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Periprosthetic hip fractures: an update into their management and clinical outcomes

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- The Vancouver classification is still a useful tool of communication and stratification of periprosthetic fractures, but besides the three parameters it considers, clinicians should also assess additional factors.
- Combined advanced trauma and arthroplasty skills must be available in departments managing these complex injuries.
- Preoperative confirmation of the THA (total hip arthroplasty) stability is sometimes challenging. The most reliable method remains intraoperative assessment during surgical exploration of the hip joint.
- Certain B1 fractures will benefit from revision surgery, whilst some B2 fractures can be effectively managed with osteosynthesis, especially in frail patients.
- Less invasive osteosynthesis, balanced plate–bone constructs, composite implant solutions, together with an appropriate reduction of the limb axis, rotation and length are critical for a successful fixation and uneventful fracture healing.

Keywords: femur; hip; hip arthroplasty; hip replacement; interprosthetic fractures; periprosthetic fractures; Vancouver classification

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Introduction

Arthroplasties of major joints represent some of the most common and successful orthopaedic procedures. Increasing demand worldwide for these surgeries is evident in all relevant registries. This phenomenon can be attributed to a number of factors including the ageing of the population, the generalized demand for improved quality of life and the desire to maintain high activity levels throughout our lifespan, as well as to the expansion of the indications for replacement surgery to even younger populations. As a result of the increasing number of arthroplasties performed, a rise in the incidence of fractures around the prosthesis (periprosthetic) is noticed globally. More people will outlive their implants and develop osteolysis, undergo revision surgery, or sustain a traumatic (high- or low-energy) event which may result in a periprosthetic fracture (PPF). The economic impact on healthcare systems when treating these injuries is quite significant.[1,2]

Femoral fractures around a hip arthroplasty (THA) represent the most common periprosthetic fractures. Their contemporary management is mostly surgical and is considered technically challenging. Effective management of these injuries requires both trauma and arthroplasty skills, multidisciplinary input, and has substantial direct medical cost implications.

The Vancouver classification system/algorithm[3] is the one most widely utilized to describe these fractures and also guide treatment. The Coventry classification has also been proposed, which divides patients into those with previously ‘happy’ vs. ‘unhappy hips’, based on the presence of radiographic or clinical evidence (prior to the fracture event) of a failing prosthesis.[4] More recently, the UCS (Unified Classification System) has been introduced, allowing the inclusion of all possible scenarios of a fracture around an arthroplasty of all major joints.[5,6]

We report on the current management, latest advancements, and clinical outcomes of periprosthetic femoral fractures around a hip arthroplasty and propose an algorithm that can successfully guide treatment.

Epidemiology

Periprosthetic fractures around the hip can occur either intraoperatively or postoperatively. They can involve both the femur and/or the acetabulum, with the latter being quite infrequent. Intraoperatively they are more common in uncemented THAs (5.4%) compared to cemented (0.3%) and are significantly higher during revision surgery (20.9%) than primary arthroplasty (3.6%).[7]

Postoperatively, the incidence of PPFs has been reported at less than 1% after primary THA and up to 4% following revision surgery.[7–9] The risk of a periprosthetic fracture following THA is estimated at about 0.4–3.5%.[10,11] PPFs are the third most common reason for revision following THA[12–14] and the second most common in patients beyond the fourth year after their primary THA[15,16] according to data from the Swedish National Hip Arthroplasty Register (SHAR).

In the vast majority of cases (86%), low-energy trauma (fall from own height) is the mechanism of injury.[15,16] Most of the PPFs around a THA affect the femur; however, they may also involve the acetabulum (1/10 of THA-related fractures). The majority of the rare acetabular PPFs occur intraoperatively (7–8/10) and can be effectively classified accordingly using the system of Pascarella et al.[17]

Risks factors

Several patient characteristics may be associated with increased risk for PPFs. Female gender and age have been named as independent risk factors by some,[18–22] but the existing evidence is not entirely consistent throughout the current literature.[23] Other factors include osteoporosis,[18,19,21] rheumatoid arthritis,[24] Paget's disease,[25] developmental hip dysplasia[26] and increased time from the initial arthroplasty.

Surgical technique (stem malposition), the presence or absence of pre-existing osteolysis or aseptic loosening, the history or number of previous surgeries to the same region,[19,21] and the type of implant have also been associated with the incidence of PPFs. Cementless femoral implants have been linked with a higher PPF incidence, both intra-[27,28] and postoperatively.[15,28,29] Abdel et al found that intraoperative fractures occur 14 times more often with uncemented components, and that female patients older than 65 years are at greater risk. Postoperative fractures where again more common with uncemented implants, but independent of age and gender.[10] Carli et al in their systematic review reported a significantly higher number of PPFs with the use of cementless femoral components. A threefold increase in PPF rates was found with the use of single-wedge, and double-wedge implants when compared with anatomical, fully coated and tapered/rounded components. Among cemented implants, Exeter-type (force closed) were found to have a higher risk of PPF than Charnley-type (composite-beam) stems.[28]

Similarly, periprosthetic acetabular fractures are relevant to uncemented press-fit elliptical cups; however, they may also occur postoperatively following high- or low-energy trauma.[17,30]

Initial assessment

Good clinical history and examination are essential. Most of the patients present with a history of low-energy trauma. It is of paramount importance to identify signs of ongoing worsening symptoms regarding the affected joint (pre-existing the injury), as these might be indicative of an already loose prosthesis. Thigh pain – especially startup pain – and pain around the groin area, should be considered signs of a failing femoral stem or acetabular component.

Infection needs to be ruled out in all cases, as periprosthetic joint infection (PJI) has been reported in 11.6% of PPFs.[31] In the same study, the positive predictive value of white cell count (WCC), erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) was poor (18%, 21%, and 29%, respectively). Thus, it is suggested that increased inflammatory laboratory markers in patients with PPFs are not indicatory of deep PJI.[31] Careful evaluation of the clinical and, when available, of the radiological history are most useful. When the suspicion for co-existing PJI is low, the surgeon can usually proceed as standard, and intraoperative tissue samples (joint fluid aspiration, tissue samples, frozen sections) could be obtained to confirm the original impression. In case there is a high clinical suspicion for PJI, joint aspiration/biopsies should be performed preoperatively.[32,33]

Radiological imaging of good quality is vital to determine the location and characteristics of the fracture, the stability and type of the prosthesis and the integrity of the cement mantle in cemented components. Full-length X-rays of the femur and the pelvis should be obtained. Previous imaging should be retrieved and assessed if possible, as the radiological history of the THA can offer useful information regarding potential component migration or the presence of pre-existing radiolucent areas (osteolysis). Computerized tomography (CT) scan is also common practice, providing information regarding the overall bone stock, the actual fracture pattern, the integrity of the cement mantle and the stability of the arthroplasty components.

