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# Radiographic and clinical characteristics associated with a positive PART (Prone Apprehension Relocation Test): a new provocative exam to elicit hip instability

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## ABSTRACT

Hip instability due to mild dysplasia can be a diagnostic challenge. The physical exam is an important adjunct to radiographic evaluation for the clinical diagnosis of hip instability. Herein, we describe a new maneuver to replicate hip instability pain, called the PART (Prone Apprehension Relocation Test). We retrospectively identified patients in our institution's hip preservation registry who presented for evaluation of hip pain. We divided patients into 'positive' or 'negative' PART and analyzed associated clinical and radiographic findings. Ninety patients (159 hips) were included, 83 female and 7 male, average age 27.3 ± 9.1 years. Thirty-four hips (21.4%) had a positive PART. There were no significant differences in hip range of motion, lateral center edge angle, or in acetabular depth. There was, however, a significant difference in acetabular version at 3 o'clock between the two test groups (18.5 ± 6.9° in negative, 21.2 ± 4.9° in positive, $P = 0.045$). There was no association between PART and previously described anterior apprehension testing. Historical methods of diagnosing hip dysplasia may not adequately identify patients with clinical hip instability. We describe a new provocative exam, the PART, which may be helpful in replicating hip instability symptoms in patients with anterior acetabular undercoverage. PART positive patients had significantly more acetabular anteversion at the 3 o'clock position, which is measured on computed tomography and is not visible on standard anteroposterior (AP) pelvis or false profile radiographs. We believe that the PART is a valuable supplement to clinical examination and radiographic measurements to identify patients with symptomatic hip instability.

## INTRODUCTION

Hip instability is a challenging clinical diagnosis. Hip dysplasia, or acetabular undercoverage as identified on a pelvis radiograph, has been classically identified with a center edge angle <25° (Fig. 1) [1]. However, it is now known that there are several additional components which can contribute to hip instability. These can include acetabular version or focal acetabular undercoverage. Focal acetabular undercoverage can be better identified on imaging modalities, such as three-dimensional (3D) reconstructed computed tomography (CT) scans, or by more classically described methods from axial CT cuts, such as the anterior acetabular sector angle (an angle formed on an axial CT between the anterior acetabular margin, the center of the femoral head and the intercapital line) [2]. Other factors include soft tissue integrity, including fatigue of periarticular muscular stabilizers or capsular microtrauma [3], the patient's ligamentous laxity or history of prior hip surgeries where the hip capsule may have been cut, and in some cases, not repaired or failed to heal [4–6]. The hip capsule, and specifically the iliofemoral ligament (ILFL), has been identified as a dynamic stabilizer of the hip joint, as have the gluteus minimus, iliocapsularis, iliopsoas and potentially the ligamentum teres [7, 8]. Excessive femoral anteversion can also play a role in the functional biomechanics of the hip joint [9–11]. Currently, there is no one clinical examination maneuver used in isolation to definitively diagnose hip instability.

Multiple examination maneuvers have been described when evaluating hip instability/hip dysplasia; however, no one exam has demonstrated the ability to reliably diagnose all hip instability, and none have provided an understanding of the underlying anatomy associated with positive findings [14, 15] (Table IV). Furthermore, many of the symptoms of hip instability can overlap with other hip pathology, so identifying a clinical examination tool that could aid the practitioner in clarifying symptoms caused by hip instability/dysplasia could guide subsequent treatment plans, including the type of surgery offered.

To that end, the purpose of the current study was to (i) describe the Prone Apprehension Relocation Test (PART) exam maneuver as an adjunct tool to clinically evaluate for hip instability which may not be apparent on plain radiographs, (ii) associate positive PART exams to the patients' radiographic measurements and (iii) associate positive PART exams to the patients' other clinical exam findings.

## MATERIALS AND METHODS

### Study design

After obtaining institutional review board approval, patients in our institution's prospectively collected hip preservation registry who presented for evaluation of hip pain between November 2016 and April 2017 were identified retrospectively.

