The urethral support system during pregnancy and after childbirth
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7.1 SUMMARY

7.1.1 Introduction

7.1.1.1 Incontinence in pregnancy and after childbirth

Pelvic floor dysfunction in women is a major health problem. Symptoms are protrusion of vaginal tissue, voiding difficulties, urinary incontinence, stool problems and sexual dysfunction. Many of these women may eventually require surgery for pelvic floor dysfunction, especially for prolaps and urinary incontinence. This thesis focuses on urinary incontinence and especially on the etiological aspects of pregnancy and childbirth. In a community survey MacLennan reported a prevalence of all types of self-reported urinary incontinence in women is 35.3%. Urinary incontinence increased after pregnancy according to parity and age. The highest prevalence (51.9%) is reported in women aged 70-74 years1-4. Until now, it is not clear to what extent pregnancy itself or vaginal delivery contributes to the development of urinary incontinence in later life. Following vaginal delivery neuromuscular damage and bladder neck hypermobility, indicating a change in pelvic floor function, has been confirmed5,6. Nevertheless in the great majority of women the incontinence has disappeared six months after delivery7,8.

7.1.1.2 The urinary continence control system

The control system for urinary continence is a complex network with several components. Anatomical it consist of the urethral support system and sphincteric closing system9. This sphincteric closing system yields a closing pressure which may deteriorate due to age10 and neurological injury11,12. Studies on the effect of vaginal birth on the sphincter mechanism reveal decreases in urethral closure pressure as a result of vaginal birth13,14. The urethral support system consists of all the structures extrinsic to the urethra that provide a supportive layer upon which the urethra rests15. The following structures can be distinguished:

1. The connective tissue sheath covering the ventral aspects of the urethra and the rhabdosphincter, which may be called ventral urethral fascia, which connects the right and left fasciae of the levator. Contraction of the levator narrows the pre urethral space and an ascending movement of the urethra and the rhabdosphincter.
2. The fasciae of the levator ani muscle, especially the right and left tendineous arch.
3. The strong dorsal structure of the urethra and the rhabdosphincter to the ventral wall of the vagina.

Ultrasound studies have shown that during coughing the inferior abdominal contents are forced to move caudo dorsally (downwards), presumably due to a simultaneous contraction of the diaphragm and abdominal wall muscles. The downward motion of the bladder neck visible in the ultrasound picture means that its surrounding tissues acquire downward momentum. This downward momentum must then be arrested by stretch resistance of the pelvic floor structures.

7.1.1.3 Definition of the problem

Overstretching of the hiatus urogenitalis during pregnancy and after childbirth. The ventral fasciae and the fasciae of the levator ani may be separated from the anterior rhabdosphincter. Also, overstretching of the vaginal wall may lead to disruption of the dorsal urethra and rhabdosphincter from the vaginal wall. As the majority of women has no symptomatic pelvic organ prolaps after vaginal delivery we postulate that both fascia and muscles must have a remarkable accommodation of the level of tissue stretch needed for vaginal birth without major injury of pelvic floor. During childbirth the urogenital hiatus has to adapt to the passing foetus in a limited time. The increase of the perimeter and/or the straining capacities of the tissue (compliance) of the hiatus urogenitalis might facilitate this process. There is great scarcity of prospective studies on urinary incontinence during pregnancy and after childbirth. The wide variation of the reported prevalence and the uncertainty concerning the changes in the continence control system, prompted us to investigate these issues in a prospective longitudinal study in a homogeneous cohort of nulliparous pregnant women. Dynamic serial perineal ultrasound measurements of pelvic floor characteristics may give us a better understanding of the role and the changes in the continence control mechanism, both during pregnancy and after childbirth.

7.1.1.4 Aims of the study

Assessment of the urethral support system during pregnancy and after childbirth, perineal ultrasonography, compliance and hysteresis. By the use of perineal ultrasound and simultaneous abdominal pressure
measurement we were able to measure the displacement and the recovery of the vesical neck in relation to the increase of abdominal pressure during coughing and during Valsalva manoeuvre. In general, deformation under load for tissue is seldomly linear. To quantify such deformation we decomposed deformation into elasticity, approximated by a linear model and hysteresis, estimated by a non linear model. These measurements were made throughout pregnancy and after childbirth resulting in serial measurement of the biomechanical properties of the vesical neck supporting structures during pregnancy and after childbirth.

