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ORIGINAL ARTICLE

Ultrasonic Assessment of the Urethra and the Vagina in Normal Continent Women and Women Suffering from Stress in Urinary Incontinence and Vaginal Prolapse

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ABSTRACT

Urinary continence depends on two factors: the presence of an intact and strong internal urethral sphincter (IUS); and on an acquired behavior, gained by learning and training in early childhood, how to maintain a high alpha-sympathetic tone at the IUS keeping it closed all the time until there is a need.

The IUS is a cylinder that extends from the urinary bladder neck to the urogenital diaphragm. It is composed of a strong collagen sheet with muscle fibers that intermingle with the collagen in the middle of the cylinder's thickness. The strong collagen sheet gives the IUS the high wall tension necessary to create the high urethral closure pressure. The muscle fibers, innervated by alpha-sympathetic nerves (T10-L2) are responsible for closure and opening of the urethra.

Rupture of the IUS causes its weakness and it will not withstand increases of abdominal pressure, and urine will leak. Rupture and split of the collagen sheet are better demonstrated by imaging by 3D US and MRI.

Normal vagina is a cylinder of collageno-elastic-muscular tissues. Its strong collagen sheet is responsible for keeping it in its normal upward and backward position. Labors cause redundancy and weakness of the vaginal walls with subsequent prolapse; and lacerations of the IUS which is intimately overlying the anterior vaginal wall.

Keywords: Three-dimensional ultrasound (3D US), Stress urinary incontinence (SUI), Internal urethral sphincter (IUS), Vaginal prolapse, Collagen, Magnetic resonance imaging (MRI).

INTRODUCTION

We put forward a novel concept on the pathophysiology of the mechanism of micturition, urinary continence and urinary incontinence.[1] Urinary continence depends on two main factors, one inherent and one acquired. The inherent factor is the presence of an intact and strong internal urethral sphincter (IUS). The IUS is a collageno-muscular tissue cylinder that extends from the bladder neck to the urogenital diaphragm in both sexes. The collagen sheet is very strong and gives the internal sphincter's wall the high wall tension. The muscle fibers lie on top of and intermingle with the collagen sheet in its middle area. The muscle fibers are innervated by alpha-sympathetic nerves T10 to L2 and are responsible for closing and opening of the urethra (Figs 1 to 6). The acquired factor is an acquired behavior gained by learning and training in early childhood how to keep the IUS closed all the time till there is a need or a desire to void.[2-4] The mother starts to teach her infant at the age 12 to 24 months how to hold up himself and not to empty his bladder involuntary irrespective of time or place.[5] This is gained by building up high alpha-sympathetic tone at the IUS keeping it closed all the time till there is a need or a desire to void and the place is suitable.[5-7] On voiding the person, through the high central nervous system, lowers the high alpha-sympathetic tone at the IUS, thus opening the urethra and urine will flow.

In women, the IUS is intimately lying over the anterior vaginal wall (Figs 5 and 7).[1-15]

We also described the vagina as a strong cylinder that is kept in its upward and backward position by the strength of its walls, mainly the collagen sheet (Figs 5 and 8). The vaginal wall is composed of a sheet of strong collageno-muscular-elastic tissues lined by stratified squamous epithelium, held up in the pelvis by the pelvic ligaments.[1,12]

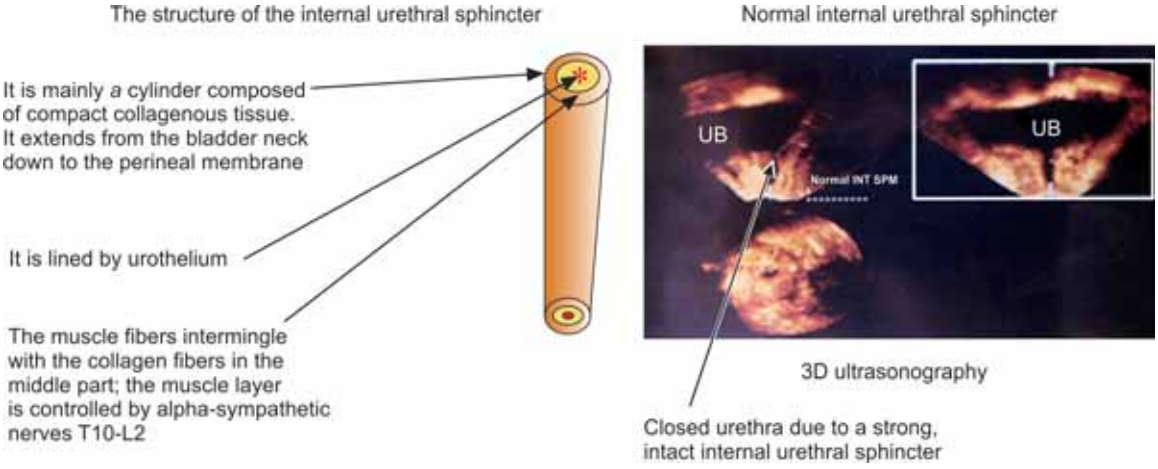


Fig. 1: On the left, an imagination drawing of the IUS as a cylinder of collagenomuscular tissue cylinder; on the right, it is an image by 3D US of a normal continent woman showing the intact IUS as a compact tissue cylinder with regular walls and a closed lumen of the urethra