Preoperative confirmation of the THA stability is sometimes challenging, and the available findings inconclusive. A discrepancy of 20% between the preoperative impression and the intraoperative findings has been reported.[34] The difficulty often is that in order to fully test the stability of the femoral component intraoperatively, an open approach to the joint is required, which is separate to the standard exposures utilized for fracture fixation. Indirect methods such as translation of the distal implant relative to the proximal cement mantle at the fracture level[32] or using fluoroscopy screening in the operating room are often employed but are considered questionable when negative.

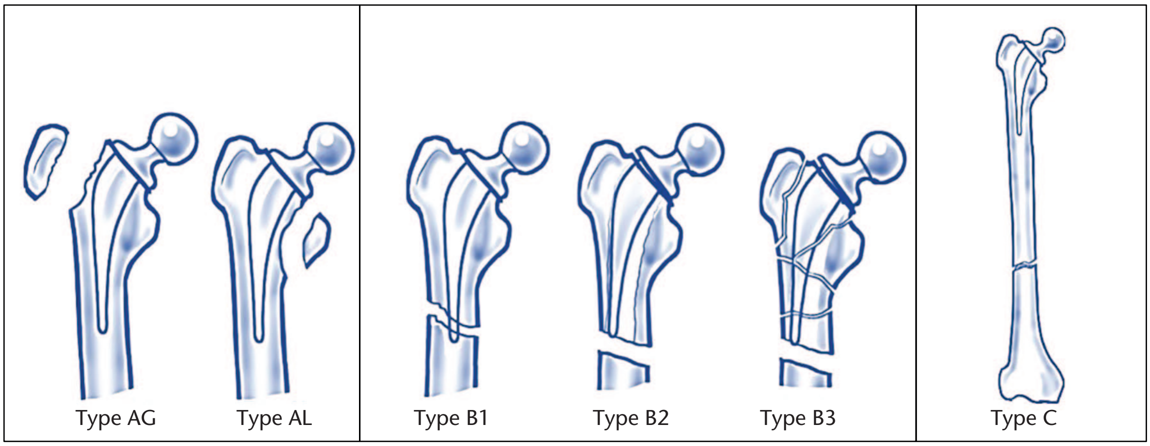

Fig. 1 The Vancouver classification: AG, greater trochanter fracture; AL, lesser trochanter fracture: B1, fracture around the tip of prosthesis-stable implant; B2, fracture associated with unstable femoral implant; B3, fracture associated with unstable femoral implant and poor bone stock; C, fracture below the tip of the femoral component.[142]

Classifications

The Vancouver classification system (Fig. 1) continues to be popular and is widely accepted to guide management.[3] It divides periprosthetic femoral fractures into three main types based on fracture location, which are further subdivided based on the stability of the implant and the quality of the surrounding bone.

Recently, the Unified Classification System (UCS) has also been proposed.[5,6] It provides a system to classify all periprosthetic fractures regardless of the anatomical site. It has been reported that it has an intraobserver agreement of 0.920 (95% CI 0.867 to 0.973) for the experts (orthopaedic surgeons), and 0.772 (95% CI 0.652 to 0.892) for the pre-experts (orthopaedic residents).[35] The UCS might serve as a useful instrument in research regarding the management, treatment and outcomes of PPFs, but its role is still to be evaluated.[6]

Periprosthetic acetabular fractures are more commonly classified according to the classic Paprosky system, the UCS, or the more recently published method of Pascarella et al.[5,6,17,36]

Management algorithms

Even though several classifications and algorithms exist to guide overall treatment, it is essential for the surgeon to understand that treatment of PPFs needs to be individualized taking into account a plethora of different parameters (patient comorbidities, implant stability, patient function levels, availability of relevant resources and expertise). Decision making requires experience and time; not rarely multidisciplinary input should also be employed. The need for focused clinical PPF pathways, similar to those for other types of common fragility fractures, has recently been highlighted.[37]

Non-operative treatment of PPFs has been associated with poor outcomes (nonunions, malunions, medical complications)[38] except probably in cases of a critically ill patient unable to undergo any major surgical intervention. With the evolution of implants and further experience in revision surgery, operative intervention is nowadays the choice of treatment. More recently, new evidence related to anabolic drug therapies in combination with non-operative protocols, even for PPFs with an unstable prosthesis, has introduced an interesting alternative method for very frail patients, or those with minimally displaced fractures.[39]

Once surgical treatment has been decided, certain fundamental principles need to be considered. Preoperative planning, including revision templating and verification of the availability of the appropriate surgical kits, are essential. The surgical approach should be carefully chosen to avoid unnecessary soft tissue damage, and backup plans should be in place since the treatment might change according to the intraoperative findings. Advanced trauma and/or arthroplasty skills are required in almost all cases.

The overall aim of the procedure is to be able to restore anatomical alignment with a stable implant, maintain bone stock, enable fracture union, allow early patient mobilization, and promote joint motion. The choice of implant and technique is, most of the time, guided by the location and complexity of the fracture, the stability of the prosthesis and the available bone stock. Patient-related factors also need to be considered, as the same type of fracture might require a different approach in patients with different physiology, bone-healing potential, severe comorbidities, or even higher body mass index (BMI).

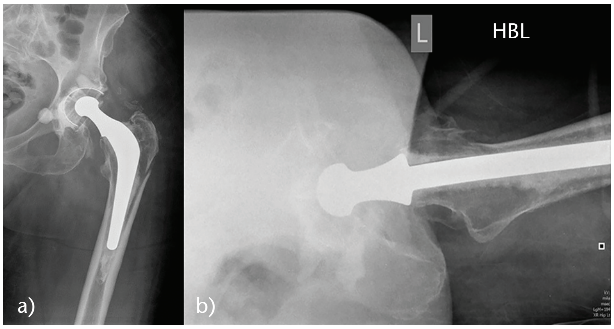

Fig. 2 Greater trochanter fracture around a cemented implant with evidence of osteolysis. (A) Anteroposterior and (B) lateral radiograph of left hip.

Vancouver Type A fractures

These fracture patterns occur proximally around the trochanteric femoral region. They involve either the greater (AG) or, the lesser trochanter (AL).

The AG fractures are usually stable and can be managed non-operatively with protected weight-bearing and restriction of active hip abduction for a period of 6–12 weeks (Fig. 2). Symptomatic nonunions with features of ongoing pain, instability, limping, weakness or significant migration > 2 cm can be addressed with surgical fixation using techniques commonly used for trochanteric osteotomies (wires, cables, or combinations with specialized plates).[33,40]

If the fracture is related to particle-induced osteolysis, which usually is the case,[41] then the underlying problem needs to be addressed. Depending on the radiological features, the extent of the osteolysis, the intraoperative findings of component stability and type of prosthesis, treatment options might vary from bearing surface exchange with grafting procedures along with fixation of the trochanter to a full acetabular and femoral stem revision.[33,42]

The AL fractures are commonly treated non-operatively unless large with extension into the calcar region that compromises the stability of the stem, which are relatively uncommon. In that case, they can be treated with cerclage wiring with or without grafting or with revision of the stem with diaphyseal fixation.[33,43] If they occur and are identified intraoperatively, cerclage wiring is advised, and a period of protected weight-bearing if identified in the postoperative X-rays.[43]

