Classifications In Brief

Paprosky Classification of Acetabular Bone Loss

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History

The incidence of THA revision has increased substantially during the last decade and is projected to nearly double by 2026 [8, 9]. Aseptic loosening and osteolysis continue to be major challenges in hip reconstruction surgery; planning surgical treatments for these conditions requires accurate preoperative characterizations of the bone loss caused by these conditions, as preoperative planning is essential to ensure the appropriate equipment and prostheses are available.

Many different classification schemes have been proposed to describe the extent of periacetabular bone loss in revision THA including those proposed by Paprosky et al. [11], D'Antonio [2] (also known as the American Academy of Orthopaedic Surgeons system [AAOS]), Saleh et al. [13], Gustilo and Pasternak [6], Gross et al. [5], Parry et al. [12], and Engh et al. [3]. These classification schemes differ in that some aim to simplify classification to improve communication and reproducibility [3, 5, 7, 12], whereas others seek to provide detailed anatomic information for defect-specific preoperative planning [2, 6, 7, 11, 13]. Other fundamental differences include the presence or absence of

standard anatomic landmarks compared with pure volumetric bone loss independent of the structures affected and the focus on bone stock remaining in contrast to bone stock required for revision [7]. Described in 1994, the Paprosky classification is a commonly used system for classifying acetabular bone loss in revision THA (Fig. 1) [11].

Purpose

Given the complexity of revision THA, the Paprosky system identifies which acetabular supporting structures are deficient for the purposes of predicting the biologic augments and synthetic components that will be needed at the time of surgery. This classification is anatomically oriented and assesses specific osseous structures for deficiency, rather than being geared toward generalized volumetric bone loss, which is the basis of several other systems [3, 5, 12]. The Paprosky system uses preoperative radiographs to classify defects by the amount of acetabular component migration and the status of the acetabular supporting structures including the anterior and posterior columns, the superior weightbearing dome, and the medial wall (Table 1). It is based primarily on “the presence or absence of an intact acetabular rim and its ability to provide rigid support for an implanted acetabular component” [11]. Based on the structures predicted to be deficient, and the degree of hip center migration, Paprosky et al. [11] offered recommendations regarding the type and amount of supplemental allograft needed for reconstruction, methods of graft fixation, and implant selection (Table 2). More recently short-, mid-, and long-term results of revision THAs using implants selected to treat specific acetabular deficiency patterns have become available [15, 16, 18].

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Fig. 1A–F An artist's renditions of the Paprosky classification of (A) Type 1, (B) Type 2A, (C) Type 2B, (D) Type 2C, (E) Type 3A, and (F) Type 3B acetabular bone loss are shown. (© 2013 American Academy of Orthopaedic Surgeons. Adapted from the *Journal of the American Academy of Orthopaedic Surgeons*, Volume 21(3),

pp. 128–139 with permission, as adapted from Paprosky WG, Perona PG, Lawrence JM: Acetabular defect classification and surgical reconstruction in revision arthroplasty: a 6-year follow-up evaluation. *J Arthroplasty*. 1994;9(1):33–44.)

Table 1. Paprosky classification of acetabular bone loss

Classification	Teardrop (medial wall)	Hip center (superior dome)	Kohler line (anterior column)	Ischium (posterior column)	Bone loss (remaining bone bed)
Type 1	Intact	No migration	Intact	Intact	Mild (> 50% cancellous)
Type 2					
2A	Intact	Mild migration < 2 cm superomedial	Intact	Intact	Moderate (< 50% cancellous)
2B	Intact	Moderate migration < 2 cm superolateral	Intact	Intact	Moderate (< 50% cancellous)
2C	Moderate lysis	Mild migration < 2 cm medial	Disrupted	Intact	Moderate (< 50% cancellous)
Type 3					
3A	Moderate lysis	Severe migration > 2 cm superolateral	Intact	Moderate lysis	Severe 10–2 o'clock loss (40%–70% sclerotic)
3B	Severe lysis	Severe migration > 2 cm superomedial	Disrupted	Severe lysis	Severe 9–5 o'clock loss (30% sclerotic)

The classification system is based on the integrity of the teardrop, hip center, Kohler line, and ischium [11]. © 2013 American Academy of Orthopaedic Surgeons. Adapted from the *Journal of the American Academy of Orthopaedic Surgeons*, Volume 21(3), pp. 128–139 with permission.

Table 2. Acetabular adjuncts

Classification	Bone graft	Fixation method
Type 1	Particulate	NA
Type 2		
2A	None, with “high” component placement Particulate Bulk femoral head	Cancellous screws
2B	Number 7 proximal femur	Cancellous crews or reconstruction plate outside acetabulum
2C	Particulate Wafer-cut femoral head	NA
Type 3		
3A	Number 7 distal femur Bulk proximal tibia	Cancellous screw or reconstruction plate outside acetabulum
3B	Proximal femur “arc” graft	Reconstruction plate outside acetabulum

NA = not applicable.