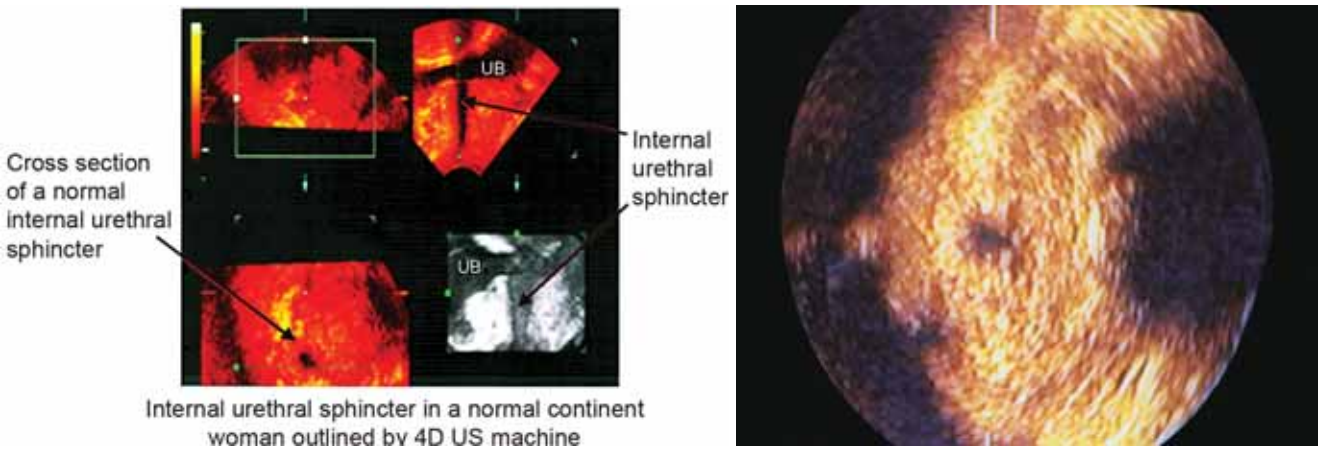


Fig. 2: Ultrasound scanning by 3-4D US of normal continent women showing the IUS as a compact tissue cylinder; in the cross section on the right, kindly notice two echoes (muscle on top of collagen and collagen alone) and a closed urethral lumen

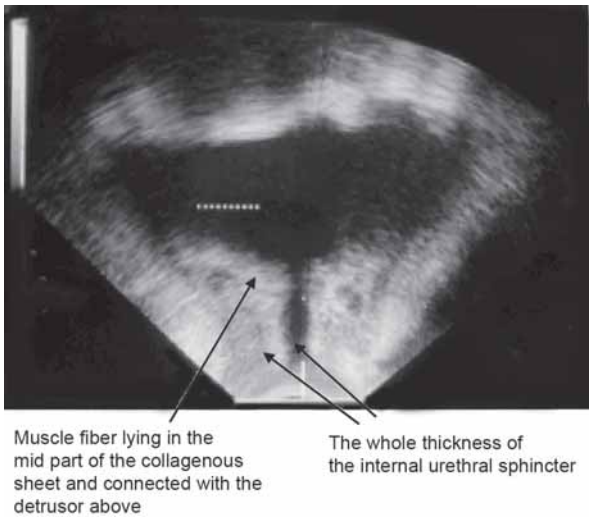


Fig. 3: Ultrasound imaging by 3D US, coronal section of a normal intact IUS in a normal continent woman; kindly notice two echoes, muscle overlying collagen, and the muscle is connected above with the detrusor muscle

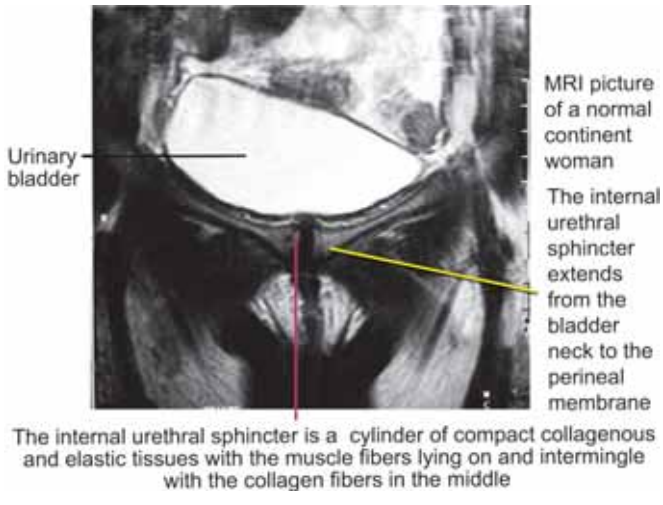


Fig. 4: MRI image, coronal section that shows a full bladder and an intact IUS as a cylinder that extends from the bladder neck down to the perineal membrane in a continent woman

Fig. 5: An image by MRI, sagittal section that shows an overdistended bladder and an intact IUS (as a compact cylinder) with a closed urethra. It also shows an intact strong vagina standing up with the anterior vaginal wall supporting the intimately lying IUS and the posterior wall of the bladder on filling

Fig. 6: A patient with müllerian duct agenesis, the IUS as a collagenomuscular tissue cylinder that extends from the UB neck to the perineal membrane

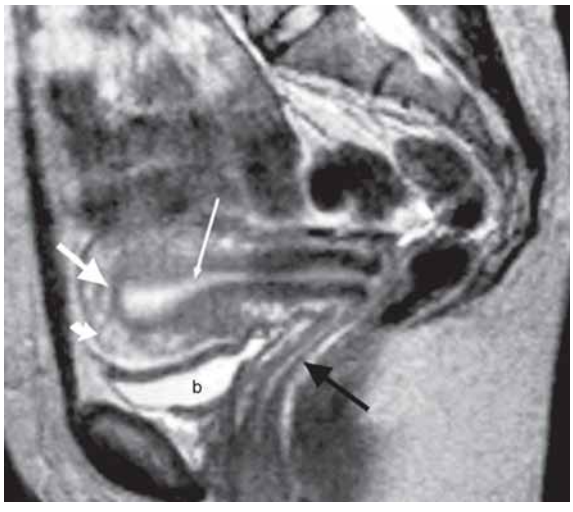


Fig. 7: The IUS as a compact tissue cylinder that extends from the bladder neck to the urogenital diaphragm. Note that the vagina is standing up depending on the strength of its collagen sheet