### Patient selection criteria

Those included in the study had a documented PART exam, all performed by the senior author, clinical exam findings documented, and radiographic and 3D CT imaging with documented radiographic measurements. Patients who had had prior hip surgery were excluded. X-ray measurements were obtained at the time of the patient's clinic visit, based on AP and false profile pelvis and Dunn lateral hip radiographs dated within 1 year of their presentation. 3D CT imaging measurements and reconstruction were performed by our musculoskeletal radiology staff.

Patients included in the study were subsequently divided into two groups—those with a positive PART exam and those with a negative PART exam. We then analyzed standard clinical exam findings, including hip range of motion and hip provocative maneuvers evaluating for intra-articular and

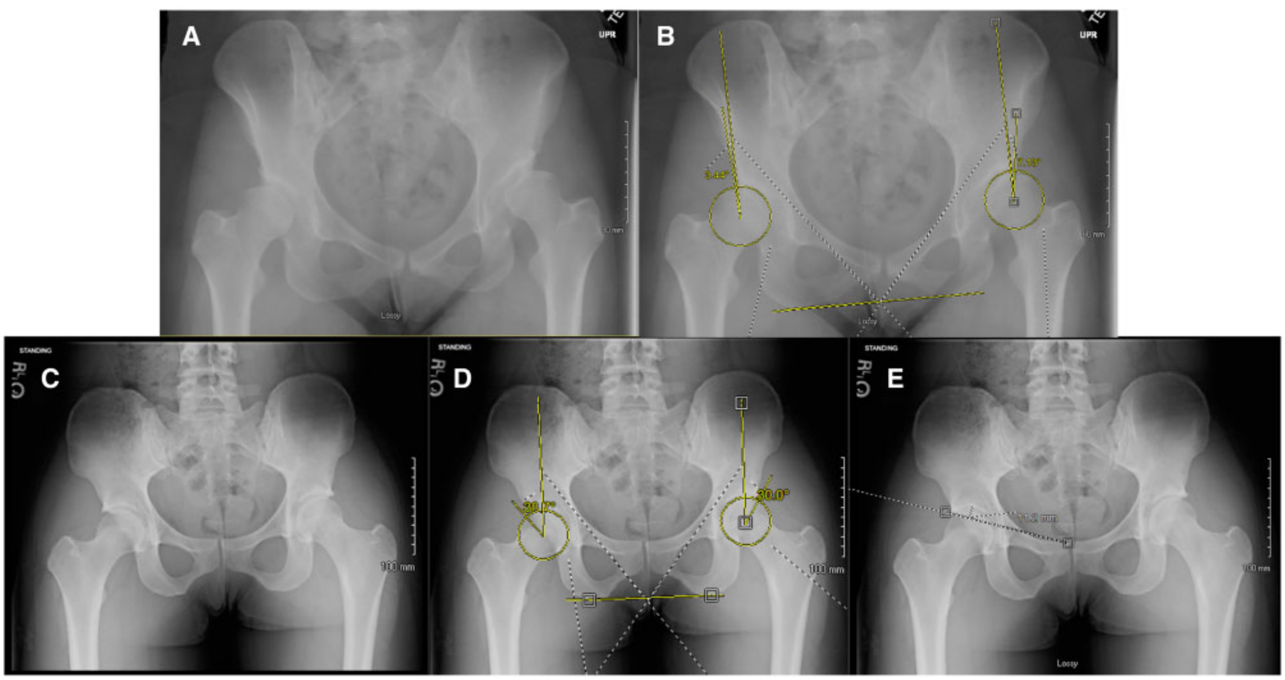


**Fig. 1.** Standing AP pelvis radiographs of (**A**) patient with radiographic diagnosis of left hip dysplasia (**B**) with bilateral LCEA <25° and (**C**) patient with no radiographic diagnosis of hip dysplasia (**D**) with bilateral LCEA >25°. (**E**) Demonstrates the acetabular depth measurement (Table II) in which a line is drawn from the superior edge of the pubic symphysis to the edge of the acetabular sourcil. A perpendicular line is drawn to the deepest portion of the acetabular roof. Measurements <9 mm are thought to represent decreased acetabular coverage [12, 13].

extra-articular hip impingement and hip instability. Provocative maneuvers included flexion adduction internal rotation, flexion abduction external rotation, subspine impingement, Stinchfield test, anterior apprehension test and others (Fig. 2) [16]. Radiographic measurements were obtained from both pelvis radiographs and the hip 3D CT scan.

