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Periprosthetic Fractures after Joint Replacement: a Unified Classification System

L.C. Howard, C.P. Duncan

Department of Orthopaedics, University of British Columbia
Complex Joint Clinic, 2775 Laurel Street, Vancouver, BC V5Z1M9, Canada

Abstract

Periprosthetic fracture associated with joint replacement is a common reason for revision arthroplasty and is increasing. Establishing universal principles of management is essential for good outcomes and a classification system that not only classifies, but offers these principles, is critical to achieve this. The Vancouver Classification System (VCS) for periprosthetic fractures involving total hip arthroplasty is validated across North America and Europe. It does not, however, consider other periprosthetic fractures in different joints. The Unified Classification System (UCS) was developed to incorporate the classification and treatment principles of all periprosthetic fractures in any anatomic location. The system is based on the simple mnemonic "ABCDEF" which corresponds to fractures characterized by the following anatomic descriptors: 1) apophyseal; 2) bed of the implant; 3) clear of the implant; 4) dividing the bone between two arthroplasties; 5) each of two bones supporting one arthroplasty; 6) facing and articulating with an implant. Initial validation for the UCS shows substantial and near-perfect inter and intra-observer agreement. Given this performance, it has the potential to evolve into the gold standard classification system for periprosthetic fractures in any joint that they occur.

Keyword: joint replacement, periprosthetic fractures, classification system.

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Перипротезные переломы после эндопротезирования суставов: единая система классификации

Л.С. Ховард, К.П. Данкан

Университет Британской Колумбии
Complex Joint Clinic, 2775 Laurel Street, Vancouver, BC V5Z1M9, Canada

Реферат

Перипротезные переломы после эндопротезирования суставов являются частой причиной ревизий, и число подобных осложнений увеличивается. Критично важным для достижения хороших исходов является определение универсальных принципов лечения, а также система классификации, которая не только систематизирует переломы, но и предлагает принципы лечения. В Северной Америке и Европе принята Ванкуверская классификация перипротезных переломов (Vancouver Classification System, VCS) при тотальном эндопротезировании тазобедренного сустава. Однако, данная система не учитывает перипротезные переломы в области других суставов. Единая классификация (Unified Classification System, UCS) объединяет в себе принципы систематизации и лечения всех перипротезных переломов любой локализации. Комплексная классификация основывается на простой мнемонической «ABCDEF» схеме обозначения переломов, исходя из следующих анатомических идентификаторов: 1) апофизарный или внесуставной/чрезсуставной перелом (Apophyseal); 2) перелом, затрагивающий ложе, или костные структуры вокруг протеза (Bed of implant); 3) перелом вне локализации протеза или после его удаления (Clear of the implant); 4) перелом длинных костей, соединяющих два замещенных сустава (Dividing the bone between two arthroplasties); 5) перелом обеих костей, вовлеченных в артропластику одного сустава (Each of two bones supporting one arthroplasty); 6) перелом суставной поверхности после гемиартропластики (Facing and articulating with an implant). Первая проверка Единой классификации (UCS) продемонстрировала значительную и высоконадежную согласованность заключений одного и нескольких исследователей в отношении ее применения. Учитывая полученные результаты, предлагаемая система может стать «золотым стандартом» классификации перипротезных переломов в области любого сустава.

Ключевые слова: эндопротезирование суставов, перипротезные переломы. классификация.

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Lisa C. Howard. 2775 Laurel Street, Vancouver, BC V5Z1M9, Canada; e-mail: lchoward25@gmail.com

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Introduction

Periprosthetic fractures associated with joint replacement are increasing in prevalence. They have been reported as among the most common reasons for revision in the Swedish, Australian and United Kingdom joint registries [1–3]. Treatment of these injuries is challenging and can be associated with poor outcomes. Therefore, it is of paramount importance to establish universal principles of management that promote good outcomes. A system that not only classifies, but offers principles in management, is critical to achieve this.