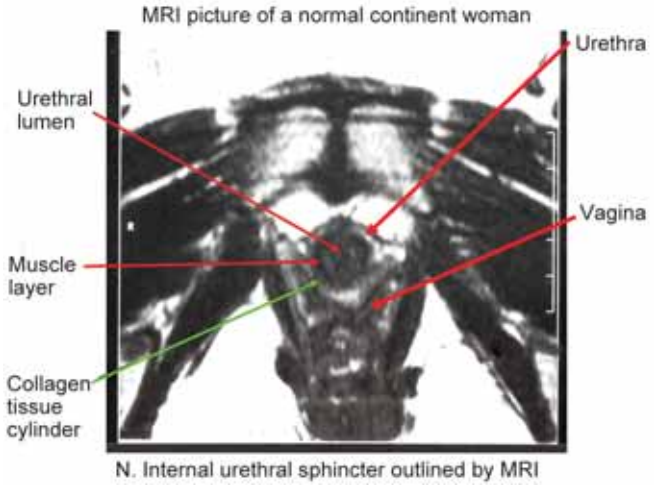


Fig. 8: An image by MRI, cross section in a nulliparous continent woman that shows H-shape vagina, and a cross section of an intact collagenomuscular cylinder of the IUS

Labors especially multiple frequent labors, difficult and instrumental labors cause overstretching, flabbiness, split and even invisible lacerations of the collagen sheet of the vagina causing its redundancy and subsequently its prolapse.

This can be seen clinically and on imaging as the vagina, in cross section, is H-shape in nulliparous women and labor changes it to transverse slit in parous women, and further overstretching leads to more redundancy of its walls and vaginal prolapse.[8-12]

The IUS is adherent intimately to the anterior vaginal wall, and it will suffer the same childbirth trauma with split and breakdown of its collagen sheet resulting in its weakness (Figs 10 and 11). The torn-weak IUS will fail against increases of abdominal pressure leading to leakage of urine. Once the woman feels she is wetting herself, embarrassing moment, a quick reactive sympathetic activity will increase the sympathetic tone at the IUS that will prevent further leak of urine.[4,10,12]

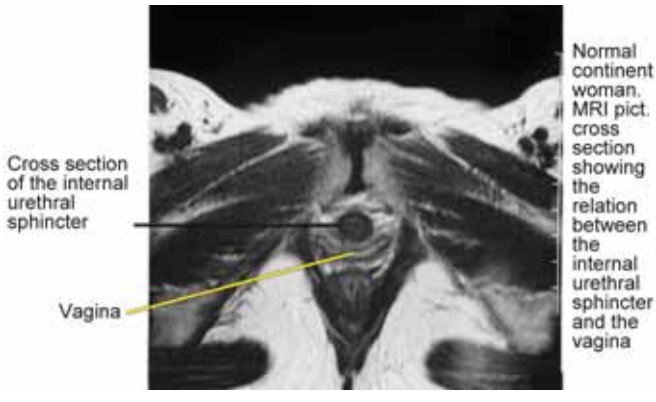


Fig. 9: An MRI image, cross section in a parous continent woman, it shows an intact IUS and the vagina is transverse slit

Furthermore, the pelvic collagen will get atrophied and weaker by estrogen deficiency after menopause. Also repeated or chronic genitourinary infections will cause degeneration of

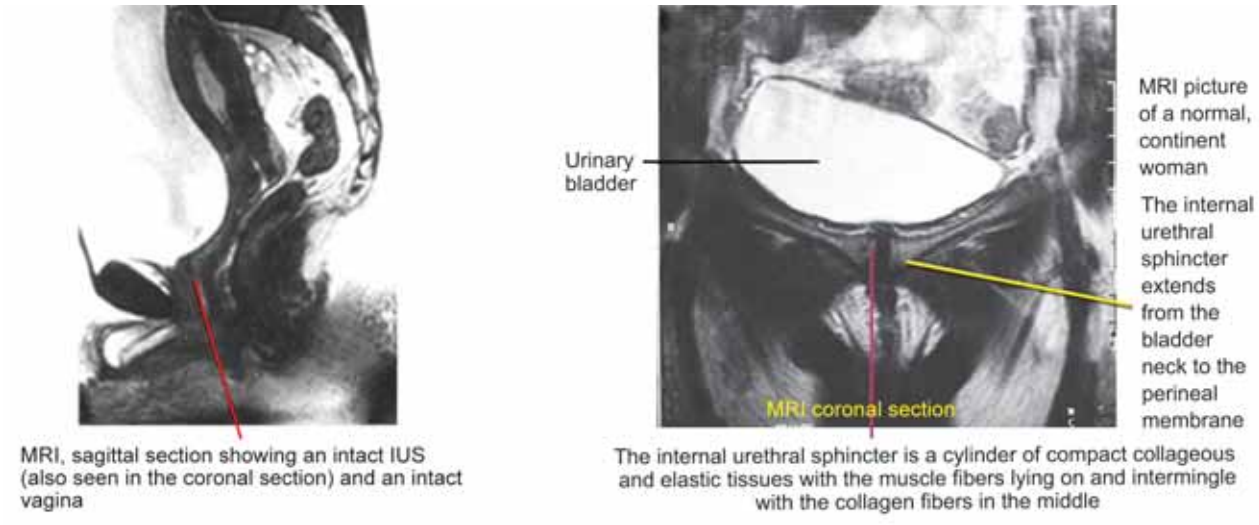


Fig. 10: Images by MRI, sagittal and coronal sections that show intact IUS as a cylinder that extends from the bladder neck down to the perineal membrane

