REVIEWS

The Clitoral Complex: A Dynamic Sonographic Study

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ABSTRACT

Introduction. The existence of the G-spot remains controversial partly because no appropriate structure and innervation have been clearly demonstrated in this pleasurable vaginal area. Using sonography, we wanted to visualize the movements of the clitoris and its anatomical relationship with the anterior wall of the vagina during voluntary perineal contraction and vaginal penetration without sexual stimulation.

Aim. The aim of this presentation is to provide a dynamic sonographic study of the clitoris and to describe the movements of the quiescent clitoral complex during a voluntary perineal contraction. We aim to visualize the mechanical consequences of the pressure of the anterior vaginal wall with women who claim to have a special sensitivity of the G-spot area and vaginal orgasm. Histology and immunohistochemistry of the G-spot and other female genital tissues are beyond the scope of this study and have not been discussed.

Method. The ultrasounds were performed in five healthy volunteers with the Voluson® General Electric® Sonography system (GE Healthcare, Zipf, Austria), with a 12-MHz flat probe, and with a vaginal probe. We used functional sonography of the quiescent clitoris with voluntary perineal contractions and with finger penetration without sexual stimulation.

Main Outcome Measures. We focused on the size of the clitoris (raphe, glans, and clitoral bodies) and of the length of the movements of the clitoris during voluntary perineal contractions.

Results. The coronal planes during perineal contraction and finger penetration demonstrated a close relationship between the root of the clitoris and the anterior vaginal wall.

Conclusions. We suggest that the special sensitivity of the lower anterior vaginal wall could be explained by pressure and movement of clitoris' root during a vaginal penetration and subsequent perineal contraction. The G-spot could be explained by the richly innervated clitoris. **Foldes P, and Buisson O. The clitoral complex: A dynamic sonographic study. J Sex Med 2009;6:1223–1231.**

Key Words. G-spot; Clitoris; Root of the Clitoris; Pelvic Contraction Reflex

Introduction

The G-spot's role in vaginal orgasm [1] remains controversial: Is it a gynecological myth [2], a mystery, an anatomical or functional structure? The variability among thought-leaders makes research difficult [3,4]. Gravina et al. noticed that "physical difference should be taken into account as a source of physiological variability in female sexual response" [5]. Alternatively, each healthy woman has what O'Connell et al. have recommended calling: the "clitoral complex," analogous to the penis in men [6]. Why then do some women have difficulties achieving vaginal orgasm if every woman supposedly had an equivalent of a penis? They should in theory be able to have an orgasm. Gravina et al. found an interesting sonographic finding: women who have vaginal orgasm have a thicker urethro-vaginal space than those who do not [5]. But is this thicker space really a cause of the vaginal orgasm? Or is it an effect of the training of the perineal muscles so strongly involved in this type of orgasm?

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Using a sonographic examination of the quiescent clitoris rather than magnetic resonance imaging (MRI) [6,7] we used functional imaging to explore the topic in greater depth. Our purpose was to demonstrate that all the components of the clitoris move under a perineal contraction. We also aimed to demonstrate that vaginal penetration and a reflex perineal contraction tightly narrow the distance between the root of the clitoris (internal clitoris) and the distal anterior vaginal wall. From a mechanical point of view, if the root of the clitoris is related to the anterior vaginal wall, why would it not play a part in vaginal pleasure? Histology and immunohistochemistry of the G-spot and other female genital tissue are beyond the scope of this study and have not been discussed.

Methods

Five healthy, normal, 34-year-old women agreed to participate in this study. The women were heterosexual and sexually active. They had no history of gynecological diseases or surgery, and no medical condition that might alter sexual function. None used contraception or medication of any kind. They had no history of alcohol or drug abuse. No previous urodynamic and neurological evaluation had been undertaken. The sonographic examinations were performed from day 4 to day 12 of the menstrual cycle because clitoral modifications have been demonstrated during the normal menstrual cycle [8]. The Female Sexual Function Index questionnaire (results ranged from 27 to 32) showed no evidence of sexual dysfunction [9]. None of them reported having fluid release with their orgasms, but all of the volunteers claimed to have vaginal orgasm during coitus without external clitoris stimulation. This study was in accordance with the Declaration of Helsinki (2000) of the World Medical Association and was submitted to our local Ethical Committee (Hospital Saint-germain-en-Laye Poissy). After detailed explanation of procedures, a written informed consent was obtained from each subject. The ultrasound studies were performed with the Voluson® General Electric® Sonography system, and a 12-MHz flat probe was used. The volunteers were in a gynecological position. To ensure good skin contact, the vulva was covered with a sufficient quantity of sonographic gel to avoid possible interference from air between the labia. The probe was placed on top of the vulva with a coronal, transversal, orientation to obtain coronal and transversal planes. The probe was placed sagittally on the majora labia to obtain a sagittal scan. An echo-scan was found to provide a fine anatomy of the clitoris and had the advantage of visualizing the displacement of the structures during movement or perineal contractions in real-time, which is impossible with MRI or autopsy studies. Sonography was performed on the clitoris, and the women were asked to make a voluntary perineal contraction. Then, they were asked to press their most pleasurable anterior vaginal area with their own finger to create a displacement of the vaginal wall, but not enough to provoke sexual stimulation. In a gynecological position, it is typically easier for a woman to press her own G-spot with her finger, and it is easier for the sonographer to place the probe on the vulva (easier than with a dildo) to obtain a coronal view of the clitoris. To rule out the possibility of an artefact, we practiced a sonographic sagittal plane with an echoic vaginal marker with one of the volunteers (a wet tampon because it was difficult with the volunteer's finger), and it confirmed the result of the coronal plane. However, a further comparative study with sonographic planes and autopsies cuts is planned.