A useful classification system incorporates clinical and radiographic information to guide management, offer a prognosis and allow for appropriate comparison of outcomes among other surgeons and centers [4]. In addition, it should be reliable and have good inter and intra-observer agreement. Various classification systems have been outlined as they apply to different joints. The Vancouver Classification System (VCS) for periprosthetic fractures involving total hip arthroplasty [5] has been subjected to validation testing in North America and Europe [4, 6]. This system, however, does not take into account other periprosthetic fractures within other joints. Furthermore, other anatomic locations, such as the patella, have multiple classification systems [7–10]. This lead to the development of the Unified Classification System (UCS) which incorporates classification and treatment principles of all periprosthetic fractures. Initial validation studies involving two field studies show substantial and near-perfect inter- and intra-observer agreement [11, 12]. An overview of this system is presented and will focus on periprosthetic fractures of the hip while a more comprehensive application to other joints is described in the original publication [13].

The goals of the UCS are threefold:

1. To expand on the VCS with three new fracture patterns that were not initially included.

2. To apply it to all joint replacements regardless of what joint has been replaced and what bone is broken.

3. To propose a common, simple language that allows clear communication among different centers and surgeons, and promotes uniform collection of data for registries and outcomes research.

The UCS Mnemonic and Types

In order to understand and easily recall the fracture types within the UCS, the following simple mnemonic has been developed:

Type A: ***A****pophyseal*
Type B: ***B****ed* of the implant
Type C: ***C****lear* of the implant bed
Type D: ***D****ividing* the bone between two arthroplasties
Type E: ***E****ach* of two bones supporting one arthroplasty
Type F: ***F****acing* and articulating with an implant although the bone itself is not resurfaced or replaced.

Type A is a fracture that involves an apophysis or protuberance of bone to which soft tissue structures are attached. Common examples are the greater and lesser trochanters of the femur as well as greater and lesser tuberosities of the humerus. Others include the upper or lower poles of the patella and the patellar tuberosity of the tibia (Fig. 1, 2). Fractures of the lesser trochanter of the femur can extend into the bed of the implant and are more appropriately classified as a UCS B2 (Fig. 2).

Type B involves the bone supporting or very closely adjacent to an implant (Fig. 3–5). Typical examples include the shaft of the humerus, femur or tibia associated with a stemmed component or a fracture of the glenoid, acetabulum or patella that have been resurfaced. As with the VCS [5], adequate sub-classification is required to apply the appropriate principles. In B1 types the implant is well fixed while in B2 types it is loose. In the B3 type the implant is loose and associated with poor bone stock as a result of osteolysis, osteoporosis or severe comminution.

Type C involves a fracture which is distant to, or separated from the bed of the implant (Fig. 6). Examples include fracture of the femoral, tibial or humeral shaft well distal to the stem of the implant or involving the hemipelvis adjacent to a hip replacement that does not extend into the acetabulum.

Type D involves a fracture of a long bone which supports two joint replacements (Fig. 7). The most common example involves the femur after a hip and a knee replacement. Other examples include a humerus fracture following shoulder and elbow replacement or the tibia following knee and ankle replacement.

Type E involves two bones supporting one replacement. Examples include the acetabulum and femur after hip replacement, femur and tibia after knee replacement or the humerus and ulna after elbow replacement (Fig. 8).

Type F is uncommon and involves fracture of a joint surface that is not replaced but is articulating with an implant. The most common example is that of an acetabular fracture facing a unipolar or bipolar hemiarthroplasty of the hip. Other examples include the glenoid after humeral hemiarthroplasty or the patella after knee replacement in which the patella was nor resurfaced. In current practice, this subtype can only involve the glenoid, lateral humeral condyle, acetabulum or patella (Fig. 9).