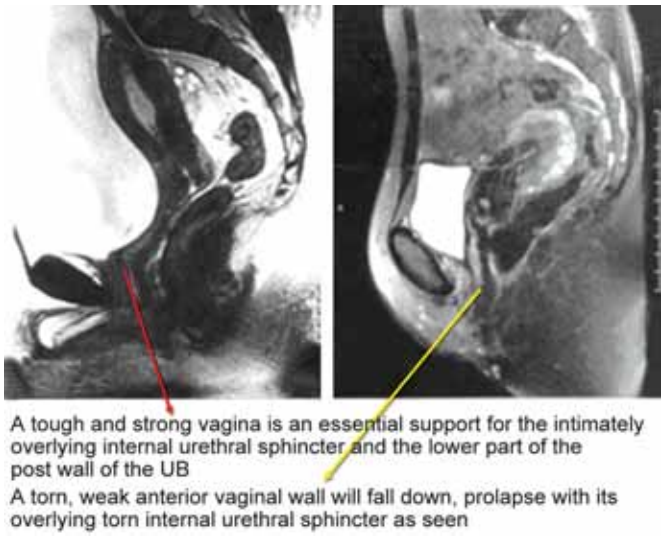


Fig. 11: Comparison between normal continent woman as seen on the left to a patient with SUI and vaginal prolapse on the right in MRI images, sagittal sections

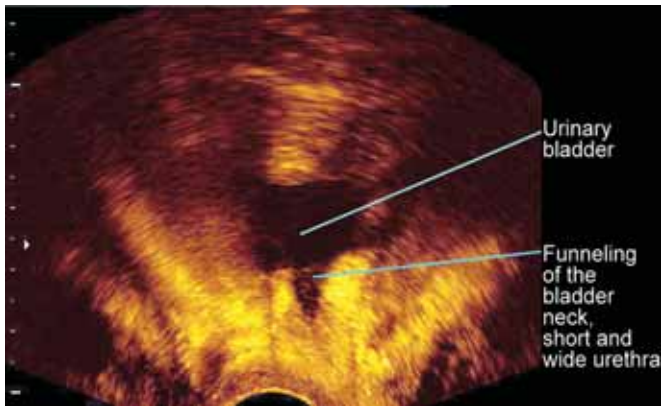


Fig. 12: Scanning by a 3D US picture of a patient with severe SUI, the IUS is torn, the upper part is funneled and the urethra is widely open

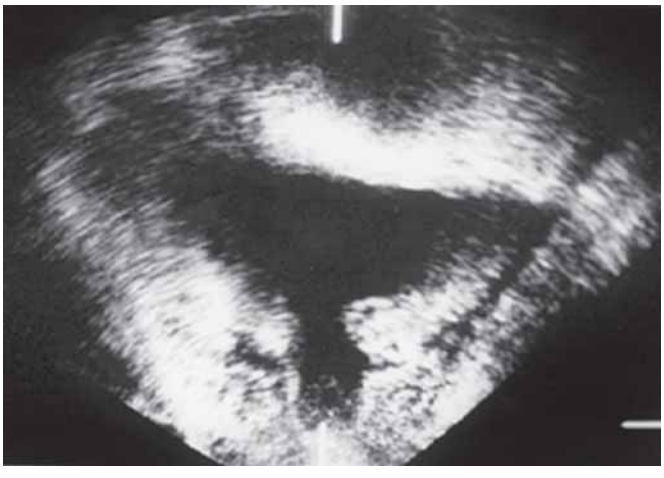


Fig. 13: Rupture affects the whole length irregularity and shortening of the urethra. Wide urethral lumen with weak torn walls of the IUS is seen

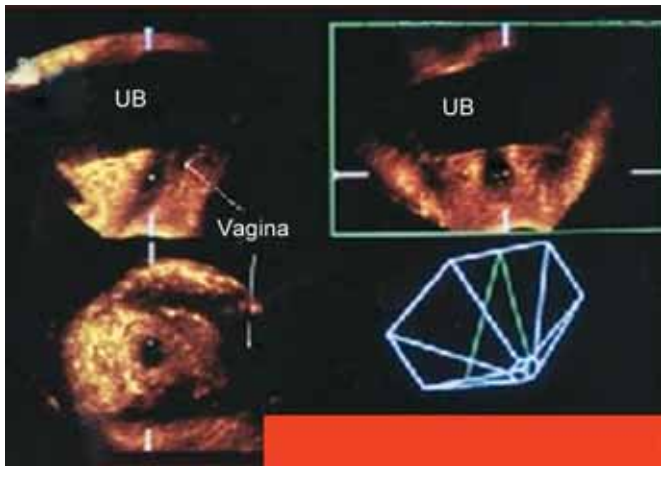


Fig. 14: Transrectal US picture of a case of SUI and anterior vaginal wall prolapse. It shows the torn anterior vaginal wall and posterior wall of the internal urethral sphincter

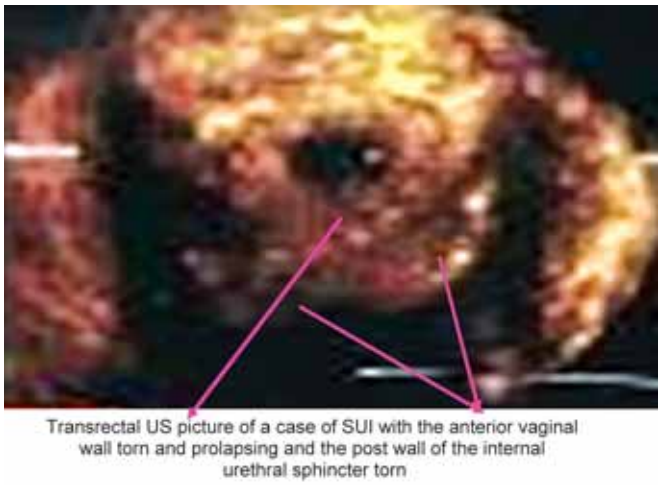


Fig. 15: Transrectal 3D US picture of a patient with SUI and vaginal prolapse. Note that the posterior wall of the IUS is torn and the anterior vaginal wall is torn and prolapsing

