscilacija na uro-genitalnom segmentu sporo se povećavaju, a veoma se naglo penju nakon eksteriorizacije uterusa, dostižući maksimum od 42,7%. Indeksi *plastičnih deformacija* pri kontrakciji zdjelične dijafragme pokazuju da njena kontrakcija ne može korigirati deterioracije sakro-genitalnih i pubo-urinarnih dijelova suspenzije, nego ona samo u medijanoj liniji »sakuplja« prolabirane organe. Indeksi plastičnih deformacija pri maksimalnom tiskanju pokazuju deterioraciju suspenzionog sistema. Kod histeroprolapsa indeksi za cijeli sistem se progresivno povećavaju, paralelno prateći stupanj prolapsa maternice (15,4%, 28,0%, 68,0% i 73,3%). Najveći indeksi se registriraju na genito-sakralnom dijelu suspenzije (maksimalne vrijednosti od 105,3%), što jasno govori da je prolaps maternice u direktnoj vezi s oštećenjem toga dijela suspenzionog sistema. Indeksi za pubo-urinarni dio su na nešto nižem nivou (maksimalna vrijednost od 53,4%). Međutim, razvoj indeksa uro-genitalnog dijela suspenzije je veoma interesantan: kod intravaginalnih histeroprolapsa oni su negativni, a nakon eksteriorizacije uterusa naglo se povećavaju, dostižući maksimalnu vrijednost od 32,3%. ***Zaključak.*** Ispitivanja jasno pokazuju da je prolaps genitalnih organa primarno povezan s oštećenjem suspenzionog sistema. Dosljedno tome kirurška terapija prolapsa treba biti primarno usmjerena na odgovarajuću korekciju oštećenja odgovarajućih dijelova suspenzionog sistema. Premda se ovakva korekcija može vršiti skraćenjem dijelova suspenzionog sistema (resekcije, duplikacije ili plikaturacije), njihova supstitucija pomoću heterogenog materijala daje bolje i trajnije rezultate.

Introduction

Mechanisms of the support of pelvic organs represent a very complex part of the pelvic biomechanics. In spite of efforts of many generations, the problem is still debatable. It is important to stress that talking about mechanisms of pelvic static and dynamic relations we focus primarily on the systems assuring support of genital organs (uterus and vagina), and thereafter on attachments of lower urinary organs and ano-rectal segment. The general opinion states that the system of uterine orientation (round ligaments) plays an interesting but only a secondary role in attachment of genital organs. Therefore, the problem of genital viscera support should be studied through the activities of suspension (endopelvic fascia and ligamentary structures) and sustention systems (pelvic diaphragm) of the utero-vaginal complex.

There are three major conceptions regarding the roles of pelvic suspension and sustention systems. Halban's and Tandler's[1,2] concept, according to which the pelvic diaphragm supports the pelvic organs, is still widely accepted and it's protagonists consider the repair of levator muscles to be the most important stage of genital prolapse surgery. On the other hand, Mackenrodt,[3] Fothergill,[4] Mengert,[5] Shirodkar[6] etc. believe that the pelvic viscera are only suspended and consequently the surgical correction of genital prolapse must involve repairing of the subperitoneal ligamentary structures. The contemporary consensus, however, appears to be a dualistic concept of attachment of pelvic viscera, where both systems contribute more or less to the position of pelvic organs.[7–13]

With the aim to shed more light on the problem we performed by using radiopelvimetry an indirect study of suspension and sustention systems of pelvic viscera, in control cases and in patients suffering of genital prolapse. Herein, the aim is to elucidate the role of the pelvic suspension system in these phenomena.

Material

The study involves 441 patients investigated at the Department of Obstetrics and Gynecology of the Medical Faculty, Skopje, during the period from April 1, 1968 to February 28, 1973 (same material previously published in this journal).[14] The patients are distributed in 4 groups.

Group A. 340 genital prolapses (mean age 46.6 years). Analyzing each prolapse element separately, there are 244 uterine prolapses classified in 2 grades: 169 intravaginal hysteroprolapses or hysteroptoses (113 hysteroptoses ≤30 mm and 56 hysteroptoses ≥31 mm) and 75 exteriorized hysteroprolapses or hysteroceles (45 subtotal and 30 total hysteroceles). Concerning vaginal wall changes, the series involves: 241 sliding bladder prolapses, 77 concomitant bladder prolapses, 170 rectoptoses and 42 rectoceles.

Group B. 52 isolated rectal (mean age 44.4 years), consisting of 11 rectoptoses and 41 rectoceles. Their pathogenesis is different from that of other prolapse elements. Therefore, they are studied separately and sometimes used as controls.

Group C. 15 isolated cases of stress incontinence without any genital prolapse element, used as controls (mean age 46.1 years);

Group D. 34 multiparous women without any element of genital prolapse, a real control group (mean age 41.3 years).

Primarily, such distribution of material permits studying of each group or each prolapse element separately. Then, if statistical analysis does not show difference between the studied control groups, they may be integrated and used as enlarged groups (C+D: n=49; or B+C+D: n=101). Otherwise, they are studied separately.

Method

All patients are submitted to the standard colpocystography using the method of Béthoux and Borry[15] modified by Lazarevski:[16,17] first pelvigraphy – during maximal contraction of the pelvic diaphragm, (position I) and second – during maximal bearing down (position II).

In order to effectuate biomechanical studies, the very complex structure of the suspension system is simplified

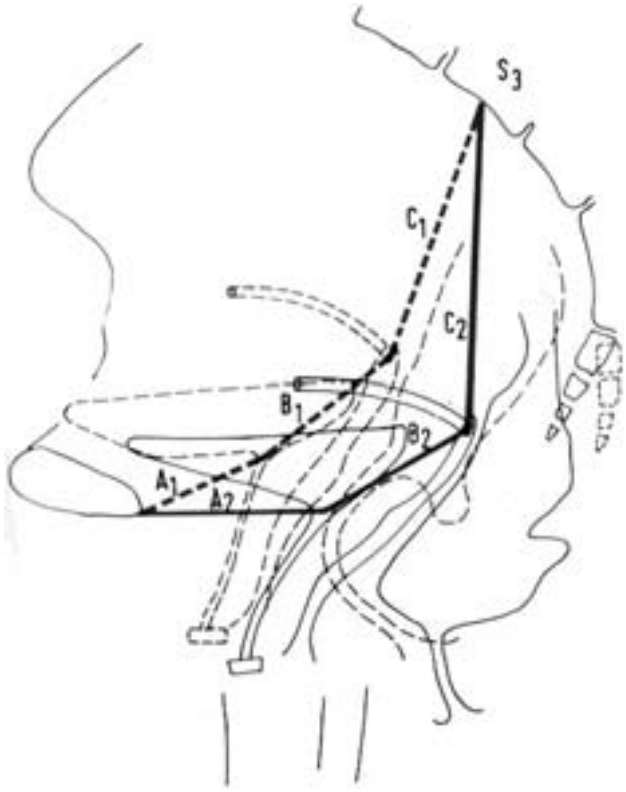

Fig. 1. Scheme of measured parameters of the suspension system. Full line – I position, dotted line – II position. A1-A2 pubo-urinary distance, B1-B2 uro-genital distance and C1-C2 genito-sacral distance