Results

Information was collected with a sonographic examination of the clitoris [10]. The coronal plane was the most informative [7,10]. It was obtained by tilting the vaginal probe to the front of the clitoris, revealing the clitoris root. The clitoris roots are made of two clitoral bodies and two bulbs below them (Figure 1A–C). A four-dimensional (4-D) reconstruction permits a surfacing of the clitoris and displays very well the double vault of the clitoris (Figure 1D). Without stimulation, it was difficult to visualize and measure the bulbs as they are limited by a delicate membrane markedly different from the thick capsule surrounding the clitoral body [11,12]. Their thickness is variable at different levels. Together they form a double vault above the vaginal plane. Beneath the summit of the vault, the urethra plane could be visualized at the anterior face of the vagina, which appeared like a hypoechogenic area in our experience (Figure 2A, B) and which was particularly easily seen on a 4-D view (Figure 1D). A sagittal scan of the clitoris was performed by placing the probe vertically on the labia majora. It showed a long and well-defined hypoechoic structure following the ischiopubic branch. At the top of the labium minus, the clitoral body made a forward angle and joined the contrololateral clitoral body to form the raphe. At the end

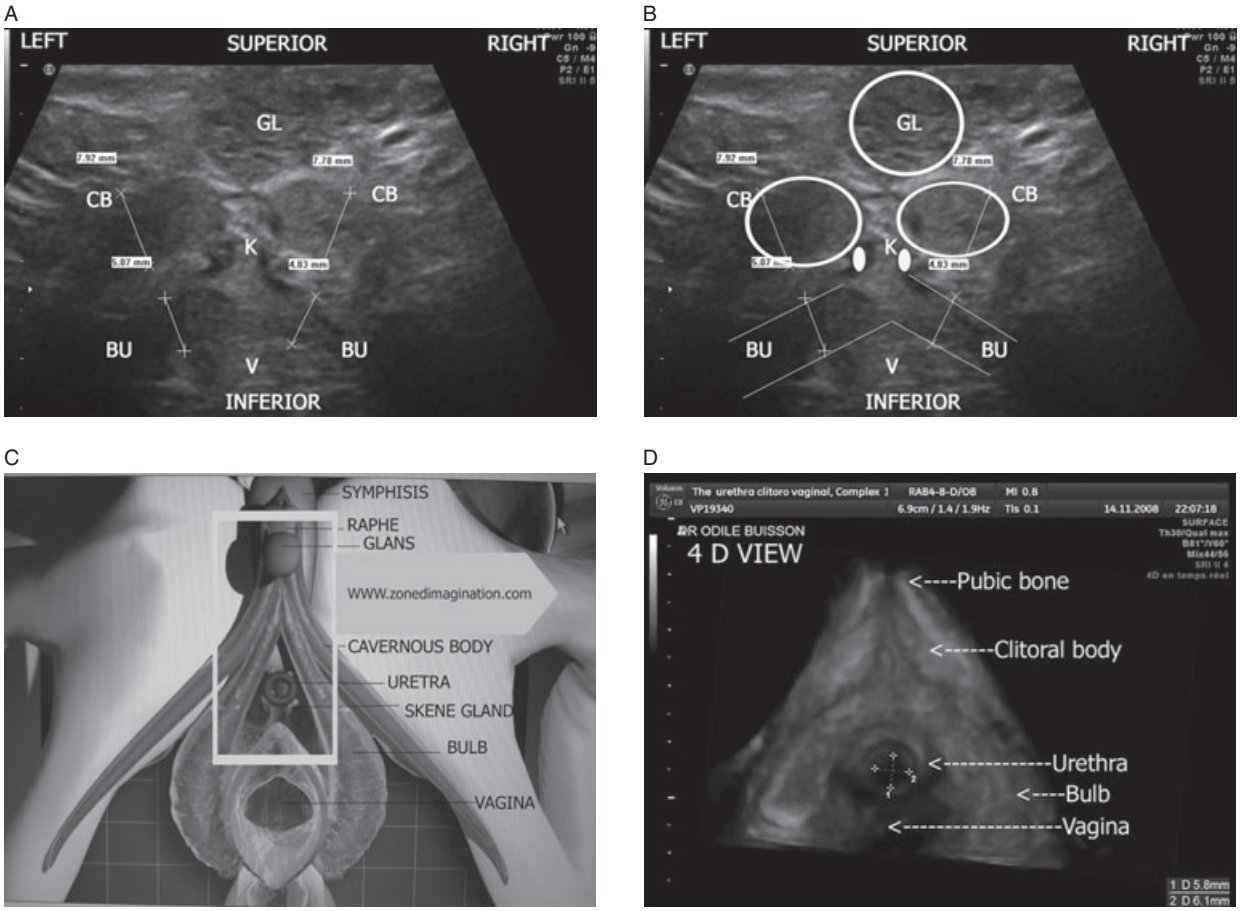

Figure 1 (A–C) Coronal section of the root of the clitoris. (D) One-dimensional view of the coronal section of the clitoral complex. GL = glans; CB = clitoral body; BU = bulb; K = Kobelt plexus; V = vagina.

of the raphe in a more caudal location, the glans was clearly visualized (Figure 3A–C). In our series, on the sagittal section, the measurements of the glans ranged from 82 to 128 mm^2, and the measurements of the raphe ranged from 12 to 20 mm (Table 1). However, an accurate placement of the cursor was sometimes difficult because the sonographic probes were not designed for the clitoris.

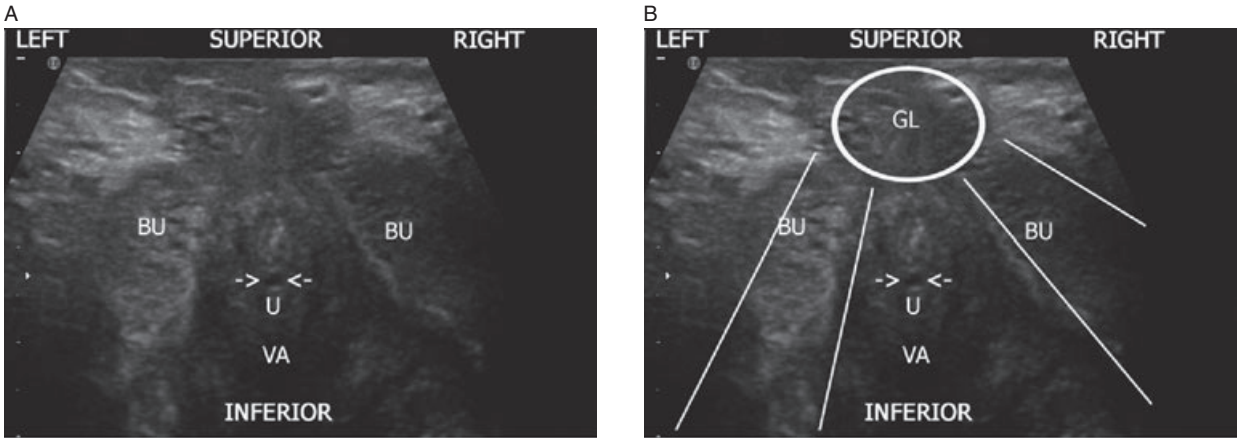

Figure 2 (A, B) Coronal section of the bulbs. BU = bulb; VA = vagina; U = urethra; GL = glans.