Vancouver Type B fractures

Most of these fractures, as suggested by a number of large registries, including the Swedish Hip Arthroplasty Register (SHAR), are of the B1 (29%: 304 out of 1049) and B2 (53%: 555 out of 1049) subtypes.[11] B3 fractures accounted for only 4% of the cases at least in the SHAR.[11]

Type B is the most challenging category in the treatment algorithm, as there is variability and difficulties in determining whether (a) the prosthesis is loose (B2 subtype) or not (B1 subtype); (b) the bone stock is compromised (B3 subtype), which usually requires advanced revision arthroplasty techniques. Most of the B1 fractures will require internal fixation alone, and the B2/B3 fractures will need revision arthroplasty options +/- internal fixation. Although studies have demonstrated the validity and reproducibility of the Vancouver classification, a Swedish study found that the surgeon’s grade of B1 was in agreement with the study radiologist’s classification only 34% of the time.[14]

The surgeon needs to be careful in identifying signs that might suggest an unstable prosthesis or evidence of the prosthesis displaying signs of loosening and failure prior to the injury. It is always recommended to check the stability of fixation of the prosthesis intraoperatively. Corten et al reported that 20% of fractures which were initially classified as Type B1 on preoperative radiographs were found to have an unstable stem intraoperatively.[34]

Subtype B1

These fractures around a stable prosthesis are usually treated with open reduction and internal fixation (ORIF). Different techniques are described in the literature, and there is no consensus regarding the best fixation strategy and device. Fixation is usually performed with extramedullary devices that use cables and plates, compression plates, cortical struts, locking plates or a combination of the above.

All extramedullary fixation implants, acting mostly as off-axis load-bearing devices, are exposed to high bending stresses which, together with the slow bone healing progress of elderly patients, often lead to early fatigue failure of the plating system prior to bony union. As demonstrated by Tsiridis et al, this type of osteosynthesis in isolation, without intra- or extramedullary bridging of the fracture site with either a long-stem or strut graft, can be associated with complications.[44]

Although good results have also been reported with ORIF of B1 fractures,[45–48] the high failure rate of others[46,49–52] is often attributed to the erroneous classification of PPF with unstable prosthesis as B1 according to the Vancouver system.[46]

Apart from that, it is also obvious that the surgeon has to overcome several challenges when addressing these injuries. The presence of osteopenic/osteoporotic bone, at the level of an existing implant/previous procedure, creates a difficult environment for fixation both from a biological, as well as a biomechanical point of view. The stem itself and the possible existence of a cement mantle might obstruct proper fixation and screw anchoring proximally, increasing the risk of failure.

The possibility of a cement mantle failure during screw insertion has also been investigated.[53–55] The occlusion of the femoral canal (implant/cement mantle), prior reaming, cement exothermic reaction, and pressurization all have a negative impact on the intramedullary blood supply.[56] Further periosteal devascularization during the procedure contributes to further biologic compromise of the local environment. All these factors need to be taken into consideration as contributing to the reported failure rates (nonunions, malunions, construct failure, implant loosening).

The use of bridging locking plates is nowadays the most popularized technique of fixation. They act as extramedullary bridging splints creating a fixed-angle construct ideal for fixation of osteopenic/porotic bone. Bridge plating, in principle, creates a mechanical environment of relative stability, which leads to early callus formation. As bridging locking plates do not rely on friction of either the plate surface to the cortex neither to screw thread purchase to the bone, they are considered more biologically friendly, preserving the periosteal blood supply, and at the same time offer greater angular stability than standard compression plating. Modern periprosthetic femoral plates also offer: anatomical designs (pre-contoured plates), which match the anatomy of the femur; variable interlocking options facilitating screw fixation around the stem; extensions capturing the greater trochanteric region; multidirectional screw placement to avoid obstacles and/or aim to available bone stock, as well as incorporation of wires/cables through the plate (inlay cerclages).

Specifically, for periprosthetic fractures in the presence of hip arthroplasty, obtaining adequate fixation proximally around the stem is a major concern, which can only be overcome if these options are feasible and not with standard non-locking non-specific plating systems. Most of these plating systems can also be applied using minimally invasive techniques (MIPO) and indirect reduction, minimizing the soft tissue damage and preserving the blood supply around the fracture area. The 'plate working length' (length of the middle part of the plate which is unprotected by screws or inlay cables and is overlying the fracture area) influences the cyclic fatigue performance and the strain of the plate, and affects the overall sitffness of the construct. Effective working length of a plate is considered to measure two to three times the width of the femur at the level of the fracture, and not less than the fracture extent, protecting the plate from stress concentration and early fatigue failure and to promote callus formation. The 'plate span width' (ratio of plate length vs. fracture length) should ideally be two to three times the length of the fracture for comminuted fractures and even more for simple patterns. The use of the longest possible plate decreases the pull-out forces on the screws, improves the active lever arm of each screw, and protects from secondary stress risers and fractures of the femur. A 'plate screw density' (ratio of plate holes vs. used screws) of < 0.5, avoiding screws clusters and spreading the screws at the diaphysis, is also suggested to optimise the overall construct stiffness.[57,58]

Fig. 3 Pre-op: X-rays (A) anteroposterior and (B) lateral of the hip with evidence of periprosthetic B1 fracture around a stable implant.
Post-op: X-rays anteroposterior (A2) and lateral (B2) femur showing open reduction and internal fixation of the fracture with locking compression plate and cerclage wires.

Bicortical fixation is biomechanically more stable, but if not possible, a combination of cerclage wires/cables (which offer mostly resistance to bending forces) with unicortical locking screws (that supplement with resistance to torsion and axial compression) should be used.[59] The rationale of using long plates to span the whole femur to protect from further future injuries is also advocated (Fig. 3).[60]

The use of indirect reduction techniques has been reported by Ricci et al in their series of 41 B1 type fractures around THAs. The study reported 100% union rates in satisfactory alignment by an average of 12 weeks following the procedure. One patient had a fractured cable, and two others had a broken screw, but all the fractures healed eventually. One early and two late infections occurred, which were treated and resolved.[47,61] Ruchholtz et al,[62] in a prospective study of 41 patients with periprosthetic fractures (17 around THA), suggested the MI (minimally invasive) technique as the preferred treatment. Kanakaris et al,[63] in a pilot randomized trial of 40 femoral osteoporotic and/or periprosthetic fractures treated with locking plates of different generations, concluded that attention to the reduction, mechanically sound construct and respect of the local fracture biology was more important than the plate design characteristics.

Cortical onlay allografts (struts) can also be used to augment fixation in a biplanar mode. The plate is usually applied on the lateral femur with the strut either anteriorly or medially. A combination of a plate with a medial strut allograft provided more mechanical stability in a biomechanical model of PPFs near the tip of a total hip arthroplasty as reported by Sariyilmaz et al.[64] Other authors recommended a combination of a lateral plate with an anteriorly placed strut as the most stable configuration.[65] Haddad et al reported the results of 40 cases with B1 type fractures treated with the use of struts alone or combined with a plate. They found 98% union rates suggesting that cortical strut grafts should be used routinely to augment fixation and healing of a periprosthetic femoral fracture. There were four malunions, all with < 10° of malalignment and one deep infection.[45] The use of struts, though, carries the disadvantage of cost, availability, potential disease transmission[66–68] and is more invasive to the soft bone and surrounding soft tissues.

