Original Research

# Reliability of shear-wave elastography (SWE) for investigating cervix elastic properties in normal and benign pathological situations

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*Background*: Our aim in this study is to evaluate the inter- and intraobserver correlation of the different shear-wave elastography (SWE) parameters (stiffness) in both control and pathological groups. *Methods*: Evaluations of cervical stiffness measurements were performed in 39 non-pregnant patients (21 cases without gynecological pathology and other 18 cases with cervical preinvasive cervical lesion susceptible to conization) aged between 18–65 years old, without vaginal infection other than HPV and without another gynecological pathology. We used SWE (shear modulus) endovaginal ultrasound. We performed the evaluation in the midsagittal plane of the uterine cervix with measurements at 0.5, 1 and 1.5 cm from external cervical OS, in both anterior and posterior cervical lips as well as the cervical canal. Sonoelastography was performed by two examiners, each one making two separate assessments of uterine cervical stiffness using SWE, in one single visit. Interclass correlation coefficients (ICC) with 95% CIs were used to assess intra and interobserver measurements repeatability. *Results*: We obtained an adequate intra and interobserver correlation (ICC 0.996–0.999) of stiffness in all anatomical sites both in normal and pathologic cervix ($p < 0.005$). The stiffness in normal cervix is from 38.28 $\pm$ 19.76 kPa vs to 61.58 $\pm$ 27.54 kPa in the pathological cervix. *Conclusion*: The SWE has an adequate intra and interobserver correlation for its use in evaluating both normal and pathological cervix.

*Keywords*

Shear-wave elastography; Cervical pathology; Cervical stiffness; Reproducibility

## 1. Introduction

Cervical cancer (CC) is the second most common malignancy in women worldwide after breast cancer [1]. Its incidence and mortality rate have decreased since the implementation of widespread cervical cancer screening using cervical cytology and/or human papillomavirus (HPV) testing [2]. Although knowledge of HPV has advanced, cervical cytology remains the mainstay of cervical cancer screening, subsequently requiring the use of colposcopy and biopsy as the next diagnostic steps [3]. There has been an important advance in the definition of colposcopy standards and terminology in the recent years, as well as in the creation of consensus guidelines for cancer precursors [3–5]. However, colposcopy still depends on examiner's experience, and it is known that the agreement in one step between colposcopy and general histology is not high [6, 7]. This leads us to an approximate underdiagnoses rate of one third of cases with high grade preinvasive cervical lesion (HSIL) [8]. Thus, the identification capacity of colposcopy and cervical biopsy for preinvasive or premalignant lesions is quite limited, which makes the introduction of new diagnostic methods, such as sonoelastography, a necessity.

Shear-wave elastography (SWE) is a new US technology that can quantitatively and qualitatively evaluate the stiffness of tissues [9, 10]. We know that elasticity is a characteristic of tissues, susceptible to change during different pathological and physiological processes and that any new formation with high stiffness is associated with a higher risk of malignancy [11]. Elastography, which has come to be known as the "visual palpation method", is already widely used in different organs, such as the liver or breast [12, 13]. However, its usefulness in the evaluation of uterine cervical pathology is very limited [14–19]. Some authors have begun to use sonoelastography to evaluate cervical uterine pathology [14] using compression elastography (strain elastography, SE); however, this method presents some issues for the evaluation of the cervix, given the lack of surrounding tissue, and the unreliability to quantify, hence reproduce, the transducer compression applied to the cervix [20]. SWE does not present these limitations, which makes it a promising technique for assessing the stiffness of the uterine cervix in pathological situations [21].

Our working group has studied the evaluation of the normal cervix using SWE, concluding that the wave transmission speed and stiffness of the uterine cervix evaluated by SWE varies according to the cervical lip and depth of the evaluation as well as according to the parity and age of the patient [22].