### PART

The PART is performed with the patient lying prone on the examination table (Fig. 3). The examiner stands on the side of the hip being examined. The examiner lifts the patient's knee, extending the hip approximately 10–15°, and supports the patient's bent knee, which ends up being approximately one 'fist' off of the examination table (Fig. 3A). The lower extremity is abducted approximately 10° from midline. The examiner then pushes downward (anterior) on the femur distal to the inferior gluteal fold. A positive PART is a replication of anterior hip pain with the downward (anterior) pressure on the femur (Fig. 3B). The anterior hip pain is then relieved when the downward (anterior) pressure is released (Fig. 3C). Pearls and pitfalls of the PART are included in Table I.

| **Clinical Exam** | | |
|---|---|---|
| | **R** | **L** |
| Hip Flexion | | |
| Internal rotation (IR) at 90° of hip flexion | | |
| External rotation (ER) at 90° of hip flexion | | |
| Hip Impingement (FADIR) | | |
| Superolateral Impingement / Anterior/superior Capsule Irritation (FABER) | | |
| Anterior Instability (Extension / ER with Anterior Pain) | | |
| Lateral Rim Impingement (Pain with abduction) | | |
| Trochanteric Pain Sign (Posterolateral pain in FABER) | | |
| Sub-Spine Impingement Sign (Anterior Pain with Flexion) | | |
| Ischio-Femoral Impingement Sign (Post pain with Ext / ER) | | |
| Prone Apprehension Relocation Test (PART) | | |

**Fig. 2.** Standard hip evaluation documentation.

### Statistical analysis

Data were compiled in Microsoft Excel (Microsoft Corp., Redmond, WA, USA) and analyzed in SPSS version 23 (IBM Inc., Armonk, NY, USA). Descriptive statistics were reported including proportions (for count data), and means and standard deviations (for continuous variables). Subjects with positive PART exams and those with negative PART exams were compared on continuous variables using Student's *t*-test and on count variables using Fisher's exact or $\chi^2$ tests, as appropriate. $P \leq 0.05$ was used as the threshold for statistical significance, and all comparative analyses were performed using two-tailed tests.

### Data Availability

The data that support the findings of this study are available from the corresponding author, A.M.S., upon reasonable request.

## RESULTS

Ninety patients (159 hips) had documented PART examinations, including 83 female and 7 male patients, average age 27.3 ± 9.1 years. Thirty-four hips (21.4%) had a positive PART. There were no significant differences in hip range of motion or lateral center edge angle (LCEA) of patients with a negative (23.1 ± 7.3°) and positive (21.1 ± 8.1°) PART, or in acetabular depth (9.1 ± 2.4 mm