Slika 1. Shematski prikaz mjerenih parametara suspenzionog sistema. Puna linija – I pozicija, isprekidana linija – II pozicija. A1-A2 pubo-urinarna distancija, B1-B2 uro-genitalna distancija i C1-C2 genito-sakralna distancija

to a system composed of three elastic elements – three arbitrary distances between well-defined points *(Fig. 1)*.

– *pubo-urinary distance* (A1-A2) is measured from the lower edge of pubic symphysis to the urethro-vesical junction, aiming to present the pubo-urinary ligamentary structures;
– *uro-genital distance* (B1-B2) between the urethro-vesical junction and the marker on external uterine orifice, aiming to present the uro-genital ligamentary structures (bladder pillars); and
– *genito-sacral distance* (C1-C2) between the marker on the external uterine orifice and the middle point of anterior surface of third sacral vertebra, aiming to represent the genito-sacral ligamentary structures.

The pelvimetric method utilizes a standard distance between the anti-cathode and the central sagittal plane of the body of patient, expressed as a middle point of the distance between her feet, slightly thrown wide apart. The radiography is centered on the level of trochanter major.[15–18] The pelvimetric measurements are made on true profile pelvigraphies in both positions. In order to decrease the statistic deviations of measured parameters due to the anthropologic differences, all measurements are expressed as functions of the sacro-cotyloid distance – distance from the posterior border of plateau of first sacral vertebra to the middle point of the line, connecting the centers of femoral heads (least changeable pelvic parameter, by Wangermez et al.).[19] Namely, the quotients obtained after division of each distance by the sacro-cotyloid distance are used in the statistical study, calculating mean arithmetic value ($\bar{X}$), standard deviation (σ), and tests of significance (p).

Biomechanical analysis of changes of the suspension system is studied by means of classic mechanical indices used for characterization of elasticity and plastic deformation of structures:[16,20] index of elastic oscillations and index of plastic deformation. This part of the study is carried out with collaboration of Professor Emilian Titaru, engineer of structures, University of Bucharest, Romania. The calculations use the means of arithmetic values ($\bar{X}$) of a respective length, during maximum con-

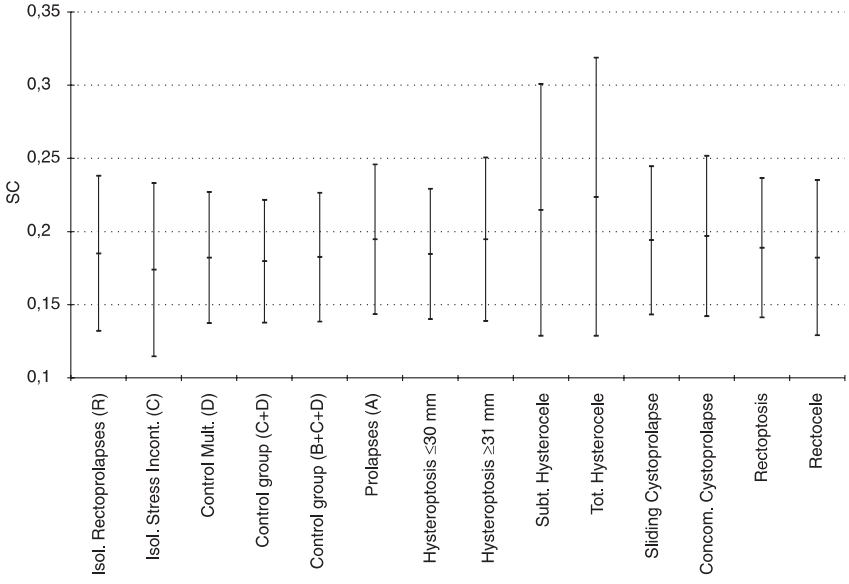

Fig. 2. Graphic drawing of $\bar{X}$ and σ of the pubo-urinary distance in first position

Slika 2. Grafički prikaz $\bar{X}$ i σ pubo-urinarne distancije u prvoj poziciji

traction of the muscles of pelvic diaphragm (position I) and during maximal bearing down (position II), in control and prolapse cases.

Index of elastic oscillations (I.E.O.) expresses the relation between the length difference of a parameter, in position II and position I, versus its length in position I. The data for control cases are considered as representing physiologic changes and the data for prolapses, as pathologic values:

$$\text{I. E. O.} = \frac{\text{Length in Position II} - \text{Length in position I}}{\text{Length in position I}} \times 100$$

Index of plastic deformation (I.P.D.) represents the length difference of a parameter in prolapse and control cases, versus its length in control cases:

$$\text{I. P. D.} = \frac{\text{Pathologic length} - \text{Control length}}{\text{Control length}} \times 100$$

The plastic deformation indices are calculated on parameters obtained during maximal contraction of the pelvic diaphragm (position I) and during maximal bearing down (position II), in controls (control length) and prolapse cases (pathologic length). It should be emphasized that in first colpocystographic position the data do not merely express qualities of suspension system, but also the effects of pelvic diaphragm contractions, trying to elevate pelvic organs. Obviously, »these miscalculations« should be accepted since it is impossible to isolate the proper effects of each part of suspension system.

Furthermore, the values for these indices are to be considered only as relative values. They do not represent isolated changes of every studied element, examined in laboratory, but changes in vivo reflecting the interaction of suspension and sustention systems. Such an indirect and simplified method of analysis by means of relative values permits better and easier understanding of these very complex biomechanical events and is scientifically fully acceptable.

