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In Brief

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Classifications in Brief: Garden Classification of Femoral Neck Fractures

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History

The incidence of femoral neck fractures in the United States is approximately 63.3 per 100,000 person/years in women and 27.7 per 100,000 person/years in men [11, 40]. There are many risk factors for femoral neck fractures, including female gender, low bone density, and reduced mobility [12, 27]. Fracture risk increases dramatically with age, with the majority of fractures occurring in older white women secondary to low-energy falls [29]. In younger patients, high-energy trauma is responsible for most of these injuries [38].

Femoral neck fractures initially were classified by Sir Astley Cooper in 1823 as either intracapsular or extracapsular, which he felt had prognostic implications [10]. As reported by Bartonicek [4], it was only later in 1935 that a biomechanical classification was presented [37]. The Pauwel classification, as it has come to be called, stratified fractures in three groups based on inclination of the fracture line relative to the horizontal: Type I, less than 30°; Type II, 30° to 50°; and Type III, greater than 50°. As the angle of inclination increases, the forces transition from being compressive to shearing [4]. An increase in vertical shearing forces results in higher risks of displacement, postreduction nonunion, and failure of fixation [37].

In 1961, Robert Symon Garden, a British orthopaedic surgeon with a focused interest in the femoral neck, described a more-comprehensive classification [19]. The Garden classification incorporates displacement, fracture completeness, and relationship of bony trabeculae in the femoral head and neck. Gardens' originally reviewed 80 patients with femoral neck fractures, which he classified in Types I to IV, and he followed these patients for at least 12 months postoperatively. He found that Types I and II fractures had a 100% union rate. Types III and IV had lower union rates of 93% and 57% respectively.

Purpose

Fracture classification systems are most valuable when reproducible, widely used, prognostic, and guide clinical management. Linton critiqued the Pauwel classification owing to the difficulty in accurate assessment of fracture line inclination, particularly in displaced fractures [30]. Garden agreed with this critique and added that fracture patterns could imitate each other in radiographs [19]. The appearance of the fracture line inclination can vary based on the rotation of the leg. For example, a Pauwel Type II fracture may appear to have a lower or higher fracture line inclination mimicking a Type I or III fracture based on the radiographs. Garden's classification therefore was designed to address these concerns.

Description

Garden's classification is based on AP radiographs of the hip (Table 1). Four types of fractures are included, incomplete and valgus impacted (Type I, Fig. 1A), complete and nondisplaced (Type II, Fig. 1B), complete and partially displaced (Type III, Fig. 1C), and complete and fully displaced (Type IV, Fig. 1D). With time, clinicians have simplified the Garden classification by grouping femoral neck fractures as either nondisplaced or displaced, as

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TABLE 1. Garden's classification for femoral neck fractures

Type	Description	Nondisplaced or displaced
I	Valgus impacted incomplete fracture, disruption of the lateral cortex while the medial cortex is preserved	Nondisplaced
II	Complete fracture	Nondisplaced
III	Complete fracture, partial displacement indicated by change in angle of the trabeculae	Displaced
IV	Complete fracture, complete displacement leading to parallel orientation of the trabeculae	Displaced

displacement is what most often guides treatment options [2, 25]. The treatment of femoral neck fractures varies based on the Garden classification.

Garden Types I and II femoral neck fractures are nondisplaced. Internal fixation with preservation of the femoral head generally is favored for nondisplaced fractures of the femoral neck. Bentley [6] looked at the treatment of impacted femoral neck fractures treated nonoperatively and found that these fractures displaced as much as 15% of the time. He therefore recommended that all Garden Types I and II nondisplaced fractures be fixed with internal fixation to allow for early weightbearing and provide stability without increasing the risk for avascular necrosis [6]. Internal fixation options include cannulated screws, dynamic hip screws, proximal femoral locking plates, and cephalomedullary nails [26, 33, 48]. A recent prospective randomized multicenter study evaluated the rates of complications and reoperations for sliding hip screws and cancellous screw fixation in the treatment of nondisplaced femoral neck fractures [17]. This study found that patients in the sliding hip screw group (9%) were significantly more likely to have avascular necrosis develop than patients in the cancellous hip screw group (5%). However, there were no differences in reoperation rates between the two groups, leading to the study conclusion that both techniques were viable options in the treatment of nondisplaced femoral neck fractures.

