

MRI of female genital and pelvic organs during sexual arousal

D. D. Suh, C. C. Yang, Y. Cao, J. R. Heiman, P. A. Garland and K. R. Maravilla

We utilized contrast enhanced magnetic resonance imaging (MRI) to delineate the anatomy of the female genital and pelvic organs during sexual arousal.

Eleven healthy pre-menopausal women and eight healthy post-menopausal women underwent MRI of the pelvis while watching an erotic video. A 1.5 Tesla MR system was used to produce T1-weighted images following administration of MS-325, a gadolinium-based blood pool contrast agent. Selected structural dimensions and enhancement were measured prior to and during sexual arousal.

In both pre- and post-menopausal subjects, vestibular bulb and labia minora width increased with arousal. Enhancement measurements increased in the bulb, labia minora and clitoris in both pre- and post-menopausal subjects, and in the vagina in pre-menopausal subjects. There were no marked changes in size or enhancement of the labia majora, urethra, cervix, or rectum during sexual arousal in pre- or post-menopausal subjects.

Using MRI, we observed specific changes in the female genitalia and pelvic organs with sexual arousal, in both pre- and post-menopausal women. MRI can potentially provide detailed anatomical information in the assessment of female sexual function, particularly with regard to changes in blood flow.

Key words: female genitalia, magnetic resonance imaging, pelvic anatomy, sexual arousal

INTRODUCTION

Female sexual dysfunction affects a large percentage of women^{1,2} and is associated with poor quality of life. There has been a dearth of research in the physiology of the female sexual response and female genital anatomy³, but there is growing interest in this area. Research has been limited by the lack of easily recognizable physical changes during sexual arousal, the inability to objectively measure genital structures non-invasively and without distortion, and the lack of a universally accepted test that can assess degrees of sexual functioning^{3–5}.

With its excellent resolution of soft tissues and its ability to show multiplanar views, magnetic resonance imaging (MRI)

technology has been utilized in the study of the female pelvic floor and pelvic organs^{6–10}. Similarly, MRI is an excellent method of studying genital anatomy¹¹. Unlike cadaver dissections or studies that require distorting probes or specula, the organs remain in their orthotopic positions with MRI and are not altered or destroyed by dissection. The aim of this study was to describe anatomic changes in the female genital and pelvic organs during sexual arousal using current MRI technology and MS-325, a gadolinium-based blood pool contrast agent (EPIX Medical, Cambridge, MA). This study was part of a larger investigation to determine the feasibility of MRI with MS-325 in healthy women during sexual arousal; Deliganis *et al.*

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reported preliminary data using this technique¹¹.

MATERIALS AND METHODS

Eleven healthy pre-menopausal women between the ages of 21 and 39 years (mean age 30.3 years), and eight healthy post-menopausal women between the ages of 40 and 65 years (mean age 56.4 years) participated in this study. All signed an informed consent approved by the Human Subjects Review Committee of our hospital. These subjects underwent screening history and physical examination, pelvic examination and PAP smear. Pre-menopausal women took a pregnancy test.

Exclusion criteria for the study included the use of estrogen or hormonal medications, acute or chronic medical conditions, history of sexual dysfunction, psychological or social conditions that might affect participation in the study, history of current pregnancy or delivery within the last 12 months, history of hysterectomy or vaginal surgery, gynecological disease or malignancy, known anatomic abnormalities of the genitalia (including pelvic floor prolapse) and pelvic inflammatory disease or vaginal infection.

All subjects underwent MRI prior to, during, and following viewing of an erotic video. The subjects viewed the video on a fiberoptic display while in the MRI scanner. Prior to and following the MRI session, each subject completed a written questionnaire assessing her subjective level of sexual arousal.

Imaging technique

A GE Signa Horizon Echo Speed 1.5 Tesla system (General Electric Medical Systems, Waukesha, WI) was used for all MRI studies. Specially designed phased-array (PA) coils built in our laboratory were utilized for imaging of the pelvis. A 10 cm PA coil was placed anterior to the pubic symphysis and a larger two coil PA receiver was placed posterior to the pelvis. Subjects were imaged using a T1-weighted fast, three-dimensional spoiled gradient recalled echo pulse sequence, acquired in an axial orientation. Voxel size measured approximately $0.9 \times 0.9 \times 2$ mm for a total voxel volume of 1.6 cubic mm. A set of baseline images was obtained prior to injection of contrast. Intravenous contrast injection of

0.05 mmol/kg of MS-325 was followed by a 3 min delay for contrast level equilibration. Serial post-contrast images were obtained prior to, during, and following viewing of an erotic video.

Using the MRI console, one investigator (D. S.), who was blinded to the subjects' demographic and medical data, measured structural dimensions and enhancement. Measurements of the labia majora and minora were made at the level of the vaginal introitus. Labia majora height was measured from the junction of the labia majora and medial thigh to the anterior margin of the labia majora. Labia majora width was measured between the lateral margins of the labia majora. Measurements of the clitoris and vestibular bulbs were made at the level of greatest prominence of the clitoral body, which was at the level of the ischial tuberosity. Measurements of the urethra, vagina and rectum were made at the level of the pubic symphysis. Vaginal canal length was calculated by multiplying the number of image slices from the introitus to the cervix by 2 (2 mm distance between slices). Structural measurements were made in two-dimensions instead of three-dimensions because it is more commonly used in clinical practice. Additionally, of all the pelvic structures examined, only the clitoris had distinct borders measurable in three-dimensions.