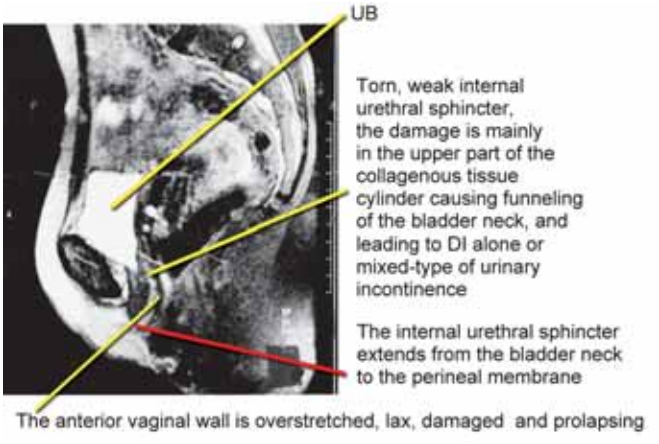


Fig. 16: An image by MRI, sagittal section that clearly shows the IUS as a cylinder that extends from the bladder neck to the perineal membrane. The IUS is torn mainly in its upper part leading to funneling of the bladder neck. Note that the anterior vaginal wall is torn and prolapsing

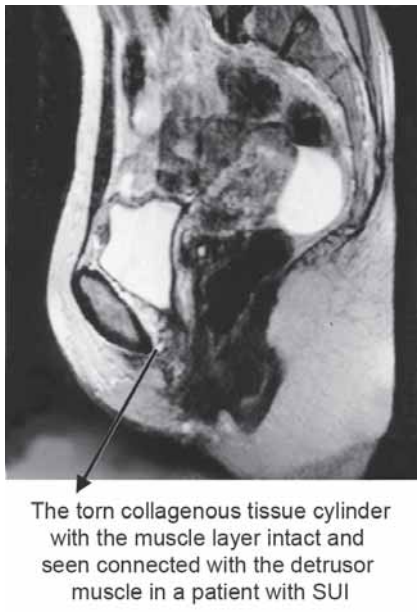


Fig. 17: MRI picture, sagittal section that shows the IUS is torn; the rupture affects the collagenous sheet leaving the muscle which can be seen connected above to the detrusor muscle

the pelvic collagen with further weakness. In addition, aging leads to atrophy of the collagen. All these factors lead to a weak IUS that causes stress urinary incontinence (SUI) and vaginal prolapse (Figs 12 to 17).[8-12]

AIM

Torn walls are better assessed by imaging. Three-dimensional ultrasound (3D US) is a volumetric scanning, with serial planes of images. MRI is also a useful tool to demonstrate the level and the extent of the rupture along the walls with its sequential images. Both will show redundancy and prolapse of the vagina and torn IUS.