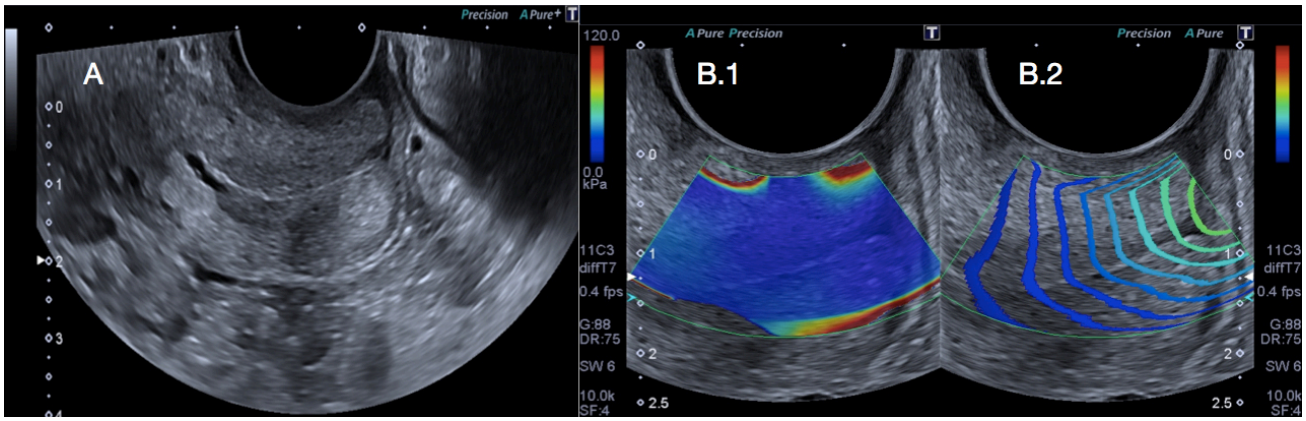


**Fig. 1. Ultrasound image of the uterine cervix in B-mode and SWE**. (A) Sagittal section of the uterine cervix in mode (B). (B.1) Shear wave elastography (SWE) of the uterine cervix. (B.2) Parallel lines are required in the study area in the wave front propagation map.

The literature shows several studies of SWE, which obtained acceptable intra and interobserver reproducibility values in most of them [23–25], although these studies applied this technique in organs with a more widespread use of SWE. Therefore, there is little work on intra and interobserver variability in the field of cervical SWE, mostly finding investigations carried out during pregnancy with favorable results [26–29]. For this reason, we propose to evaluate intra and interobserver variability in the assessment of the uterine cervix using SWE in both control and pathological groups.

## 2. Methods

We conducted a prospective observational cohort study with 39 non-pregnant women between February 2018 and September 2018 at the Valme University Hospital. Ethical approval was given by the Biomedical Ethics Committee of the Junta of Andalusia (1001-N-18), Spain, and informed consent was obtained from all patients.

### *2.1 Subjects*

***Group of pathological patients* (*PG*)**: patients with cervical pathology (diagnosed by cytology, colposcopy and cervical biopsy) with indication of cervical conization [2, 30], only cases of preinvasive lesion, both high-grade (HSIL) and low-grade (LSIL) are included.

Once the diagnosis of uterine cervical lesion and indication of the cervical conization as treatment are made, and only if the patient is between 18 and 65 years old, she is invited to participate in the study. In case of acceptance of participation in the study, after the informed consent has been signed, a transvaginal ultrasound in B mode prior to sonoelastography was performed in the gynecological ultrasound unit of the H.U.Valme.

***Group of normal patients* (*Normal G*)**: patients who came to the hospital for routine heath check-ups. Patients were selected using a randomization table, by age (older or younger than 35 years) and parity (nulliparous or multiparous). The patients studied were women aged between 18 and 65 years without previous cervical pathology (normal cytology in the last year) and without the presence of vaginal infection (other than HPV infection). Patients signed the informed consent. In a single visit, the technique to be performed was explained to the patients, and they were invited to participate in the study; a complete gynecological examination was performed, including transvaginal ultrasound in B mode prior to sonoelastography.

We considered exclusion criteria in both cohorts to be patients under 18 and over 65 years old, pregnant patients, patients who present a vaginal infection other than HPV, and patients who present another gynecological pathology (myoma or functional or organic adnexal pathology) that would prevent perform a direct sonographic evaluation of the uterine cervix.