Because signal intensity in MRI is not standardized against a fixed reference (as in computed tomography), we expressed enhancement as a percentage change from pre-contrast signal intensity, calculated by using the following formula:

$$\% \text{ change} = 100 \times [\text{SI}_{\text{structure}}(t) - \text{SI}_{\text{structure}}(t_0)] / \text{SI}_{\text{structure}}(t_0)$$

where SI(t) refers to signal intensity measurement of the structure at time (t) post-contrast injection and SI(t_0) refers to signal intensity measurement of the structure pre-contrast. Post-contrast measurements in the non-aroused state were made using images taken approximately 9 min following administration of contrast, to allow for sufficient equilibration of contrast distribution. Post-contrast measurements during the sexually aroused state were made using images taken approximately 9 min into the erotic video to allow adequate time for sexual arousal. Paired Student's *t*-test was used to compare structural and enhancement changes with arousal.

RESULTS

All 19 subjects experienced sexual arousal during viewing of the erotic video based on questionnaire results; on a scale of 1 ('not at all' sexually aroused) to 7 ('intensely' sexually aroused), mean questionnaire score was 1 (SD=0) prior to the video and 4 (SD=1.4) during the video. All subjects displayed poor visualization or non-visualization of genital structures on the T1-weighted images prior to contrast injection. All showed excellent visualization of genital and pelvic anatomy on the T1 post-MS325 images. There was considerable enhancement of the labia, vestibular bulbs, clitoris, urethra, vagina, cervix and rectum compared to pre-contrast baseline images. Optimal contrast enhancement occurred at 6–9 min post-injection and this high level of enhancement and anatomic delineation persisted for the entire 45 minute imaging session.

Labia

There were no discernable changes in the size or shape of the labia majora between the neutral and aroused state in pre- and post-menopausal women (Figures 1 and 2). Labia minora width and enhancement increased during arousal in pre- and post-menopausal women (Tables 1–4). There were no changes in the relationships between the labia majora and minora, or between the labia and the surrounding structures during sexual arousal in either pre- or post-menopausal subjects.

Bartholin's glands

The Bartholin's glands were well-visualized (Figures 1 and 3). They are pea-shaped structures imbedded in the soft tissue of the posterolateral introitus, at the posterior aspect of the labia majora. There were no distinct changes in shape, position or enhancement of the Bartholin's glands between the neutral and aroused states in either pre- or post-menopausal subjects.

Vestibular bulbs

The bulbs are oblong-shaped structures on either side of the midline, positioned just posterior to the clitoral bodies. They have a slight convexity in the center, and track alongside the clitoral crura. The two bulbs

converged anteriorly in the midline at the commissure, where they appeared to be inseparable from the clitoris. We observed an increase in the measured width and enhancement of the bulbs in the aroused state in pre- and post-menopausal subjects (Tables 1–4). The shape of the bulb and its relation to the clitoris did not change in the images prior to and during arousal in pre- and post-menopausal women (Figures 1 and 3).

Clitoris

The clitoris is comprised of two elongated bodies that track along the ischial rami, converge in the midline and extend slightly away from the body to end in the rounded glans (Figures 1 and 3). Clitoral body width did not increase in pre- or post-menopausal women during sexual arousal (Tables 1 and 3). There were large increases in enhancement of the clitoris during the aroused state in both pre- and post-menopausal subjects (Tables 2 and 4). We did not observe any changes in clitoral shape or relationship to the surrounding structures (e.g. urethra, bulbs and ischial rami) during arousal.

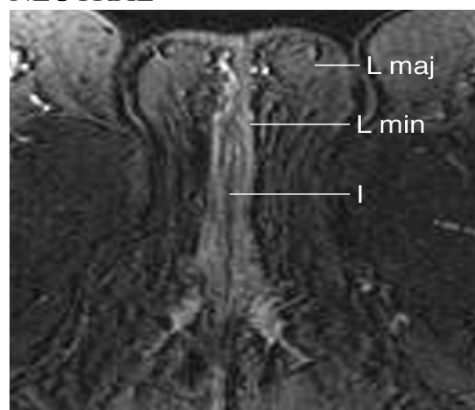
Urethra/bladder

Urethral diameter and enhancement measurements did not differ markedly between the neutral and aroused states in pre- and post-menopausal subjects. The shape of the urethra and bladder base did not change during arousal (Figures 1 and 4). Bladder contents had a higher signal intensity in the arousal images but this was attributed to a greater amount of contrast excreted in the urine by that time, and was not considered to be a change due to sexual arousal *per se* (Figure 1). We did not observe any changes in the anterior vagina and urethra, where the Grafenberg spot (G-spot) is purported to be^{12,13}.

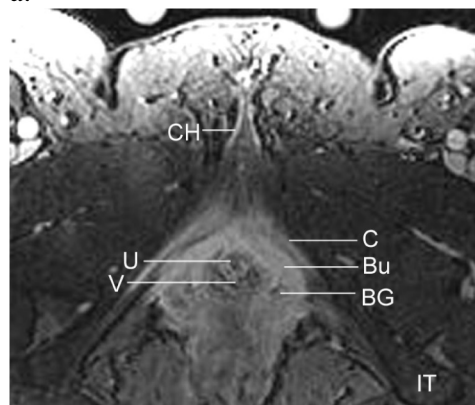
Vagina

Measurements of vaginal width, wall thickness and canal length did not change with arousal in both pre- and post-menopausal groups (Tables 1 and 3). Vaginal wall enhancement increased with arousal only in pre-menopausal subjects. In the pre-menopausal subjects there were numerous infoldings of the vaginal mucosa (rugae),

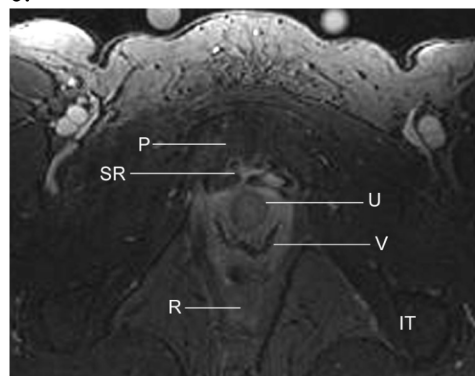
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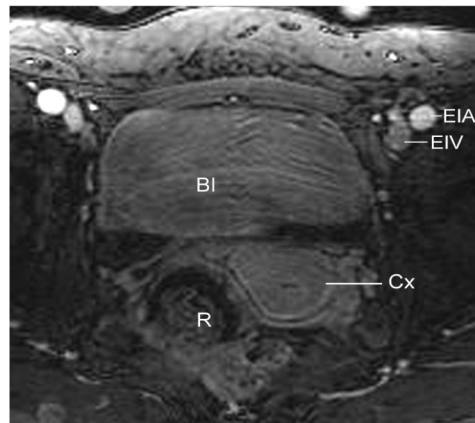
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c.

