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IN BRIEF

In Brief

Classifications in Brief

Brooker Classification of Heterotopic Ossification After Total Hip Arthroplasty

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History

THA is a frequently performed surgery for the treatment of patients with osteoarthritis, rheumatoid arthritis, avascular necrosis, developmental dysplasia, and many other forms of hip pathology. Heterotopic ossification (HO) is a common complication after THA with a frequency of 26% to 41% reported in recent studies [2, 20, 21]. The majority of HO is not clinically important, but severe HO may lead to decreased hip ROM [12] and increased pain [7].

Multiple different classification schemes have been proposed to describe the degree of HO after THA, including those by Brooker et al. [3], Hamblen et al. [9], DeLee et al. [5], and Kjaersgaard-Andersen et al. [11] as well as by Arcq [1] within the German literature. All of the classification systems use plain radiographs in at least the AP plane, but some make use of other radiographic views as well. The Brooker classification system was one of the earliest systems described and remains very widely used in contemporary literature. Some groups have suggested modifications or additions to the Brooker system with the goal of improving consistency and predictability [6, 19, 23], whereas others have focused on simplifying the Brooker system to improve communication and reproducibility [22]. Although these authors have argued that their revisions demonstrate an improvement over the Brooker classification, the original Brooker classification remains a commonly used system for classifying HO after THA.

Purpose

In their 1973 article, Dr Andrew Brooker and colleagues [3] recognized that HO was a common radiographic finding after THA, but only occasionally did it affect functional outcomes. The authors therefore set out to "present a system whereby ectopic-bone formation following THA may be classified and to report the incidence of ectopic-bone formation following total hip replacement." They evaluated 100 consecutive patients treated with THA at The Johns Hopkins Hospital and reviewed AP pelvic radiographs at a minimum of 6 months postoperatively. Although subsequent classification schemes have incorporated additional radiographic views [19], the Brooker classification uses only AP projections. Brooker et al. also collected pre- and postoperative Harris hip scores (HHSs) in an attempt to correlate HO with functional outcomes.

Description

The Brooker classification divides the extent of HO formation after THA into four classes (Fig. 1). Class 1 is described as islands of bone within the soft tissues about the hip. Class 2 includes bone spurs originating from the pelvis or proximal end of the femur, leaving at least 1 cm