Assessment of functional changes of the pelvic floor. (Functional) injury of pelvic floor, leading to changes of pelvic floor stretch resistance may lead to pelvic floor dysfunction, which includes urinary incontinence. Part of our study therefore was to measure the incidence of this symptom of pelvic floor dysfunction. Women completed questionnaires and visual analogue scales on symptoms of urinary incontinence, moreover 24 hour pad tests were used to objectify urine loss.

In chapter 2 we assessed the prevalence and the development of urinary incontinence in nulliparous pregnant women, both subjectively and objectively, and we investigated the relation of urinary incontinence with the mobility of the urethro-vesical junction measured by perineal ultrasound.

In chapter 3 we assessed the prevalence of urinary incontinence after spontaneous vaginal delivery and its relation with changes in the static and dynamic function of the pelvic floor.

In chapter 4 we compared women with spontaneous and operative vaginal delivery for urinary incontinence data and for pelvic floor characteristics.

In chapter 5 we focused on displacement and recovery of the vesical neck position during pregnancy and after childbirth, especially we discriminated between compliance of the vesical neck supporting structures with and without pelvic floor contraction.

In chapter 6 we assessed the clinical usefulness of the 24 hour pad test in pregnancy and after childbirth in terms of the relationship between objective urine loss and the self reported symptoms of urinary incontinence.

Chapter 7 is the summary and the general discussion.
7.1.2 Anatomical and functional changes in the lower urinary tract during pregnancy

The function of the pelvic floor is thought to play an important part in the mechanism of continence in women, and so we investigated the changes in pelvic floor function during pregnancy and its relation to incontinence. We used simultaneous recording of abdominal pressure and the consequent changes in the position of the urethrovaginal junction. The proximal urethra and the anterior vaginal wall are intimately connected and attached to the muscles of the pelvic diaphragm and to the arcus tendineus fasciae pelvis. Support of the urethra comes from both its attachments to the arcus tendineus fasciae pelvis and the resting tone of the muscles of the pelvic diaphragm. Therefore, the mobility of the urethrovaginal junction can be used as an index of the mobility of these pelvic floor structures.

Up to 35% of the women reported urinary incontinence in pregnancy, and 20% had a positive pad test.

The resting angle of the urethrovaginal junction ($A_0$) widened significantly during pregnancy, from $51.5\, \text{degrees}$ at 12-16 weeks to $62.0\, \text{degrees}$ at term ($p<0.001$). During coughing there was a significant increasing trend in the displacement/pressure coefficient during pregnancy. For the Valsalva manoeuvre no significant change in the displacement/pressure coefficient was found throughout pregnancy.

No relationship was found between measurements of the urethrovaginal junction and the women’s perception of urinary incontinence. This applied to all variables studied during coughing as well as during the Valsalva manoeuvre: the angle of the urethrovaginal junction at rest, the angle of the urethrovaginal junction at maximum pressure and the displacement/pressure coefficient. Also, no statistically significant relationship could be demonstrated between these variables and the results of the pad tests.

The results of the present study indicate that the changes in the mobility of the UVJ (a marker for changes of the quality of the connective tissue or muscles of the pelvic floor are not responsible for the higher prevalence of urine incontinence in pregnancy. Our study focussed on the changes in the extrinsic mechanism of continence, pelvic floor muscle and fascia.
7.1.3 Anatomical and functional changes in the lower urinary tract following spontaneous vaginal delivery

Incontinence in pregnancy is interpreted as a result of interaction between predisposing hereditary factors and uterine pressure upon the bladder, in combination with hormonal effect upon the suspension ligaments of the urethra. Persisting incontinence post partum is mainly the result of changes of the pelvic floor function and anatomy, due to delivery. The (partial) irreversibility of these changes may indicate why stress incontinence appearing for the first time after vaginal delivery has a more serious prognosis than incontinence developing during pregnancy.

After delivery, reported urinary incontinence was reduced 16% and 15% at six weeks and six months after delivery, respectively. Even lower rates were measured by the 24-hour pad test which revealed a decrease to 10% and 5% at 6 weeks and 6 month postpartum, respectively. Our study demonstrates that spontaneous vaginal delivery causes transient as well as long lasting changes in the lower urinary tract. It seems likely that the long lasting changes that we observed six months after delivery will be permanent. Parturition alters urethral support and as a consequence, the position of the bladder neck at rest becomes permanently descended. The changes in pelvic floor reaction to coughing, as measured by an increase of the displacement/pressure coefficient, indicates reduced pelvic floor stiffness due to coughing. This finding adds to the effect of pregnancy, where we observed already a significant decrease in pelvic floor stiffness during coughing. As in pregnancy we did not find any relation between incontinence measurements, urethro-vesical junction measurements and obstetric variables.

