Ultrasound and MRI before and after radical hysterectomy: does the operation affect the pelvic floor muscles?

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Summary

Purpose: To evaluate pelvic floor muscles and bladder neck mobility before and after radical hysterectomy for cervical cancer with magnetic resonance imaging (MRI) and ultrasound.

Methods: A prospective follow-up study of 22 patients studied with MRI and ultrasound preoperatively, three and 12 months after radical hysterectomy was carried out.

Results: Bladder neck mobility was decreased three months postoperatively, but one year after the operation, it had almost attained the preoperative level. The size of the pelvic floor muscles was reduced three months after the operation, but one year postoperatively, muscle size had almost returned to the preoperative level. Age and number of deliveries affected the starting point in muscle size and the mobility of the bladder neck, but the development was identical in all the women.

Conclusions: We showed that pelvic floor muscle size and mobility of the bladder neck were reduced three months after radical hysterectomy, and that they regenerated to a level only slightly below the preoperative level one year later.

Key words: Radical hysterectomy; Pelvic floor muscles; MRI; Ultrasound.

Introduction

Cervical cancer is the second most common cancer among women worldwide [1]. Radical hysterectomy for cervical cancer was developed by Ernest Wertheim, who performed the first operation in 1898 [2].

Functional disorders of the lower urinary tract are the most common long-term complications after radical hysterectomy [3]. Nevertheless, the pathophysiology of these complications is still not fully understood. The pelvic floor muscles play a role in the continence control system, but basic knowledge about their physiologic function is incomplete [4].

The nerve fibres to the pelvic floor muscles and the lower urinary tract system can be interrupted at several stages during radical hysterectomy: during dissection of the sacrouterine ligaments, during vaginal dissection and mobilization of the bladder, and during resection of the cardinal ligaments [5].

Hypothetically, nerve dysfunction and, consequently, atrophy of the pelvic floor muscles could partly explain the functional disorders after radical hysterectomy.

Urethral closure pressure is enhanced when the pelvic floor muscles contract. This contraction prevents involuntary loss of urine. To maintain continence, detrusor activity is inhibited by pelvic floor muscle contraction under sympathetic nervous system control [6].

The pelvic floor muscles include the levator ani and the puborectalis muscles [7].

Because magnetic resonance imaging (MRI) provides images of pelvic floor structures [8], it could prove helpful in understanding possible changes in the levator ani and puborectalis muscle size after radical hysterectomy.

Ultrasound can be used in the examination of urinary incontinent women [9]. Increased bladder neck mobility during the Valsalva manoeuvre is a typical observation with ultrasound in women with stress incontinence [10, 11].

The purpose of the study was to evaluate the pelvic floor muscles and bladder neck mobility with MRI and ultrasound before and after radical hysterectomy.

Material and Methods

This was a prospective cohort study with 22 participants who underwent radical hysterectomy (as first described by Wertheim with modifications as given by Meigs) [2, 12] for cervical cancer, Stages 1B and 2A without the need of adjuvant radiation therapy, at Aarhus University Hospital, Denmark. All the operations were performed or supervised by the same gynecological oncologist. Data were collected from 2001 to 2004.

The women in the cohort answered a validated questionnaire before and one year after the operation, including questions on background information and lower urinary tract function [13, 14].

All women were examined with ultrasound and MRI by the same investigator before the radical hysterectomy and three and 12 months after the operation.

Ultrasound

Bladder neck mobility was evaluated with ultrasound. The ultrasound signal was detected with a 7.5 MHz sector transducer with an emission angle of 80° for introital sonography using an Acuson Seqouia™ 512 (Acuson Corporation, CA 94043, USA). Patients were examined in the lithotomy position with a bladder volume of 300 ml.