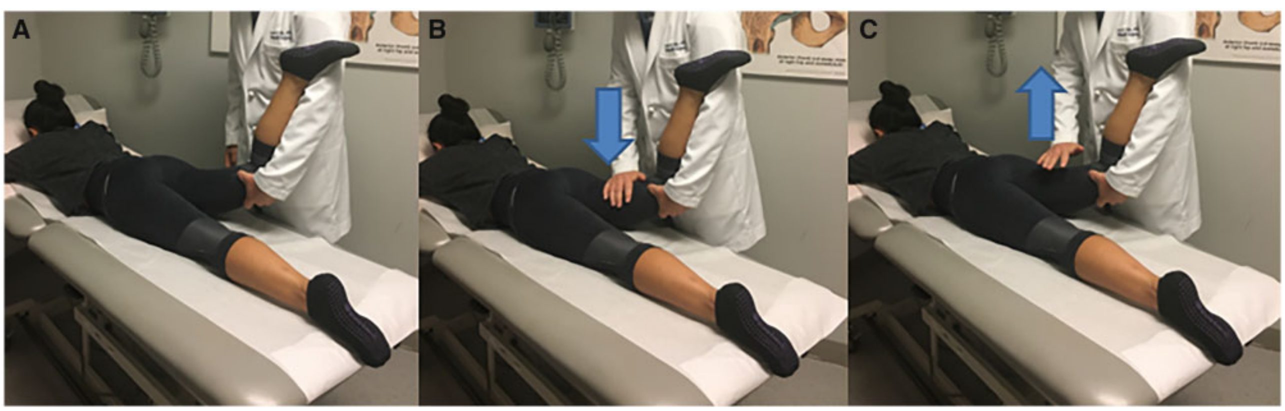


**Fig. 3.** The PART. (**A**) The patient lies prone on the examination table with the affected hip held in extension. The examiner supports the patient's bent knee. (**B**) The examiner pushes downward on the femur while supporting the knee. A positive test replicates the patient's anterior hip pain. (**C**) The examiner releases downward pressure on the femur and this relieves the patient's anterior hip pain.

**Table I. Pearls and pitfalls of the PART**

| *Pearls* | *Pitfalls* |
|---|---|
| • Having the patient in the prone position stabilizes the pelvis against the examination table anteriorly.<br>• The examiner should stand on the side of the hip being examined.<br>• The limb being examined is lifted into approximately 10–15° of hip extension (the knee is approximately one ‘fist’ off of the examining table).<br>• The limb being examined is slightly abducted from neutral (about 10°) toward the examiner.<br>• A positive test is defined as anterior hip pain which is replicated with anterior force on the femur, applied distal to the inferior gluteal fold and relieved when that pressure is relaxed. | • Occasionally the patient will describe pain anteriorly with extension of the hip (as the knee is lifted in preparation of the PART exam). If the patient has pain with extension that does not change with the addition or removal of pressure on the femur, this is considered a negative PART.<br>• If the patient has pain at the posterior thigh where pressure is being applied but no anterior pain, this is also considered a negative PART. |

**Table II. Radiographic measurements of LCEA and acetabular depth compared in patients with a negative and positive PART**

| | *PART test* | N | *Mean*[a] |
|---|---|---|---|
| LCEA (XR) | Negative | 123 | 23.1 ± 7.3° |
| | Positive | 34 | 21.1 ± 8.1° |
| Acetabular depth (XR) | Negative | 124 | 9.1 ± 2.4 mm |
| | Positive | 34 | 8.2 ± 2.5 mm |

*Note*: See Fig. 1 for more detailed description of acetabular depth measurement.
[a]No significant differences were found. $P > 0.05$ for all measures.

in negative PART patients; 8.2 ± 2.5 mm in positive PART patients) (Table II).

There was, however, a significant difference in acetabular version at 3 o’clock in the two test groups (mean version of 21.2 ± 4.9° in positive, 18.5 ± 6.9° in negative, $P = 0.045$) (Table III). There was no association between positive PART and positive anterior apprehension testing.

## DISCUSSION

The Prone Apprehension Relocation Test (PART) is a new provocative exam maneuver which is associated with patients who have focal anterior undercoverage of the acetabulum that may not otherwise be visible on standard radiography. While hip dysplasia has been classically defined as an LCEA of <25° on AP pelvis radiograph [1, 17], hip dysplasia is a 3D pathology which is difficult to truly appreciate using two-dimensional (2D) imaging. Patients with LCEAs of 25° or greater on AP pelvis radiographs may have focal anterior or posterior acetabular undercoverage, leading to symptomatic hip instability. We describe focal acetabular undercoverage in a region not clearly visible on AP pelvis radiograph as ‘occult’ instability, which may become more evident with 3D imaging modalities such as CT or MRI (Fig. 4). This undercoverage may also be missed on standard false profile radiographs, which project 2D images of the anterior hip coverage and can be falsely elevated with increasing pelvic tilt [18]. With this in mind, the Ottawa Classification, published by Wilkin *et al.* [19], further classifies symptomatic acetabular dysplasia as either (i) anterior instability, (ii) posterior instability or (iii) lateral/global instability. In recent years, multiple morphological studies of the acetabulum have resulted in a better understanding of the bony anatomy of the acetabulum and areas which may be subject to ‘occult’ instability/dysplasia. Hatem *et al.*’s [20] careful study of the inferior acetabular morphology demonstrated a decreased anterior and posterior horn absolute width in females, but no gender-dependent differences when adjusted for the diameter of the acetabulum. In their study of 300 adult pelvises, they did, however, find higher acetabular version in female acetabulae compared to male [20]. Steppacher *et al.*’s [21] evaluation of the size and shape of the lunate surface demonstrated a decreased absolute size of the lunate surface in lunate hips with no gender-dependent differences noted. Govsa *et al.*’s [22] detailed characterization of the anterior acetabulum confirmed significant anatomic variability of the acetabulum, and identified four distinct configurations of this area (curved, angular,

