Dynamic MR of the pelvic floor: Influence of alternative methods to draw the pubococcygeal line (PCL) on the grading of pelvic floor descent

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ABSTRACT

Objective: To evaluate the impact of the pubococcygeal line (PCL) position on hiatal descent grading, comparing the method recommended by the official guidelines with the other two most common methods reported in literature.

Methods: Female patients prospectively included performed dynamic-MR (1,5 T) in supine position. Rectum and vagina were filled with ultrasound gel. MR protocol included TSE T2 weighted sequences on axial/sagittal/coronal planes and steady-state sequences (FIESTA) on midsagittal plane during three phases (rest, strain and defecation). On each phase, the posterior point of PCL was traced in the region recommended by the official guidelines (last coccygeal joint or PCLcc) and in the other two regions: coccyx's tip (PCLtip) and sacrococcygeal joint (PCLsc). The resulting grades of pelvic floor descent (according to HMO-System) were compared. Inter-reader and intra-reader agreement were evaluated.

Results: The final population consisted of 60 patients (56yy ± 10). No significant differences in grading were observed using PCLtip and PCLcc in all phases ($p = 0.3016/0.0719/0.0719$ during rest/strain/defecation). Using PCLsc, the grading was significantly overestimated compared to PCLcc in all phases ($p = 0.0041/0.0001/0.0001$ during rest/strain/defecation). Inter-reader and intra-reader agreement were significantly higher using PCLtip ($p < 0.05$).

Conclusions: PCLtip is a reliable and highly reproducible option to the official PCLcc to correctly grade the pelvic floor descent and could be used when the PCLcc is not clearly visible. The use of PCLsc overestimates the grading compared to the official PCLcc and should not be used to avoid wrong patients' management.

1. Introduction

Pelvic floor dysfunction (PFD) is a common disorder affecting around 24% of women in the general population [1]. It influences the woman's quality of life causing urinary and fecal incontinence, difficult defecation and pelvic pain and often requires surgical treatment [2]. Female sex and increasing age are considered the greatest risk factors [3]. Dynamic Magnetic Resonance (MR) of the pelvic floor is the only imaging modality that allows the simultaneous evaluation of all pelvic organs during the defecation. Therefore, it has emerged as technique to evaluate the PFD also because it provides an objective grading of this disorder [3,4]. The grading obtained during dynamic study of the dynamic MR exam is based on HMO classification system [5], which depends on three reference lines: H line, Pubococcygeal line (PCL) and M Line. This classification allows to evaluate both pelvic organs prolapse and pelvic floor relaxation, which are the two main components of PFD

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[4].

The pelvic organ prolapse depends on the location of the organs (bladder, rectum and uterus) below the H line, while the pelvic floor relaxation depends on the hiatal enlargement (measured by H line) and the hiatal descent (measured by M line). The position of the PCL affects the M line and, therefore, the hiatal descent quantification. The official guidelines recommend to place the posterior point of PCL on the last coccygeal joint [6]. However, this point is not always clearly visible on MR images for different reasons (e.g. individual misalignment of the spine, patients' movements during the exam, bone fusions, etc.). The incorrect position of this line could result in an incorrect grading of the hiatal descent and therefore lead to an uncorrected treatment and prognosis.

Therefore, the first aim of the current study was to investigate the impact of the PCL position on hiatal descent grading, comparing the method recommended by the official guidelines with the other two most common methods reported in literature (PCL posterior point located at the tip of the coccyx [7] and at the sacroccygeal joint [8]). The second aim of the study was to evaluate and to compare the reproducibility of these three different approaches.