The transducer was placed on the vulva in a sagittal orientation to obtain views of the bladder, bladder neck, urethra, and pubic symphysis. Ultrasound measurements included three

Revised manuscript accepted for publication January 25, 2007

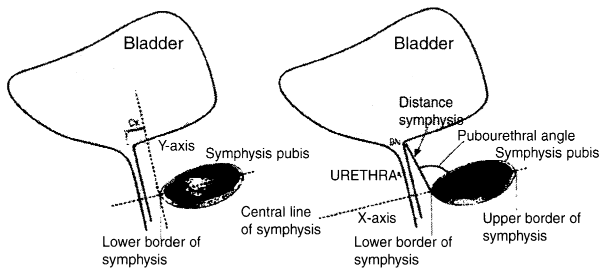


Figure 1. — Techniques used for ultrasound measurement of the bladder neck (BN) position and the pubourethral angle.
A rectangular coordinate system was set up with the origin at the lower border of the symphysis. The x-axis was determined by the central line of the symphysis, which ran between its lower and upper borders. The y-axis was constructed perpendicular to the x-axis at the lower symphysis border. Dx was defined as the distance between the y-axis and the middle of bladder neck at the internal urethral orifice. For precise localisation of the bladder neck, the point in the middle of the upper abdominal and ventral point of the urethral wall at the immediate transition into the bladder was used.
Left: measurement of the bladder neck position with the distance, Dx. Positive numbers on the right side of the y-axis, negative numbers on the left side of the y-axis.
Right: measurement of the pubo-urethral angle, which was the angle between the line from the bladder neck to the inferior border of the symphysis and the central line of the symphysis.

positions: rest, maximal Valsalva manoeuvre, and maximal contraction of the pelvic floor muscles [10].

Figure 1 shows the technique used for ultrasound measurement of bladder neck mobility as a distance (Dx) and an angle (the pubo-urethral angle).

A rectangular coordinate system was set up with origin at the lower border of the symphysis. The x-axis was determined by the central line of the symphysis, which ran between its lower and upper borders. The y-axis was constructed perpendicular to the x-axis at the lower border of the symphysis. Dx was defined as the distance between the y-axis and the middle of the bladder neck at the internal urethral orifice. For precise localization of the bladder neck, the point in the middle of the upper abdomin and ventral point of the urethral wall at the immediate transition into the bladder was used. Dx was given by positive numbers on the right side of the y-axis and negative numbers on the left side of the y-axis.

The pubo-urethral angle was measured as the angle between the line from the bladder neck to the inferior border of the symphysis and the central line of the symphysis in the three positions: rest, Valsalva, and contraction. Measurements were based on techniques described in reviews of perineal ultrasound [9, 15].

MRI

Axial and coronal T2 weighted fast spin echo sequences (echo time 81 ms; repetition time 2500 ms) were performed on each woman's pelvis by use of a 1.5 Tesla superconducting magnet (Twin Speed, General Electric, Milwaukee, WI) with version 4.0 software. The slice thickness was 3 mm with a slice spacing of 0.3 mm in the axial scans and a spacing of 0.5 mm in the coronal scans. A 240 × 240 mm field of view and an imaging matrix of 256 × 224 with 4 nex were used. The axial slices were placed parallel to a line running from the tip of the coccygeal bone to the bottom of the symphysis. The coronal slices were perpendicular to the axial plane.

The bony landmarks noted were the pubic bone and the tuberal region of the ileococcygeal bone. The axial and coronal measurements of the thickness of the levator ani were performed at the level of the middle of the urethra, placed so that the rectum had the same distance to the bony landmarks on both sides.

The levator muscles were measured on the left and the right side at the axial and coronal level, and the mean was calculated. Figure 2 shows an example of the coronal measurement of the levator ani muscle.

Measurements of the puborectalis muscle (area) were performed at the level of the tuberal region of the ileococcygeal bones, placed so that the rectum was in the middle with the same distance to the bony landmarks on both sides (Figure 3). Measurement of the puborectalis muscle was performed on the right and left side and a mean calculated. In the present study, the term "size" was used for practical reasons to describe the muscles, even though the terminology "diameter" (levator ani) and "area" (puborectalis) would be appropriate.