Although the vast majority of B1 fractures have historically been treated with osteosynthesis, there are some situations where this might not be the best option even in the presence of a stable prosthesis.[69] Some of the most challenging to treat fractures are the short oblique or transverse B1 fractures, precisely at the tip of the stem.

The use of an extramedullary bridging splint (plate) is usually technically feasible and fully consistent with the standard principle of fixing the PPFs with a stable prosthesis. However, even when using modern systems with the previously mentioned features and advantages, the overall bone/plate construct remains an off-axis load-bearing system. Achieving the optimal biomechanical strain environment at the limited contact areas of the main fracture fragments, when stress transition occurs acutely from the highly stiff proximal fragment (adding the effect of a well-fixed stem that acts as an intramedullary strut and of the extramedullary proximal part of the plate) to the distal femoral fragment is very difficult. The result is often delayed progress of healing and plate fatigue failure. Use of 90-90 constructs with anatomic reduction and the combinations of plate-strut allograft or double plating have been advocated for these challenging cases either primarily or as a second surgery after a failure.[45,64] However, one of the most effective strategies in these challenging cases remains revision arthroplasty with a long stem bridging the fracture (intramedullary splint). The increased surgical hit of the revision of an otherwise stable femoral stem is counterbalanced by the fixation of the fracture with a biomechanically advantageous in-axis load-sharing device (i.e. the femoral stem).[70–72] Yasen and Haddad, in their review article regarding the management of B1 fractures, concluded that there is evidence to suggest B1 fractures can be subdivided into those which can be fixed and those which may benefit from revision surgery.[66] Pavlou et al, in their series of 221 PPFs, concluded that these types of fractures patterns should be revised with a long-stem prosthesis.[70] The stem should bypass the fracture level by at least two cortical diameters.[73]

In general, a patient-specific approach should be employed, balancing decisions in favour of the technique that will allow the patient to survive the surgery, mobilize effectively sooner, and lead to an uneventful postoperative course.[74]

Subtype B2

In this subtype of PPFs, the stability of the prosthesis is compromised, and there is adequate bone stock. In general, long-stem revision arthroplasty alone or supplemented by plate and/or allograft strut fixation, represent the consensus.

Khan et al, in a systematic review of 22 studies with a mean follow-up of 32–74 months, found that out of 343 B2 type fractures, 298 (86.8%) were treated with revision arthroplasty and 45 (12.6%) with ORIF. The B2 fractures treated without revision were found to have higher re-operation rates.[75] Data from the Swedish National Hip Arthroplasty Register also support this, indicating a higher re-operation percentage for B2 fractures treated with ORIF alone without revision of the stem (32%), than with those treated with revision (10%) or a combination of revision and internal fixation (23%).[14,75]

In B2 fractures, revision surgery will require a stem that will bypass the defect, either a long porous-coated cementless stem[41,76] or tapered fluted modular titanium stem (TFMT)[41,77,78] +/- adjuvant fixation (cables, plates, struts) if advocated. Revision arthroplasty of the acetabular component might take please if required. Cemented stems can also be used, usually for the most frail or unreliable patients, or for fractures with more distal extension and poor bone stock.[41,79] The stem should bypass the most distal fracture line by at least two cortical femoral diameters.

Type B fractures around cemented polished tapered stems (force closed) always involve an unstable prosthesis given the taper slip principle. This type of stem must be able to subside within the cement mantle, generating radial stresses which increase compression at the bone–cement and prosthesis–cement interfaces, so by design and in contrast with composite beam stems, there is no implant–cement bond. Even though revision of the femoral stem to a longer stem that bypasses the fracture still remains the gold standard, PPFs around cemented components might benefit from open reduction and internal fixation alone.[80] The long-term results for these stems are excellent, and probably have been well fixed before the injury with a sufficient bone–cement interface. For that reason, some authors propose that reducible fracture patterns with adequate bone stock might benefit from ORIF alone (well-fixed cement mantle, no loss of fragments) or ORIF with cement-in-cement revision (deficient mantle, fragment loss).[56] Achieving an anatomic reduction in these scenarios to avoid failure is highlighted by Goudie et al in their series of 79 patients with PPFs around cemented polished tapered stems.[81] This treatment strategy is probably less demanding and quicker than the traditionally recommended long-stem revision. A single-centre study comparing the results of patients with B2 fractures around cemented polished tapered stems treated with either ORIF or revision (with or without ORIF) showed shorter operating and anaesthetic time, fewer blood transfusions and fewer complications in the ORIF-only cohort.[82]

Even though most authors suggest that B2 type fractures are to be treated with revision arthroplasty, as the component was either unstable before the injury or became unstable during the traumatic event, some studies, and our experience, suggest good results with ORIF in specific patient groups.[51]

Joestl et al, in their study of 36 patients comparing locking compression plates versus revision, demonstrated good results with 100% union rates for the fractures treated with ORIF with no signs of secondary stem migration, neither malalignment nor metalwork failures. The average surgical time, though not statistically significant, was shorter in the ORIF group. They concluded that ORIF might be a viable alternative, especially for the elderly with multiple comorbidities as a less complicated and quicker procedure.[83] Baum et al reported similar results in their series of 59 patients (35 treated with revision arthroplasty vs. 24 treated with locking plates). There was a 10% nonunion rate in the follow-up of the plate group, and three (12.5%) refractures.[84] In a recent systematic review comparing fixation versus revision arthroplasty in Vancouver Type B2 but also B3 patterns, successful outcomes were demonstrated without the need for revising a loose component. In the presence of good bone stock around an uncemented stem or a polished tapered stem with an intact cement mantle, provided that the fracture can be anatomically reduced, ORIF might be an option for treating these injuries.[85]

As previously mentioned, there is also evidence of the effect of anabolic agents such as teriparatide for the conservative management of even minimally displaced B2 fractures around cemented stems with good results.[39]

Subtype B3

In B3 type fractures, apart from the loose prosthesis, the challenge is the inadequate bone stock. They are usually treated with either femoral component revision, proximal femoral allograft, or proximal femoral replacement. Impaction grafting has also been used for large contained defects with good results.[41,86–88]

Many different implants are available for surgeons to choose (fully porous-coated stems, tapered, modular or monobloc, distally locking, proximal femoral replacement prostheses) and the options have been evolving over recent decades.[89] Cementless fully coated curved stems or, more commonly, tapered revision stems are used.[90] More importantly though, the surgeon needs to be familiar with the implant and to create a reproducible surgical technique.