**Table III. Three-dimensional CT measurements of patients with negative and positive PART exams**

| *Radiographic measurement (CT)* | *PART test* | N | *Mean (°)* | P-*value** |
|---|---|---|---|---|
| Alpha angle | Negative | 84 | 59.0 ± 10.2 | >0.05 |
| | Positive | 31 | 57.5 ± 9.3 | |
| Tönnis angle | Negative | 70 | 7.4 ± 5.3 | >0.05 |
| | Positive | 23 | 8.6 ± 6.5 | |
| Femoral version | Negative | 93 | 17.7 ± 9.2 | >0.05 |
| | Positive | 29 | 18.0 ± 8.2 | |
| Acetabular version 1:00 | Negative | 82 | 9.1 ± 8.2 | >0.05 |
| | Positive | 32 | 9.8 ± 8.6 | |
| Acetabular version 2:00 | Negative | 81 | 15.3 ± 8.0 | >0.05 |
| | Positive | 32 | 16.0 ± 5.8 | |
| Acetabular version 3:00 | **Negative** | **81** | **18.5 ± 6.9** | **0.045** |
| | **Positive** | **32** | **21.2 ± 4.9** | |
| Coronal CEA | Negative | 83 | 26.7 ± 7.1 | >0.05 |
| | Positive | 31 | 24.6 ± 9.6 | |

*Note*: No significant difference was found in patients with dysplasia (defined as LCEA <25° on pelvis radiograph, CT coronal CEA or CT sagittal CEA) and those without dysplasia regarding whether they had a negative or positive PART.

*A significant difference of $P$ <0.05 was noted in the acetabular version at 3:00 ($P = 0.045$) (values in bold). Those with a positive PART had significantly more acetabular version at the 3:00 position. All other measures were found to have $P > 0.05$.

irregular and straight), bringing to light the nuances in bony anatomy of the anterior acetabulum.

In many patients with the diagnosis of borderline hip dysplasia, defined as an LCEA 18°–25°, it is not always clear as to whether a periacetabular osteotomy (PAO) or hip arthroscopy is the appropriate surgical procedure and whether these patients are actually more dysplastic than previously believed [23, 24]. Patients with borderline dysplasia have demonstrated improvement in patient reported outcomes after PAO [24] as well as with hip arthroscopy [25–28]. Those with borderline dysplasia have also shown poorer results after hip arthroscopy than patients with normal acetabular coverage [29–32]. Performing hip arthroscopy for primary hip instability pain could not only fail to provide adequate symptom relief for the patient [29–31] but could potentially worsen symptoms by aggravating hip instability [4]. Patients with hip dysplasia have been reported to comprise a high percentage (13%) of total hip arthroscopy patients amongst high volume hip arthroscopists [17]. The high prevalence of dysplastic patients undergoing hip arthroscopy, as well as the conflicting data on the outcomes of hip arthroscopy in dysplastic patients suggests that further pre-operative investigation into the

**Fig. 4.** A 3D CT scan demonstrating anterior acetabular undercoverage in a patient with positive PART with the fovea of the femoral head visible. This patient's CEA measured 25° on AP pelvis radiograph therefore based on LCEA alone the diagnosis of dysplasia would not have been made.

patient's true diagnosis is warranted to provide the optimal treatment. Additionally, we are now aware that in hip dysplasia patients, who ultimately require a PAO surgery for treatment of their symptomatic instability, having a prior hip arthroscopy surgery could result in lower post-operative patient reported outcome scores [33]. It is thus increasingly prudent for surgeons to make the correct diagnosis prior to offering surgical intervention, and additional tools such as the exam maneuver we describe could assist in making this correct diagnosis.