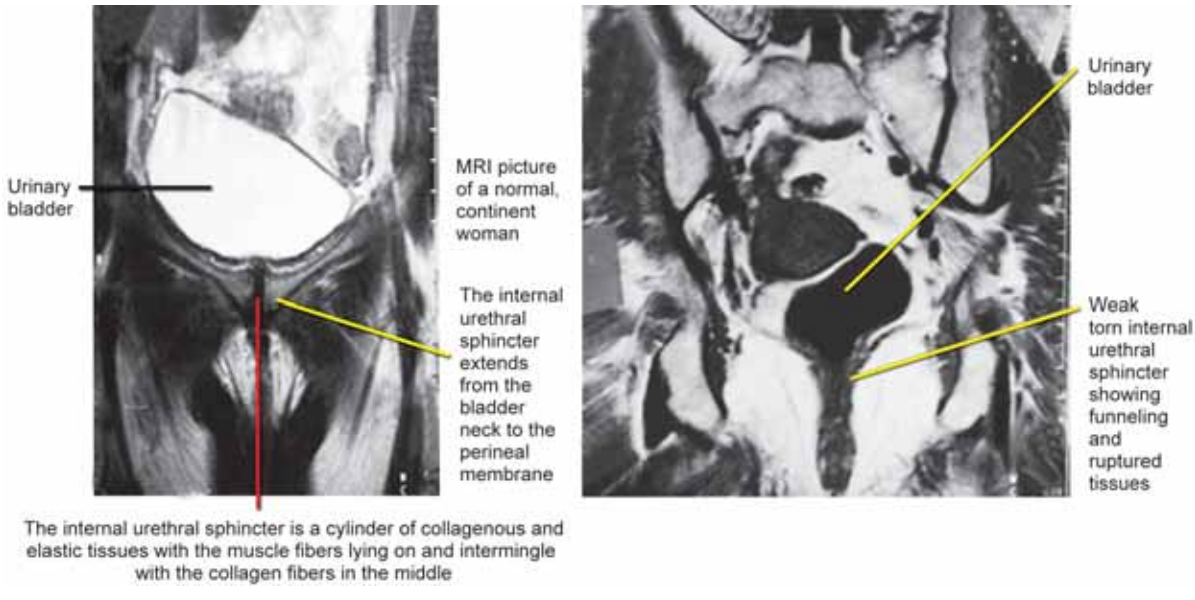
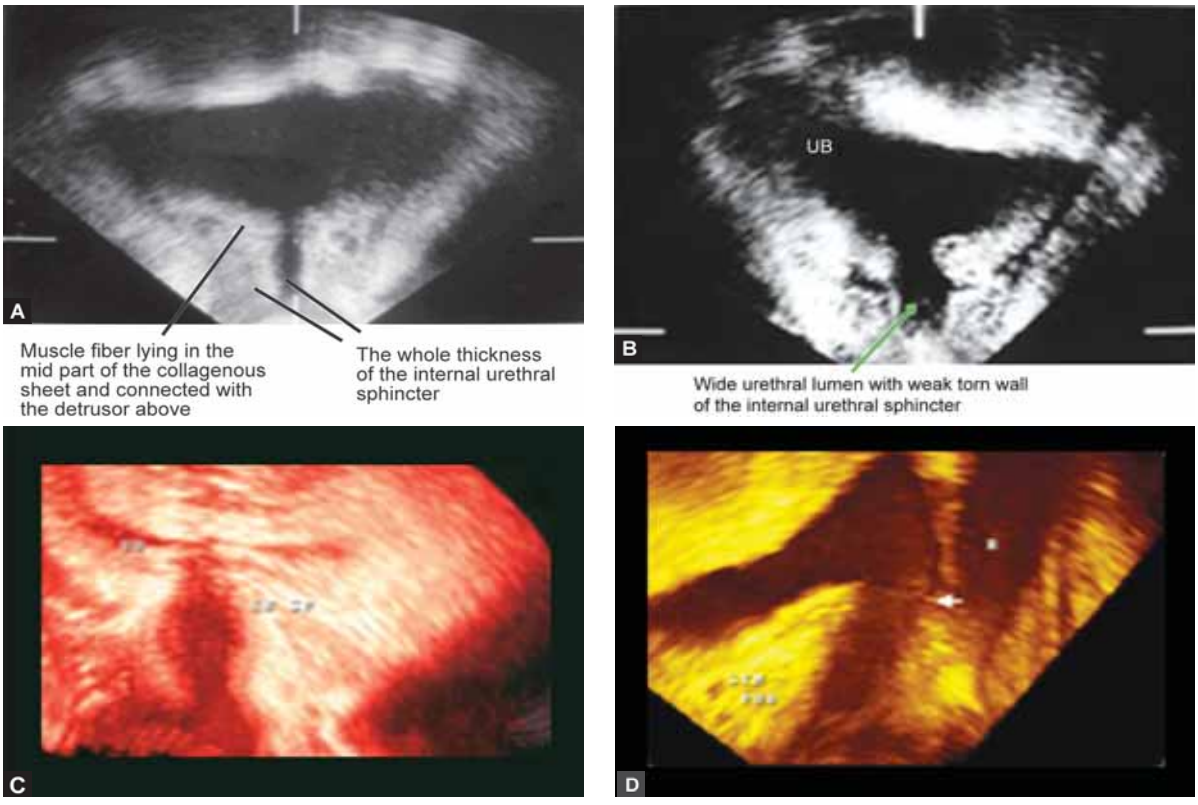
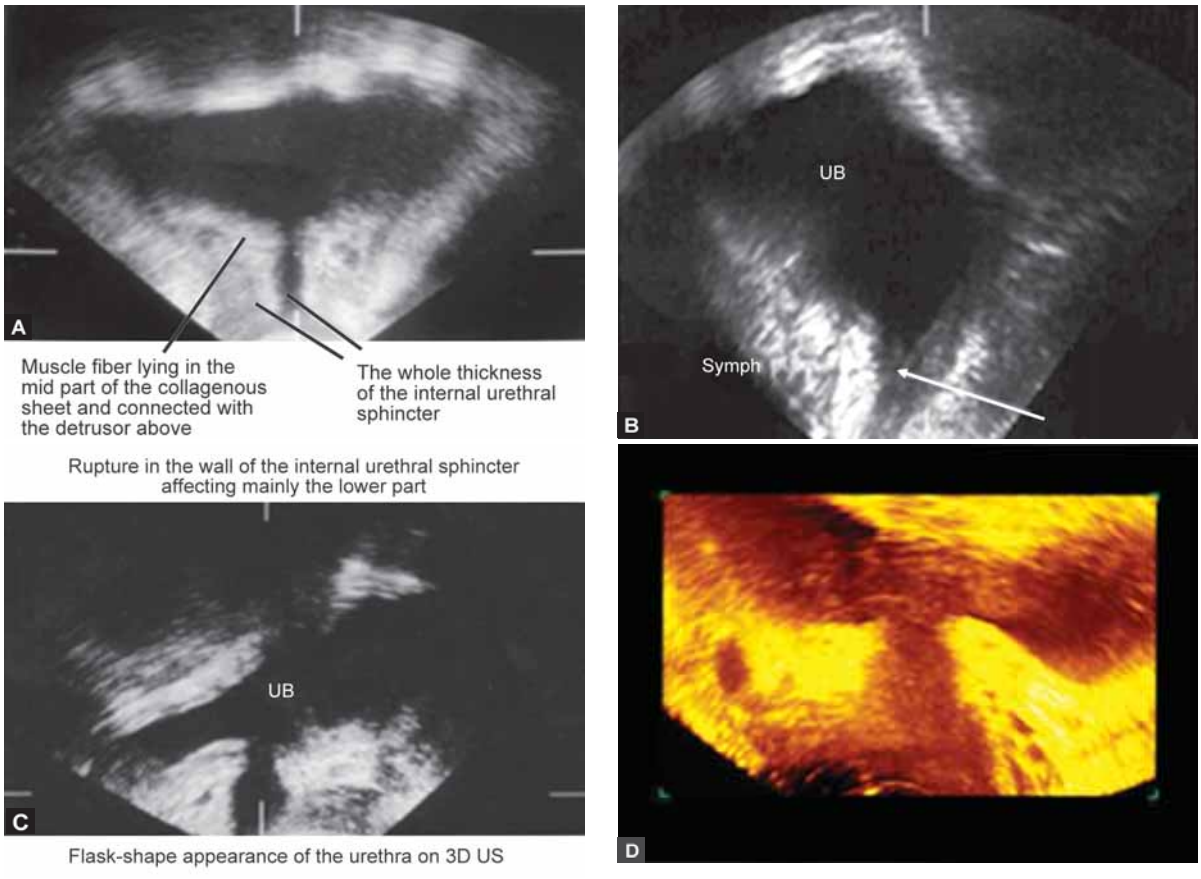