### *2.2 Imaging techniques*

Sonoelastography evaluation was performed by two examiners with more than 5 years of experience and exclusive dedication to gynaecologinal ultrasound, and with specific training in sonoelastography. A Toshiba Aplio 500 PlatinumTM ultrasound scanner (Canon Medical systems, Tochigi, Japan) with an 11C3 PVT-781VTE was used. Before the ultrasound assessment, recommended settings were applied [22, 27, 28]. The evaluation of stiffness by SWE (shear modulus) is carried out in the midsagittal plane, without compression of the uterine cervix, following Canon instructions for an appropriate wave propagation [22] (Fig. 1).

Three measurements were made in each study area to obtain main and standard deviation of stiffness (Kilopascals) of the tissue at 0.5, 1 and 1.5 cm from the external cervical os, in both the anterior and posterior cervical lips as well as the cervical canal (Fig. 2).

All patients were evaluated in one single visit. The first examiner took the first measurements using SWE (measures 1), and five minutes later, also did the second examiner. Two hours after the first assessment, both examiners take second measurements, each five minutes apart (measures 2).

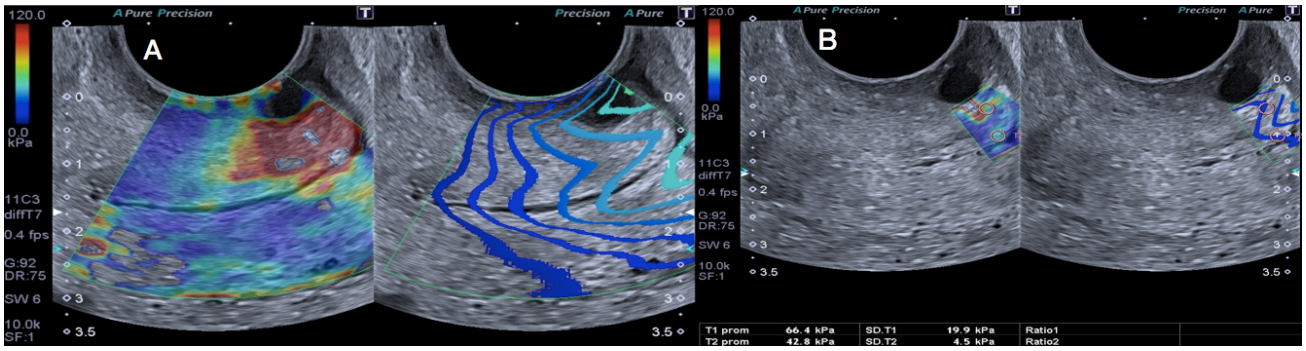


**Fig. 2. Evaluation of the cervix by SWE.** (A) Uterine Shear-wave elastography (SWE) in case of preinvasive cervical lesion (high-grade, HSIL) with the presence of areas of high stiffness (red). (B) SWE evaluation of uterine cervix with quantitative measurement of wave propagation stiffness and speed at 0.5 cm in the anterior lip, cervical canal.