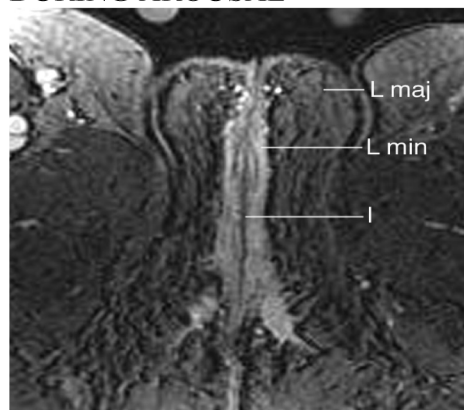


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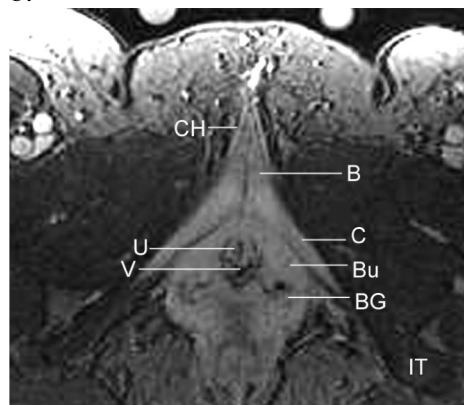


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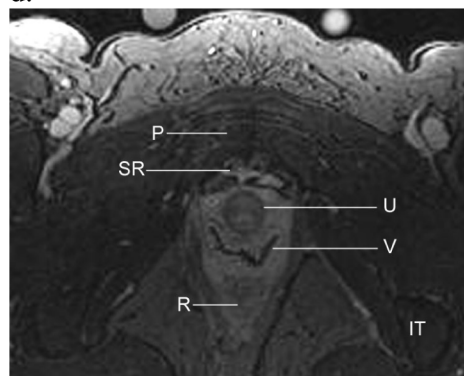
DURING AROUSAL



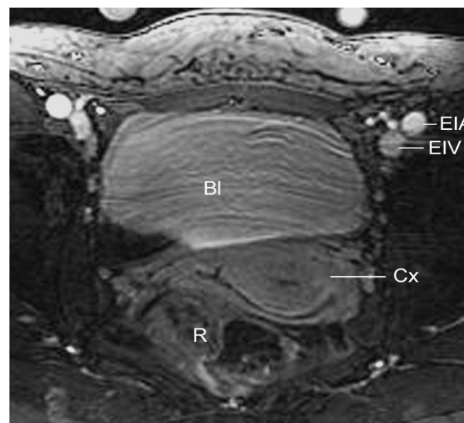
b.



d.



f.



h.

Figure 1 T1-weighted post-contrast images in a 26 year-old woman. (a) prior to, and (b) during arousal at the level of the introitus. Increased

creating an irregular surface. Post-menopausal subjects did not have distinguishable mucosal rugae or clearly separate layers of the vagina, presumably due to atrophy and flattening of the vaginal walls (Figure 4). Thus, the lack of enhancement in the post-menopausal group was attributed to smaller tissue volume. There were no discernable changes

in the shape, position, or axis of the vagina during the aroused state.

Cervix

The cervix did not appear to change in size, position, or enhancement with arousal in both pre- and post-menopausal subjects (Figure 1).