Fig. 18: Comparison between normal intact IUS (on the left) and torn IUS (on the right) in coronal section of MRI. The torn IUS is showing funneling in the upper part and a 'flask-shape' in the lower part



Figs 19A to D: Three-dimensional ultrasound pictures of normal continent woman: (A) With an intact IUS compared to the others, (B) shows torn IUS affecting the whole length with irregular walls and apparent shortening of the urethra, (C) the IUS is torn mainly in the lower part showing a 'flask-shape' appearance, while in (D) the rupture in the IUS is mainly in the upper part with loss of the urethrovesical angle



Figs 20A to D: Three-dimensional ultrasound pictures of normal continent woman: (A) With an intact IUS compared to the others, (B) shows torn IUS affecting mainly the upper part leading to funneling of the bladder neck and apparent descent of the bladder neck below the pelvic floor; (C) the IUS is torn mainly in the lower part showing a 'flask-shape' appearance, while in (D) the rupture in the IUS affects the entire length with funneling of the upper part and wide open urethra and apparent shortening of the urethra

METHODOLOGY

Scanning using a vaginal probe multifrequent 5 to 7.5 MHz Kretz-Medison 3D US machine and General Electric, integrated 3D-4D Unit (GE Volosone) 730 Pro V machine, are used to scan 150 patients with SUI and vaginal prolapse. Fifty normal women, who do not suffer from SUI or vaginal prolapse, were also scanned (Figs 1 to 3, 12 to 15 and 19 to 21).

Also MRI imaging was used to assess normal women and women with SUI and vaginal prolapse. 3D US imaging is faster, simpler and cheaper than MRI. We performed MRI scanning to confirm our concept and they were comparable to 3D US scanning (Figs 4 to 11, 17, 18 and 22 to 24).

RESULTS AND DISCUSSION

The IUS, as it is a cylinder, the level and extent of the rupture along the cylinder will determine the type and the degree of urinary incontinence as well as the configurational shape seen on imaging.[1]

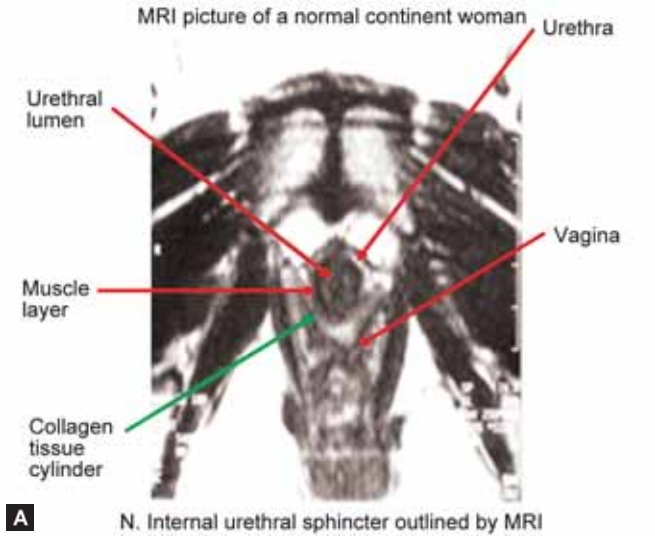
If the rupture affects mainly the upper part of the IUS, it will lead to detrusor overactivity (DO); as urine enters the upper part of the urethra, it will cause a desire to void, irritable bladder, overactive bladder, detrusor instability or DO. By 3D US, it will show funneling of the bladder neck, loss of urethra-vesical angle and apparent descent of the bladder neck below its normal position (Figs 11, 12, 16, 17, 19 and 20).

If the rupture affects mainly the lower part, it will lead to genuine SUI and a 'Flask-shape' appearance on 3D US scanning (Figs 19 to 21).

If the rupture affects the whole length of the IUS, it will lead to mixed type of urinary incontinence, which is more common, irregular walls and apparently short urethra (Figs 13, 14, 18 to 21, 23 and 24).

So, we can correct the classic dictum which says 'urine will flow if the pressure in the bladder exceeds the pressure in the urethra' and, instead, we will say urine will flow when the pressure in the urethra drops, and this will happens:

1. Voluntary, on voiding the person will lower the acquired high alpha-sympathetic tone at the IUS, thus opening the urethra
2. Involuntary, a weak torn IUS with a lower urethral closure pressure on increase of abdominal pressure will lead to a leak of urine from the urethra. This will evoke a reactive rise of sympathetic tone that will prevent further urine leak.[1,12-15]



The vagina in nulliparous women is H-shape with longitudinal folds and transverse rugae

Figs 22A and B: Diagrammatic drawing of the vagina in a nulliparous woman and MRI picture, cross section showing the H-shape vagina and an intact IUS