There have been studies looking into the overall performance of tapered fluted modular titanium stems (TFMT) in the treatment of PPFs. Da Assunção et al, in their study of 27 patients treated for PPF with TFMT stems, reported on short-term outcomes. All fractures went on to union. At mean follow-up of 35 months the average Oxford Hip Score (OHS) was 35, and poorer OHS was associated with comorbidities (higher American Society of Anaesthesia – ASA score). Three patients needed further surgery, one for periprosthetic infection, one for a second periprosthetic fracture, and one for recurrent dislocations, but none of the three required revision of the system. Three other patients underwent closed reduction for dislocation.[91]

The surgical technique is of paramount importance. Adequate stem stability needs to be achieved distally in the diaphysis. Preoperative templating is essential as well as careful intraoperative leg length and stability assessment. The surgeon needs to preserve as much proximal metaphyseal bone during preparation, and the remaining femur with its soft tissue attachments can be wrapped around the prosthesis to provide stability and optimize function.[90]

Allograft prosthetic composites can be used with either uncemented, cemented or partially cemented techniques.[92,93] They can be a valuable option in the presence of massive bone loss, especially in young patients.[90,94]

Finally, Klein et al reported that despite a relatively high complication rate, a proximal femoral replacement could be a viable option for the treatment of PPFs, especially for older patients with severe bone deficiency.[95]

Vancouver Type C fractures

Vancouver C fractures occur at the distal third of the femur, well below the femoral stem (more than two to three times the femoral diameter at that area) . They do not compromise the stability of the hip prosthesis, but their management does need to take into consideration the presence of the hip prosthesis in order to minimize the risk of secondary fractures/stress risers. Open reduction and internal fixation by standard osteosynthesis techniques (mostly bridge plating and rarely retrograde nailing) are used for treatment. There is controversy regarding the clinical relevance of the biomechanical evidence of a safe zone between two implants (more than 2.5 diameters of

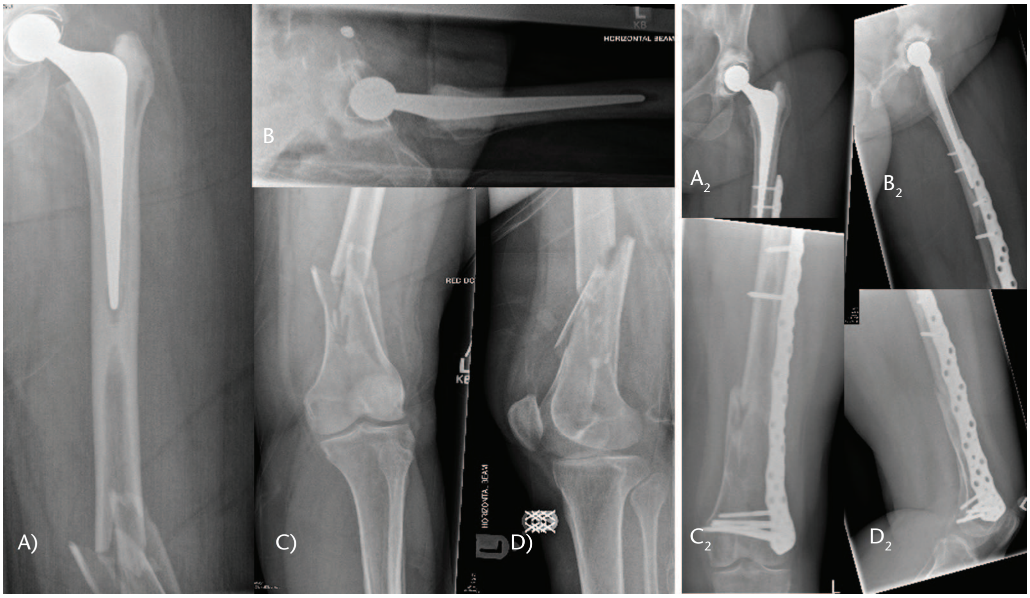

Fig. 4 X-rays of a Type C fracture distally to a well-fixed hip implant treated with open reduction and internal fixation.
Pre-op: (A) Anteroposterior of the hip, (B) lateral of the hip, (C) anteroposterior of the knee, (D) lateral of the knee.
Post-op: (A_2) Anteroposterior of the hip, (B_2) lateral of the hip, (C_2) anteroposterior of the knee, (D_2) lateral of the knee.

the femoral diaphysis or over 6 cm).[96,97] In general, these fractures are treated with an overlap of the plate proximally over the stem to avoid stress risers.[98]

Even if the fracture pattern would allow a short lateral plate below the stem and the distance between the tip of the plate and the stem could be considered adequate according to the stress riser biomechanical criteria,[96,97] the contemporary consensus is to protect the whole diaphysis overlapping the femoral component and anchoring proximally with either cerclage cables or screws.

This is based mostly to the fact that (a) with a longer plate the surgeon can balance better his fixation construct (working length, plate span width, plate screw ratio); (b) it is highly likely that the patient will at some stage have another fall, which may lead to a second femoral fracture if parts of the diaphysis are left unprotected. Most authors prefer to span the whole femur with a retrograde locking plate with maximum fixation at the distal metaphysis and a combination of screws and cables proximally (Fig. 4).[41]

Overall outcomes

Mortality/morbidity

Periprosthetic hip fractures, in the acute phase, carry a similar mortality risk to that of the neck of femur fracture elderly population, as recently published.[63,99] That risk seems to drop after the first six months post surgery. The one-year mortality rate was reported at 9.7%.[99] Another study demonstrated that the overall complication rate for PPFs at 30 days was 45% (22% major and 13% minor), including 30-day mortality of 10%.[100] An AMTS (Abbreviated Mental Test Score) of 8/10 or less and a delay to surgery of more than 72 hours were found to be significant risk factors for an adverse outcome.[100]

General functional and radiological outcome

There are limited data regarding functional outcomes following this type of injury. This has to do with the differences in the fracture patterns, the different treatment modalities, the high morbidity and mortality rates, the sometimes low AMTS (mentally impaired patients) and the limited follow-up.

Young et al,[101] based on data from the National Joint Registry, compared outcomes for patients undergoing revision surgery for PPFs vs. revision for aseptic THA loosening. They reported worse outcomes for patients undergoing revision for PPF with a mean Oxford 12 hip score of 29 vs. 24, ($p = 0.006$) compared to reference patients. For patients below the age of 65, however, no statistically significant difference was found. Mortality rates at six months were also higher in the PPF group (7.3% vs. 0.9%, $p < 0.001$), along with an increased chance of re-revision (7.3% vs. 2.6%, $p = 0.06$). Zuurmond et al, in their analysis of 71 cases, found a mean OHS of 27.8 (range: 12–57) which was also significantly higher in cases that had complications ($p = 0.02$) and in patients with a PPF following revision surgery ($p = 0.02$). They concluded that the long-term results are compromised by potential complications.[102] Similar results were also reported in a retrospective study of 50 patients treated in a single institution