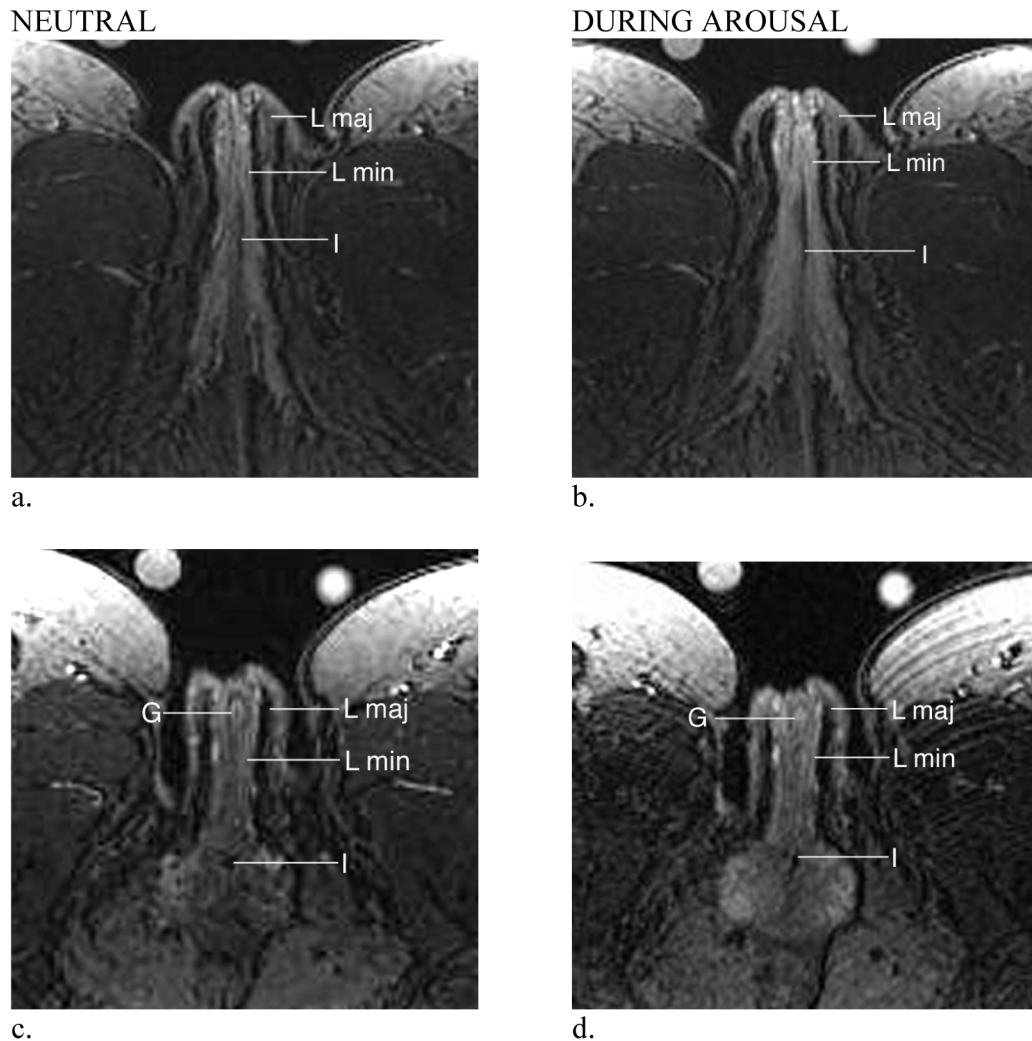


Figure 2 T1-weighted post-contrast images at the level of the introitus. (a) prior to arousal in a pre-menopausal woman. (b) during sexual arousal in same pre-menopausal woman. (c) prior to arousal in a post-menopausal woman. (d) during sexual arousal in same post-menopausal woman. Similar changes occur in both pre- and post-menopausal women. Increased signal intensity, reflecting an increase in blood flow, is evident in the labia minora, but not the labia majora. G = glans of clitoris; L maj = labia majora; L min = labia minora; I = introitus

signal intensity, reflecting an increase in blood flow, is evident in the labia minora, but not the labia majora. (c) prior to, and (d) during arousal at the level of the ischial tuberosity. Both the clitoris and the vestibular bulbs demonstrate increased signal intensity with arousal, reflecting increases in blood flow. (e) prior to, and (f) during arousal at the level of the pubic symphysis. There are no obvious changes in the urethra, vagina, or rectum with arousal. Distinct layers of the urethra and vaginal wall are discernible. (g) prior to, and (h) during arousal at the level of the cervix. The cervix, bladder, and rectum do not change significantly with arousal. The appearance of the cervix is unchanged, suggesting that there has not been significant uterine movement between the neutral and aroused states. Increased signal intensity within the bladder resulted from excretion of contrast into the urine. L maj = labia majora; L min = labia minora; I = introitus; CH = clitoral hood; B = body of clitoris; C = crus of clitoris; Bu = bulb of vestibule; BG = Bartholin's gland; U = urethra; V = vagina; R = rectum (with feces); P = pubis; SR = space of Retzius; IT = ischial tuberosity; Bl = bladder; Cx = cervix; EIA = external iliac artery; EIV = external iliac vein

Table 1 Mean structural measurements in pre-menopausal subjects. All measurements were made using T1 post-contrast images. Average $\pm$ SD (in mm), range expressed in parentheses. NS=not significant ($N=11$)

	Neutral	Arousal	Difference	P value
Labia majora height	22 $\pm$ 7 (11–33)	22 $\pm$ 7 (11–33)	0 $\pm$ 1 (–2–3)	NS
Labia majora width	44 $\pm$ 11 (33–65)	46 $\pm$ 12 (33–71)	1 $\pm$ 2 (–1–6)	NS
Labia minora width	11 $\pm$ 2 (9–15)	13 $\pm$ 2 (10–15)	1 $\pm$ 1 (–1–4)	$P < 0.01$
Clitoral body width	10 $\pm$ 1 (8–12)	11 $\pm$ 2 (8–14)	1 $\pm$ 2 (–1–5)	NS
Bulb width	8 $\pm$ 1 (6–10)	9 $\pm$ 2 (7–14)	1 $\pm$ 1 (0–4)	$P < 0.01$
Urethral diameter	12 $\pm$ 2 (10–15)	13 $\pm$ 2 (10–16)	1 $\pm$ 1 (–1–3)	NS
Vaginal length	77 $\pm$ 7 (62–84)	78 $\pm$ 7 (62–86)	1 $\pm$ 1 (–2–4)	NS
Vaginal width	34 $\pm$ 5 (28–44)	34 $\pm$ 5 (26–43)	0 $\pm$ 2 (–3–2)	NS
Vaginal wall thickness	5 $\pm$ 1 (3–8)	6 $\pm$ 2 (4–9)	0 $\pm$ 1 (–1–1)	NS
Cervical diameter	25 $\pm$ 6 (12–31)	26 $\pm$ 6 (20–32)	1 $\pm$ 1 (–1–3)	NS

Table 2 Mean tissue enhancement post-contrast in pre-menopausal subjects. Average $\pm$ SD (expressed as % change from pre-contrast signal intensity), range expressed in parentheses. NS=not significant ($N=11$)