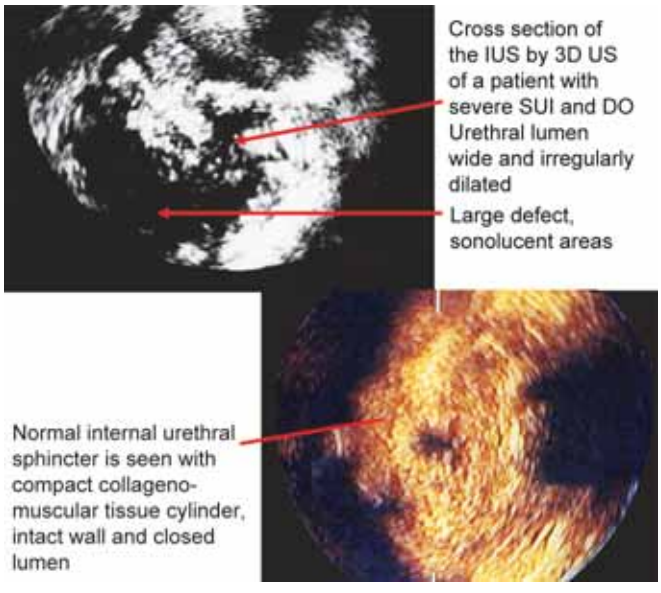
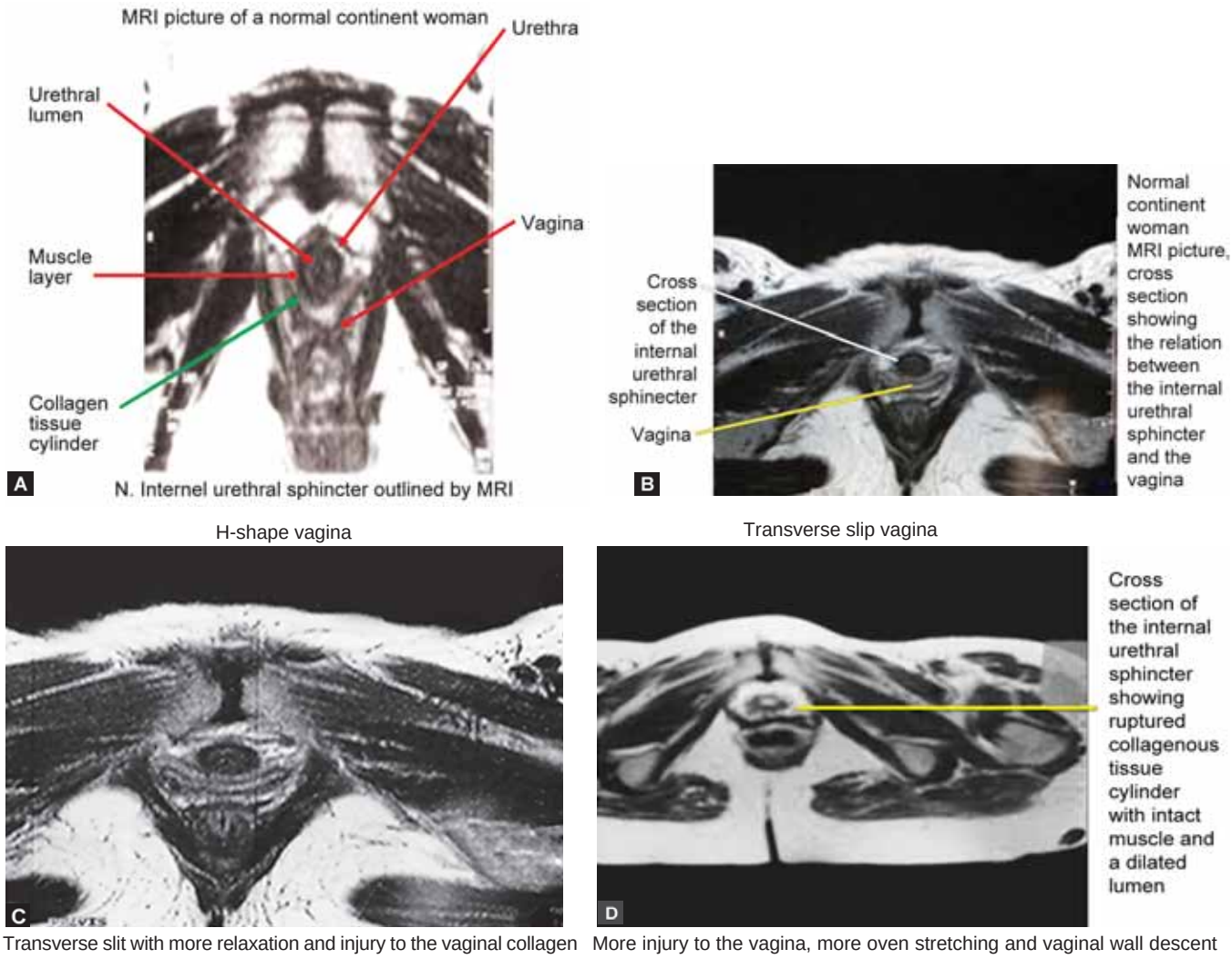


Fig. 21: Cross section of 3D US pictures of a patient with severe SUI, on the top, with large echolucent areas compared to a normal intact IUS



Figs 23A to D: MRI pictures, cross section that compare a nulliparous woman with H-shape vagina (A) and an intact IUS to parous women with transverse slit vagina and intact IUS in (B and C) contrary to a patient with SUI and vaginal prolapse as evidenced in torn IUS and vagina (D)

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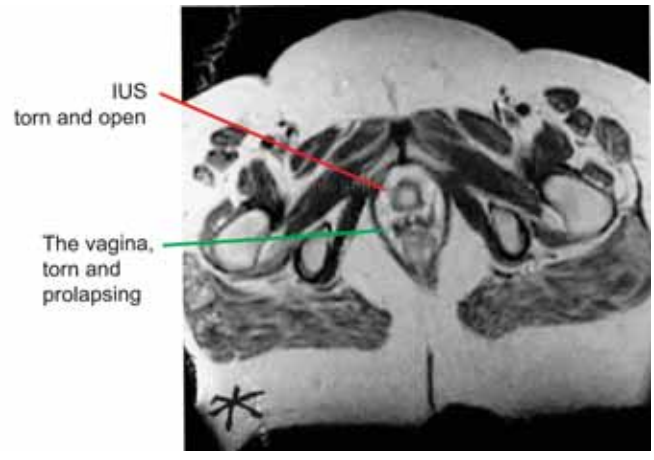

Fig. 24: MRI picture, cross section that shows torn IUS with wide open urethra and torn prolapsed vagina

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