2. Materials and methods

2.1. Patient population

This prospective, single-center, Health Insurance Portability and Accountability Act-compliant study was approved by the Institutional Review Board and patients gave written informed consent before enrolment. Consecutive female patients coming at our hospital to perform dynamic MRI for clinical suspicion of pelvic floor dysfunction from July 2016 to October 2017 were potentially included in the study. Patients with previous pelvic surgery, with absolute contraindications for MR and with evident prolapse at the clinical evaluation were excluded. The subjects' accrual flowchart (Fig. 1) is based on the Standards for Reporting of Diagnostic Accuracy (STARD) initiative [9]. The study was conducted in agreement with the good clinical practice guidelines [10].
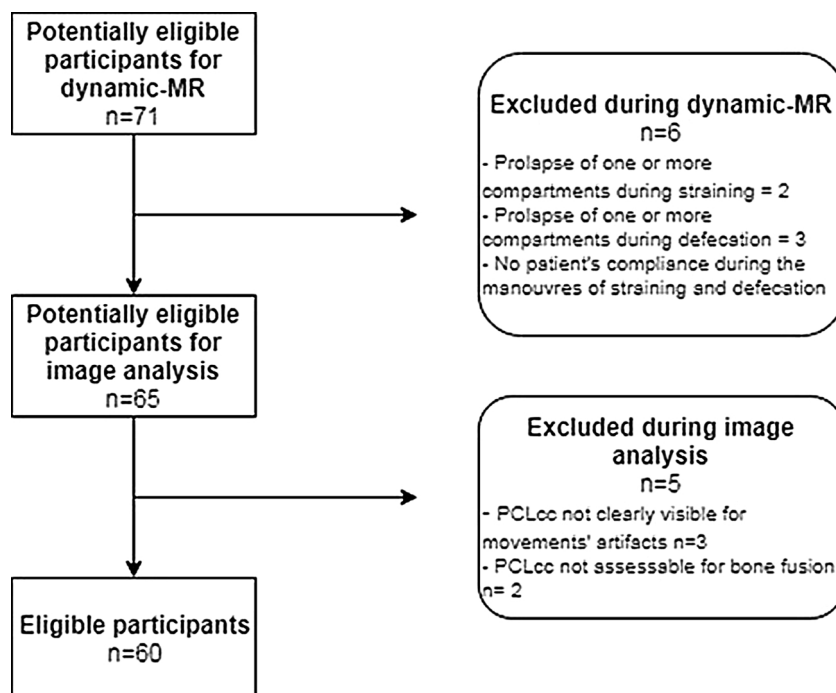
2.2. Patient's preparation

Prior to the examination patients were trained on how to correctly perform the dynamic phases. For maximum straining, patients were instructed to bear down as much as they could without an effective defecation. For the evacuation phase, patients were instructed to defecate repeating the evacuation maneuvers until the rectum was emptied. To decrease possible patient's discomfort, a protective pad or a diaper pant was offered to the patient, which helps to increase patients' compliance during evacuation phase.

2.3. MRI technique

All exams were acquired on a 1,5 T scanner (SIGNATM Voyager; GE Healthcare). No oral or intravenous contrast was used. MR acquisition was performed with the patient in supine position with the knees elevated on a wedge. The rectum and the vagina were filled with 150–200 ml and 50 ml of warm ultrasound (US) gel, respectively. A distended bladder was required for a proper evaluation of the anterior compartment. The examination started with a T1-weighted localizer sequence with a large field of view (FOV) for the identification of the midsagittal plane. The localizer was followed by turbo spin echo (TSE) T2-weighted sequences in axial, sagittal and coronal planes for depicting pelvic anatomy and any muscle defects (thinning or tears). The last part of the examination was characterized by the acquisition of the dynamic study. It was performed by using Fast Imaging Employing Steady-state Acquisition (FIESTA) sequence in the midsagittal plane during straining and defecation; acquiring one image per second for 60 s. The parameters of sequences are summarized in Table 1.

2.4. Image analysis

Image analysis was performed only on midsagittal FIESTA dynamic sequences acquired during straining and defecation and on midsagittal TSE T2w sequences acquired during rest. For each phase (rest, straining and defecation) three lines were drawn: M line, H line and PCL. The quantification of hiatal descent was measured according to the M line length. The M line was traced perpendicularly from the PCL to the

Fig. 1. Study population. Fow chart detailing the patient selection process.

Table 1
The table shows the dynamic MR protocol used.