Statistics

Wilcoxon's signed rank test was applied for statistical evaluation. As a correlation coefficient, Spearman's rho was used to measure the strength of the association between continuous variables. Mean values with range or standard errors in brackets are presented, when appropriate. The level of statistical significance was defined as $p \leq 0.05$.

Statistical analysis was undertaken using STATA version 8.2 for windows (Stata Statistical Software. College Station, TX: Stata Corporation) statistics package.

Ethics: The research protocol was approved by the Regional Committee for Ethics in Science.

Results

Mean age of patients was 42 (range: 28-61) years. Mean number of vaginal deliveries was 2 (range: 0-5).

Two women reported urinary incontinence before the operation (stress incontinence). Five women reported urinary incontinence one year after the operation (three with stress incontinence including the two before the operation, one with urge incontinence, and one with mixed incontinence).

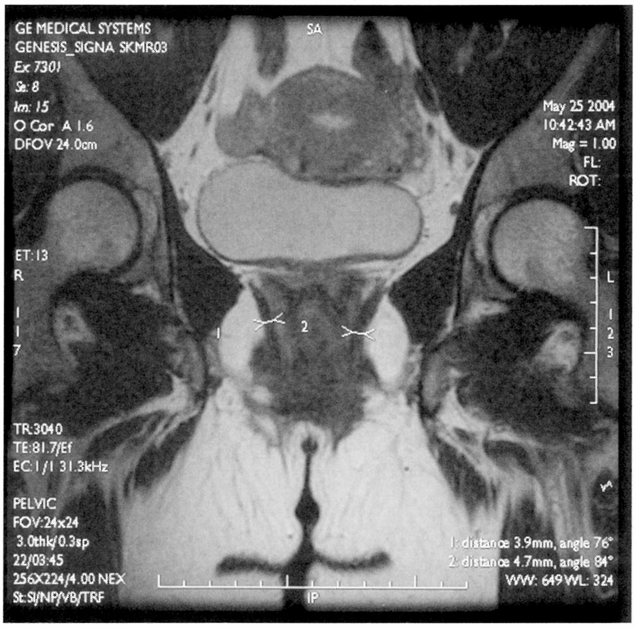
MRI

Figure 4 shows the diagrammatic development of the puborectalis muscle in each woman.

The levator ani muscle, on both the left and the right side measured both axially and coronally, was reduced in size at the 3-month examination compared with the preoperative level. One year after the radical hysterectomy, the levator ani muscle had almost returned to its preoperative size

Ultrasound

In the majority of the women, the ability to move the bladder neck both at contraction of the pelvic floor muscles and during Valsalva manoeuvre decreased three ig. 2