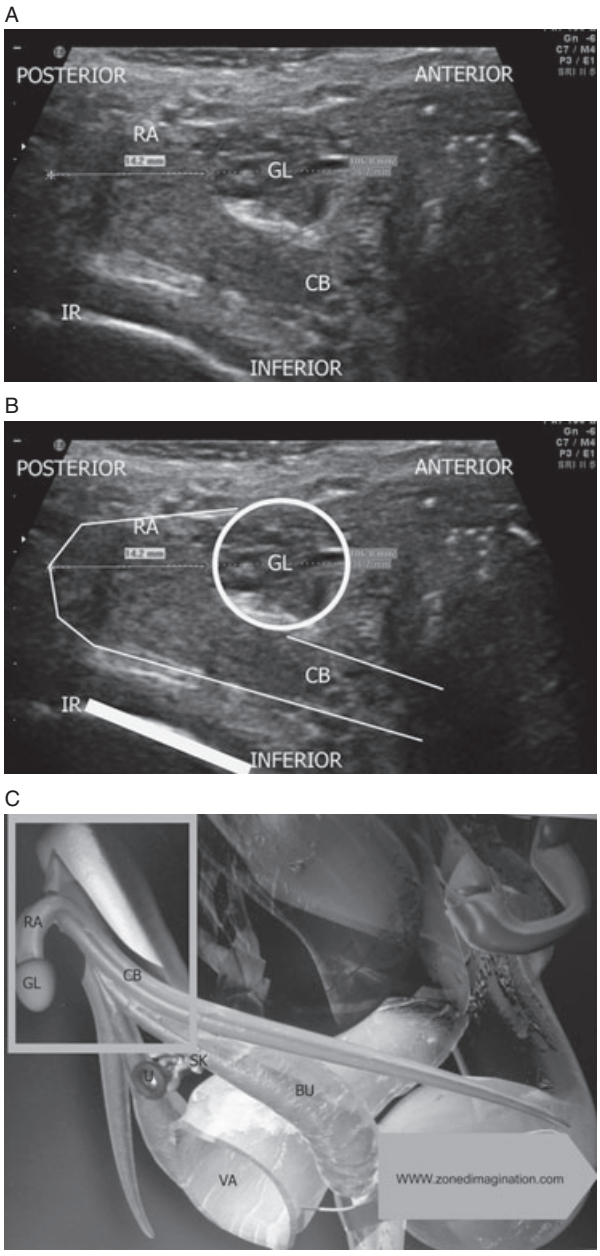

Figure 3 (A–C) Sagittal section of the clitoral body. GL = glans; CB = clitoral body; RA = raphe; IR = ischio rami; SK = Skene glands; U = urethra; BU = bulb; VA = vagina.

The weight of the probe might have created an imaging distortion, especially for the glans, which is easily crushed and has less defined borders because of its proximal position in the ultrasound array. However, the measurements of this little series were not intended as a standard value. However, for future improvement, it would be interesting to convince an ultrasound company to design and manufacture a clitoris probe: a light, small, microconvex, high-frequency, linear probe. The cross-section of the clitoris was made possible by placing the probe transversally at the top of the vulva. The plane of the two clitoral bodies were well defined (Figure 4A, B). They joined on the median line and formed the raphe (Figure 5A, B). Anterior to the raphe, in the medium line, a lacunary and vascular structure was visualized: the glans (Figures 3A and 4A). We began our functional studies by asking the patients to make voluntary pelvic contractions. During the contractions, sonographic movements of the clitoris were demonstrated. On the coronal section, the clitoral bodies had a descending movement in our series. The length of the movements ranged from 2.5 to 5 mm (Table 2); the obtuse angle formed by the two clitoral bodies decreased. The decrease in the angle ranged from 13° to 87° (Figure 6A, B). On the sagittal section, the clitoral body seemed to slide down (Figure 7A, B) while the raphe seemed to be pushed in an anterior direction. The angle between the clitoral body and the glans increased (Figure 7A, B). On the cross-section, the two clitoral bodies seemed to telescope strongly pushing up the glans (Figure 8A, B). The raphe moved anteriorly. The length of the movement ranged from 1.6 to 5.75 mm (Figure 9A, B). The women were then asked to press with their fingers on their most pleasurable anterior vaginal area. We observed that the double vault of the clitoris was close to the area marked by the echogenicity of the finger [10]. The simple penetration of the finger created a perineal contraction reflex, which generated a movement of the double vault toward the

Table 1 Measurements of the clitoris

	Measures glans (mm)	Surface glans (mm^2)	Circumference glans (mm)	Measures clitoral bodies (mm)	Measures glans (mm)	Surface glans (mm^2)	Circumference glans (mm)	Measures clitoral body (mm)	Measures raphe (mm)
Case 1	12 × 15	144	43	7/7	11 × 14	107	37	6	14
Case 2	9 × 18	114	41	4/5	9 × 17	128	43	5	14
Case 3	12 × 16	141	44	5/5	10 × 19	82	36	5	19
Case 4	10 × 11	92	35	4/4	8 × 15	92	35	6	20
Case 5	14 × 14	131	41	4/5	9 × 16	104	37	4	12
	Transversal scan			→←			Sagittal scan		