**Table 1. Epidemiological characteristics of study population. Data are given as mean ± SD or n (%).**

| Study group | Total n = 39 | | | Normal n = 21 | | | Pathological n = 18 | | | *p* |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | 37.4 ± 11.96 | | | 37.9 ± 13.1 | | | 36.9 ± 10.8 | | | 0.816 |
| BMI | 24.6 ± 4.04 | | | 24.8 ± 4.1 | | | 24.5 ± 4.0 | | | 0.844 |
| | Yes | No | | Yes | No | | Yes | No | | |
| Smoker | 17 (43.6%) | 22 (56.4%) | | 7 (33.3%) | 14 (66.7%) | | 10 (55.6%) | 8 (44.4%) | | 0.206 |
| | 20–34 | 35–49 | 50–65 | 20–34 | 35–49 | 50–65 | 20–34 | 35–49 | 50–65 | |
| Age group | 19 (48.7%) | 12 (30.8%) | 8 (20.5%) | 9 (42.9%) | 7 (33.3%) | 5 (23.8%) | 10 (55.6%) | 5 (27.8%) | 3 (16.7%) | 0.719 |
| | Nulliparous | Primiparous | Multiparous | Nulliparous | Primiparous | Multiparous | Nulliparous | Primiparous | Multiparous | |
| Parity | 18 (46.2%) | 6 (15.4%) | 15 (38.5%) | 11 (52.4%) | 2 (9.5%) | 8 (38.1%) | 7 (38.9%) | 4 (22.2%) | 7 (38.9%) | 0.517 |
| | Amenorrhea | 1st phase | 2nd phase | Amenorrhea | 1st phase | 2nd phase | Amenorrhea | 1st phase | 2nd phase | |
| Menstrual cycle phase | 8 (20.5%) | 16 (41.0%) | 15 (38.5%) | 6 (28.6%) | 5 (23.8%) | 10 (47.6%) | 2 (11.1%) | 11 (61.1%) | 5 (27.8%) | 0.061 |
| | Yes | No | | Yes | No | | Yes | No | | |
| Menopause | 6 (15.4%) | 33 (84.6%) | | 4 (19.0%) | 17 (81.0%) | | 2 (11.1%) | 16 (88.9%) | | 0.667 |
| | Normal/LSIL | HSIL | | Normal | LSIL/HSIL | | LSIL | HSIL | | |
| Citology | 27 (69.2%) | 12 (30.8%) | | 21 (100%) | 0 (0%) | | 6 (33.3%) | 12 (66.7%) | | — |

### *2.3 Statistical analysis*

The statistical analysis was carried out using IBM SPSS Statistics software version 26 (IBM, Armonk, NY). The quantitative variables were summarized with means and standard deviations or, in the case ofasymmetrical distributions, with medians and percentiles ($P_{25}$ and $P_{75}$) while percentages were used for qualitative variables. The intraobserver and interobserver concordance was analysed using intraclass correlation coefficients and their 95% confidence intervals, including the mean and confidence interval for the differences of the intra-observer and interobserver measurements. For qualitative variables, we used Cohen's Kappa concordance coefficients and their 95% confidence intervals [31]. The sample size was determined in order to estimate the intraclass correlation coefficient as a measure of reliability between measurements performed by different methods on the same subjects. For the calculation of this size, we assume an expected intraclass correlation coefficient of 0.95 in the worst case scenario (obtained from previous experience), a confidence level of 95%, an accuracy or amplitude of the range of 0.07 and performance of 2 replicates/observers per measurement. Taking all of this into account, the evaluation of 39 cases is needed.

## 3. Results

We evaluated 39 patients using cervical SWE (18 patients with pathological cervix (Pathological group) and 21 normal patients (Normal group)).

The mean age of all the patients evaluated was 37.4 years with a standard deviation of 11.9 years, being 37.9 ± 13.1 years in the Normal group (NG) and 36.9 ± 10.8 years in the Pathological group (PG). The rest of the epidemiological variables analyzed in our study can be seen in Table 1.

Within the PIL group, 6 (33.3%) patients had an LSIL cytology and 12 (66.7%) had a HSIL cytology. None of the epidemiological variables in our study reached statistical significance.

To study the inter and intra-observer variability, measurements of the same patients were carried out by two experienced explorers. This measurements of stiffness in the anterior lip, cervical canal and posterior lip at 0.5, 1 and 1.5 cm from the external os by both explorers are detailed in Table 2.

When stratifying the groups into normal (NG) and pathological (PG), we obtain the stiffness measures taken by both explores as shown in Table 3. In this table, we can also see the existing differences in stiffness between the NG and the PG (38.28 ± 19.76 vs 61.58 ± 27.54).