Garden Types III and IV femoral neck fractures are displaced. Fixation options for displaced femoral neck fractures include hemiarthroplasty,

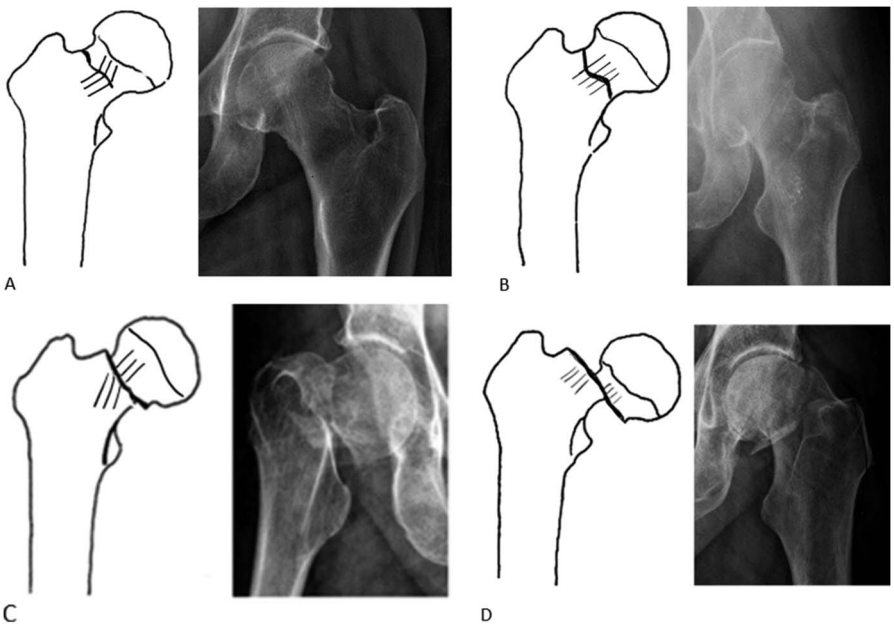

Fig. 1A-D The Garden classification is shown in the drawings and corresponding radiographs for Garden Types **(A)** I, **(B)** II, **(C)** III, and **(D)** IV femoral neck fractures.

THA, and internal fixation. Arthroplasty often is used for displaced femoral neck fractures in the elderly while internal fixation is still favored in younger patients. Lu-Yao et al. [31], in a meta-analysis, found a high incidence of nonunion (33%) and avascular necrosis (16%) after primary internal fixation of displaced femoral neck fractures. Tidermark et al. [44] compared internal fixation and THA in healthy elderly patients with displaced femoral neck fractures. They found higher revision rates in the internal fixation group (42%) compared with the arthroplasty group (4%) [44]. In more recent years, there has been an overall trend toward arthroplasty in the treatment of displaced femoral neck fractures, particularly in older patients, despite short-term increased mortality compared with internal fixation within the first 4 months (relative risk [RR] = 1.27; 95% CI, 0.84-1.92) [32]. However, mortality is reported to equalize at 1-year followup (RR = 1.04; 95% 0.84-1.29) [32]. In patients older than 60 years who are less active and have comorbidities, hemiarthroplasty provides satisfactory function [39]. In active older patients with displaced femoral neck fractures, a THA may be considered as it can provide better functional outcomes with lower rates of reoperation compared with hemiarthroplasty [24, 28]. Nevertheless, in individuals younger than 60 years with femoral neck fractures, there may be a potential benefit for femoral head preservation with internal fixation to meet higher functional demands [7, 32].

Validity

The validity of the Garden classification has been examined, with interobserver Kappa values between 0.03 and 0.56 [3, 5, 16, 18, 23, 35, 36, 43, 46, 49]. In an attempt to improve the reliability of the Garden classification, some authors recommended adopting a simplified classification system using only two categories: displaced versus nondisplaced [5, 35, 36]. Better Kappa values between 0.67 and 0.77 have been reported with this simplified classification [5, 43]. Nevertheless, Van Embden et al. [46] compared the interobserver reliability of the original and simplified classifications and although they reported better reliability in the simplified system (kappa = 0.31 and 0.52 respectively), the overall result remained poor.