Fig. 2 The supporting structures of the acetabulum used by the Paprosky classification as seen on routine AP radiographs of the pelvis include the teardrop (medial wall, red arrow), hip center migration (superior wall/dome, green bracket), the Kohler line (anterior column/medial wall, blue line), and the presence or absence of ischial lysis (posterior column/posterior wall, yellow square).

Description

The original classification included preoperative and intraoperative evaluations of 147 failed THA acetabular components and the associated surrounding osseous support [11]. The Paprosky classification is based on the amount of hip center migration and the integrity of four acetabular supporting structures as evaluated on preoperative AP radiographs of the pelvis [11, 14] (Fig. 2; Table 1).

The Paprosky classification is divided into three types with increasingly severe degrees of bone loss; Types 2 and 3 are further divided into subtypes (Fig. 1). Type 1 defects have minimal focal bone loss with maintenance of the hemispheric shape of the acetabulum. The supporting

structures, including the acetabular walls and columns, are all intact and with no hip center (component) migration.

Type 2 defects have moderate bone loss, deficient walls but intact acetabular columns, and less than 2 cm of hip center migration. Type 2 defects are further subdivided into A, B, and C based on defect location and resultant direction of component migration. Type 2A defects have global cavitation of the acetabulum with direct superior hip center migration; sufficiently intact superior dome and teardrop prevent concomitant lateral or medial displacement, respectively. Type 2B defects are characterized by a deficient superior dome, allowing for superior and lateral component migration owing to the lack of a lateral stabilizing buttress, normally provided by the lateral margin of the superior dome. Type 2C defects have a deficient medial wall (teardrop) causing direct medial migration of the hip center; the superior dome is intact, preventing vertical displacement.

Type 3 defects have extensive global erosion of the acetabulum with attenuation or destruction of all supporting structures and greater than 2 cm of hip center migration; these defects can be associated with pelvic discontinuity. Type 3A defects have moderate-to-severe destruction of the acetabular walls and posterior column, rendering these structures nonsupportive. Kohler's line remains intact preventing significant medial displacement of the component, and the hip center migrates superolateral (known as an “up and out” deformity). If the acetabulum is considered as a circular structure represented by a clock face, then in Type 3A defects, the acetabular rim is deficient from 10 o'clock to 2 o'clock and 30% to 60% of the supporting bone stock has been destroyed. Type 3B defects are the most severe and are characterized by destruction of all acetabular supporting structures including both walls and both columns, causing the hip center to migrate in a

superomedial direction (known as “up-and-in” deformity). The acetabular rim is deficient from 9 o’clock to 5 o’clock, representing greater than 60% destruction of the supporting bone stock. Although the original description denotes hip center migration as more or less than 2 cm [11], a more recent publication liberalizes this migration to less than or greater than 3 cm [14].

Reliability and Validity

Reliability refers to the classification’s ability to consistently grade the amount of bone loss across reviewers (interobserver reliability) and by the same reviewer across time (intraobserver reliability). Validity refers to how closely the preoperative radiographic classification predicted the actual defect found at the time of surgery. The kappa (κ) analysis is a representation of the proportion of agreement beyond that expected by chance [10]; a value of zero indicates no agreement better than chance and a value of 1 indicates agreement between two scorers is perfect [10].

Intraobserver reliability for the Paprosky classification has varied with reported κ values ranging from 0.14 to 0.75 [1, 4, 12, 19]. Most of the time the values were between 0.3 and 0.6, indicating poor to good agreement. Interobserver reliability has shown even greater variability with reported κ values ranging from 0.02 to 0.79 [1, 4, 12, 19] with the majority of values between 0.4 and 0.6, suggesting anything from good agreement to essentially no agreement better than that is the result of chance. The source of this heterogeneity is likely multifactorial and includes the loosely defined and relatively subjective categories of mild, moderate, and severe used by the Paprosky system, the partial obstruction of acetabular features by the radiopaque cup on routine radiographs, and potential discrepancies in the measurement of hip center migration between reviewers which is a major differentiating feature between Types 1 and 2 defects.

Two studies have compared reliability between designated “expert” cohorts, comprised of practicing orthopaedic surgeons with an arthroplasty focus, and “nonexpert” cohorts, consisting of senior level orthopaedic residents or their British equivalents [1, 4]. Intraobserver κ values for the expert group were poor to moderate ($\kappa = 0.14$ and 0.33 for two separate reviewers in one study [4], and average $\kappa = 0.46$ [0.27–0.60] for a cohort of three reviewers in another study [1]), whereas the nonexpert group was fair to moderate ($\kappa = 0.31$ and 0.41 for two separate reviewers in one study [4], and average $\kappa = 0.37$ (0.26–0.50) for a cohort of three reviewers in another study [1]), unexpectedly showing greater variability in the experts’ analysis and no substantial

improvement over the nonexperts’ evaluation. Interobserver reliability was similarly inconsistent; expert κ values were substantially improved compared with nonexperts in one study (expert, $\kappa = 0.56$; nonexpert, $\kappa = 0.27$) [4], and approximately equivalent in another study (experts, $\kappa = 0.25$ and 0.27 ; nonexperts, $\kappa = 0.18$ and 0.31) [1].