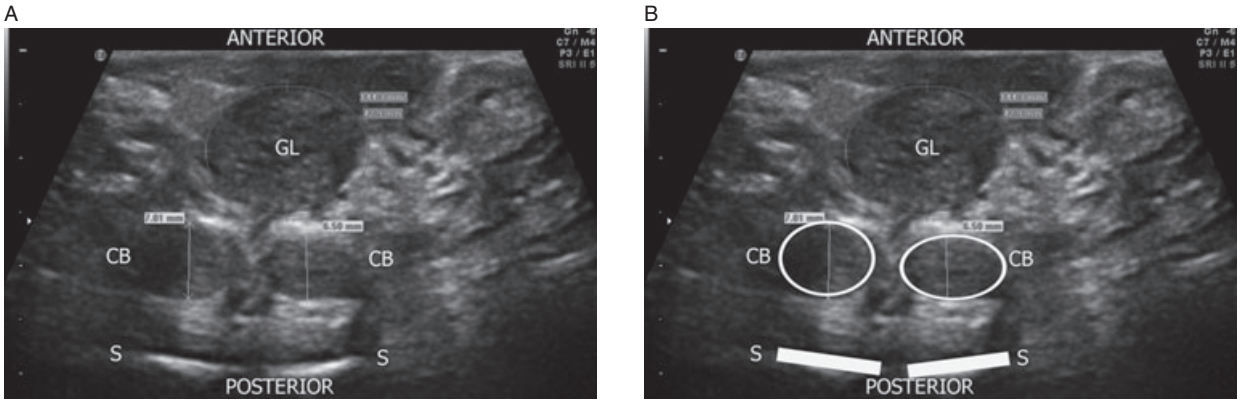

Figure 4 (A, B) Cross-section of the clitoral bodies and the glans. GL = glans; CB = clitoral body; S = symphisis.

finger marker (Figure 10A, B). With one volunteer, we reproduced the same effect with a sagittal plane, but with a different echoic marker (wet tampon), because using the volunteer's finger as a vaginal marker of the sagittal view had revealed to be technically more difficult. On the sagittal scan, the root of the clitoris is seen descending and making contact with the anterior vaginal wall. This allows us to rule out the possibility of an artefact, because coronal and sagittal plane were coherent: there was an increasing proximity between the root of the clitoris and the so called "G-spot" (Figure 11).

Discussion

Ultrasound (2-D and 4-D) is a very useful, but highly underestimated, tool to conduct dynamic images study of the female genitalia. Ultrasound demonstrated that under a perineal contraction, the five components of the clitoris (glans, raphe, bodies, crura, and bulb) move in a certain way. The

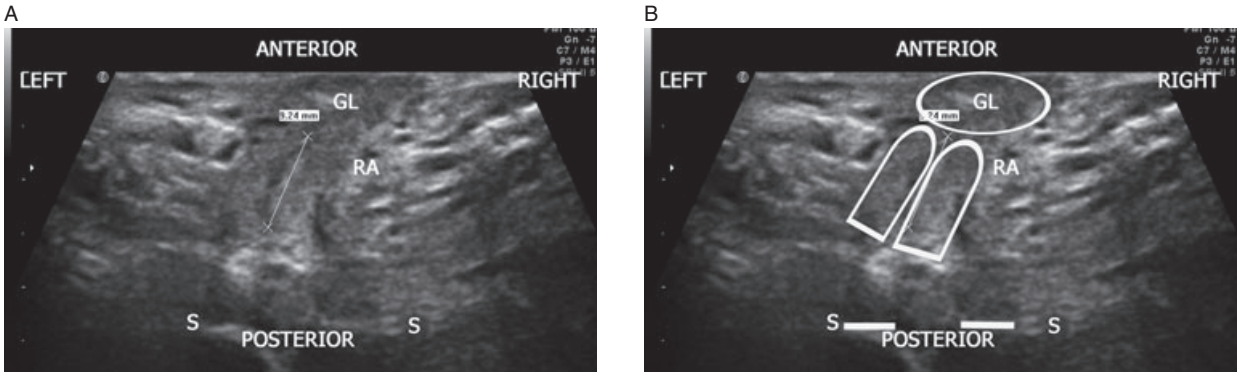

Figure 5 (A, B) Cross-section of the raphe. GL = glans; RA = raphe; S = symphisis.

Table 2 Length of the movement of the clitoris under perineal contraction

Under perineal contraction	Transversal scan Raphe anterior movement	Sagittal scan Raphe clitoral body descending movement	Sagittal scan Increasing angle glans/clitoral body	Coronal scan Decreasing angle vault of the clitoral body
Case 1	5.5 mm	5 mm	20°/46°	102°/89° (13°)
Case 2	1.85 mm	3.9 mm	10°/24°	170°/110° (60°)
Case 3	1.6 mm	4 mm	17°/26°	160°/73° (87°)
Case 4	4.18 mm	2.5 mm	11°/22°	135°/105° (30°)
Case 5	5.75 mm	5 mm	16°/41°	137°/106° (31°)