It is concluded that pregnancy and spontaneous vaginal delivery significantly permanently alter the static condition of bladder neck descent. The dynamics of the pelvic floor are affected as well. This effect is temporary for Valsalva and permanent for coughing. Urinary incontinence, quite common during pregnancy, disappears post partum in most women. No evidence was found for a significant association between pelvic floor function measurement and urinary incontinence, nor at 6 weeks, nor at 6 months postpartum. As the onset of symptoms of urinary incontinence later in life is thought to be due to the combined effect of occult trauma during pregnancy and delivery and the progression of neuropathy during lifetimethe persistent anatomical and functional changes in the lower urinary tract that we found, could play an important role in the aetiology of urinary stress incontinence later in life.
7.1.4 Pelvic floor characteristics after spontaneous and operative vaginal delivery. Serial studies prior to labor up to six months postpartum

In this study post partum (hyper) mobility is not influenced by the type of delivery, but by the ante partum mobility and therefore seems to be determined by (intrinsic) patient characteristics. The present data showed no significant differences for urinary incontinence between the group of women who delivered spontaneously and the group who had an operative vaginal delivery. Women with operative and spontaneous vaginal delivery have comparable ante partum and postpartum pelvic floor characteristics. Therefore, if these changes are predictors of incontinence later in lifetime, in both groups women are at the same risk to develop incontinence later.

Birth parameters, such as duration of labor, birth weight and head circumference did not correlate with pelvic floor characteristics as well. The finding that these extrinsic factors do not influence pelvic floor characteristics is in agreement with the conclusions of others who emphasize the influence of intrinsic factors, such as genetically determined characteristics of the collagen tissue\(^{21-23}\).

In conclusion we found that pelvic floor characteristics change as a result of vaginal delivery in nulliparous women. These changes occur after spontaneous as well as after operative vaginal delivery. As to these changes we found no significant differences between the spontaneously and the operatively delivered group. Also for urinary incontinence, both measured subjectively and objectively, we found no significant differences between the two groups of women. Extrinsic factors predicting pelvic floor dysfunction, such as birth related factors, were not identified. As we found that ante partum compliance is significantly correlated with post partum values, intrinsic factors, such as collagen characteristics, could be more important.

7.1.5 Displacement and recovery of the vesical neck position during pregnancy and after childbirth

We focussed on the biomechanical properties of the vesical neck supporting structures during pregnancy and after childbirth. Generally, tissue distensibility is determined not only by the elasticity of the constituent muscle and connective fibers itself but also by the geometrical arrangement of those fibers. Two parameters are in use to describe the mechanical properties of tissue: Young’s modulus, or its reciprocal (the compliance), to quantify the pure elastic behaviour of tissue in which the geometrical structure of the fibers remain unaltered, and hysteresis: the failure
of tissue to follow the same course during relaxation as it did during distension. The latter parameter is thought to be the result of shifts in the geometrical structure of the fibers with respect to each other, and can be interpreted as a form of internal friction within the tissue. Also, inertial effects involved may effect the return of the tissues to a normal position. In our study the increase in hysteresis seems to be permanent. Since hysteresis, the phenomenon that tissue does not follow the same course during distention as during relaxation, depends on shifts of the constituent fibers with respect to each other, an increase in hysteresis means that the geometrical structure becomes looser. Both compliance and hysteresis contribute to the stiffness of the pelvic floor and our data suggest that a decrease in stiffness of the pelvic floor after child birth is mainly due to a more loosely coupling of the various fibers in the pelvic floor tissue to each other. Reduced fascial strength and decreased muscle tone tend to make the pelvic floor more flaccid so that the necessary back pressure cannot be produced leading to hypermobility of the Urethro Vesical Junction, significantly related with genuine urinary stress incontinence. Hysteresis showed an increase after child birth at least persisting until six months post partum, showing that delivery may stretch and or load beyond the physiological properties of the pelvic floor tissue and in this way may lead to irreversible changes in tissue properties which play an important role in the urethral support continence mechanism.