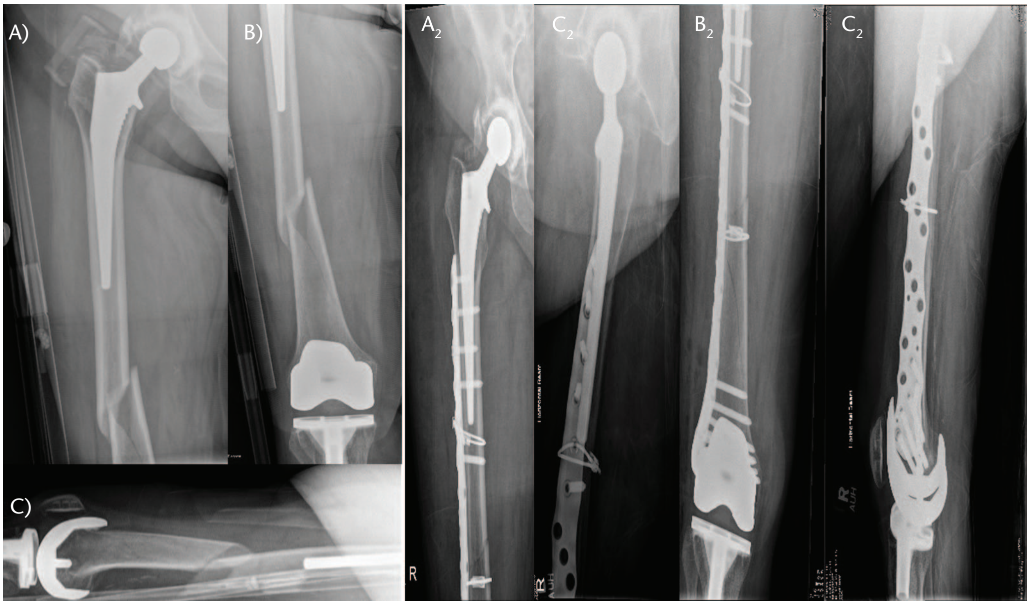

Fig. 5 X-rays of interprosthetic femoral fracture (Pires classification type IA) between a stable hip and knee implant treated with open reduction and internal fixation.
Pre-op: (A) Anteroposterior hip, (B) anteroposterior femur, (C) lateral femur.
Post-op: (A_2) Anteroposterior hip, (B_2) anteroposterior femur, (C_2) LAT X-ray of the hip and femur.

following revision surgery with a mean Harris Hip Score (HHS) of 73.1 and OHS of 30.3 for all fracture types at a mean follow-up of 3.3 years.[103]

Moreta et al,[104] in a retrospective review of 58 patients treated for PPF, although reporting good radiological outcomes and union rates of 92% found that 52% of the patients (31 patients) did not return to their pre-injury walking status. The mean HHS postoperatively was 67.9. Several other studies have reported similar scores with a mean HHS from 59 to 73.[14,103,105–107] In a more recent study regarding B2/B3 fractures in patients above the age of 65 years (mean follow-up of five years) although good results for fracture healing were reported (93% union rates), functional impairment (41.9% of the patients did not return to their previous ambulatory status) and a high rate of complications were found.[106] In terms of outcomes correlated with the fracture type, Legosz et al showed that the most unfavourable prognosis is after a B3 fracture.[108]

Arthroplasty longevity

There are limited data in the literature regarding the overall implant longevity following revision arthroplasty for periprosthetic fractures. That is probably due to the high mortality rates and the limited long-term follow-up.

Abdel et al, in their series of 44 fractures (B2 and B3) treated with fluted tapered stems in the same institution reported 98% healed fractures with radiological features of stable implants with a mean follow-up of 4.5 years.[77] Park et al, in a series of 27 PPFs around the hip treated with revision arthroplasty (modular fluted tapered stem – TMFT), found union rates of 92.6%. Two stems revealed evidence of subsidence postoperatively, with one patient requiring revision and the other one finally achieving union regardless. The mean follow-up was 4.8 years.[109] Berry, in his series of eight patients with Vancouver Type B3 fracture treated with revision surgery (long titanium modular fluted tapered – TMFT stems), reported stable implants and healed fractures at final follow-up (mean 1.5 years).[110] However, more studies are desirable to shed more light on the overall survivorship of revision implants following PPFs.

Interprosthetic fractures

Interprosthetic femoral fractures (IFFs) occur between an ipsilateral hip and knee implant. These fractures were first described by Dave et al back in 1995[111] in their case report of an IFF which was internally fixed with a Mennen plate. Later on, Kenny et al[112] reported four cases all with failure of the fixation. In 2003, Della Valle et al used a DCS (dynamic condylar screw) as a treatment option for an interprosthetic fracture.[113]

The true number of IFFs is still unknown in the literature. Kenny et al reported an incidence of 1.25% in their series of 320 patients.[112] Most recent research suggests that 5–7% of all PPFs are actually interprosthetic.[114,115]

Several classifications have been proposed (modifications of the Vancouver and the French Society of