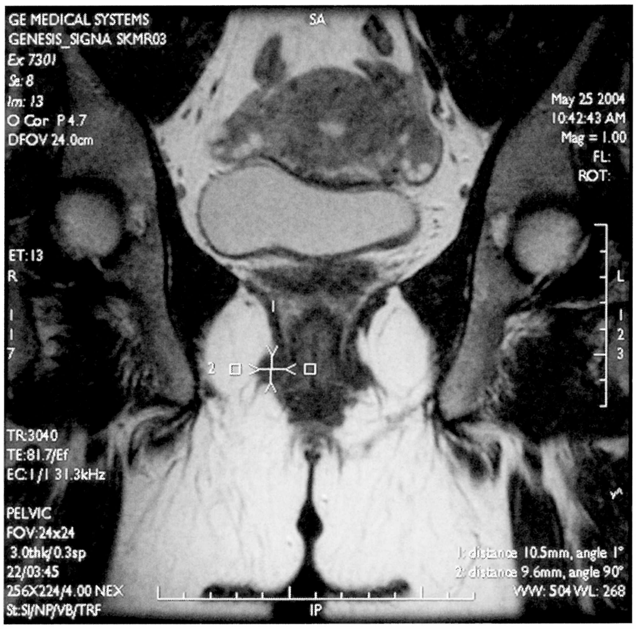


Fig. 3

Figure 2. — Coronal MRI measurement of the levator ani. The axial slices were placed parallel to a line running from the tip of the coccygeal bone to the bottom of the symphysis. The coronal slices were perpendicular to the axial plane. The bony landmarks noted were the pubic bone and the tuberal region of the ileococcygeal bones. The coronal measurements of the thickness of the levator ani were performed at the level of the middle of the urethra, placed so that the rectum had the same distance to the bony landmarks at both sides.
Figure 3. — MRI measurement of the puborectalis muscle. Measurements of the puborectalis muscle (area) were performed at the level of the tuberal region of the ileococcygeal bones, placed so that the rectum was in the middle with the same distance to the bony landmarks on both sides.

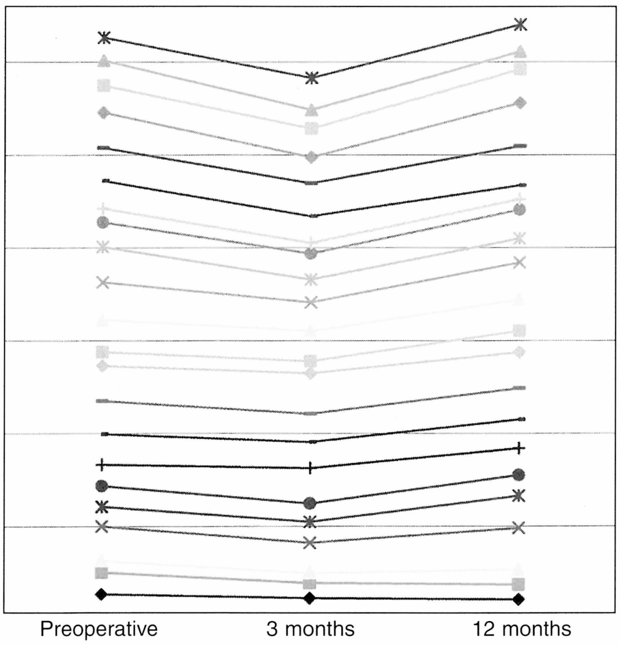


Figure 4. — MRI measurement of the puborectalis muscle (diagram). MRI measurements of the puborectalis muscle area in a prospective follow-up study in women treated for cervical cancer with radical hysterectomy before the operation, three months, and one year postoperatively (no. = 22). Each line represents a woman and shows the development of the area of the puborectalis muscle measured three times. X-axis: First measurement, preoperative = Mean area of the puborectalis muscle before radical hysterectomy; Second measurement, 3 months = Mean area of the puborectalis muscle three months postoperatively; Third measurement, 12 months = Mean area of the puborectalis muscle one year postoperatively; Y-axis is arbitrary.

months postoperatively, but returned to almost the preoperative level one year postoperatively. The same pattern was seen with the pubo-urethral angle. The two women with urinary incontinence before the radical hysterectomy showed greater bladder neck movements during the Valsalva manoeuvre than did the continent women before the operation ($p = 0.01$) and one year postoperatively ($p = 0.05$). The three women who reported de-novo urinary incontinence after the operation showed greater bladder neck movements during the Valsalva manoeuvre than did the continent women before the operation ($p < 0.001$) and one year after the operation ($p = 0.01$).

Muscle size and bladder neck mobility

The puborectalis muscle more than regained its size, and the effort to contract and move the bladder neck one year after the operation overshot the preoperative levels (Table 2). Table 2 also shows that the same pattern occurred during the observation period in all the women in the study, except for the axial imaging of the levator muscle.

Influence on starting points

Preoperatively, the women demonstrated markedly differences in both muscle size (Figure 4) and mobility.