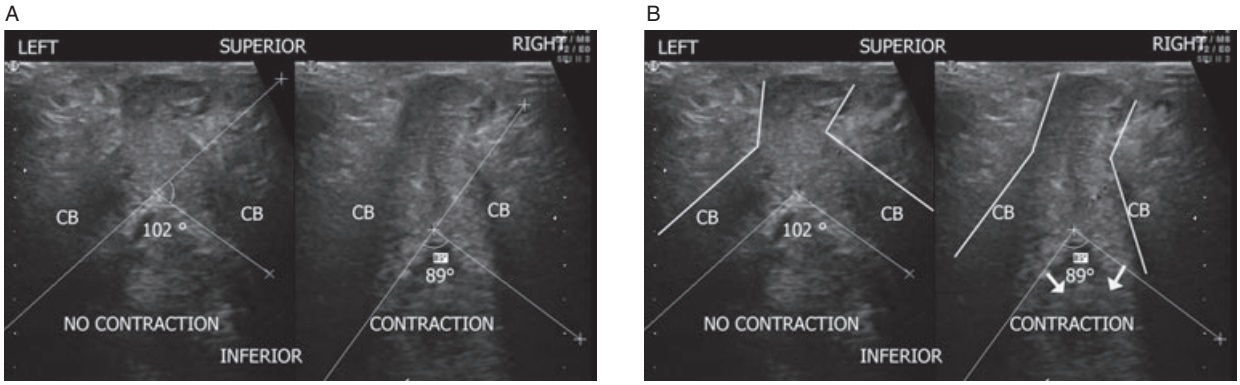

Figure 6 (A, B) Descending movement and decreasing angle of the double vault of the clitoris under contraction. CB = clitoral body.

clitoris is not an inert organ: the vault of the clitoris is descending, the body/glans angle and the angle of the double vault decrease, the raphe pushes the glans anteriorly and downward. The vaginal distension by penetration creates genital reflexes, which are the contraction of the pelvic muscles (contractions of the bulbocavernosus and ischiocavernosus striated muscles). This was termed "vaginocavernosus reflex," and it was demonstrated that the magnitude of contraction increases with the volume of vaginal inflation [13]. If the reflex perineal pelvic contractions narrowed

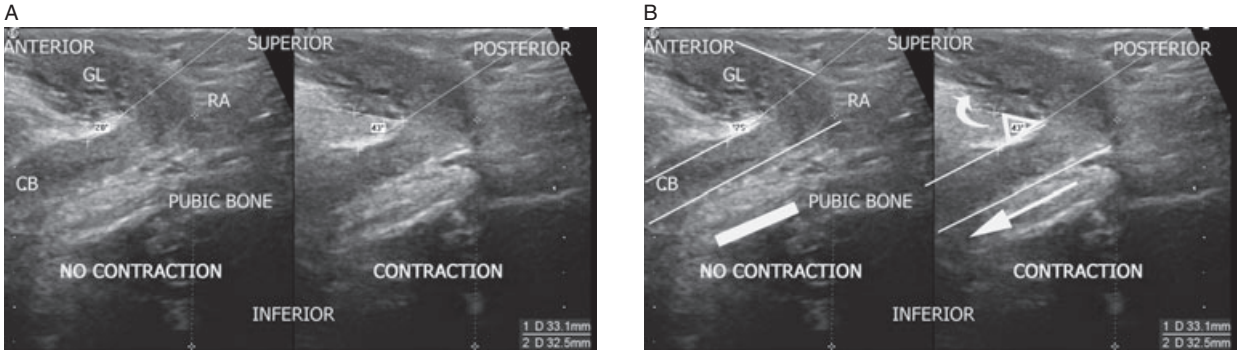

Figure 7 (A, B) Descending movement of the raphe and the clitoral body, and increasing clitoral body/glans angle under contraction. GL = glans; CB = clitoral body; RA = raphe.