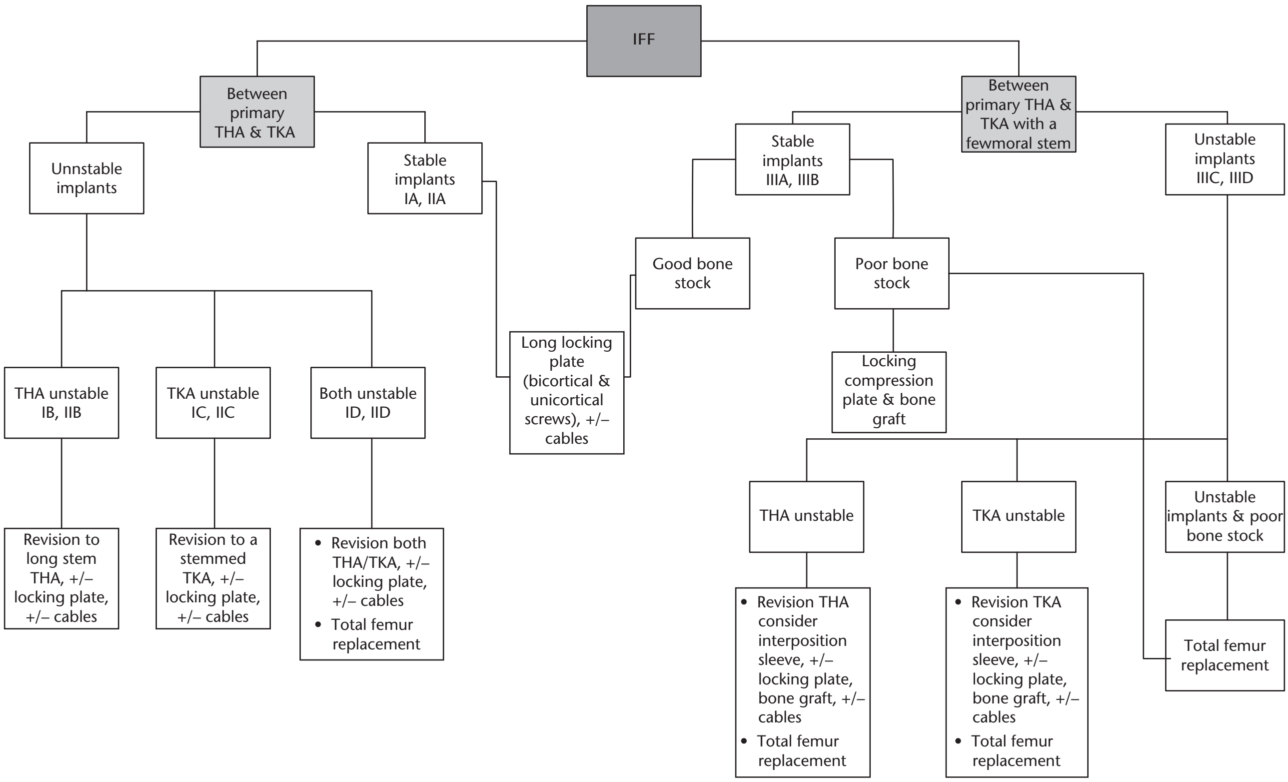

Fig. 6 Algorithm of management for the treatment of interprosthetic femoral fractures based on the classification by Pires et al.[116]

Orthopaedic Surgery and Traumatology classifications) with the most recent and comprehensive being by Pires et al in 2014.[115,116] In that classification system, IFFs are divided into three major categories based on the location of the fracture, the stability of the existing hip and knee implants and the presence or absence of a stemmed knee femoral component. They are further subdivided into subgroups. Pires et al also proposed a treatment algorithm based on their classification to guide the management of these complex injuries.

Operative management in IFFs with stable implants will require fracture fixation where patients with unstable implants will benefit from revision arthroplasty, most of the time supplemented by internal fixation. Locking plates are currently the implant of choice for IFFs requiring internal fixation (Fig. 5).[117–119]

Intramedullary options, strut grafting and revision stems can also be used according to the fracture configuration and location. A combination of these methods (composite constructs) can provide intra- and extramedullary stability. It is vital, whatever the chosen strategy is, to bypass the fracture, avoid stress risers and overlap the prosthesis by at least two cortical diameters or, better, to span the whole femur.[60,119]

Cases with loose components will require arthroplasty options +/- adjuvant fixation or even total femur replacement for Pires Type ID, IID (unstable hip and knee prostheses) and IIIB, IIIC, IIID due to poor bone stock (Fig. 6).[116]

In the most relevant studies around this topic the nonunion rates were reported at around 8%, the mortality rates at 6.5% and the revision rates for failure at 10.7%.[114,117,120–124]

Bonnevialle et al studied 51 patients with IFFs and reported much higher mortality rates (31%) and revision rates of 24% highlighting that the fragile nature of this patient cohort requires proper surgical planning and techniques to avoid errors that can lead to failures.[114]

Periprosthetic acetabular fractures

Periprosthetic acetabular fractures are less common than femur PPFs but are often severe and challenging to treat. As with proximal femur PPFs, the incidence of these injuries is expected to rise with the increasing numbers of elderly and a more active population. These fractures can occur either intraoperatively or postoperatively following THA.

Intraoperatively these injuries are mostly related to uncemented components[125,126] inserted in a press-fit manner (uncemented elliptical cups more likely than hemispherical),[127,128] while fractures during cemented implantation are very rare. Takigami et al have also described pelvic discontinuity caused by acetabular overeaming during primary THR.[129] Acetabular PPFs can occur

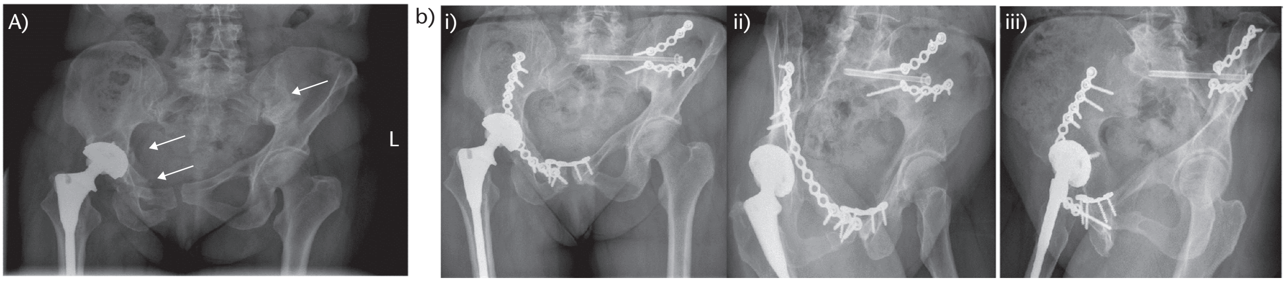

Fig. 7 (A) Anteroposterior pelvic X-ray of a 56-year-old female who sustained right periprosthetic acetabulum fracture and left ilium fracture of the pelvis following a fall. (B) (i) Anteroposterior pelvis X-ray, (ii) obturator oblique X-ray, (iii) iliac oblique X-ray of right acetabulum three years later demonstrating union of the fractures following open reduction and internal fixation.

during revision surgery more often than primary THRs due to a combination of patient- (osteoporosis, poor bone stock) and surgeon-related factors (technical errors, well-fixed implants).[130]

Postoperatively, periprosthetic acetabular fractures can present as a result of trauma or, more commonly, in the presence of severe bone loss (osteoporosis, aseptic loosening, osteolysis, pelvic discontinuity, malignancy, infection).

One of the first classifications was that of Peterson and Lewallen[125] distinguishing between two types of fractures according to implant stability (Type I: stable, Type II: unstable). The most commonly used classification is that of Paprosky, describing all variants of acetabular PPFs (intraoperative during component insertion, intraoperative during component removal, traumatic, spontaneous, pelvic discontinuity).[36] Davidson et al provided a simplified version with three fracture types describing though only the intraoperative ones.[131] More recently Pascarella et al have presented a comprehensive classification system which can direct the surgical planning based on the timing of its diagnosis, the stability of the acetabular prosthesis, and the preinjury state of the arthroplasty.[17]

It is essential when treating PPFs of the acetabulum to identify and classify the fracture, and determine the stability of the involved implant. In the situation of an intraoperative fracture, the surgeon should have a high level of suspicion as these injuries may be challenging to identify, and a full assessment of the implant and pelvic stability should be performed. Intraoperative fluoroscopic evaluation might be useful. Postoperatively they can present acutely as a result of trauma (rare) or more often as chronic periprosthetic fractures around the acetabular component. These conditions usually present with pain, loss of function and reduced range of motion (ROM) of the affected side, inability to fully weight-bear, leg-length discrepancy, and, in the case of an acute traumatic injury brushing, echymosis as long as life-threatening bleeding can be present.[132] Plain radiographs (anteroposterior [AP] pelvis) need to be obtained, supplemented by Judet and inlet/outlet views. CT scan with 3D reconstruction will provide more information regarding the fracture pattern, and in cases of a traumatic event or in severe displacement, CT angiography is recommended to rule out vascular injuries or determine the proximity between the fracture, implant and vessels.