	Neutral	Arousal	Difference	P value
Labia minora	431.3 $\pm$ 85.2 (274.9–584.6)	500.4 $\pm$ 111.4 (336.6–677.8)	69.2 $\pm$ 81.1 (–10–177.4)	$P < 0.01$
Clitoris	356 $\pm$ 144.2 (161.7–615.1)	578.9 $\pm$ 222.9 (181–837)	222.9 $\pm$ 161.9 (–40.8–542.5)	$P < 0.01$
Bulb	469.7 $\pm$ 123.5 (219.1–685.4)	547.5 $\pm$ 138.6 (272.7–793.7)	77.7 $\pm$ 43.3 (12.3–160.3)	$P < 0.01$
Urethra	418 $\pm$ 79.9 (328.2–607.9)	408.1 $\pm$ 80.8 (287.2–557.3)	–9.9 $\pm$ 30.3 (–50.6–38)	NS
Vagina	406.1 $\pm$ 72.7 (264–499.5)	425.9 $\pm$ 85.2 (299.1–544)	19.8 $\pm$ 29.3 (–27.5–65.5)	$P < 0.05$
Rectum	292.8 $\pm$ 55.8 (216.1–378.0)	298.4 $\pm$ 57.6 (205.9–405.7)	5.6 $\pm$ 24.5 (–28.1–33.6)	NS

Table 3 Mean structural measurements in post-menopausal subjects. All measurements were made using T1 post-contrast images. Average $\pm$ SD (in mm), range expressed in parentheses. NS=not significant ($N=8$)

	Neutral	Arousal	Difference	P value
Labia majora height	22 $\pm$ 8 (12–37)	23 $\pm$ 8 (13–37)	0 $\pm$ 1 (0–2)	NS
Labia majora width	53 $\pm$ 14 (29–79)	53 $\pm$ 12 (31–75)	1 $\pm$ 3 (–4–5)	NS
Labia minora width	9 $\pm$ 2 (7–13)	10 $\pm$ 2 (7–14)	1 $\pm$ 1 (0–2)	$P < 0.01$
Clitoral body width	9 $\pm$ 2 (7–12)	9 $\pm$ 2 (7–12)	0 $\pm$ 1 (–1–2)	NS
Bulb width	5 $\pm$ 2 (3–8)	6 $\pm$ 2 (5–10)	1 $\pm$ 1 (0–2)	$P < 0.01$
Urethral diameter	12 $\pm$ 2 (9–15)	12 $\pm$ 2 (10–14)	0 $\pm$ 1 (–2–1)	NS
Vaginal length	75 $\pm$ 5 (68–82)	75 $\pm$ 4 (74–80)	0 $\pm$ 2 (–2–2)	NS
Vaginal width	29 $\pm$ 3 (24–34)	29 $\pm$ 4 (23–33)	0 $\pm$ 1 (–2–2)	NS
Vaginal wall thickness	4 $\pm$ 2 (2–7)	4 $\pm$ 1 (3–7)	0 $\pm$ 1 (–1–1)	NS
Cervical diameter	16 $\pm$ 4 (12–23)	16 $\pm$ 3 (13–21)	0 $\pm$ 2 (–3–2)	NS

Table 4 Mean tissue enhancement post-contrast in post-menopausal subjects. Average $\pm$ SD (expressed as % change from pre-contrast signal intensity), range expressed in parentheses. NS=not significant ($N=8$)

	Neutral	Arousal	Difference	P value
Labia minora	371.1 $\pm$ 58.6 (310–459.1)	428.5 $\pm$ 68.7 (314.5–515.8)	57.4 $\pm$ 42 (1.9–106.4)	$P < 0.01$
Clitoris	480.1 $\pm$ 165.8 (314.3–835.1)	671 $\pm$ 166.7 (474.0–1007.6)	191 $\pm$ 85.2 (40.6–317.7)	$P < 0.01$
Bulb	446 $\pm$ 190.8 (260.2–768.5)	562.7 $\pm$ 200.7 (300–867.8)	116.7 $\pm$ 61.7 (8.3–201.0)	$P < 0.01$
Urethra	399 $\pm$ 98.8 (299.2–612.2)	414.4 $\pm$ 73.4 (291.1–502.2)	15.4 $\pm$ 61.8 (–110–70.9)	NS
Vagina	377.6 $\pm$ 130.9 (246.7–606)	395.8 $\pm$ 108.3 (237.8–546.0)	18.2 $\pm$ 42.3 (–60–79.8)	NS
Rectum	338.1 $\pm$ 61.7 (267–414.9)	349.5 $\pm$ 66.6 (266.4–458.8)	11.4 $\pm$ 23.3 (–9.9–54.8)	NS

Rectum

Measurements of the diameter and wall thickness of the rectum were not made due

to variations between subjects related to stool content. During sexual arousal there were no discernable changes in rectal morphology in pre- and post-menopausal