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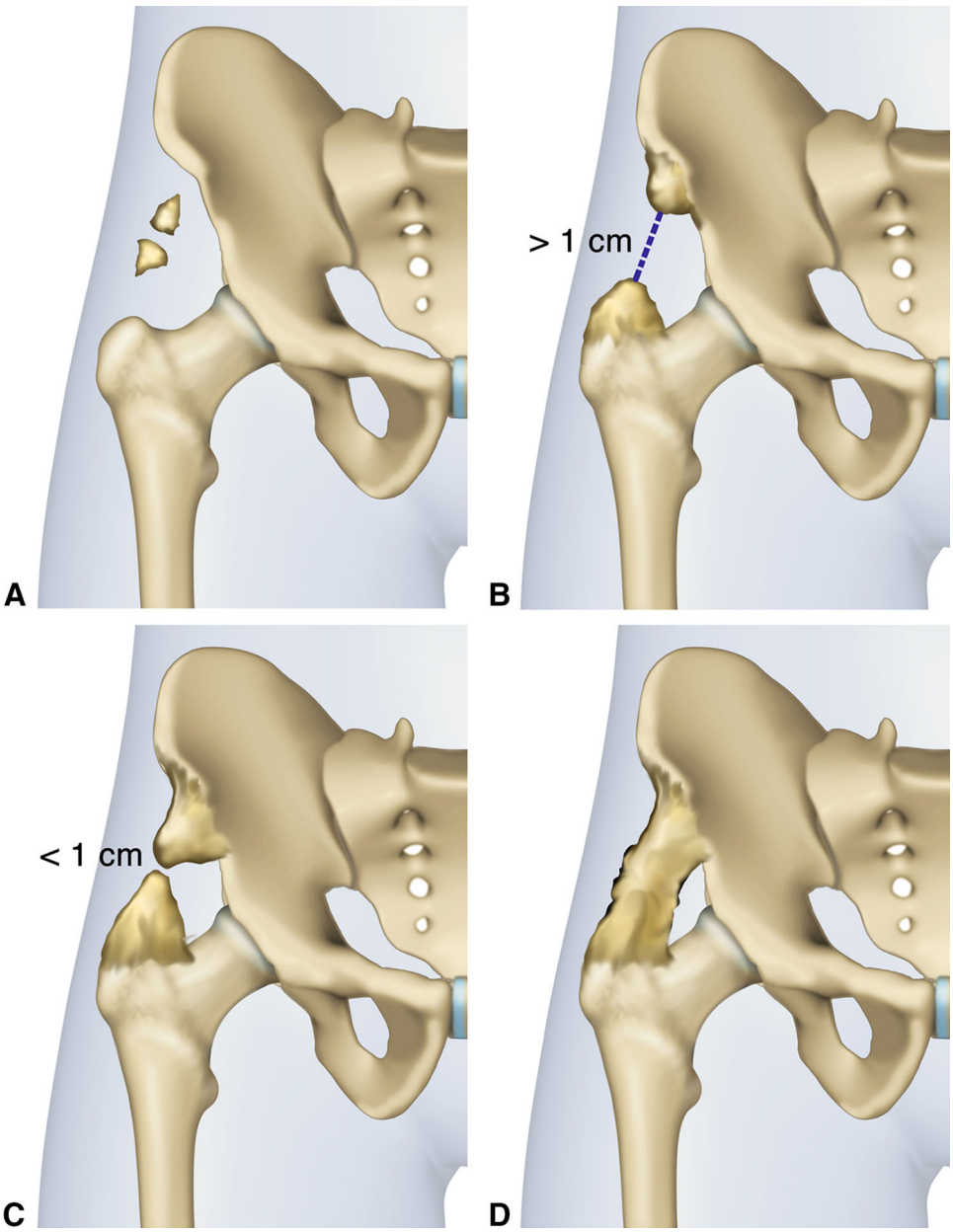

Fig. 1A–D The Brooker classification divides the extent of HO formation after THA into four classes: (**A**) Class 1 is described as islands of bone within the soft tissues about the hip; (**B**) Class 2 includes bone spurs originating from the pelvis or proximal end of the femur, leaving at least 1 cm between opposing bone surfaces; (**C**) Class 3 consists of bone spurs originating from the pelvis or proximal end of the femur, reducing the space between opposing bone surfaces to less than 1 cm; and (**D**) Class 4 shows apparent bone ankylosis of the hip. Reproduced with permission from Kate Sweeney.

between opposing bone surfaces. Class 3 consists of bone spurs originating from the pelvis or proximal end of the femur, reducing the space between opposing bone surfaces to less than 1 cm. Class 4 shows apparent bone ankylosis of the hip. Brooker did not describe a Class 0 in his original manuscript, but subsequent studies using the Brooker classification have defined Class 0 as the absence of radiographic HO [17, 18, 23].

Validation

In 1994, Wright et al. [23] were the first group to independently evaluate and modify the Brooker classification. They identified specific radiographic traits that were common sources of interobserver disagreement and offered a list of clarifications to improve concurrence. They stated that a small amount of bone proximal to the superolateral lip of the acetabulum or below the resected neck of the femur did not constitute HO. Additionally, bone restricted to areas around a fracture, osteotomy, or bone graft did not constitute HO. Finally, they argued that small amounts of bone isolated to the area between the lesser trochanter and the ischium should be classified as Class 2 HO irrespective of the distance between bony surfaces.

Wright et al. [23] also assessed the reliability and validity of the Brooker classification. Seventy-seven AP pelvic radiographs were evaluated 6 months after THA by

two orthopaedic surgeons who were blinded to prior gradings and all identifying marks. The surgeons did not discuss the criteria used for grading before radiographic evaluation. Two evaluators reviewed discrepancies between the gradings of the first set of images, modified the criteria as described previously, and reviewed another 76 images. They found improvement in their interobserver reliability with kappa improved from 0.57 to 0.68 and overall agreement improved from 68% to 77% with their modifications. Intraobserver reliability was also good with one surgeon having 86% agreement with a kappa of 0.69 and the other surgeon having 77% agreement with a kappa of 0.68. The class of HO correlated with hip ROM ($r = -0.25$; $p = 0.005$) but did not correlate with the HHS.