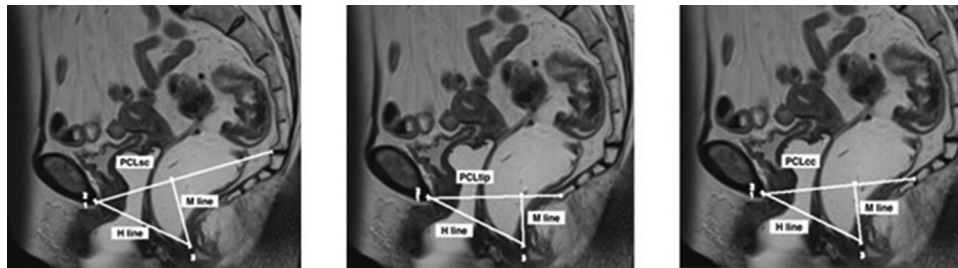| MRI protocol						
Sequence	Plane	Patient Position	TR/TE (ms)	FOV (mm)	Matrix	Slice Thickness (mm)
TSE	Sagittal	Rest	5460/80	200 × 200	256 × 205	5
TSE	Coronal	Rest	5460/80	200 × 200	256 × 205	5
TSE	Axial	Rest	5460/80	200 × 200	256 × 205	5
FIESTA	Sagittal	Strain	3.7/1.7	200 × 200	188 × 288	12
FIESTA	Sagittal	Evacuation	3.7/1.7	200 × 200	188 × 288	12

Fig. 2. The three different ways to draw the pubococcygeal line (PCL) were shown on the same patient. The posterior point was placed on the sacrococcygeal joint(a), the coccix's tip(b) and the last coccygeal joint(c).

posterior end of the H line. The H line was traced between the inferior margin of the symphysis pubis and the convex posterior margin of the puborectalis muscle sling. Finally, the PCL was traced in three different ways. The anterior point placed at the inferior margin of the symphysis pubis while the posterior point was placed at three levels: the tip of the coccyx (PCLtip), the sacrococcygeal joint (PCLsc) and the last coccygeal joint (PCLcc) (Fig. 2). For each patient three different M lines (Mtip, Msc and Mcc) were obtained from the three different PCL (PCLtip, PCLsc and PCLcc, respectively) in each phase (rest, straining and defecation). Thus, a total of 9 M lines were obtained for each patient. Then, the grading of pelvic diaphragm relaxation according to the M lines lengths was scored according to HMO classification system [5]. A normal hiatal position was considered for M line ranging between 0 and 2 cm (grade 0), a mild descent was considered for M line ranging between 2 and 4 cm (grade 1), moderate descent was considered for M line ranging between 4 and 6 cm (grade 2) and severe descent was considered for M line greater than 6 cm (grade 3). Measurements were performed by two independent radiologists with 10 and 7 years of experience in pelvic imaging. One of the two radiologists evaluated all exams after three months to avoid recall bias.

2.5. Statistical analysis

All continuous variables were expressed as mean and standard deviation (SD). The mean of M line lengths obtained by the two readers (during the three phases and using the three PCL) were compared using the t-test. The inter-reader and intra-reader agreement between the M lines lengths obtained the two readers were also evaluated by using κ statistics. Agreement was considered poor for K values < 0.20, fair for K values between 0.21 and 0.40, moderate for K values between 0.41 and 0.60, good for K values between 0.61 and 0.80 and very good for K values between 0.81 and 1.00.

The hiatal descent grades resulted from the M lines obtained with the different PCL was identical between the two readers, so one value was compared. Since PCLcc was considered the reference standard, the comparison was made between the grading obtained with PCLcc and PCLsc and between the grading obtained with PCLcc and PCLtip using Mann-Whitney U test.

Statistical analyses were carried out using a commercially available statistical software (MedCalc Statistical Software version 16.4.3, MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org;

2016 and GraphPad Prism version 5.0, GraphPad Software, La Jolla, California, USA).

A two-tailed P < 0.05 was considered statistically significant.

3. Results

Our final population consisted of 60 female patients (Fig. 1). The mean age was 56.07 years (31–73; ± 10.52), the mean body mass index was 26.4 (21–29; ± 2.34) kg/m2 and the mean parity was 1.3 (0–3; ± 0.8) births. Twenty patients presented with urinary incontinence, 16 with difficult defecation, 18 with unspecified pelvic pain and 6 with unspecified pelvic pain and urinary incontinence.

The mean M line lengths (Mtip, Msc and Mcc) derived from the three different PCL did not show statistically significant differences between readers in all phases (rest, straining and defecation) (Table 2).