Results

For easier understanding, the computer data of the $\bar{X}$ and the σ of studied parameters are graphically presented.

Changes of the pubo-urinary ligamentary structures

The $\bar{X}$ and the σ of *pubo-urinary distance* during maximal contraction of the pelvic diaphragm are presented on the *Fig. 2*. It is evident that the data for control groups B, C and D are very similar (C:D / $p<0.315$; C+D:B / $p<0.281$); these cases can be used as an integral control BCD group with $\bar{X}=0.183\pm0.044$. On the other hand, in genital prolapse group as a whole (A), this distance has an $\bar{X}=0.195\pm0.051$ and is different from control BCD group (BCD:A / $p<0.008$). Analyzing the hysteroprolapses only, a progressive increase of the pubo-urinary distance, paralleling degree of uterine descent is evident.

The $\bar{X}$ and the σ of *pubo-urinary distance* during maximal bearing down are graphically presented on *Fig. 3*. The data for control groups are very similar, as well (C:D/ $p<0.341$; C+D:B / $p<0.161$), permitting formation of an integral control group (BCD), with $\bar{X}=0.189\pm0.053$. For genital prolapse group as a whole (A), however, this distance is significantly longer $\bar{X}=0.244\pm0.064$ and this group is very different from controls (BCD:A / $p<0.000001$). Among different grades of uterine prolapse, the pubo-urethral distance increases progressively and parallels the degree of hysteroprolapses. Due to almost equal standard deviations, these data are highly significant.

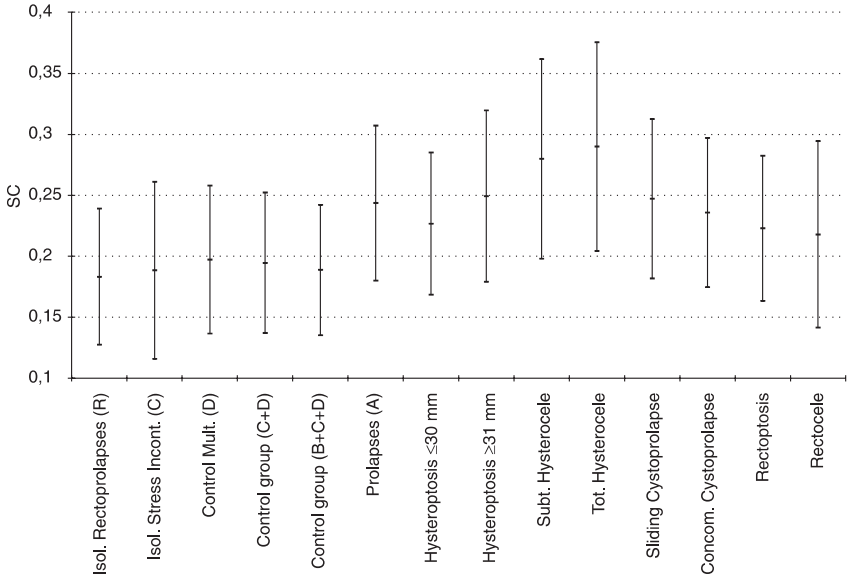

Fig. 3. Graphic drawing of $\bar{X}$ and σ of the pubo-urinary distance in second position.
Slika 3. Grafički prikaz $\bar{X}$ i σ pubo-urinarne distancije u drugoj poziciji.

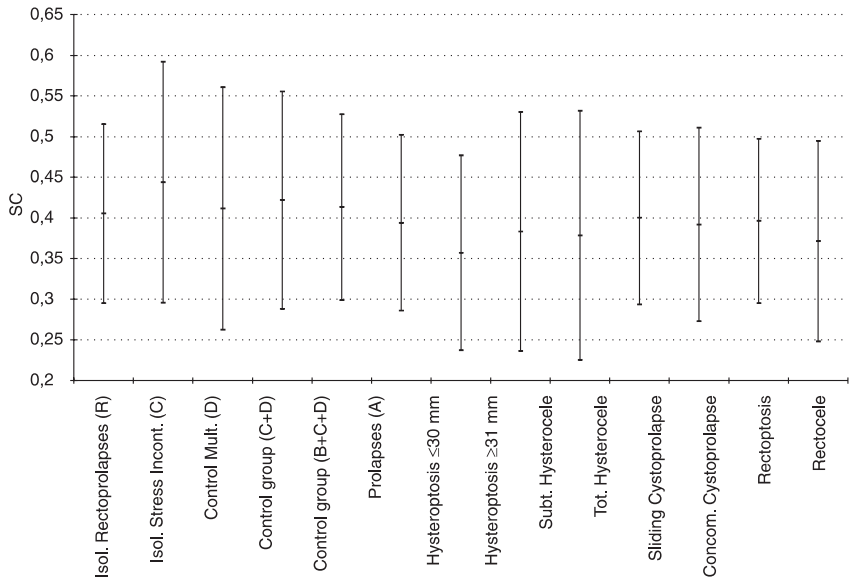

Fig. 4. Graphic drawing of $\bar{X}$ and σ of the uro-genital distance in first position
Slika 4. Grafički prikaz $\bar{X}$ i σ uro-genitalne distancije u prvoj poziciji

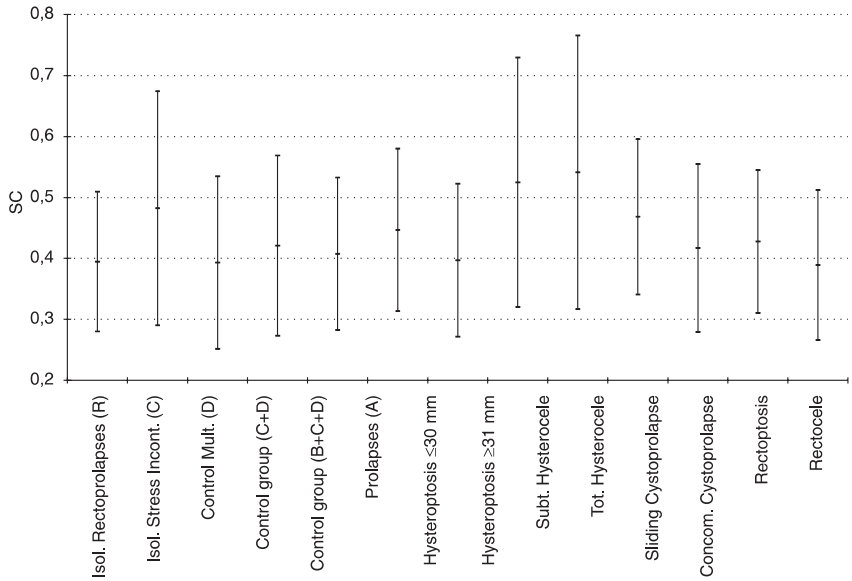

Fig. 5. Graphic drawing of $\bar{X}$ and σ of the uro-genital distance in second position.
Slika 5. Grafički prikaz $\bar{X}$ i σ uro-genitalne distancije u drugoj poziciji.