7.1.6 The diagnostic strength of the 24-hour pad test for self reported symptoms of urinary incontinence in pregnancy and after childbirth

In our study during pregnancy and after childbirth pad test results had only limited diagnostic value for self reporting of incontinence. Pregnancy seems to modulate this perception in such a way that it cannot be measured by pad test. As pad testing did not show to have high sensitivity and specificity for self reported urinary incontinence in pregnancy and after childbirth there remains confusion about the accurate diagnosis. This becomes important in deciding on management options such as offering preventive physiotherapy in selected cases or strategies which influence the mode of delivery. From our study we conclude that pad testing may measure fluid loss over a certain period, but does not quantify self reported symptoms of urinary incontinence. Both
measurements may be of interest, but cannot replace each other. Stressing of the pelvic floor by pregnancy and childbirth modulates the sensation of urinary leakage as measured by the pad test in such a way that women in this state do report symptoms of urinary incontinence more frequently than nulliparous premenopausal women do.

When using these figures to establish the role of pregnancy and childbirth in the risks of the development of urinary incontinence one should realise this modulation effect.

7.2 CONCLUSIONS

7.2.1 Assessment of the urethral support system during pregnancy and after childbirth, perineal ultrasonography, compliance and hysteresis

In our study on pelvic floor parameters during pregnancy we were able to measure adaptation effects. The resting angle, a marker for perineal descent, is widening, already at 12-16 weeks of pregnancy. We also measured an increase of the compliance both during Valsalva and during coughing. In conclusion two main elements of adaptation can be distinguished. First of all the lengthening of the tissue sling surrounding the vagina, the birth canal, and secondly more distensibility of this sling.

We described an adaptive effect of pregnancy on the capacity of the birth canal in such a way that vaginal birth can be realized without either serious tearing of the hammock tissue or serious damage to the passing fetal head.

These changes were found at least until 6 months post partum and must therefore be considered as definitively. First of all the widening of the resting angle, marking the lowering of the central point of the perineum, at which the pelvic floor tissue inserts from right, left anterior and posterior. This lowering will lead to changes in supportive properties of the pelvic floor because of the longer distance between the urethral back side and the supportive structures, which may even lead to prolaps of the vaginal anterior wall.

Moreover the dynamic properties of the tissue changes as can be concluded from the increased compliance. Hysteresis, a measurement of internal tissue friction due to rearrangement of tissue under load, is not affected by pregnancy. Tissue load keeps up with physiological margins. But after delivery a remarkable increase in
hysteresis occurred, remaining al least until 6 months. If considered as a persisting phenomenon the dynamics of the urethral support system are affected definitively. We concluded that there is a change in the supportive structures of the urethra during pregnancy and after childbirth. These changes were measured both after spontaneous and after operative vaginal delivery. Because of the limited numbers caution must be taken to conclude about the preferable way of delivery. Caesarean Sectio numbers were too small and indications were heterogeneous, we did not report about these data. In this study post partum (hyper) mobility is not influenced by the type of delivery, but by the ante partum mobility and therefore seems to be determined by (intrinsic) patient characteristics.

7.2.2 Assessment of functional changes of the pelvic floor

During pregnancy we found an increase of women complaining about symptoms of urinary incontinence, already decreasing as early as 6 weeks post partum. We did not find any relation between incontinence parameters and pelvic floor parameters. Either there is no such relationship, or this relationship is overruled by other systems contributing to urinary continence in women.

In this thesis we focused on the extrinsic urinary continence system. The intrinsic urethral sphincteric closing system is also known to contribute to continence in women. This intrinsic system physiologically declines with age. This means that continence in elder women is more and more depending on the extrinsic urethral supporting system. Occult damage to the urethral support system may become recognizable only in later life.

Incontinence in pregnancy may be more dependent on the sphincteric closing system as already early found by van Geelen en Iosif. Our research was pointed to the changes in the urethral supportive system in pregnancy and after childbirth. This may explain why we did not find a relation between our pelvic floor parameters and incontinence measurements, confounded by the role of the intrinsic sphincteric system.

As patients and doctors do feel that incontinence in pregnancy needs preventive strategy, an objective measurement is needed. We tested the diagnostic strength of the 24-hour pad test for self reported symptoms of urinary incontinence in pregnancy and after childbirth. The 24 hour pad test did not meet the criteria for a reliable clinical test. In many ways it did not distinguish between women with and without reporting of urinary incontinence.
The results of our study raise the question whether or not ultrasound measurement reveals prognostic data on which selection of patients for preventive strategies is thoughtful. As we found that post partum change in pelvic floor function is only related with ante partum values, and if we think that post partum pelvic floor parameters are prognostic for GSI later in life, ultrasound could be helpful. This is only speculative and should be the issue of future investigation.

**REFERENCE LIST**

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