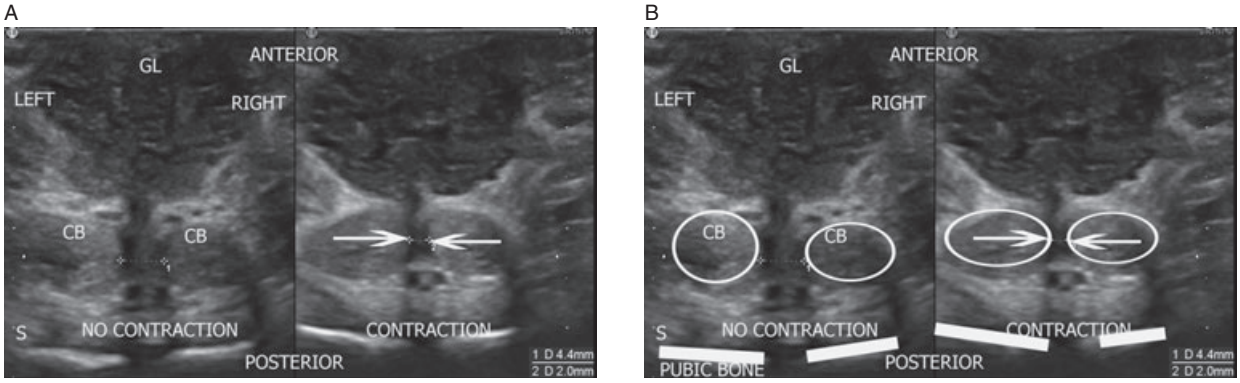

Figure 8 (A, B) Telescoping of the clitoral bodies under contraction. GL = glans; CB = clitoral body; S = symphisis.

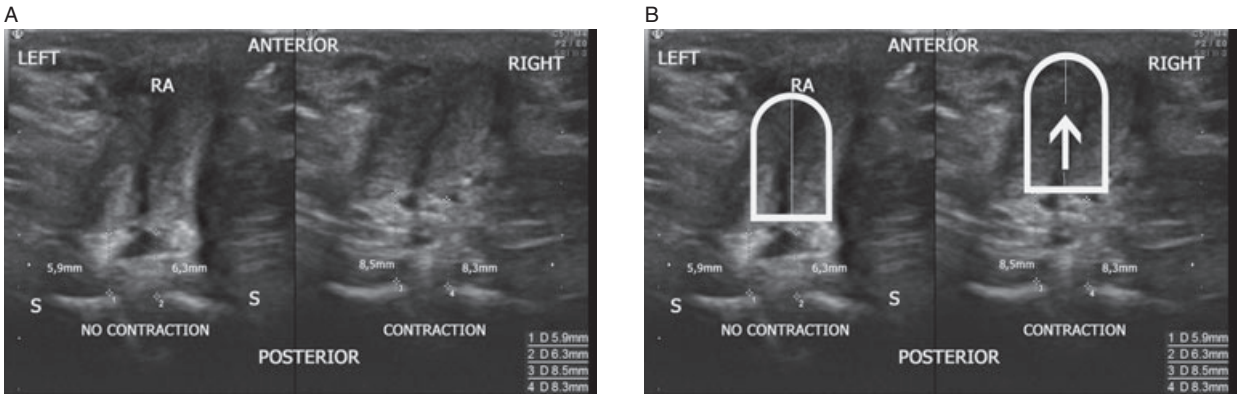

Figure 9 (A, B) Anterior movement of the raphe under contraction. RA = raphe; S = symphisis.

the vaginal orifice [13], it also generated a descending movement of the clitoris [10]. Shafik hypothesized that during pelvic contraction, the fibers crossing over the dorsum of the clitoris potentiate glans' erection through compression of the dorsal vein of the clitoris, and through compression of the corpus and bulbous erectile tissue [13], however, except for the angle modification, we did not notice changes in the measurement of the glans during a contraction (Figure 9A, B). Ultrasound also permits visualization of the clitoris during vaginal penetration—a more difficult feat with an MRI. The patient located her own G-spot with her finger, the echoes of the finger were found at close proximity to the clitoris root, and the pressure movement of the finger displaced the clitoris. A reflex or a voluntary pelvic contraction, subsequent to a vaginal penetration, generates a series of neuromuscular mechanisms that bring the root of the clitoris closer to the G-spot. With erotic stimulation [14–16], neuromuscular reflex [13,17] and vasomotor events have been found. We suggest that these events could increase the contact between the vagina and the richly innervated and congestive clitoris. The root of the clitoris (internal clitoris) could explain the pleasurable area of the G-spot. This fact is important because the poor innervation of the vagina is the usual argument for those who have denied the existence of the G-Spot. Thus D'amati et al. and Jannini et al. have separately demonstrated large differences in vaginal anatomy existing among individuals [3,4]. Pauls et al. has demonstrated in a prospective study yielding 110 biopsy specimens that vaginal nerves were located regularly throughout the anterior and posterior vagina: "there was no vaginal location with increased nerve density" [18]. MRI studies did not demonstrate periurethral tissues in signal intensity or size with arousal; consequently, Maravilla did not confirm this area as the G-spot [19,20]. In our small series, no glandular structure (Skene's gland