Although Wright et al. added minor radiographic changes to Brooker's scheme, in 2002, Della Valle et al. [6] proposed a new system in an attempt to improve reliability. Della Valle et al. suggested combining hips without radiographic evidence of HO and Brooker Class 1, citing both groups as having minimal clinical significance and recurring as a common source of discrepancy. They also combined Brooker Classes 3 and 4 into a single group characterized by the presence of HO that potentially reduced hip ROM, because they felt that differentiating Classes 3 and 4 (ie, determining the presence of ankylosis on AP radiograph) was a further source of discrepancy. Finally, Della Valle et al. defined bone island size and spur separation distance to minimize discrepancies between large islands partially overlying native bone and small spurs on single-view radiographs. The rating system Della Valle et al. proposed is therefore as follows: Grade A = absence of HO or presence of greater than or equal to one island of bone less than 1 cm in length; Grade B = presence of one or more islands of bone, at least 1 cm in length, and presence of bone spurs from the pelvis or femur leaving at least 1 cm between opposing bone surfaces; and Grade C = presence of bone spurs from the pelvis or femur leaving less than 1 cm between opposing bone surfaces and apparent bone ankylosis [6].

Della Valle et al. used six observers to review the plain AP radiographs of 169 patients who had undergone THA and found an interobserver kappa of 0.43 and an intraobserver kappa of 0.74 using the original Brooker classification. With their proposed rating system, they found interobserver kappa increased to 0.59 and intraobserver kappa increased to 0.78 ($p = 0.0085$). They noted improved consistency and ability to identify and classify significant HO (using the combined Brooker Classes 3–4/Della Valle Grade C) from 52% to 76%.

Limitations

Although the Brooker classification continues to be a widely used scheme for quantifying HO, the limitations of the system have inspired subsequent modifications. The majority of the Brooker classification's limitations relate to poor intraobserver and interobserver reliability during radiographic interpretation. HO overlying the edges of native bone on AP imaging is often difficult to characterize as either an island or a spur. Similarly, overlapping islands or spurs are often confused with ankylosis. The Brooker classification uses only one radiographic projection, so these ambiguities cannot be clarified with orthogonal views. Additionally, the radiographic technique itself can be considered a limitation to the Brooker classification. Variable xray beam penetration can alter the apparent size of HO or even render HO undetectable, depending on exposure. Furthermore, variations in technique often make measuring absolute distances impossible using radiographs.

A good classification system should ultimately translate into useful information for clinical practice. A limitation of the Brooker classification is that it correlates poorly with outcome measures such as the HHS. This is likely the result of the observation that HO is rarely clinically important until it severely impedes patient ROM [12]. Furthermore, the extent to which the Brooker classification is able to predict propensity toward future HO in individual patients undergoing subsequent surgical procedures has not been studied. However, most authors agree that the occurrence and quantity of HO does not change past 1 year postoperatively [10, 16]. Multiple groups have published modifications increasing the complexity of the Brooker classification to improve reliability and clinical use [6, 13, 19, 22, 23]; however, a good classification system must balance ease of use with accuracy. More complex modifications to the Brooker classification can be burdensome to use and apply. Despite more recent suggested modifications [6, 19, 22, 23], the original Brooker classification remains widely used in the literature.

Recently, use of the Brooker classification has been expanded to hip-related HO with etiologies other than THA such as neurologic injury [14] or acetabular fracture fixation [8]. These studies have also incorporated CT scans into radiographic evaluation of HO. Furthermore, a modified Brooker classification has been applied to HO in animal models [18] but these applications have not yet been validated. Topics of ongoing research include HO prophylaxis and optimal surgical treatment of HO, and the Brooker classification continues to be an integral component of research in the field [4, 15].

Conclusions

The Brooker classification used plain AP pelvic radiographs to grade HO after THA. Despite its imperfect interobserver reliability, the Brooker classification has

many advantages, including its widespread familiarity, simplicity of use, and the ubiquity of AP pelvic radiographs after THA. Although numerous modifications have been proposed, the Brooker classification remains a widely cited and used classification system for management of and research on HO.

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