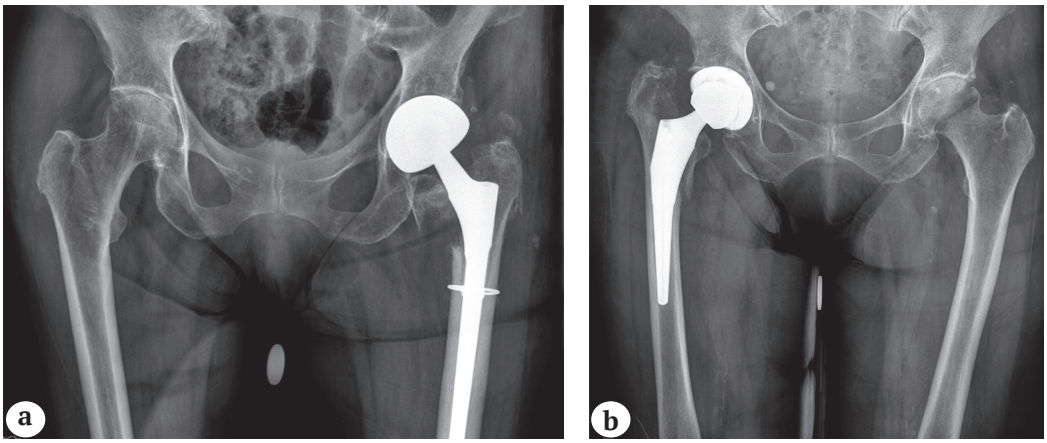

Fig. 1. Demonstrating UCS type A fracture patterns:
a — anteroposterior radiograph of a left hip arthroplasty demonstrating a UCS type A fracture of the lesser trochanter. It does not require surgical management as the implant stability is not compromised and its soft tissue attachment (iliopsoas tendon) is not vital for hip function;
b — anteroposterior radiograph of a right hip arthroplasty demonstrating a UCS type B2 fracture.
Despite its involvement of the lesser trochanter, careful analysis reveals that is involves the bed of the implant with subsidence of the stem. Surgical intervention is required for this pattern

Treatment Principles

Type A. Treatment of these fractures involves two important questions:

1) How important is the attached soft tissue to the function of the adjacent joint replacement?

2) Is the fracture displaced?

If the attachments are unimportant then the fracture can be managed non-surgically despite displacement. Common examples of this include the lesser trochanter of the femur (See fig. 1) or the coracoid process of the scapula. The Illiopsoas tendon or coracoacromial ligament are not considered critical for prosthetic joint function. Fractures of the greater trochanter, distal pole of patella or avulsion of the deltoid ligament should be surgically addressed when displaced as their respective attachments are important for associated prosthetic joint function (See fig. 2).

Type B. Management of these injuries depends on the subtype (Fig. 3–5). If it is classified as B1, management will depend on the previously determined outcomes of operative vs nonoperative treatment of the fracture type. For example, fracture of the femur around a well fixed proximally coated stem is best managed with minimally invasive plate osteosynthesis (MIPO) [14, 15]. In the case of a B2 fractures, revision with a longer stem is a common method of treatment. For B3 fractures, a more complex reconstruction will sometimes be required. In the case of femoral B2 and B3 fractures, revision with long tapered fluted stems is a generally accepted treatment method with good outcomes [16–21] however more complex options may be required for some B3 patterns. These principles of management, namely implant stability and bone quality, are also be applied to other regions of the skeleton (Fig. 5).