Despite the poor reliability reported in several studies [1, 18, 21, 46], the Garden classification is still the most commonly used system. Zlowodzki et al. [49] conducted a survey among orthopaedic surgeons to determine the preferred classification system for femoral neck fractures and the ability of participants to differentiate the four types of fractures in the Garden classification. Two hundred ninety-eight surgeons responded [49]. The Garden classification was the preferred classification of 72% of respondents. However, only 39% believed they could differentiate between the four types of fractures in the classification. In another study, eight reviewers were asked to evaluate preoperative radiographs of 100 femoral neck fractures [18]. The observers agreed on the Garden type in only 22% of cases. However, when asked to identify fractures as simply displaced or nondisplaced, 77% agreement was obtained [18].

The other two commonly used classification systems are those of Pauwels [37] and the AO [34]. van Embden et al. [47] evaluated interobserver reliability of the Pauwels classification by having five trauma surgeons and five orthopaedic residents review radiographs of 100 patients with femoral neck fractures. The overall kappa value was 0.31 (0.38 for the surgeons and 0.27 for the residents). Turgut et al. [45] reported on the inter- and intraobserver reliability of the Garden, Pauwels, and AO classification systems and whether surgeon experience influenced results. In their study, 15 observers were asked to review preoperative AP radiographs of 107 patients with femoral neck fractures on two separate occasions. Intraobserver reliability was highest for the Garden classification (0.759). In a study by Gasper et al. [21], comparing the three classifications, the Garden classification was found to have the highest inter- and intraobserver reliability of the three classifications.

Limitations

The Garden classification does have limitations. Its fracture types are based solely on AP radiographs. However, most femoral neck fractures are evaluated with radiographs in multiple planes or even with advanced imaging. With advancement in CT, many femoral neck fractures that are classified as Type I on plain radiographs may potentially be Garden Type II or III fractures. In a study comparing digital radiography with CT for classifying Garden fractures, Chen et al. [8] found that all fractures classified as Type I necessitated recategorization as Garden Type II when CT was used. In another study, Du et al. [15] found that 41 of 48 Garden Type I fractures showed substantial rotational and spatial displacements of the femoral head with three-dimensional imaging that

may not have been appreciated on plain radiographs.

Although the Garden classification was designed to aid practitioners in clinical decision-making, the quality of fracture reduction and the risk of nonunion and avascular necrosis do not correlate with Garden types [5, 16, 18, 23, 36, 43, 49]. In addition, other important variables known to affect outcomes are not part of the classification. These include patient age, comorbidities, quality of reduction, and concomitant injuries [20, 35, 36]. In a study of 52 patients older than 70 years with Garden Types I and II femoral neck fractures, Han et al. [22] found that major complications occurred in 23% of patients with Garden Type I fractures (three of 13 patients) and 38% of patients with Garden Type II fractures (15 of 39 patients), with a reoperation rate of 30% (16 patients).

The Garden system also fails to subclassify Type I valgus impacted fractures. This is important, as Type I fractures with retroversion have a higher risk of fixation failure, leading some orthopaedic surgeons to classify this subtype of valgus impacted fractures as Garden Type III injuries [14, 41, 42]. Song et al. [41] found that fractures with more than 15° posterior tilt experienced greater shortening of the femoral neck, a higher risk of osteonecrosis, lower Harris hip scores, and a greater need for second surgical procedures.

Another limitation of the Garden classification is its failure to incorporate the location of the fracture in the femoral neck, which has implications regarding operative planning and outcomes [9, 13]. Patients with subcapital femoral neck fractures are more likely to have a nonunion or avascular necrosis develop compared with those with transcervical fractures [13].

Conclusion

The Garden classification describes femoral neck fractures as a function of displacement. Despite its limitations, the classification is well accepted and widely used by orthopaedic surgeons. It will be important for future studies to determine whether the Garden classification can be enhanced via incorporation of advanced imaging modalities and patient characteristics, such as age.

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