Table 3 summarises the reasons for the differences in starting points. In the ultrasound measurements, the main difference was different resting phases of the bladder neck which was positively correlated to increasing age. The ability to move the bladder neck during

Table 1. — *Development in mobility of the bladder neck and size of pelvic floor muscles. Bladder neck mobility assessed with ultrasound and levator ani and puborectalis muscle size measured with MRI before (exam 1), three months after (exam 2), and one year after (exam 3) radical hysterectomy for cervical cancer for all patients in a prospective follow-up study (no. = 22).*
Ultrasound measurements were determined in three positions: at rest, during the Valsalva manoeuvre, and during maximal contraction of the pelvic floor muscles.
vs = versus
Values are given as means (standard error).

	Exam 1	Exam 2	Exam 3	p (1 *vs* 2)	p (2 *vs* 3)	p (1 *vs* 3)
Ultrasound						
Distance Valsalva manoeuvre (mm)	11.59 (2.10)	7.50 (1.02)	8.59 (1.14)	0.17	0.18	0.55
Distance contraction (mm)	-5.14 (1.00)	-3.73 (0.76)	-5.36 (1.20)	0.21	0.12	0.96
Angle Valsalva manoeuvre (degrees)	-34.55 (4.91)	-24.41 (2.94)	-30.14 (3.52)	0.17	0.10	0.58
Angle contraction (degrees)	13.73 (2.52)	10.45 (2.35)	14.55 (3.28)	0.31	0.26	0.78
MRI						
Levator ani axial (mm)	3.98 (0.26)	3.48 (0.23)	3.50 (0.21)	0.01	0.86	0.02
Levator ani coronal (mm)	3.74 (0.17)	3.44 (0.18)	3.53 (0.24)	0.08	0.52	0.09
Puborectalis (mm^2)	57.11 (3.81)	54.49 (3.79)	59.03 (4.28)	0.31	0.31	0.61

contraction was significantly reduced by the number of vaginal deliveries. In the MRI measurements, coronal views of the levator ani muscle-sizes were influenced by both age and number of deliveries.

Discussion

The present study demonstrated reduction in size of the pelvic floor muscles and reduced mobility of the bladder neck three months after radical hysterectomy compared with the preoperative status. In the majority of women, however, an almost total restoration of muscle size and mobility was seen after one year. With the exception of the size of the levator ani muscle, all women developed identically. Furthermore, the size of the puborectalis muscle and the bladder neck mobility during contraction were greater one year after the operation compared with preoperative levels.

Regeneration of the pelvic floor muscles and bladder neck mobility

The incomplete regeneration of the pelvic floor muscles seen in this study could be considered in light of nerve damage, recovery, and, perhaps to a lesser degree, aging (women gained a year during the study period) [16]. Although imaging suggested almost complete

Table 2. — *Influence of age and number of deliveries on pelvic floor muscles. Bladder neck mobility assessed with ultrasound and levator ani and puborectalis muscle size measured with MRI before radical hysterectomy for cervical cancer for all patients in a prospective follow-up study (no. = 22).*
The strength of the association between bladder neck mobility and MRI measurement of the size of the levator ani and the puborectalis muscles was tested against age and number of vaginal deliveries.
Ultrasound measurements were determined in three positions: at rest, during the Valsalva manoeuvre, and during maximal contraction of the pelvic floor muscles.

Ultrasound or MRI measurement	p value for association to age	p value for association to number of vaginal deliveries
Preoperative resting distance	0.01	0.12
Preoperative resting angle	0.02	0.15
Preoperative Valsalva manoeuvre distance	0.39	0.55
Preoperative Valsalva manoeuvre angle	0.13	0.82
Preoperative contraction distance	0.49	0.05
Preoperative contraction angle	0.54	0.11
Preoperative mean of the left and right levator ani muscle in an axial view	0.32	0.29
Preoperative mean of the left and right levator ani muscle in a coronal view	0.03	0.04
Preoperative mean of the left and right puborectalis muscle	0.65	0.17

restoration of the muscles, potential operative-induced nerve damage could have influenced the function of the muscles [16]. A reduction in the velocity of the muscle contraction, as well as other parameters of functional behaviour, i.e. mechanical strength and duration of contraction, could not be evaluated in the present set up.