**Table 2. Evaluation of stiffness (kPa) assessed by shear wave elastography (SWE) of the total study population according to explorer. Data are given as mean ± SD.**

| | | | Stiffness | | | |
|---|---|---|---|---|---|---|
| | | | Explorer 1 (n = 39) | | Explorer 2 (n = 39) | |
| | | | 1st measure | 2nd measure | 1st measure | 2nd measure |
| | | | mean and SD | mean and SD | mean and SD | mean and SD |
| Anterior lip | 0.5 cm | Mean | 39.82 | 40.07 | 40.32 | 48.36 |
| | | SD | 36.74 | 36.47 | 36.48 | 59.32 |
| | 1 cm | Mean | 46.67 | 46.94 | 46.99 | 46.94 |
| | | SD | 37.03 | 37.08 | 37.12 | 37.21 |
| | 1.5 cm | Mean | 54.52 | 57.22 | 57.18 | 57.18 |
| | | SD | 45.94 | 46.37 | 46.32 | 46.43 |
| Cervical Canal | 0.5 cm | Mean | 48.64 | 48.9 | 47.7 | 46.94 |
| | | SD | 42.94 | 42.78 | 42.72 | 42.51 |
| | 1 cm | Mean | 53.83 | 53.34 | 54.72 | 54.13 |
| | | SD | 42.57 | 43.91 | 42.49 | 42.64 |
| | 1.5 cm | Mean | 62.56 | 63.92 | 64.02 | 63.06 |
| | | SD | 41.51 | 41.67 | 41.42 | 42.01 |
| Posterior lip | 0.5 cm | Mean | 35.22 | 35.83 | 35.63 | 35.88 |
| | | SD | 23.61 | 23.74 | 23.70 | 23.64 |
| | 1 cm | Mean | 46.34 | 45.96 | 46.04 | 45.94 |
| | | SD | 27.13 | 26.34 | 26.21 | 26.38 |
| | 1.5 cm | Mean | 46.34 | 47.57 | 47.55 | 47.42 |
| | | SD | 29.77 | 30.03 | 29.56 | 29.78 |

**Table 3. Evaluation of stiffness (kPa) assessed by shear wave elastography (SWE) for study groups (normal and pathological group) according to explorer. Data are given as mean ± SD.**

| | | | Stiffness | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Normal group 38.28 ± 19.76 | | | | Pathological group 61.58 ± 27.54 | | | |
| | | | Explorer 1 (n = 21) | | Explorer 2 (n = 21) | | Explorer 1 (n = 18) | | Explorer 2 (n = 18) | |
| | | | Measure 1 (a) | Measure 2 (b) | Measure 1 (a) | Measure 2 (b) | Measure 1 (a) | Measure 2 (b) | Measure 1 (a) | Measure 2 (b) |
| Anterior lip | 0.5 cm | Mean | 33.43 | 33.7 | 33.82 | 33.81 | 47.28 | 47.5 | 47.9 | 65.34 |
| | | SD | 29.33 | 29.56 | 29.25 | 29.37 | 43.55 | 42.85 | 43.08 | 79.28 |
| | 1 cm | Mean | 35.55 | 35.6 | 35.52 | 35.61 | 59.65 | 60.16 | 60.37 | 60.17 |
| | | SD | 21.77 | 21.63 | 21.53 | 21.51 | 46.65 | 46.6 | 46.73 | 46.98 |
| | 1.5 cm | Mean | 43.86 | 44.49 | 44.56 | 44.46 | 66.95 | 73.95 | 73.74 | 73.89 |
| | | SD | 32.25 | 32.55 | 32.54 | 32.53 | 56.49 | 56.76 | 56.76 | 56.91 |
| Cervical Canal | 0.5 cm | Mean | 33.42 | 33.08 | 31.49 | 30.19 | 65.56 | 66.48 | 66.62 | 66.48 |
| | | SD | 36.69 | 35.48 | 34.9 | 33.98 | 43.96 | 44.21 | 44.06 | 43.93 |
| | 1 cm | Mean | 37.14 | 35.11 | 37.66 | 37.32 | 73.31 | 74.61 | 74.62 | 73.75 |
| | | SD | 27.21 | 27.39 | 26.6 | 26.8 | 49.33 | 50.38 | 49.25 | 49.64 |
| | 1.5 cm | Mean | 43.35 | 45.31 | 45.16 | 43.33 | 83.9 | 84.61 | 84.97 | 84.98 |
| | | SD | 30.33 | 31.39 | 30.33 | 31.43 | 42.49 | 42.63 | 42.68 | 42.08 |
| Posterior lip | 0.5 cm | Mean | 31.05 | 31.65 | 31.16 | 31.7 | 40.09 | 40.71 | 40.85 | 40.76 |
| | | SD | 18.01 | 18.43 | 17.96 | 18.27 | 28.59 | 28.52 | 28.69 | 28.45 |
| | 1 cm | Mean | 40.45 | 40.81 | 40.9 | 41.03 | 53.21 | 52.71 | 52.79 | 52.38 |
| | | SD | 19.99 | 20.08 | 20.07 | 20.07 | 32.9 | 32.29 | 32.03 | 32.03 |
| | 1.5 cm | Mean | 40.92 | 42.7 | 42.35 | 42.49 | 52.37 | 53 | 53.32 | 52.91 |
| | | SD | 21.77 | 22.64 | 20.8 | 21.51 | 36.42 | 36.49 | 36.75 | 36.77 |