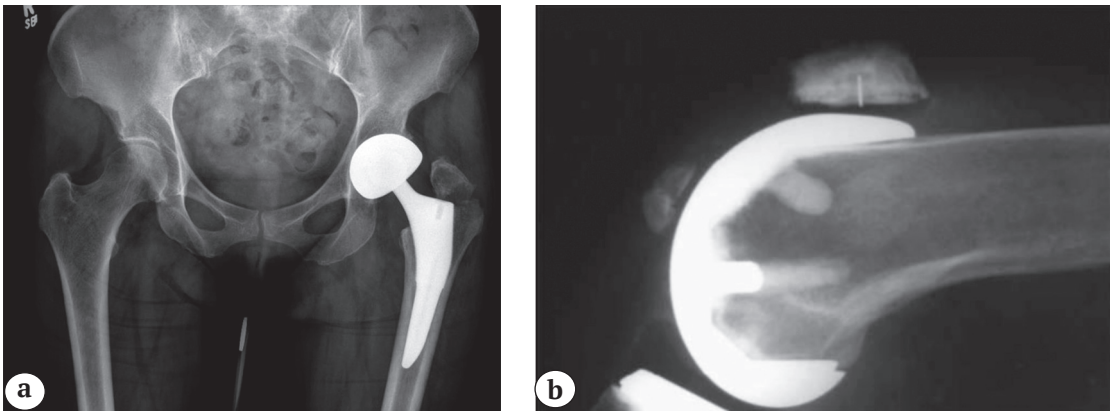

Fig. 2. Anteroposterior radiograph demonstrating a UCS type A fracture of the greater trochanter adjacent to a femoral prosthesis (a); lateral radiograph demonstrating a UCS type A involving the inferior pole of the patella. Both fractures require surgical management for proper joint function (b)

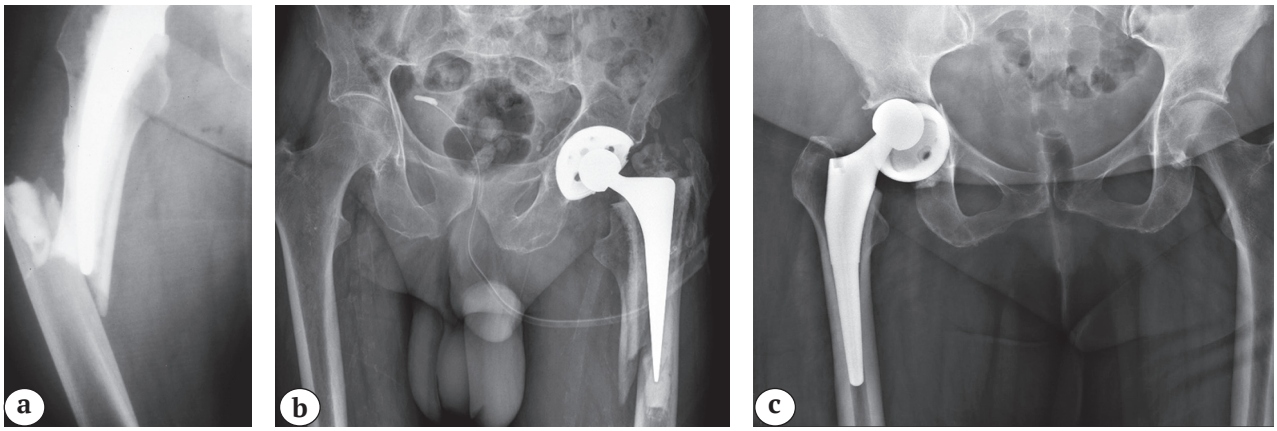

Fig. 3. Demonstrating UCS B1 and B2 fractures:
a — anteroposterior radiograph of a UCS B1 femur fracture in which the prosthesis remains stable. This fracture is best managed with a MIPO technique;
b — anteroposterior radiograph of a UCS B2 femur fracture in which the prosthesis is loose;
c — anteroposterior radiograph of a UCS B2 acetabular fracture.
Revision arthroplasty is required for both 3b and c