Urinary incontinence

Women with antenatal urinary stress-incontinence appear more likely to have persistent postpartum incontinence, and incontinent women show greater bladder neck mobility on performing the Valsalva manoeuvre both before delivery and postpartum compared with a continent group [17]. In an earlier study, we showed that urinary incontinence before radical hysterectomy was a risk factor for incontinence after the operation [14]. The cohort in this study was small, but examinations with ultrasound (bladder neck mobility during Valsalva manoeuvre) could predict the risk of urinary incontinence after radical hysterectomy.

Forces of the study

Mobility of the bladder neck is influenced by an individual's constitution, pregnancy and delivery status. The morphological changes are not associated with functional disturbances [18]. MRI studies show vaginal birth as a source of levator ani muscle injuries [19]. In this study we addressed these considerations in the design. We followed the development of bladder neck mobility and the size of the levator ani and the puborectalis muscle in each woman. We found the development identical in all women, except for the axial measurement of the levator ani muscle. The latter could be caused by the small sample size. We tested the influence of age and number of deliveries, based on reports that the relaxed position of the pelvic floor depends on parity and age [20, 21]. We could only detect an association with age in the relaxed position of the bladder neck (ultrasound) and with age and deliveries in the coronal view of the levator ani (MRI), again, presumably because of the small sample size in this study.

Limitations

Ultrasound measurements were standardised according to recommendations [15], but the MRI measurements described were performed in other ways [8, 19].

The hospital was not able to offer dynamic MRI, which was the reason why the indirect way of measuring muscle size was chosen. Dynamic MRI studies could contribute to the description of pelvic floor muscle function to a higher degree than the present methods did [22].

We measured the size of the levator muscle and not the density. Measurement of density could perhaps have provided additional, useful information. However, Tunn *et al.* could not demonstrate findings typical of urinary incontinence in a study of the morphometry of the levator musculature [23].

Performing the Valsalva manoeuvre and contraction of the pelvic floor were not standardized, but the same investigator did all the ultrasound examinations, and the same information was given to all the women. Preoperatively, the examination situation could have affected the women, causing them to push and contract to a lesser degree than under normal conditions. If so, the preoperative results would not differ realistically from the postoperative results, and maybe women did not strain as hard at the 3-month examination because of pain or weakness as they did at the 12-month examination.

The reduction in muscle size at three months could have been caused by inactivity postoperatively rather than any disturbance of the innervation.

Further studies should include examination with electromyography [24], and measurement of the velocity of the pudendal nerve, in order to study the neurological aspect, is another option [25].

Perspective

Another study demonstrated that even patients with very poor functioning of the pelvic floor could improve bladder behaviour and hence improve lifestyle and social confidence with encouragement and pelvic floor exercise [26].

We showed regeneration of both muscle size and bladder neck mobility, but actually we did not show whether the function of the muscles regenerated.

Randomized trials need to be conducted to determine whether exercising the pelvic floor muscles before and after radical hysterectomy will change the development in the muscle size, mobility of the bladder neck and the frequency of urinary incontinence postoperatively.

Conclusion

We showed that pelvic floor muscle size and mobility of the bladder neck were reduced, as assessed with MRI and ultrasound three months after radical hysterectomy, and that they regenerated to a level only slightly below the preoperative level one year later. Muscle size and bladder neck mobility were dependent on age and number of deliveries.

Acknowledgements

The authors would like to thank the following people: Mogens Nyland, MD, for performing or supervising all radical hysterectomies. Michael Vaeth, PhD, Department of Biostatistics, University of Aarhus, for his advice in the statistical analyses.

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