(a) First measure of the same explorer. (b) Second measure of the same explorer.

**Table 4. Evaluation of intra and interobserver correlation of the of stiffness assessed by shear wave elastography (SWE).**

| | Intraobserver correlation | | | | | | Interobserver correlation | | |
|---|---|---|---|---|---|---|---|---|---|
| | Explorer 1 | | | Explorer 2 | | | | | |
| Stiffness | ICC | CI (95%) | Significant difference ($p$) | ICC | CI (95%) | Significant difference ($p$) | ICC | CI (95%) | Significant difference ($p$) |
| Anterior lip | | | | | | | | | |
| 0.5 cm Total group | 0.999 | 0.998–1.000 | <0.0005 | 0.688 | 0.405–0.836 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 |
| 0.5 cm normal group | 0.999 | 0.999–1.000 | <0.0005 | 0.388 | -0.082–0.717 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 |
| 0.5 cm pathological group | 0.999 | 0.997–1.000 | <0.0005 | 0.559 | -0.178–0.835 | <0.0005 | 0.998 | 0.998–1.000 | <0.0005 |
| 1 cm total group | 0.999 | 0.998–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 | 0.997 | 0.997–1.000 | <0.0005 |
| 1 cm normal group | 0.999 | 0.997–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 |
| 1 cm pathological group | 0.998 | 0.997–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1.5 cm total group | 0.999 | 0.998–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1.5 cm normal group | 0.999 | 0.998–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 |
| 1.5 cm pathological group | 0.999 | 0.997–1.000 | <0.0005 | 0.998 | 0.997–1. 000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| Cervical canal | | | | | | | | | |
| 0.5 cm total group | 0.999 | 0.998–0.999 | <0.0005 | 0.997 | 0.995–0.999 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 |
| 0.5 cm normal group | 0.997 | 0.999–1.000 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 | 0.999 | 0.997–0.999 | <0.0005 |
| 0.5 cm pathological group | 0.999 | 0.997–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1 cm total group | 0.989 | 0.979–0.994 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1 cm normal group | 0.949 | 0.874–0.979 | <0.0005 | 0.999 | 0.998–0.999 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 |
| 1 cm pathological group | 0.999 | 0.998–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1.5 cm total group | 0.999 | 0.999–1.000 | <0.0005 | 0.996 | 0.993–0.998 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1.5 cm normal group | 0.999 | 0.998–1.000 | <0.0005 | 0.987 | 0.968–0.995 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 |
| 1.5 cm pathological group | 0.999 | 0.998–1.000 | <0.0005 | 0.998 | 0.997–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| Posterior lip | | | | | | | | | |
| 0.5 cm total group | 0.999 | 0.997–1.000 | <0.0005 | 0.998 | 0.999–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| 0.5 cm normal group | 0.998 | 0.997–1.000 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| 0.5 cm pathological group | 0.998 | 0.997–1.000 | <0.0005 | 0.998 | 0.998–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| 1 cm total group | 0.999 | 0.997–1.000 | <0.0005 | 0.999 | 0.999–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| 1 cm normal group | 0.997 | 0.994–1.000 | <0.0005 | 0.996 | 0.994–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| 1 cm pathological group | 0.998 | 0.997–1.000 | <0.0005 | 0.998 | 0.996–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |
| 1.5 cm total group | 0.999 | 0.998–0.999 | <0.0005 | 0.999 | 0.998–0.999 | <0.0005 | 0.998 | 0.996–0.999 | <0.0005 |
| 1.5 cm normal group | 0.996 | 0.990–0.998 | <0.0005 | 0.996 | 0.991–0.999 | <0.0005 | 0.992 | 0.981–0.997 | <0.0005 |
| 1.5 cm pathological group | 0.996 | 0.993–1.000 | <0.0005 | 0.997 | 0.996–1.000 | <0.0005 | 0.999 | 0.998–1.000 | <0.0005 |

CC, Intraclass correlation coefficient; CI, Confidence intervals.