Changes of the uro-genital ligamentary structures

During maximal contraction of the pelvic diaphragm *(Fig. 4.)* control B, C and D groups behave as a homogenous statistical specimen (C:D / p< 0. 245, C+D:B / p<0.251) and these cases could be incorporated in an enlarged control group (BCD), with $\bar{X}$=0.413±0.114. Surprisingly, in prolapse group as a whole (A), this distance is smaller $\bar{X}$=0.394±0.108 than in control BCD group, but the result is not significant (BCD:A / p<0.66). It is the same with the hysteroprolapses, where important variations and different σ of this distance diminish their statistical significance.

During maximal bearing down *(Fig. 5.)*, control cases also behave homogeneously (C:D / p<0.054, CD:B / p<0.161).), so they can be incorporated in an integral control BCD group, with $\bar{X}$=0.407±0.125. With prolapses as a whole group (A), the uro-genital distance is longer $\bar{X}$=0.447±0.133 than in control BCD group and statistical calculations show a significant difference (BCD: A / p<0.003). With intravaginal hysteroprolapses, this distance shows even diminution, but as it has to be expected, a progressive increase, paralleling the degree of uterine exteriorization, is evident. It is important to notice, that with sliding bladder prolapses, the uro-genital distance is longer than with the concomitant ones. It is the same with the rectoptoses versus the rectoceles.

Changes of the genito-sacral ligamentary structures

With maximal contraction of the pelvic diaphragm *(Fig. 6.)*, there is no difference between control groups (C:D / p <0.232; CD:B / p<0.500); an enlarged control

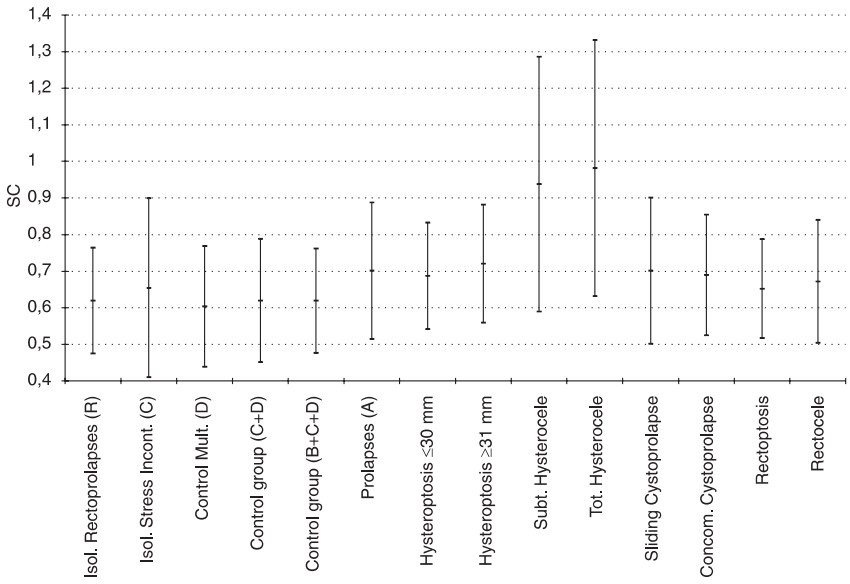

Fig. 6. Graphic drawing of $\bar{X}$ and σ of the genito-sacral distance in first position
Slika 6. Grafički prikaz $\bar{X}$ i σ genito-sakralne distancije u prvoj poziciji

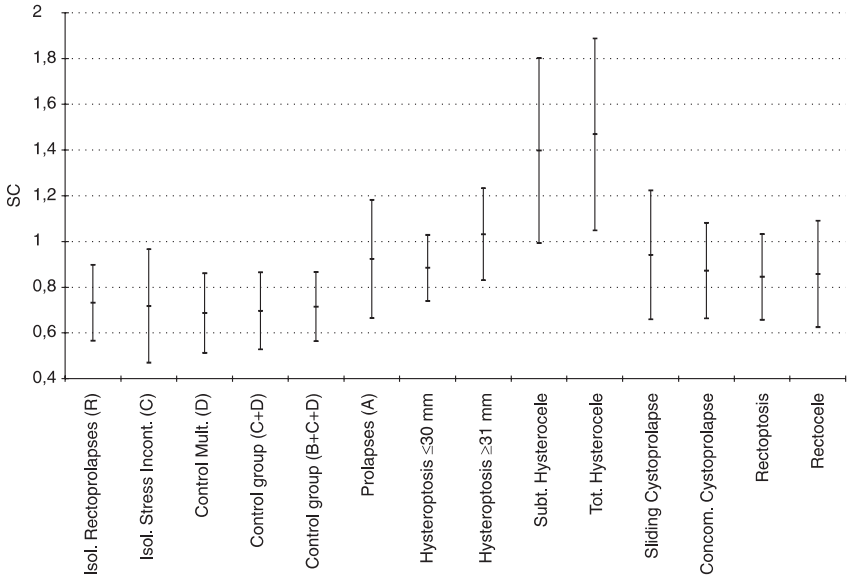

Fig. 7. Graphic drawing of $\bar{X}$ and σ of the genito-sacral distance in second position
Slika 7. Grafički prikaz $\bar{X}$ i σ genito-sakralne distancije u drugoj poziciji

BCD group could be formed with $\bar{X}$=0.620±0.143. In genital prolapse group as a whole (A), this distance shows a considerable increase $\bar{X}$=0.701±0.187, and this group is highly different from controls (BCD:A / p<0.00002). In hysteroprolapses, the genito-sacral distance progressively lengthens, paralleling the degree of uterine descent.