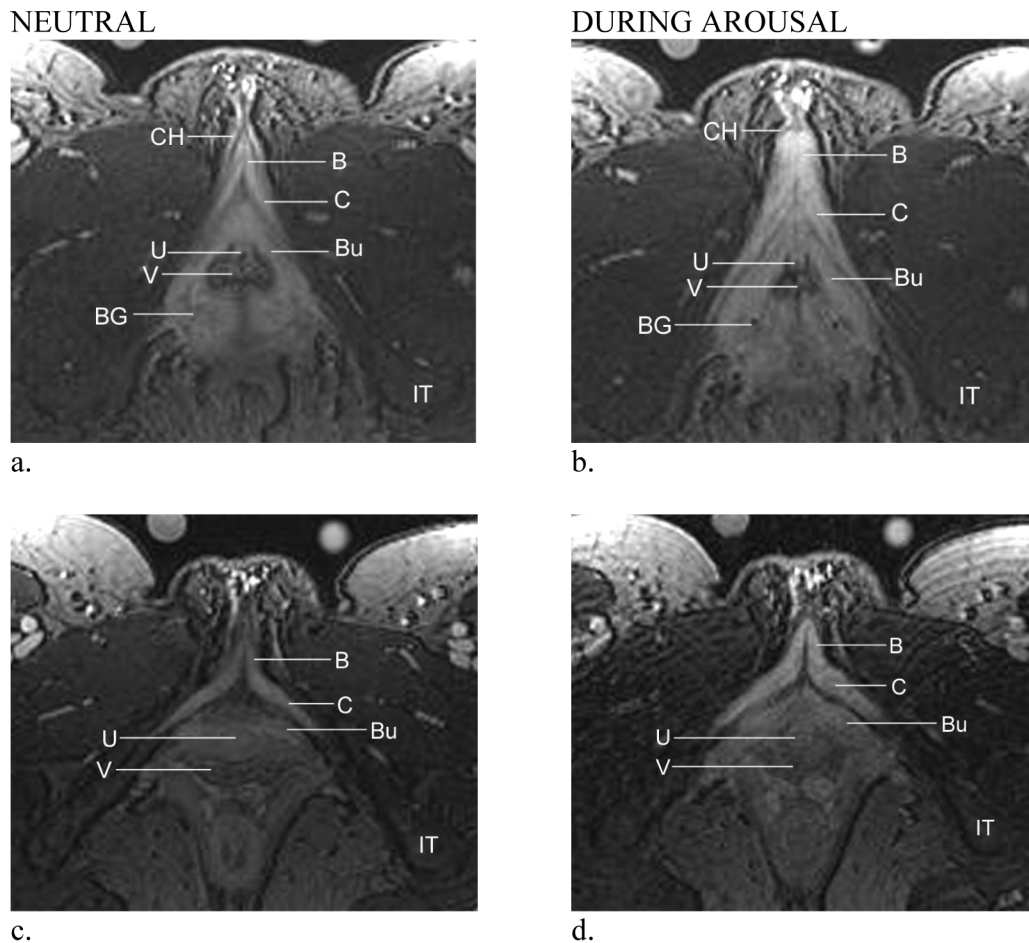


Figure 3 T1-weighted post-contrast images at the level of the ischial tuberosity. (a) prior to arousal in pre-menopausal woman. (b) during sexual arousal in same pre-menopausal woman. (c) prior to arousal in post-menopausal woman. (d) during sexual arousal in same post-menopausal woman. Similar changes occur in both pre- and post-menopausal women. Both the clitoris and the vestibular bulbs demonstrate increased signal intensity with arousal, reflecting increases in blood flow. CH = clitoral hood; B = body of clitoris; C = crus of clitoris; Bu = bulb of the vestibule; U = urethra; V = vagina; BG = Bartholin's gland; IT = ischial tuberosity

subjects (Figures 3 and 4). Enhancement of the rectal wall was similar in all subjects prior to and during arousal (Tables 2 and 4).

DISCUSSION

This study examined the female genital and pelvic organs during sexual arousal. Our primary findings were increased enhancement of the clitoris, bulbs and labia minora in both pre- and post-menopausal women during sexual arousal. This corroborates existing histological data that these are vascular structures and behave as erectile tissues during sexual arousal^{14,15}.

The most notable change within the pelvis was the increase in contrast enhancement within the clitoris, 62.6% in pre-menopausal and 39.8% in post-menopausal women. The clitoris has long been known as a sexual organ in women¹⁶, and these

changes were expected. The bulbs and labia minora are less recognized as sexual organs. There were increases in width and enhancement of the bulbs during sexual arousal in pre- and post-menopausal women. The bulbs have been described as paravaginal erectile bodies during sexual arousal¹⁵ and are homologous to the penile bulb and corpus spongiosum in the male¹⁷. *In vivo*, the erectile tissue of the bulbs consists of a spongelike system of vascular spaces lined by endothelium and separated by delicate fibroelastic septa which is similar to the erectile tissue of the clitoris. Blood enters these spaces during arousal, resulting in engorgement of the bulbs and clitoris¹⁸. MRI highlighted the close relationship of the bulbs to the clitoris, reinforcing the concept proposed by O'Connell *et al.* that the vestibular bulbs are more related to the clitoris than the vestibule, as their name