The PART (Fig. 3) is a clinical exam maneuver which was designed to elicit positive findings in patients with symptomatic hip instability, which may not be clearly evident on radiographic examination. Similar to the anterior apprehension test in the shoulder [34], the position of the femoral head when the examiner extends the hip and pushes anteriorly on the femur places pressure on the anterior restraints of the hip joint. Other exam findings have been described to elicit hip instability, including the anterior apprehension test [8, 14], the abduction-extension-external rotation (ER) test, the prone ER test, the log roll test, the axial distraction test, the prone instability test [15, 35], and the foot progression angle walking test [36] (Table IV). Of the previously published hip instability clinical exam maneuvers, the most similar exam to our PART is the prone instability test described by Domb *et al.* [28] and Philippon *et al.* [37]. In the prone instability test, the patient is similarly placed prone. However, instead of a slightly abducted position of the leg, the leg is maximally externally rotated. Instead of pressure applied anteriorly against the femur as is performed in the PART, in the prone instability test, pressure is applied to the greater trochanter to translate the femoral head anteriorly. Each of the previously described tests (Table IV) assesses the hip

**Table IV. Summary of previously described tests for hip instability**

| *Previously described test for hip instability* | *Patient position* | *Description of how to perform exam* |
|---|---|---|
| Log roll test (also known as the dial test) [14] | Supine | Examiner internally rotates foot past neutral and releases foot. |
| | | Foot will fall into ER; if ER is greater than contralateral side, this is suggestive of anterior capsular laxity (especially if foot table angle is $<20°$) and is a positive test. |
| Anterior apprehension test (also known as hyper-extension-ER test) [14] | Supine | Buttock of side being examined is at edge of table. |
| | | Affected lower extremity extended and externally rotated with contralateral limb in flexion. |
| | | Positive test reproduces anterior hip pain. |
| Posterior apprehension test [14] | Supine | Affected hip in 90° flexion. Additional adduction and internal rotation of affected hip. |
| | | Posterior force is applied. Test is positive if pain or apprehension is reproduced. |
| Prone ER test [28, 37] | Prone | Affected hip is maximally externally rotated. Anterior pressure is placed on the posterior greater trochanter in an attempt to translate the femoral head anteriorly. |
| | | Positive test replicates patient's symptoms. |
| Axial distraction test [15] | Supine | Patient's hip and knee flexed 30°. Examiner's knee beneath affected thigh, against ischium. Axial distraction of hip results in positive test if patient's pain or apprehension is replicated, or whether hip toggles. |
| Abduction-extension-ER test [42] | Lateral | Hip is abducted to 30° and externally rotated. Pressure is placed on posterior aspect of greater trochanter. Leg is extended from 10° of flexion to full extension while anterior force is applied through greater trochanter. |
| | | Positive test reproduces the patient's symptoms. |