The intra and interobserver correlation of the SWE in the different anatomical regions was adequated ($p < 0.005$) in all three groups (total sample, pathological group, normal groups) as shown in Table 4.

## 4. Discussion

Our group has shown that SWE is a valid technique for the evaluation of the uterine cervix [22]. In this study, we intend to take a step further and evaluate the inter and intra-observer variability of this technique in order to evaluate its realibility.

Our study demonstrates that it is possible to objectively evaluate wave transmission stiffness in healthy and pathological cervix. Furthermore, we conclude in our work that the measurements obtained, by one single or two different observers for different regions of the uterine cervix in non-pregnant women are reliable and reproducible.

Several authors have evaluated the inter and intraobserver variability of elastography in the uterine cervix. Seol *et al.* [26] observed an intra and inter-observer variability of 0.838–0.887 and 0.901–0.988, respectively. Molina *et al.* [27] and Światkowska-Freund *et al.* [28] described similar findings, with values ranging between 0.70–0.92. Frutane *et al.* [29] even reported an intra and inter-observed variability of 0.91 and 0.96. All these findings are similar to our own results, thus one could argue that they do not provide any new information to the existing literature. However, all these previous works were carried out using strain elastography in pregnant women. In our study, we used shear-wave elastography (SWE), given that it is a more objective elastography technique [32], and we wanted to evaluate the intra and inter-observed variability in the evaluation of uterine cervix in non-pregnant women. Furthermore, we included both normal and pathological cervix in our study, observing that the intra and inter-observer variability of stiffness using SWE is adequate, and this technique could be used in the assessment of uterine cervix in non-pregnant women.

SWE has been successfully used to evaluate malignancy of the breast, liver, thyroid, or prostate, as malignant tumors have proven to be more rigid than benign ones [33–35]. However, in these studies, the rigidity of malignant tumors is compared to that of benign tumors within a generally homogeneous tissue such as the liver [36], unlike SWE in healthy cervix, which is limited by the lack of a homogeneous reference tissue [37] for comparison, as argued by Molina *et al.* [27]. This could make it difficult to establish a normal curve for a healthy cervix with which to compare pathological cervixes. Even so, we observe differences in the stiffness between the healthy and the pathological uterine cervix and the use of SWE could help the study of cervical pathology. Other authors had already obtained similar results using SE [14–16].

Thus, we consider that our study has its limitations, as listed: the small sample size; to have taken all stiffness measurements only in one single visit; to have used SWE, given that the assessment in heterogeneous tissues, such as the uterine cervix [37], is more complicated, as well as the lack of a normal curve of healthy uterine cervix defined by SWE.

Fruscalzo *et al.* [29], for their part, emphasize the need to standardize the technique to achieve acceptable variability values as tried to develop by our group. We believe that sonoelastography could be used in the future to assess the uterine cervix in non-pregnant women, and thus improve our diagnoses and management of preinvasive and invasive cervical lesions, as well as bring brand new information to the table, which stress the need for further studies in this regard.

## 5. Conclusions

The SWE has an adequate intra and interobserver correlation for its use in evaluating both normal and pathological uterine cervix in non-pregnant women.

## Author contributions

These should be presented as follows: LCP, JAGM and JAS designed the research study. RG performed the research. AFP analyzed the data. RG, AH, LC, JAGM and JAS wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

## Ethics approval and consent to participate

The study protocol was reviewed and approved by the Ethics Committee of Valme University Hospital (1001-N-18), and informed consent was obtained from all patients.


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## Conflict of interest

The authors declare no conflict of interest.

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