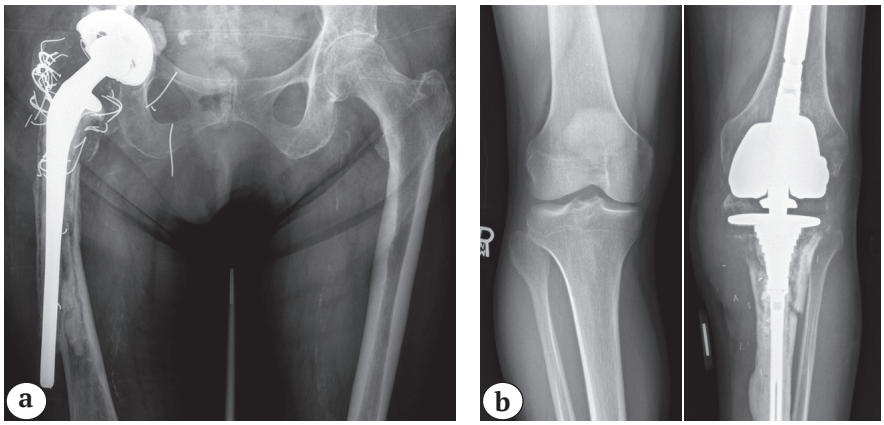

Fig. 4. Demonstrating UCS B3 fractures around a total hip and total knee replacement:
a — anteroposterior radiograph of the pelvis and femurs showing a UCS B3 fracture of the femur;
b — anteroposterior radiograph of the pelvis showing a UCS B3 fracture of the tibia.
Both fractures will require revision arthroplasty with specialized techniques to address the poor bone quality

Fig. 5. Demonstrating the utility of the UCS to classify periprosthetic fractures in other regions of the body:
a — lateral radiograph of a UCS B2 fracture involving the ulnar implant of a total elbow prosthesis;
b — anteroposterior radiograph of a UCS B3 fracture involving the humeral implant of a total elbow prosthesis.
As per the principles of management in total hip and total knee arthroplasties, revision arthroplasty of each of these patterns is required.
In Figure 5b a complex reconstruction will need consideration

Type C. These fractures are managed based on modern principles of fracture management and the prosthesis can generally be ignored. Specialized techniques such as unicortical screws or cerclage wires may be required if the fixation plate overlaps the bed of the implant (Fig. 6).

Type D. An exercise, termed "block out analysis" is useful for management of this uncommon type. The most common type is a fracture involving the femur between a hip and knee arthroplasty (Fig. 7). The surgeon is prompted to block out the knee while analyzing or classifying the fracture with reference

to the hip. Next the hip is blocked out while the fracture is analyzed with reference to the knee. From this will flow a type B or C for each joint, and a rational treatment plan. In Figure 7, this block out analysis reveals a type C for the hip and a type C for the knee. Therefore, the fracture can be managed as a C for each joint and the arthroplasties do not need to be touched.

Type E. The "block out analysis" is also useful for these fractures. Each fracture, bone stock and implant stability are assessed on each side of the arthroplasty. In Figure 8 there is a fracture involving both bones that support a hip replacement; therefore type E. If the femur is blocked out, it clearly is a type B3 for the acetabulum requiring complex reconstruction. While if the acetabulum is blocked out, it is a B2 for the femur and a less complex stem revision will suffice.

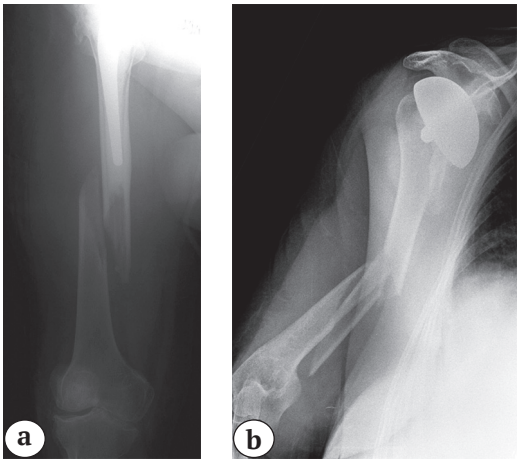

Fig. 6. Demonstrating UCS type C involving the femur and the humerus:
a — anteroposterior radiograph of a UCS type C involving the femur distal to a femoral stem;
b — anteroposterior radiograph of a UCS type C involving the humerus distal to a proximal humeral resurfacing.
Both fractures are managed based on principles of femoral and humeral shaft fracture fixation independent of the prosthesis