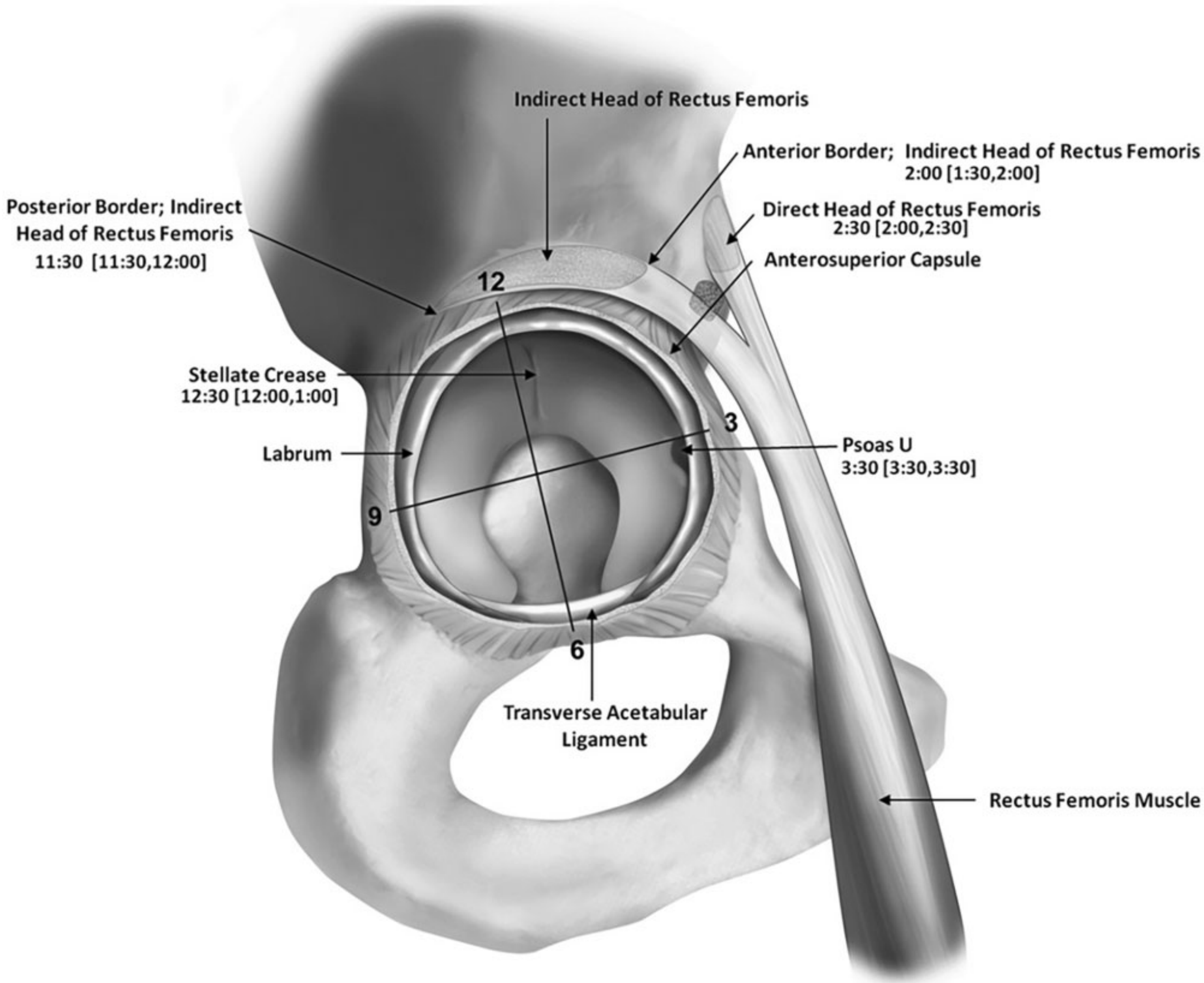


**Fig. 5.** A diagram demonstrating the clock face of the acetabulum. Acetabular version is typically reported at the 1, 2 and 3 o'clock positions based on CT measurements [41]. Reproduced with permission from Wolters Kluwer. Image from Ref. [41]. jbjs.org. The Creative Commons license does not apply to this content. Use of the material in any format is prohibited without written permission from the publisher, Wolters Kluwer Health, Inc.

in different dynamic positions, and as of yet, none has become the definitive test for hip instability.

In associating positive PART exams to patients' radiographic measurements, we found that patients with a positive PART had significantly more acetabular anteversion (and resultant anterior hip undercoverage) at the 3:00 position (Fig. 5) [38]. The acetabulum is a structure that is smaller than a hemisphere with consistent wave-like prominences and depressions [39]. Given that the position of the femoral head during the PART places pressure on the anterior structures of the hip joint, if the patient is lacking anterior acetabular coverage, as is the case in significant anterior acetabular anteversion, the soft tissues of the anterior hip are subject to increased pressure and pain. The position of the PART examines the hip in a different plane (coronal, anterior) than would be involved in typical activities of daily life (e.g. walking and running), which put increased pressure on the anterosuperior region of the acetabulum [40].

We also sought to associate positive PART exams to patients' other clinical findings. There was no association between a positive PART and any other standard clinical exam finding, including the anterior apprehension test. The anterior apprehension test, also called the hyperextension-ER test, is performed with the patient lying supine. The examiner abducts, externally rotates and extends the hip being evaluated, and a positive exam replicates anterior hip pain [14]. Range of motion was not associated with a positive PART, which is consistent with prior research indicating that hip ROM is not a reliable indicator of acetabular dysplasia and may be more associated with femoral morphology [43]. Exam maneuvers testing for intra- and extra-articular hip impingement were also not associated with a positive PART. Given that patients with a positive PART had less bony coverage at the anterior acetabulum, we would not expect impingement tests to be positive, as these are typically associated with excess bone at the acetabulum, femur or extra-articular hip locations.