During maximal bearing down *(Fig. 7)* $\bar{X}$ of controls are similar (C:D / p<0.333; CD:B / p<0.158), permitting formation of an increased control group (BCD), with $\bar{X}$= 0.714±0.151. In prolapses as a whole group (A), the genito-sacral distance is significantly longer $\bar{X}$=0.924± 0.259 and statistically highly different from controls (BCD:A / p<0.0000001). Among the hysteroprolapses, this distance increases progressively with grade of uterine descent.

Changes of the indices of elastic oscillations (I.E.O)

For easier presentation, the values of these indices are shown graphically on the *Fig. 8*. Pragmatically speaking, out of the elasticity of suspension system, they also express the resistance and ability of pelvic diaphragm contractions to reintegrate the prolapsed organs.

In control patients (BCD), the I.E.O. index of whole suspension system is 7.8%, but every one of its parts does not comport uniformly. The most important oscillations are registered at the level of genito-sacral part (15.3%) and much smaller at pubo-urinary distance (3.3%). Concerning uro-genital part of the system, the I.E.O. is even negative (–1.5%), demonstrating that during maximal straining, the distance between bladder neck and uterine cervix even decreases.

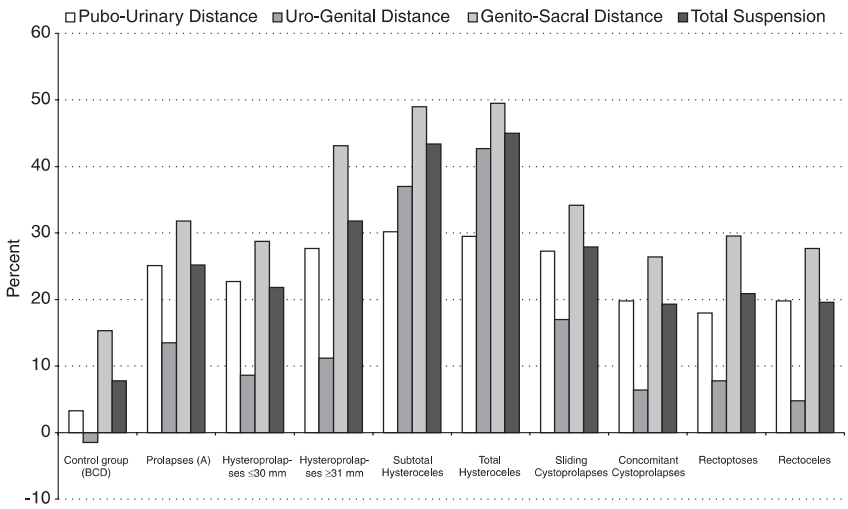

Fig. 8. Graphic drawing of the of elastic oscillation indices of the suspension system
Slika 8. Grafički prikaz indeksa elastičnih oscilacija suspenzionog sistema

These findings impose very interesting conclusions about the physiology of pelvic support. Contrary to classical opinions, claiming that genito-sacral part represents the most rigid and non-elastic portion of the suspension system, permitting only pendulum like movements of uterus around the third sacral vertebra,[5–8,15] the data of our control group show important elastic oscillations in the genito-sacral area. Furthermore, pubo-urinary portion exhibits smaller elastic oscillations – the finding opposing to current concepts, that this part of the suspension is endowed by very high elasticity. However, from the stand-point of pelvic statics, the most important finding of our analysis is decrease of the uro-genital distance during straining.

In genital prolapses as an integral group (A), the I.E.O. of whole suspension system is 25.2% bigger than in controls. As mentioned before, except the amount of dislocations, these findings indirectly demonstrate a low resistance of the pelvic diaphragm and incapacity of its contractions to reintegrate the prolapsed organs. The analysis of separate portions of suspension shows that the greatest oscillations are registered at the level of genito-sacral part (31.8%), and some smaller at pubo-urinary portion (25.1%). As for the uro-genital part, which has a negative index in control cases, its length increases (13.5%) in cases of prolapses.

The analysis of hysteroprolapses demonstrates that the I.E.O. of the whole suspension system increase proportionally to the degree of descent, reaching their maximum in cases of total uterine prolapses (45%). The genito-sacral portion indices parallel the levels of the whole system, but their values are always highly positioned, reaching maximum value of 49.5%. Consequently, presenting highest dislocations, the genito-sacral portion of suspension plays surely a very important role in prolapse pathogenesis. The pubo-urinary portion indices show slowest increases and reach maximal value of 29.5%. However, they are always at lower levels versus those for the whole suspension system. The uro-genital portion indices increase very slowly (about 10%) with intravaginal hysteroprolapses, demonstrating that intravaginal uterine position somehow protects this part of the system from loading and deterioration. However, very rapid increases of I.E.O. are registered after uterine exteriorization, reaching maximal value of 42.7%.

Changes of the index of plastic deformation during maximum contraction of pelvic diaphragm (I.P.D.-I)

Pragmatically speaking, these indices represent plastic deterioration (elongation) of the studied parameters, which could not be »corrected« by pelvic diaphragm contraction. In other words, they speak about their capacity in reposition of pelvic organs. The graphical presentation of I.P.D.-I is shown on *Fig. 9*. At first glance, negative indices in all studied groups are very important finding, showing that contractions of pelvic diaphragm decrease the uro-genital distance.

In prolapses (A), the I.P.D.-I for whole suspension system is small (6.1%), demonstrating that contractile capacity of pelvic diaphragm is still preserved. The highest changes are registered at the level of genito-sacral part of suspension (13.1%) and some smaller changes at pubo-urinary ligamentary structures (6.6%). Contrarily, uro-genital portion presents a negative index (–4.6%), demonstrating that distance between bladder neck and uterus is smaller than in control cases. Therefore, the genito-sacral part of suspension system is the most deteriorated area, whose elongation could not be »corrected« by contractions of the pelvic floor.