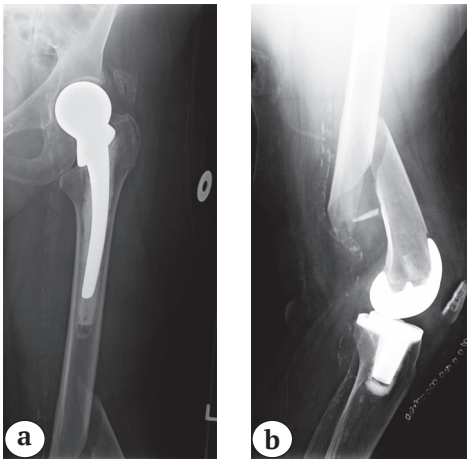

Fig. 7. Demonstrating a UCS type D of the femur:
a — "block our analysis" of the knee reveals a UCS type C of the femur;
b — blocking out the hip also reveals a UCS type C of the knee.
As such, both fractures are managed as UCS type C fractures

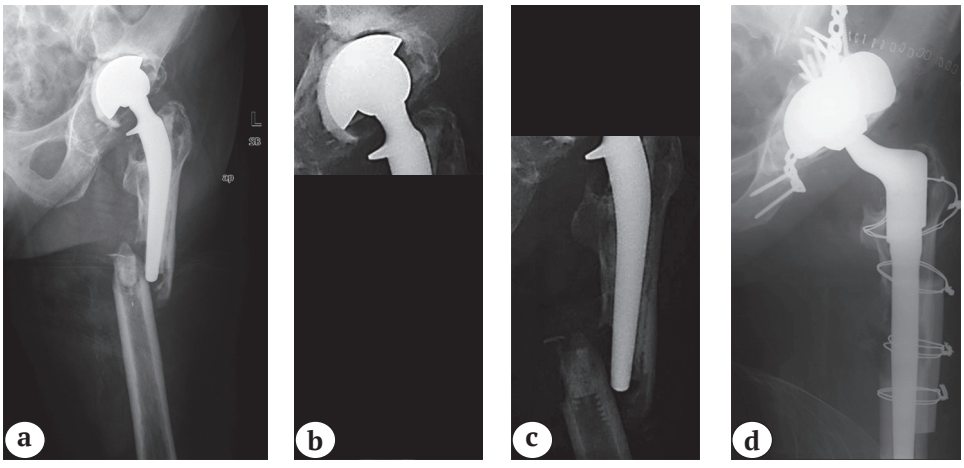

Fig. 8. Demonstrating "block out analysis" of a UCS type E fracture:
a — anteroposterior radiograph of a left UCS type E pattern involving the femur and acetabulum;
b — blocking out the femur reveals a UCS type B3 of the acetabulum;
c — blocking out the acetabulum reveals a UCS type B2 of the femur;
d — application of the UCS principles indicates that the most appropriate management is a complex revision of the acetabulum with a revision arthroplasty and fixation of the femur

Type F. Management of these fractures depends on the degree of displacement as well as the general health and level of function of the patient. A mildly displaced acetabular fracture, for example, could be managed non-operatively with a delayed total hip arthroplasty for persistent symptoms. Displaced fractures may require early osteosynthesis in the appropriate surgical candidates (Fig. 9)