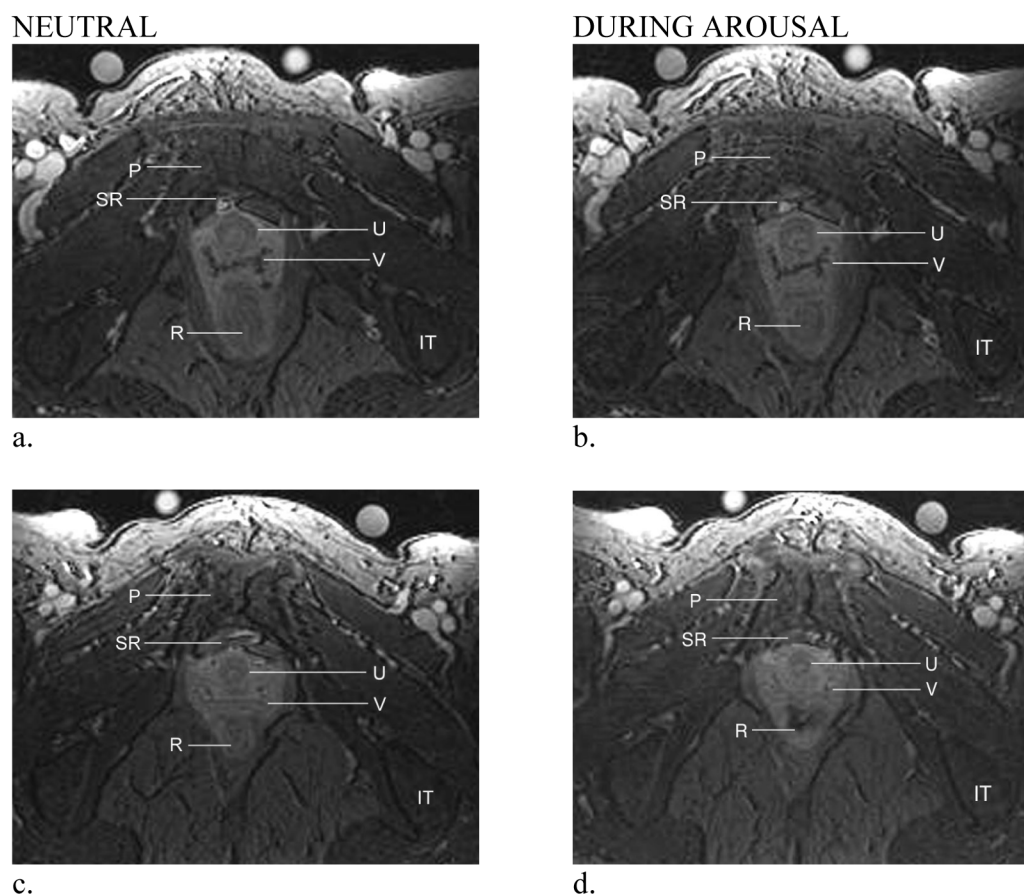


Figure 4 T1-weighted post-contrast images at the level of the pubic symphysis. (a) prior to arousal in pre-menopausal woman. (b) during sexual arousal in same pre-menopausal woman. (c) prior to arousal in post-menopausal woman. (d) during sexual arousal in same post-menopausal woman. There are no obvious changes in the urethra, vagina, or rectum with arousal. Distinct layers of the urethra are discernible. Numerous infoldings (rugae) of the vaginal mucosa create an irregular surface in pre-menopausal subjects. Post-menopausal subjects did not have distinguishable mucosal rugae or clearly separate layers of the vagina. U = urethra; V = vagina; IT = ischial tuberosity; R = rectum (with feces); P = pubis; SR = space of Retzius

suggests¹⁹. MR images suggested an area of communication at the bulb commissure; previous texts have described anastomoses between vessels of the commissure and the glans clitoris¹⁴.

The labia minora also displayed enhancement during sexual arousal in pre- and post-menopausal women. The labia minora are thin, hairless skin folds with a rich supply of blood vessels and nerves. The labia minora are homologous to the penile skin and the urethral folds, which are adjacent to the erectile bodies in the male²⁰. A similar relationship between the labia minora and the overlying erectile bodies of the bulbs and clitoris is highlighted on MRI. The labia minora, vestibular bulbs and clitoris comprise the predominant zone of enhancement during sexual arousal, reflecting a significant increase in blood flow.

Less vivid, but still significant, were the dimensional changes of the erectile organs

of the female pelvis. Labia minora and bulb width increased with arousal in both pre- and post-menopausal women, which would be expected with increases in blood flow to these structures. It is interesting to note that of the dimensional changes, the most statistically significant were those in the post-menopausal women, in both the bulb width and labia minora width. This implies that though there is genital tissue atrophy following hormonal withdrawal, the tissue is still responsive to sexual stimulation, supporting the findings of Laan and van Lunsen²¹. Clitoral body width did not increase in either group, probably because the fibrous tunica precludes a substantial increase of clitoral girth.

The most carefully documented anatomic studies of female subjects during sexual arousal were performed by Dickinson¹⁶ and Masters and Johnson²². These observations of female anatomy were based on physical

examination during tactile and psychogenic stimulation. Dickinson observed enlargement of the labia minora, distension of the bulbs and clitoral erection (in 10%) during sexual arousal. He also noted vaginal enlargement, increased number and prominence of the rugose folds of the vagina and involuntary distention of the external urethral meatus during arousal and orgasm. Masters and Johnson reported engorgement of the labia majora and minora, with protrusion of the engorged labia minora between the labia majora and a vasocongestive reaction of the clitoral glans and shaft. They observed lengthening and distention of the inner two-thirds of the vaginal barrel, marked vasocongestion of the outer one-third, an increase in uterine size and elevation of the uterus ('tenting') during arousal.

Our findings corroborate some, but not all, of the earlier observations. We noted increases in the width of the labia minora and vestibular bulbs, as well as increases in enhancement of the labia minora, vestibular bulbs and clitoris during sexual arousal. In pre-menopausal subjects, the vagina enhanced with sexual arousal as well. However, we did not observe marked changes in the size of the labia majora, clitoris or vagina during arousal. Absence of these changes does not imply that the events were not occurring; it may well be that MRI was not able to detect them. In a preliminary study, Deliganis *et al.* noted a significant increase in clitoral size with arousal, using MRI with three-dimensional reconstruction¹¹. We used two-dimensional measurements, which may not give the most accurate representation of these three-dimensional structures. However, of the genital and pelvic structures measured, only the clitoris had reasonably distinct three-dimensional boundaries from which to calculate volume. Volume measurements of structures other than the clitoris (labia majora and minora, bulbs, urethra and vagina) were not possible due to indistinct borders. Since there are other sexually responsive pelvic structures other than the clitoris, it is reasonable to make uniform measurements between them.

Other MRI studies examined the female genitalia during coitus. Schultz *et al.* noted lengthening of the vaginal canal by approximately 1 cm and elevation of the uterus, but were unable to distinguish between the vaginal wall, urethra and clitoris²³. Faix *et al.* were unable to comment on changes in

female sexual organs during MRI of a male and female during intercourse²⁴.