With intravaginal hysteroprolapses, the I.P.D.-I of whole system are very small (2.1% and 4.7%), still demonstrating sufficient capacity of the pelvic floor contractions. Analyzed separately, the greatest changes are found at the genito-sacral part of suspension. Its indices parallel the curve of the system as a whole, but always they are positioned at a higher level. The pubo-urinary portion exhibits the same trend, following the curve of system as a whole, but always at a lower level. The most interesting findings are highly negative indices of the uro-genital portion. After uterus exteriorization, the

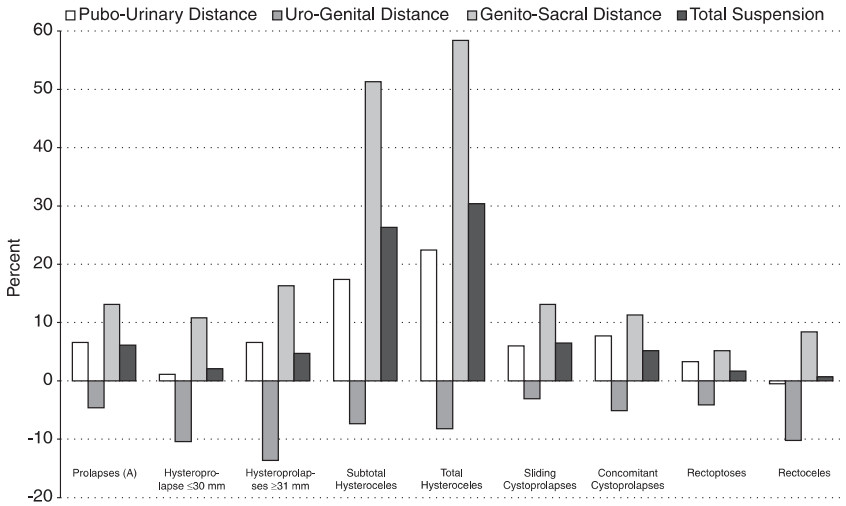

Fig. 9. Graphic drawing of the plastic deformation indices of suspension system in first position
Slika 9. Grafički prikaz indeksa plastičnih deformacija suspenzionog sistema u prvoj pozici

I.P.D.-I of the whole system continue to increase and reach a maximal value of 30.4%. The indices of genito-sacral part, however, increase more sharply, reaching maximal value of 58.4%, while indices of the pubo-urinary part are lower and reach a maximum of 22.4%. Contrarily, the indices of the uro-genital part still continue expressing negative values, oscillating between –7.3% and –8.2%.

In our opinion, the negative indices of genito-urinary part of suspension are due to elongations of genito-sacral and pubo-urinary parts of the suspension. Thus, the prolapsed organs lie flaccidly on the pelvic diaphragm and consequently, its contractions elevate and bring them together (»concentrate them«) in the medial pelvic region.

Changes of the index of plastic deformation during maximum bearing down (I.P.D.-II)

Except lengthening due to deterioration, the I.P.D-II of suspension system during bearing down furnish an indirect analysis of loading of the system. As pelvic diaphragm limits the dorso-caudal dislocations of pelvic organs, these indices also speak indirectly about its resistance. The I.P.D.-II changes are graphically presented on *Fig. 10*.

In genital prolapses (A) the I.P.D.-II for the whole suspension system reaches a maximal value of 23.1%. Analyzed separately, the elongations of genito-sacral (28.2%) and pubo-urinary (29.1%) parts are almost equal. Contrarily, the index of uro-genital part is significantly smaller, reaching up to 9.8%.

With hysteroprolapses the I.P.D.-II of whole system increase rectilinearly, paralleling prolapse progression (15.4%; 28.0%; 68.0% and 75.3%). Such a trend imposes a conclusion that pathogenesis of the uterine prolapses should be in very close, possibly in unique relation with deteriorations of suspension system. Herein, the genito-sacral part of suspension presents the highest deteriorations: they parallel indices of the system as a whole and reaches maximal value of 105.3%. In other words, in total hysteroceles, genito-sacral part of suspension is about twice longer than in controls. The I. P.D.-II of pubo-urinary part of suspension show same progressive increases, but they reach smaller values – maximum 53.4%. Therefore, this part of suspension is half the length longer than in control cases. The changes of uro-genital part of suspension are very interesting. With intravaginal hysteroprolapses its indices are negative (–1.2% and – 2.4%) showing that this part of the system is somehow protected from loading. As a matter of fact, the intravaginal position of prolapsed organs protects the genito-urinary region from deterioration. However, after exteriorization of the uterus, sharp increases of these indices are achieved, reaching maximal value of 32.3%. Finally, this part of suspension becomes one third the length longer than in controls.

To summarize, comparing total uterine prolapses with controls, the plastic deformation (elongation) of the suspension system reaches approximately the following values:

– Suspension system as a whole is longer 75%;
– Its genito-sacral part is longer 100%;
– Its pubo-urinary part is longer 50%;

and

– Its uro-genital part is longer 33%.

Pragmatically speaking, these data should be also used for estimating the extent of correction of each part of the suspension system – correction, which should be realized during surgical procedures treating total uterine prolapses.

The changes within cystoprolapses are very interesting, too. With concomitant bladder prolapses, deterioration index of whole suspension system is 16.3%. The deteriorations of pubo-urinary (24.9%) and genito-sacral (21.9%) parts are similar, however, the plastic deformation index of uro-genital part is extremely small (2.4%). Contrarily, with sliding bladder prolapses, the deterioration of whole suspension system is higher (26.3%). Pubo-urinary (30.7%) and genito-sacral (31.6%) parts present similar changes, but deterioration index for uro-

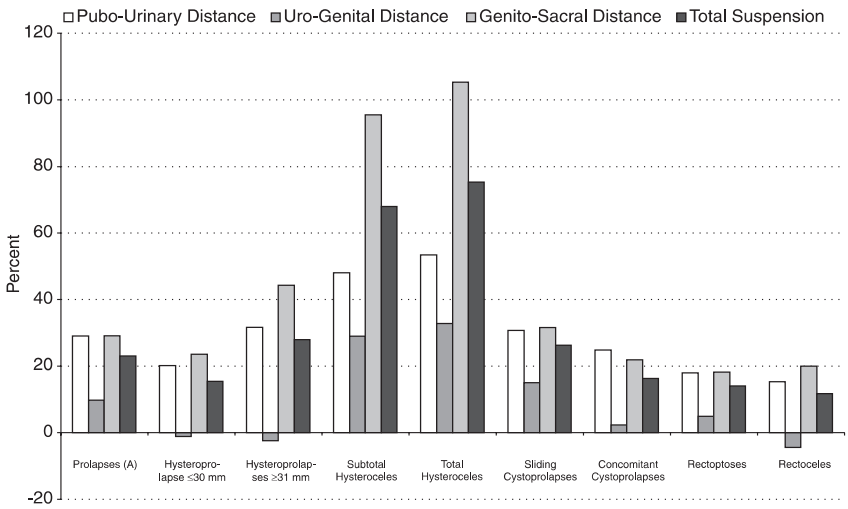

Fig. 10. Graphic drawing of the plastic deformation indices of suspension system in second position
Slika 10. Grafički prikaz indeksa plastičnih deformacija suspenzionog sistema u drugoj poziciji

genital portion is higher (15.0%) in comparison to that registered in concomitant bladder prolapses. In other words, with sliding bladder prolapses, uro-genital part (bladder pillars) of suspension is about six times more elongated than with concomitant ones (15.0%:2.4%).