Limitations of this study include the retrospective nature of our analysis. Patients with missing data points, either clinical examination documentation or radiographic or CT imaging, were excluded from our cohort. An additional limitation is the apparent higher LCEA as measured on CT compared to radiographs. We classified patients with dysplasia if they had any one of the following: LCEA $<25^\circ$ on AP pelvis radiograph, CT coronal CEA or CT sagittal CEA. The CT coronal CEA is often measured as higher than the LCEA on radiograph because the CT cannot identify the difference between weight bearing acetabulum and os acetabuli, calcified labrum or non-weightbearing acetabulum on individual cuts. This is evidenced by our average CEAs on AP pelvis radiographs versus CTs (Tables II and III), where patients with a positive PART had an average CEA of $21^\circ$ on AP pelvis radiograph but $24.6^\circ$ on CT; those with a negative PART had an average CEA of $23.1^\circ$ on AP pelvis radiograph but $26.7^\circ$ on CT. This relationship between radiographic LCEA and CT has been shown by other investigators as well [44]. While we found statistically different degrees of acetabular version at the 3:00 acetabular position, it is unclear what the clinical significance of these differences in version are. Another limitation of our current study is that we did not have quantifiable data on the ligamentous laxity of our patients. Currently, the authors collect a Beighton score [45] on each patient as standard of care; but these data were not available for our study cohort. We recognize that the dynamic stabilizers of the hip (including the capsule, labrum, extra-articular musculo-tendinous contributions and potentially also the ligamentum teres) play a role in hip instability [8, 15, 40]. Our current study focuses on the bony anatomy, known to be a significant contributor to hip stability. In the prone position of the PART, we expect that the differences seen due to variations in capsule or labral tissue will be minimized due to the position of the femoroacetabular joint (Fig. 3). In this prone position, with slight hip hyper-extension, the role of dynamic stabilization of the gluteus minimus/medius tendons is minimized [46]. The ligamentum teres tightens most in adduction, flexion and ER [8], which are not positions utilized for the PART exam. Of the four hip capsule structures (the pubofemoral ligament, the ischiofemoral ligament, the zona orbicularis and the ILFL), the ILFL, or Y ligament of Bigalow, is thought to contribute the most to hip stability. The ILFL inhibits both internal and ER in extension so should be actively engaged in the position of the PART [47]. As we excluded all patients with prior hip surgeries, there should not have been any iatrogenic injury to the ILFL in our patient cohorts. All PART exams and clinical exams were performed by the senior author, which eliminated variability introduced by multiple examiners. This brings to light a limitation in applying our results to general practice. However, based on unpublished work by our authors, we do know that the interrater reliability of the PART exam is very high.

In conclusion, the PART exam provides a useful adjunct to standard clinical examination of the painful hip, which correlates to radiographic anterior acetabular undercoverage. Given the high percentage of radiographically diagnosed dysplastic patients undergoing hip arthroscopy, and the mixed results of patients with borderline dysplasia after hip arthroscopy, we suggest using the PART in evaluation of all hip preservation patients to aid the surgeon in identifying those who may have focal anterior undercoverage of the acetabulum. This is especially important given that anterior undercoverage is not readily seen on standard radiographic views. The PART is, therefore, a valuable supplement to clinical examination and radiographic measurements in identifying patients with symptomatic hip instability, especially those with 'occult hip dysplasia' or dysplasia not diagnosed by LCEA criteria.

## CONFLICT OF INTEREST STATEMENT

Andrea M. Spiker is a paid consultant for Stryker. Peter D. Fabricant is on the editorial or governing board of Clinical Orthopaedics and Related Research, and is a board or committee member of Pediatric Orthopaedic Society of North America, Pediatric Research in Sports Medicine Society, and Research in OsteoChondritis of the Knee (ROCK). Ernest L. Sink is a board or committee member of AAOS.

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