MRI allows for examination of organs that is not possible with physical examination or other imaging modalities such as ultrasound and CT. The use of PA coils gives excellent anatomical detail and an appreciation of regional anatomy and inter-organ relationships, without the presence of an invasive probe. MS-325 is an investigational, gadolinium-based contrast agent. Upon IV injection, it is reversibly bound to albumin with 80–90% bound, which dramatically reduces extravasation into the interstitial tissues²⁵. When bound to albumin, it has very high relaxivity, resulting in a strong T1 enhancement effect, particularly in blood vessels and tissues with large vascular capillary/cavernous spaces²⁶. This allowed for an indirect measurement of regional vascular tissue that may be useful in the assessment of blood flow changes during sexual arousal. In contrast to our preliminary study¹¹, we chose to measure signal intensity change rather than calculate relative regional blood volume, since it was easier to perform and did not require extra calculations to account for fluctuations in femoral vein signal intensity. It appears that the clinical utility of the signal intensity change is adequate.

There were several caveats to our study. Due to the small number of subjects, the structural measurements are included for descriptive purposes and to comment on general differences observed, not to establish baseline values which are to be used as standards for comparison. We were able to observe specific changes with sexual stimulation but were not able to correlate the observed findings to specific levels of arousal, e.g. low, moderate or high. This is in keeping with other reports that physiologic changes and subjective sexual arousal are not always associated. The use of only psychogenic stimuli may have affected the level or capacity of arousal attained.

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REFERENCES

1. Laumann EO, Paik A, Rosen RC. Sexual dysfunction in the United States: prevalence and predictors. *JAMA* 1999;281:537–44

2. Simons JS, Carey MP. Prevalence of sexual dysfunctions: results from a decade of research. *Arch Sex Behav* 2001;30:177–219
3. Berman JR, Berman L, Goldstein I. Female sexual dysfunction: incidence, pathophysiology, evaluation, and treatment options. *Urology* 1999;54:385–91
4. Bachmann GA. Influence of menopause on sexuality. *Int J Fertil Menopausal Stud* 1995;40:16–22
5. Lavoisier P, Aloui R, Schmidt MH, et al. Clitoral blood flow increases following vaginal pressure stimulation. *Arch Sex Behav* 1995;24:37–45
6. Tan IL, Stoker J, Zwamborn AW, et al. Female pelvic floor: endovaginal MR imaging of normal anatomy. *Radiology* 1998;206:777–83
7. Togashi K, Nakai A, Sugimura K. Anatomy and physiology of the female pelvis: MR imaging revisited. *J Magn Reson Imaging* 2001;13:842–849
8. McCarthy S. Magnetic resonance imaging of the normal female pelvis. *Radiol Clin North Am* 1992;30:769–75
9. Baudouin CJ, Soutter WP, Gilderdale DJ, et al. Magnetic resonance imaging of the uterine cervix using an intravaginal coil. *Magn Reson Med* 1992;24:196–203
10. Tunn R, DeLancey JO, Quint EE. Visibility of pelvic organ support system structures in magnetic resonance images without an endovaginal coil. *Am J Obstet Gynecol* 2001;184:1156–63
11. Deliganis AV, Maravilla KR, Heiman JR, et al. Dynamic MR imaging of the female genitalia using MS-325: initial experience evaluating the female sexual response. *Radiology* 2002;225:791–9
12. Alzate H, Hoch Z. The “G Spot” and “Female Ejaculation”: a current appraisal. *J Sex Marital Ther* 1986;12:211–20
13. Hines TM. The G-spot: a modern gynecologic myth. *Am J Obstet Gynecol* 2001;185:359–62
14. Romanes GJ. *Cunningham's Textbook of Anatomy*, 11th edn. London: Oxford University Press, 1972
15. Stenchever M, Droegemueller W, Herbst AL, et al. *Comprehensive Gynecology*, 4th edn. St. Louis: Mosby, 2001
16. Dickinson RL. *Human Sex Anatomy*. Baltimore: The Williams and Wilkins Company, 1949
17. Williams PL et al. *Gray's Anatomy: The Anatomical Basis of Medicine and Surgery*, 38th edn. Edinburgh: Churchill Livingstone, 1995
18. Scott JR, ed. *Danforth's Obstetrics and Gynecology*, 6th edn. Philadelphia: J.B. Lippincott, 1990
19. O'Connell HE, Hutson JM, Anderson CR, et al. Anatomical relationship between urethra and clitoris. *J Urol* 1998;159:1892–7
20. Hollinshead WH, Rosse C. *Textbook of Anatomy*, 4th edn. Philadelphia: Harper and Row, 1985
21. Laan E, van Lunsen RH. Hormones and sexuality in postmenopausal women: a psychophysiological study. *J Psychosom Obstet Gynaecol* 1997;18:126–33
22. Masters W, Johnson VE. *Human Sexual Response*. Boston: Little, Brown and Company, 1966
23. Schultz WW, van Andel P, Sabelis I, et al. Magnetic resonance imaging of male and female genitals during coitus and female sexual arousal. *Brit Med J* 1999;319:1596–1600
24. Faix A, Lapray JF, Caldele O, et al. Magnetic resonance imaging of sexual intercourse: second experience in missionary position and initial experience in posterior position. *J Sex Marital Ther* 2002;28:63–76
25. Laufer RB, Parmelee DJ, Dunham SU, et al. MS-325: albumin-targeted contrast agent for MR angiography. *Radiology* 1998;207:529–38
26. Grist TM, Korosec FR, Peters DC, et al. Steady-state and dynamic MR angiography with MS-325: initial experience in humans. *Radiology* 1998;207:539–44

Current knowledge on this subject

- Knowledge on female genital response during sexual arousal is limited because of a lack of research, inaccurate descriptions in textbooks, and the inability to measure genital structures objectively, non-invasively and without distortion.

What this study adds

- an in-depth examination of the organs within the female pelvis during sexual arousal
- objective documentation of the dimensional and blood flow changes that occur

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