Changes of rectoceles versus rectoptoses are similar, except for uro-genital part of the suspension, the P.D.I.-II of which is negative.

Discussion

In our study, the very complex three-dimensional fascial sheet (endopelvic fascia with many ligamentary condensations) of the suspension pelvic system is simplified following Delbet's[21] anatomic descriptions, which claim that this system represents a two sagittal band construction (lames sacro-recto-génito-vésico-pubiennes), holding pelvic organs. Furthermore, this »two sagittal band system« is compared to a chain, composed of three (if the rectum is analyzed of four) separate links. Obviously, each of these links has its own elasticity and resistance and is exposed to particular loading. In other words, each link of the chain should be endowed by very specific mechanical properties, related to its function, in pelvic viscera support. Finally, the biomechanical analysis of such a system is carried out by study of elastic and plastic deformation indices, calculated on colpocystographic images.

Contrary to current opinions on the physiology of pelvic support, which consider that genito-sacral part of suspension system represents the most rigid and non elastic part, permitting only pendulum like movements of uterus around the third sacral vertebra,[5–8,15] the data of our control group show important elastic oscillations in this area. On the other side, the pubo-urinary portion exhibits elastic oscillations approximately four times smaller than those of the genito-sacral portion (3.3%: 15.3%) – the finding also opposing the current physiological concepts that this part of suspension is endowed by the very highest elasticity. However, the most important finding is the shortening of uro-genital portion of suspension system during straining. Reasons for such a shortening should be sought in the relatively higher mobility of the bladder (which, during bearing down, is braced by a more firmly attached utero-vaginal complex), and also in the anatomy of vaginal canal, which imposes direction of the organ's descent. This may be the way how »nature spares the ureters« (laying in the bladder's pillars) from abnormal distension.

Progressive increases of I.E.O. of the whole suspension system, paralleling the grade of uterine descent, evidently connect its pathogenesis to changes of this system. The indices of the genito-sacral part are the most pronounced and completely parallel changes of the system as a whole. Positioned at a lower level, the indices of pubo-urinary portion exhibit identical relations. Nevertheless, the I.E.O. of the uro-genital part are very interesting. With intravaginal hysteroprolapses, their increases are not as important as that of other parts of the system, demonstrating the considerable limit of resistance of pelvic diaphragm and the fact that its contractions could still elevate the prolapsed organs. However, their sharp increase after uterine exteriorization demonstrates absence of its resistance and inability of its contractions to influence descending of organs.

The plastic deformation indices illustrate the extent of deterioration of suspension system. Like the elastic oscillation indices, they are progressive and parallel to degree of the hysteroprolapse, thus confirming that pathogenesis of uterine prolapse is in very close relations with deteriorations of suspension system. The separate analysis of segments of suspension system demonstrates the most important deteriorations at the genito-sacral part. It poses the question of whether this part of the suspension system is its weakest portion or the finding is simply a product of greatest loading in this area? The pubo-urinary part of suspension manifests progressive deteriorations, paralleling the severity of disease, as well. However, its deteriorations are less pronounced than those of the genito-sacral part. Therefore, the same dilemma should be clarified: whether this part of suspension is stronger or is simply exposed to smaller loading? Fi-

nally, the indices of uro-genital part demonstrate that this portion is the least deteriorated. With intravaginal uterine prolapses, its plastic deformation indices are negative, but after uterine exteriorization, deteriorations of genito-urinary part become evident, as well. However, they are always lowest, when compared to those of other constituents of the suspension system. The same question is: whether this part is the strongest or it is the least loaded element of the suspension system?

Concerning bladder prolapses, the concomitant ones are associated with bigger deteriorations of pubo-urinary part of suspension, while the deteriorations of its uro-genital part are several times more important with sliding bladder prolapses. The deterioration indices of suspension system in rectoceles and in rectoptoses are very similar, except for the uro-genital distance, the index of which is negative in the rectoceles (bulging of the posterior vaginal wall !?).

Biomechanical analysis of the changes of the suspension system

Although deteriorations of the suspension system are progressive and parallel the degrees of hysteroprolapse, there is no alteration uniform for all its parts. Biomechanical analysis aids the explanation of these findings. First, due to highest position (in erectile posture) and effects of gravitation force, the genito-sacral part of suspension is exposed to direct downwards tractions and to heaviest loadings, as well. The pubo-urinary part, which has only to resist the horizontal tractions of the system, is exposed to smaller loading. Because of its middle position in the system, the genito-urinary portion supports very small loadings and is naturally spared from distention.

Further clarification of these data is achieved by application of a classic mechanical low, named – ***»Theory of the weakest link of a chain system«.***[16,20]

In our study, the suspension system is compared to a chain composed of various elements – links. These links have different dimension and texture. Therefore, they have different resistance capacity, as well. Mechanically speaking, the security quotient of any link of any chain is defined as ratio between resistance capacity and internal forces developed within the element. In our cases, resistance capacity and internal forces of any link of suspension are unknown, but we positively know that they are different.

From mechanical stand point, dealing with a system composed of elements of unknown characteristics, makes it clear that the rupture always occurs in the element possessing the smallest security quotient – in other words – in the element with smallest resistance capacity.

Evidently, application of this theory is very useful in explanation of prolapse pathogenesis. It allows conclusion that its pathogenesis should be primarily connected with deteriorations of the suspension system. It also explains the pathogenesis of an enormous number of types and of variations in grade and combinations of elements included in prolapse pathology. Finally, it imposes a conclusion that the deterioration of each element of the suspension system determines the type and severity of genital prolapse: *a) genito-sacral portion is responsible for uterine prolapse; b) pubo-urinary portion, for concomitant bladder prolapse and c) uro-genital portion, for sliding bladder prolapse.*

However, it is clear that genital prolapse physiopathology is not so simple. Its study needs additional analyses of the effects of processes of compression and competitions among prolapse elements, which play an important role in portraying the definitive clinical picture of a particular case.