A very good inter-reader agreement was observed for M lines obtained using PCLtip at rest (k = 0.852; 95% CI: 0.763−0.872), straining (k = 0.821; 95% CI: 0.735−0.846) and defecation (k = 0.837; 95% CI: 0.758−0.854). A good inter-reader agreement was observed for M lines obtained using PCLcc and PCLsc at rest (k = 0.654; 95% CI: 0.542−0.683 and K = 0.719; 95% CI: 0.682−0.731, respectively), straining (k = 0.732; 95% CI: 0.662−0.758 and k = 0.772; 95% CI: 0.702−0.795, respectively) and defecation (k = 0.697; 95% CI: 0.606−0.721 and k = 0.710; 95% CI: 0.632−0.748, respectively). Inter-reader agreement was significantly higher using PCLtip compared

Table 2
The table illustrates the mean M line lengths (Mtip, Msc and Mcc) obtained by the two readers (A and B) during the three phases according to the three pubococcygeal lines resulted from the three different posterior points (PCLtip, PCLsc and PCLcc, respectively). The p-values resulting from the comparison between the two readers are also shown.

		Mtip (cm)	Msc (cm)	Mcc (cm)
Rest	A	18.72 ± 6.73	28.01 ± 8.69	21.09 ± 7.44
	B	17.24 ± 5.41	29.34 ± 7.23	22.32 ± 6.78
	P value	0.432	0.325	0.254
Straining	A	29.95 ± 14.57	41.26 ± 16.55	33.25 ± 15.59
	B	28.73 ± 15.32	42.74 ± 15.78	32.54 ± 14.23
	P value	0.524	0.215	0.345
Defecation	A	42.79 ± 15.34	56.74 ± 15.97	46.77 ± 15.70
	B	41.87 ± 14.78	57.33 ± 16.08	47.19 ± 14.92
	P value	0.425	0.254	0.357

Table 3

The table shows the p-values resulting by the comparison of the grading during the three phases (rest, straining and defecation) obtained by the M lines derived from the standard PCLcc and the other two PCL (sc and tip). Using PCLsc, the grading was significantly different in all phases, while there are no significant differences between PCLcc and PCLtip.

P-value	PCLsc-PCLcc	PCLtip-PCLcc
Rest	0.0457	0.3016
Straining	0.0130	0.4483
Defecation	0.0086	0.5680

to PCLsc or PCLcc (p < 0.05).

A very good intra-reader agreement was observed for M lines obtained using PCLtip at rest (K = 0.837; 95% CI: 0.715 − 0.856), straining (K = 0.805; 95% CI: 0.714 − 0.827) and defecation (K = 0.851; 95% CI: 0.737 − 0.868). A good intra-reader agreement was observed for M lines obtained using PCLcc and PCLsc at rest (K = 0.683; 95% CI: 0.592 − 0.728 and K = 0.692; 95% CI: 0.573 − 0.732, respectively), straining (K = 0.769; 95% CI: 0.743 − 0.795 and K = 0.731; 95% CI: 0.711 − 0.747, respectively) and defecation (K = 0.632; 95% CI: 0.601 − 0.658 and K = 0.698; 95% CI: 0.672 − 0.712, respectively). Intra-reader agreement was significantly higher using PCLtip compared to PCLsc or PCLcc (p < 0.05).

The resulting grading of the hiatal descent was identical in each phase between the two readers, so one measurement was considered for comparison.

The grading derived from the M line obtained from PCLsc was statistically different compared to the PCLcc in all phases (rest, straining and defecation) (Table 3). The overestimation was always of one grade. More specifically, with PCLsc the grading was overestimated in 18 patients (30%) at rest, in 30 patients (50%) during straining and in 28 patients (46.6%) during defecation. Among the 18 patients at rest, in 12 patients the grading was normal when PCLtip and PCLcc were used and mild when PCLsc was used and in 6 patients was mild when PCLtip and PCLcc were used and moderate when PCLsc was used. Among the 30 patients during straining, in 8 patients the grading was normal when PCLtip and PCLcc were used and mild when PCLsc was used, in 16 patients was mild when PCLtip and PCLcc were used and moderate when PCLsc was used and in 6 patients was moderate when PCLtip and PCLcc were used and severe when PCLsc was used. Among the 28 patients during defecation, in 2 patient the grading was normal when PCLtip and PCLcc were used and mild when PCLsc was used, in 6 patients was mild when PCLtip and PCLcc were used and moderate when PCLsc was used and in 20 patients was moderate when PCLtip and PCLcc were used and severe when PCLsc was used.