To evaluate the teachability of the Paprosky classification, one investigation showed greater improvement in intraobserver reliability for participants who engaged in three dedicated Paprosky classification teaching sessions (κ improved from 0.66 to 0.71, $p < 0.001$) [19], compared with those who did not have dedicated teaching (κ improved from 0.50 to 0.53).

Interestingly, another study asked the surgeon who originally created the classification to evaluate the AP and Judet radiographs of 33 hips on two separate occasions [1]; intraobserver reliability was good ($\kappa = 0.75$) but not excellent. These findings suggest that regardless of surgeon experience level, the Paprosky classification is unlikely to achieve excellent intraobserver reliability.

One study compared the Paprosky classification with other classification systems [12]. The Paprosky classification fared well, showing an intraobserver reliability of $\kappa = 0.62$, slightly inferior to the AAOS ($\kappa = 0.67$) [2] and Parry ($\kappa = 0.85$) systems [12]. Interobserver reliability was moderate ($\kappa = 0.59$ and 0.60 on two occasions) [12] but superior to the AAOS ($\kappa = 0.1$ and 0.07) and Parry ($\kappa = 0.51$ and 0.35) systems.

There have been fewer studies on the degree to which the classification actually reflects surgical findings (validity). In the most robust evaluation of the validity of the Paprosky classification [19], the correlation between defect size quantified on preoperative radiographs compared with intraoperative findings reached significance for the superior dome ($p < 0.0001$), medial teardrop ($p = 0.0015$), and Kohler line disruption ($p = 0.0011$). However, there was no correlation for the posterior acetabular wall or ischial defects; this was believed to be the result of the radiopaque acetabular cup obscuring these features on standard AP radiographs of the pelvis. Yu et al. [19] concluded that the Paprosky classification is valid, but can be subjective, and requires a standardized and objective scoring protocol. Paprosky et al. [11], in their original study describing the classification, indicated that 100% of Type 1, 89% of Type 2, and 95% of Type 3 defects classified preoperatively were found to accurately reflect findings at the time of surgery. In another study, Gozzard et al. [4] reported good validity ($\kappa = 0.65$) when comparing defects on preoperative radiographs with intraoperative findings; however, the exact method used to describe intraoperative defects was not characterized.

Limitations

Intraobserver and interobserver reliabilities have been shown to be highly variable, but generally achieve only fair to moderate agreement [1, 4, 12, 19]. Five years after the original study, Campbell et al. [1] reported that even Paprosky found only good agreement, further highlighting the difficulty of analyzing acetabular bone loss by someone maximally familiar with the classification scheme. This is further complicated by the system's subjective classification of categorical data such as severity of bone loss into the loosely defined categories of mild, moderate, and severe; these assessments may be influenced by a surgeon's particular experience or scope of practice. Additionally, it is worth remembering that the English-language literature on reliability and validity for the Paprosky system, while reasonably large for evaluations of a classification scheme, is still based on the findings of only 18 orthopaedists and 175 hips [1, 4, 12, 19]. Additionally, when developing their original classification, Paprosky et al. reported that their population had an average of 2.6 surgeries before revision THA [11], but the nature of these surgeries was not described.

The original Paprosky classification is based on analysis of AP radiographs of the pelvis and therefore attempts to classify complex three-dimensional structures using a two-dimensional image. Smaller areas of lysis may not be seen well on radiographs alone and certain structures such as the ischium may be obscured by the radiopaque cup making accurate determinations of defect size difficult. CT is used increasingly in preoperative planning; however, we are unaware of a classification system that incorporates this modality. Finally, femoral bone stock also must be considered because a successful outcome depends on appropriate management of both sides of the hip. To this end, Della Valle and Paprosky proposed a classification system for femoral bone loss [17], which was intended to be used in conjunction with the acetabular classification.

Conclusions and Uses

The development of a reliable, valid, and universally accepted classification for acetabular bone loss in revision THA continues to be problematic. Despite its limitations, the Paprosky classification has many advantages including its widespread familiarity, simplicity of use, the availability of routine perioperative radiographs, and reasonable reliability and validity. Furthermore, given the Paprosky classification can be used to predict implant needs, this system is being used in an increasing number of studies to report midterm and long-term outcomes for revision THA

with acetabular bone loss [15, 16, 18]. Although agreement is limited, the Paprosky classification performs as well as or better than other acetabular classification schemes. This suggests that, despite its shortcomings, it is one of the best options available to help surgeons anticipate and plan for findings at the time of revision surgery. Furthermore, one study showed that it has increased reliability with dedicated teaching [19], suggesting that the classification may be more reliable when surgeons are specifically trained in its use.

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