Evidently, our data favor concepts that the pelvic diaphragm has a secondary role in physiology of pelvic support. Namely, it represents a second barrier which gives only a non-specific support to the pelvic organs – merely during greater increases of the intra-abdominal pressure. Consequently, it appears that, if the resistance of suspension system is adequate, the prolapse will not occur, regardless of the status of the pelvic diaphragm (as in complete perineal tears, intravaginal elongation of uterine cervix etc.)!

Concerning treatment, the genital prolapse surgery should be directed towards correcting as much as possible the quality and the extent of deteriorations of the suspension system. Generally speaking, there are two possibilities for such a correction: ***shortening*** (resection, folding, duplication etc)[4,6,7,12,22] of a deteriorated autochthonous element or its ***substitution*** by heterogeneous material.[23] It is undisputable, that substitution by very resistant heterogeneous material gives more successful and more durable results. However, any case imposes a specific correction, corresponding to the extent of deterioration of each part of the suspension system. The indications and the choice of operation represent an extremely complex subject depending on many parameters. Nevertheless, the selection of operation for correction of different prolapse elements, from more than 300 procedures proposed in contemporary literature, should be easier and more effective if directed by the results obtained from our biomechanical investigations.

Conclusion

Our investigation clearly demonstrate that pathogenesis of genital prolapse primarily depends on deteriorations of the pelvic suspension system. From a biomechanical standpoint, this system could be compared to a chain composed of several links. Depending on elasticity, resistance and exposure to load, each of these links has a very specific function in the support of pelvic viscera. The specificity of deteriorations of any of the links of the suspension system easily explains both the enormous number of combinations of prolapse elements, included in any case of prolapse, and their diversity and intensity. As a matter of fact, deterioration of a certain

part of this system is responsible for the pathogenesis of a corresponding type of the prolapse element: genito-sacral portion is responsible for uterine prolapse; pubo-urinary portion, for concomitant bladder prolapse and uro-genital portion, for sliding bladder prolapse.

The genital prolapse surgery should be directed towards correcting the respective extent of deteriorations of suspension system. Substitution by heterogeneous material has proven to offer better and more durable results than the intervention of shortening of any deteriorated autochthonous tissue.

References

1. Halban J, Tandler J. Die Anatomie und Aetiologie der Genitalprolapse beim Weibe. Wien: W Braumueller, 1907:32–46.

2. Halban J. Gynäkologische Operationslehre. Berlin: Urban & Schwartzenberg, 1932:166–68.

3. Mackenrodt A. Über die Ursachen der normalen und pathologischen Lagen der Uterus. Arch Gynäk 1895;48:393–402.

4. Fothergill WE. The support of pelvic viscera: a review of some recent contributions to pelvic anatomy, with clinical introduction. Proc Roy Soc Med 1907;1:43–51.

5. Mengert WF. Mechanisms of uterine support and position. Factors influencing uterine support. Am J Obstet Gynecol 1936;31:775–81.

6. Shirodkar VN. Reorientation de nos idées sur l'anatomie des ligament de l'uterus et nouvelles techniques opératoires pour traitement des prolapsus utérins. Rev Franc Gynéc 1954;49:332–9.

7. Ulfelder H. The normal mechanisms of uterine support and its clinical implications. West J Surg 1960;68:81–9.

8. Jamain B, Legros R. Les troubles de la statique utérine. Rev Prat 1965;2:1952–64.

9. Howkins J, Hudson CN. Shaw´s textbook of operative gynecology. Edinburgh: Churchill Livingstone, 1977:176–97.

10. Richter K. Lageanomalien. In: Ober KG, Thomson K (eds.). Speziale Gynakologie I. Stuttgart: Georg Thieme Verlag, 1985;4:14–8.

11. DeLancey JOL, Richardson AC. Anatomy of genital support. In: Benson JT (ed.). Female pelvic floor disorders. New York: Northon Medical Books, 1992:19–26.

12. Nichols DH, Randal CL. Vaginal surgery. Baltimore: Williams Wilkins Co, 1996:119–39.

13. Pigné A, Bourcier AP, Scotti RJ. Risk factors for pelvic organ prolapse. In: Appel RA, Bourcier AP, La Torre F (eds.). Pelvic floor dysfunction. Roma: Casa Editrice Scientifica Internationalle, 1999:27–34.

14. Lazarevski MB. Pelvic bone system changes and pathogenesis of genital prolapse – a radiopelvimetric study. Gynaecol Perinatol 2004;13:1–12.

15. Béthoux A, Bory S. Les mechanisms statiques viscéraux pelviens chez la femme à la lumière de l'exploration fonctionnelle du dispositif en position débout. Ann Chir 1962;16: 887–93.

16. Lazarevski M.B. Morpho-topographic, static and dynamic changes of the small pelvis in genital prolapses and urinary stress incontinence. Thesis. Skopje: Medical Faculty, 1974: 214–313.

17. Lazarevski MB, Lazarov A, Novak J, Dimcevski D. Colpocystography in cases of genital prolapse and urinary stress incontinence. Am J Obstet Gynecol 1975;122:704–16.

18. Hannah WJ. Radiopelvimetry, critical appreciation, Am J Obstet Gynec 1965;91:33–47.

19. Wangermez J, Malgouyat R, Wangermez A. L'axe sacro-cotyloidien. Aplication à l'étude de l'antéversion utérine et de la position de l'utérus dans le pelvis, Bul Mem Soc Antropol 1968;3:77–87.

20. Lazarevski MB. Biomechanics of genital prolapse and urinary stress incontinence. Kumanovo: Makedonska Riznica, 2001:163–220.

21. Delbet P. In: Poirier P, Charpy A. Traité d'anatomie humaine, II Ed. Tome V, Paris, Masson Cie, 1923:134–87.

22. Fothergill WE. Anterior colporrhaphy and amputation of cervix combined as a simple operation for use in the treatment of genital prolapse. Am J Surg 1915;29:161–9.

23. Ripstein CB. Surgical cure of massive rectal prolapse. Dis Colon Rectum 1965;8:34–8.

Paper received: 1. 03. 2006.; *accepted:* 28. 05. 2006.

Address for correspondence: Prof. dr. sc. Momčilo B. Lazarevski, Partizanski odredi 109 1/3, 1000 Skopje, Macedonia. E-mail: m.lazarevski@mt.net.mk