The grading derived from the M line obtained from PCLtip was not statistically different compared to the PCLcc in all phases (rest, straining and defecation) (Table 3). The difference found was always an underestimation of one grade with PCLtip. Precisely, in 8 patients at rest the grading was mild with PCLcc and normal with PCLtip, in 8 patients during straining it was moderate (n = 4) and mild (n = 4) with PCLcc and mild and normal with PCLtip, respectively, and in 8 patients during defecation it was moderate (n = 6) and mild (n = 2) with PCLcc and mild and normal with PCLtip, respectively.

4. Discussion

The most important result of our study is the absence of statistically significant difference between the PCLtip and the reference line suggested by the official guidelines, i.e. the PCLcc. At the same time, we found a higher inter and intra-reader agreement with the PCLtip compared to the other two lines, probably due to the greater ease with which the tip of the coccyx is found. These results, if confirmed in a larger cohort of patients, could make the PCLcc a highly reliable and even more reproducible alternative to the PCLcc, allowing to use them

interchangeably. Indeed, it is well known in clinical practice that the last coccygeal joint is not always clearly detectable for many reasons, such as the single sagittal plane used during dynamic evaluation, the possibility of artefacts related to movements during dynamic sequence, the lower spatial resolution of the FIESTA compared to normal sagittal T2-weighted sequence and the intercoccygeal fusion that is increasingly common in the last joints [11]. The reproducibility of dynamic MR has also been investigated and a great variability of pelvic MR measurements, including the M line, performed at separate institutions by different readers was found [12]. Therefore, having an alternative and highly reproducible measure could be particularly useful.

On the other side, we found a significant overestimation of the grading of the pelvic floor descent when the M line was measured using the PCLsc as reference instead of the official PCLcc in all phases (rest, straining and defecation). This could be risky because it could lead to a wrong patient's management. The correct grading of the pelvic floor relaxation is important to helping the decision of treatment for PFD and also to evaluate the risk of prolapse. There is no in literature a unique treatment recommendation based exclusively on the grading of pelvic floor relaxation/prolapse. Moreover, many combinations of pelvic floor relaxation and pelvic organ prolapse can occur in a given patient [4]. The preferable treatment of PFD depends on many factors: successful treatment includes clinical, anatomical, functional and psychosocial considerations. In case of pelvic floor relaxation, there are new surgical techniques aimed at limiting the hiatal enlargement and the hiatal descent, such as the use of polypropylene mesh, with a high percentage of symptom improvement (98%) and low percentage of recurrence (4%) [13]. These results are better compared to the outcome of prolapse surgical treatments, that has a high percentage of failure: approximately 30% of the operations performed are re-operations [14]. The value of the preventive treatment of prolapse is still under investigation. However, the high prevalence of re-operations indicates the need for preventive strategies and a robust and reproducible system for preoperative assessment to minimize treatment failures. Therefore, the correct grading of severity of pelvic floor relaxation with MR could allow to plan a preventive treatment before the prolapse [4].

At our knowledge, the grading resulting from different PCL was never compared. Maddill S et al. found statistically significant differences in the length and position of PCL by comparing two different posterior points: sacrococcygeal joint and tip of the coccyx [15]. Concerning the grading of pelvic floor relaxation established by the HMO classification, the important aspect is not the length of PCL but rather the position, because it directly influences the length of the M line (which is, in fact, the criterion to measure the pelvic floor descent). However, they did not investigate if the different positions found would result or not in different grading.

The major limits of our study are the small cohort of patients and the lack of the outcome evaluation. A larger population size and a longer patient follow-up are needed to assess the long-term efficacy of a possible preventive approach compared to classical surgical treatment of prolapse.

5. Conclusions

To conclude, according to our results, since a significant difference in the grading of pelvic floor descent was found between the standard line and the PCLsc, this last should not be used to avoid wrong treatment's choice and prognosis. By contrast, the lack of differences in the grading between the standard line and the PCLtip and the high reproducibility of the PCLtip measurement could allow to use them interchangeably during all phases (rest, straining and defecation).

Conflict of interest declaration

We have no conflict of interest to declare.

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