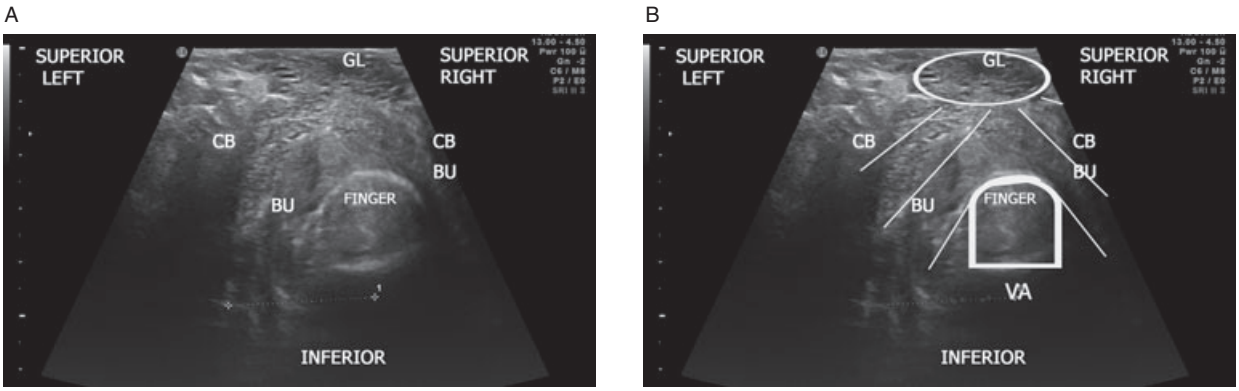

Figure 10 (A, B) Close relationship between marker of the anterior vaginal wall and the clitoris roots on coronal section. GL = glans; CB = clitoral body; BU = bulb; VA = vagina.

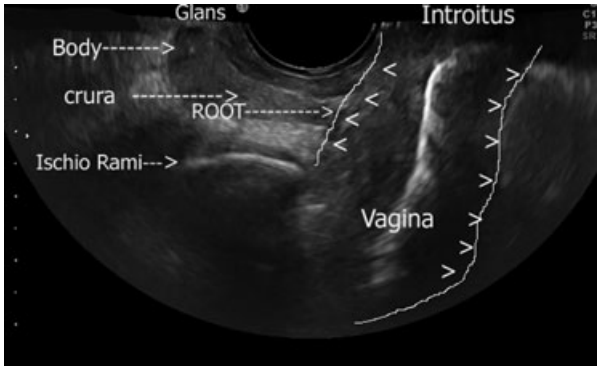

Figure 11 Close relationship between root of the clitoris and anterior vaginal wall on the sagittal section.

or prostatic structure) surrounding the urethra was visualized, but the studies were practiced without sexual stimulation, and it might be possible that the Skene's ducts were not seen because of the absence of an anechoic amount of expelled fluid. Wimpissinger et al. [21] found, in two women who ejaculated during orgasm, a sonographic structure consistent with a so-called female prostate. However, in response, some authors suggest a possible overinterpretation of this ultrasound data, and thought these sonographic structures could be the striated urethral sphincter. Recently, Gravina et al. measured the sonography of the urethrovaginal space, but could not visualize the anatomical structures within the urethrovaginal space and raised the question "what anatomical structure did we measure?" [5]. Until now, no sonographic prostatic tissue has been clearly demonstrated on quiescent genitalia. As none of the volunteers of our series had experienced female ejaculation, we could suppose either that their prostate were not developed sufficiently to be visualized or that their prostatic structures might appear in case of sexual stimulation (because of the hypoechogenocity of the prostatic secretions). There is no further evidence to assert that the vaginal pleasure is due to the so-called female prostate or the urethra, because "little is said in the literature or in textbooks about the innervation of the urethral glands or blood vessels" [22]. So, we suggest that the displacement of the anterior vaginal wall with the finger and the movement of the clitoris during reflex or voluntary perineal contraction could provoke a close contact between the internal root of the clitoris and the anterior vaginal wall. The special sensitivity of the lower anterior vaginal wall could be explained by the location of the clitoris at this particular moment. We hypothesize that during arousal, the engorgement and enlargement of the clitoral complex make the connection between the distal anterior vaginal wall and the root of the clitoris even stronger. Would internal-stimulated clitoris provide vaginal orgasm? Further research concerning the sonography of coitus should be undertaken to improve our understanding of vaginal orgasm [20].

Conclusions

The pleasurable area called the "G-spot" could be caused by contact of the internal clitoris and the anterior vaginal wall. The proximity of the contact could be enhanced by reflex perineal contractions and vasomotors events, which occur in the case of erotic stimulation. The position of the richly innervated clitoris could explain the special sensitivity of this area. It may partially solve the mystery of the innervation of the G-spot.

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Statement of Authorship

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Category 2

(a) Drafting the Article
Odile Buisson
(b) Revising It for Intellectual Content
Pierre Foldes; Odile Buisson

Category 3

(a) Final Approval of the Completed Article
Pierre Foldes; Odile Buisson

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