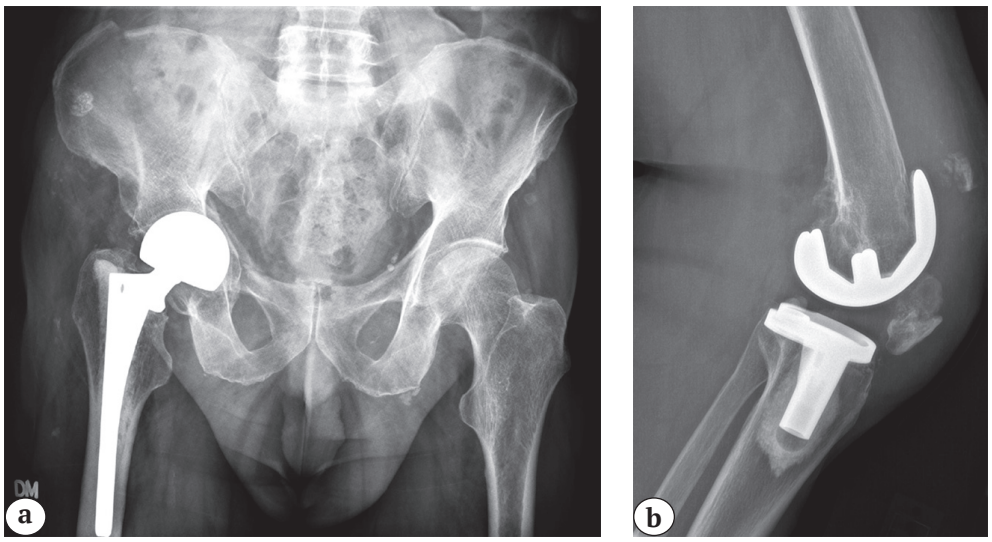

Fig. 9. Demonstrating a UCS type F fracture of the hip and knee:
a — anteroposterior radiograph of a UCS type F fracture of the acetabulum. In the appropriate clinical scenario, this pattern could be managed with delayed conversion to a total hip arthroplasty, if required;
b — lateral radiograph of a UCS type F fracture of the superior pole of an unresurfaced patella in which surgical intervention is required

Discussion

The UCS was constructed based on the need for a more standardized and universal classification system of periprosthetic fractures. Ideally, this would encourage a more standardized treatment algorithm and improved communication among health care providers which in turn would lead to improved patient care. Furthermore, a good classification system should be easily recalled and applied such that experts and non-experts are able to utilize it effectively. The widely accepted and validated principles of the VCS [4–6], namely fracture location, implant stability and bone quality, have served as a platform on which the UCS has been based. Despite some increased complexity, the UCS has performed extremely well in two separate studies, focusing on total knee and total hip periprosthetic fractures. Both studies compared the inter and intra-observer kappa agreement in "pre-experts" (resident Orthopaedic trainees) to "experts" (fellowship trained orthopaedic surgeons with an interest in reconstructive surgery). The inter and intra-observer agreement in both studies among the experts was very high while the agreement in pre-experts was only slightly lower. As such, the UCS is not only valuable as a communicative tool amongst experts, but is also a valuable learning tool for trainees.

The UCS is an easily applied classification system that promotes standardized management principles of periprosthetic fractures. The substantial agreement of the UCS between observers of varied levels of experience emphasizes the simplicity of its application. In the age of subspecialized Orthopaedics, a common language of classification is important to promote patient-centered care. Given its current performance to reliability testing, the UCS has the potential to evolve into the gold standard classification for periprosthetic fractures for any joint in which they occur.

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INFORMATION ABOUT AUTHORS:

Lisa C. Howard — Clinical and Research Fellow, Division of Adult Hip and Knee Reconstruction, Department of Orthopaedics, University of British Columbia, Vancouver, Canada

Clive P. Duncan — Professor and Emeritus Chair, Department of Orthopaedics, University of British Columbia, Vancouver, Canada

ИНФОРМАЦИЯ ОБ АВТОРАХ:

Лиза К. Ховард — врач и научный сотрудник, отделение восстановительной хирургии тазобедренного и коленного суставов, кафедра ортопедии, Университет Британской Колумбии, Ванкувер, Канада

Клайв П. Данкан — профессор, почетный председатель, кафедра ортопедии, Университет Британской Колумбии, Ванкувер, Канада