Treatment

The treatment principles require a stable acetabulum (columns) able to support the acetabular component and to avoid micromotion at the implant–bone interface. Adequate bone stock with or without additional augmentation is needed to allow for secure implantation (Fig 7).

Undisplaced intraoperative identified fractures with a stable component can be treated by leaving the cup in situ with standard rehabilitation protocols as suggested by Della Valle et al.[36] However, supplemented screw fixation of the cup is generally recommended.[126,128] In the case of an unstable cup and fracture displacement, posterior column plating and insertion of a revision cup is advised. In the case of missed intraoperative fractures, close follow-up is needed to look out for fracture displacement and cup migration, in which case revision surgery will provide the solution.

In acute traumatic events around an undisplaced fracture with a stable cup, conservative treatment with a period of protected weight-bearing and gentle mobilization can be the treatment.[125] Close follow-up (serial radiographs) is mandatory as secondary loosening can occur even if the fracture heals. In that case, revision surgery can be performed over a consolidated acetabular bone stock. If the fracture fails to heal, osteosynthesis as long as revision surgery is required. In the presence of an unstable fracture pattern with an unstable component, ORIF of the fracture (mostly posterior column fixation) and revision surgery is needed.

Pelvic discontinuity (PD) treatment remains challenging. There are several treatment options, and controversy exists regarding the optimal technique. The treatment of choice needs to take into account the quality and quantity

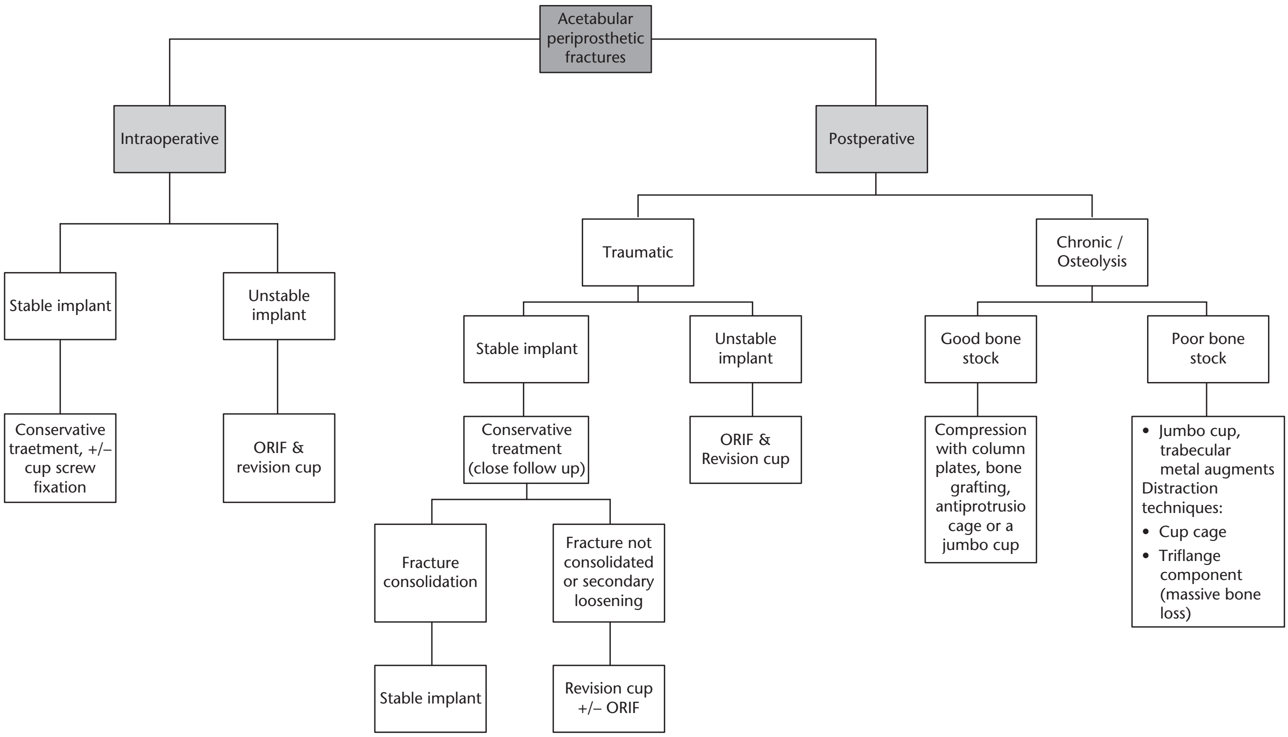

Fig. 8 Algorithm of management for the treatment of periprosthetic acetabular fractures.

of the bone stock, the soft tissue environment as well as the patient's overall health status.[133] Rogers et al proposed a treatment algorithm[134] which differentiates between the acute (traumatic) discontinuity which is mobile and a chronic more rigid discontinutiy. In the case of an acute injury, this is treated as described above for traumatic fractures with unstable implants (ORIF and revision surgery) where, in the chronic scenario, the use of a cup-cage reconstruction was recommended.

In acute or in chronic PD cases with good healing potential and minor bone loss, compression can be applied and healing is possible with the use of column plates, grafting and implantation of an antiprotrusio cage or a jumbo cup.[133,135] In chronic cases with little support and poor and avascular bone stock, a jumbo cup with trabecular metal augments or distraction techniques (cup cage) can be useful.[133,135,136] In the situation of massive bone loss, a triflange component is usually required (Fig. 8).[133,135–137]

Conclusions

Periprosthetic fractures around the hip following THAs represent a challenging situation in regard to the patient's profile (age, comorbidities), the optimal fixation mode (internal fixation vs. revision arthroplasty), the decision making and surgical planning (location and extent of the fracture, the stability of the prosthesis, the available bone stock), the reduction techniques and the construct configuration. Quite often, logistics and parameters such as the availability of combined advanced arthroplasty and orthopaedic trauma skillset, as well as of appropriate implants, play a significant role in the overall management strategy and the patient's outcome.

The Vancouver classification is still a useful tool of communication and stratification of these injuries, whilst the more comprehensive UCS should be proven helpful for large databases and registries. We believe that the Vancouver classification/algorithm does still represent the basis for our routine communication, but besides the three parameters that classification takes into account (location/stem stability/bone stock) contemporary clinicians should also assess others (i.e. patient's frailty, type of stem, evidence of infection).

The number of publications around this topic has risen massively in the last few years and has provided new data and answers, but there is an ongoing need for more evidence, especially in an era where arthroplasty surgery is becoming more and more common, and the number of these fractures is rising. In our proposed algorithm (Fig. 9) B1 fractures are subclassified into those that will be treated the traditional way (i.e. with internal fixation) and those that might benefit from revision surgery (simple, short oblique and transverse fractures, bisphosphonate-related atypical fractures). Fixation as a treatment option for some B2 fractures has also been proposed, mostly in frail patients with a high ASA score, unable to undergo major revision surgery. The mainstay of treatment for Type C fractures is internal fixation

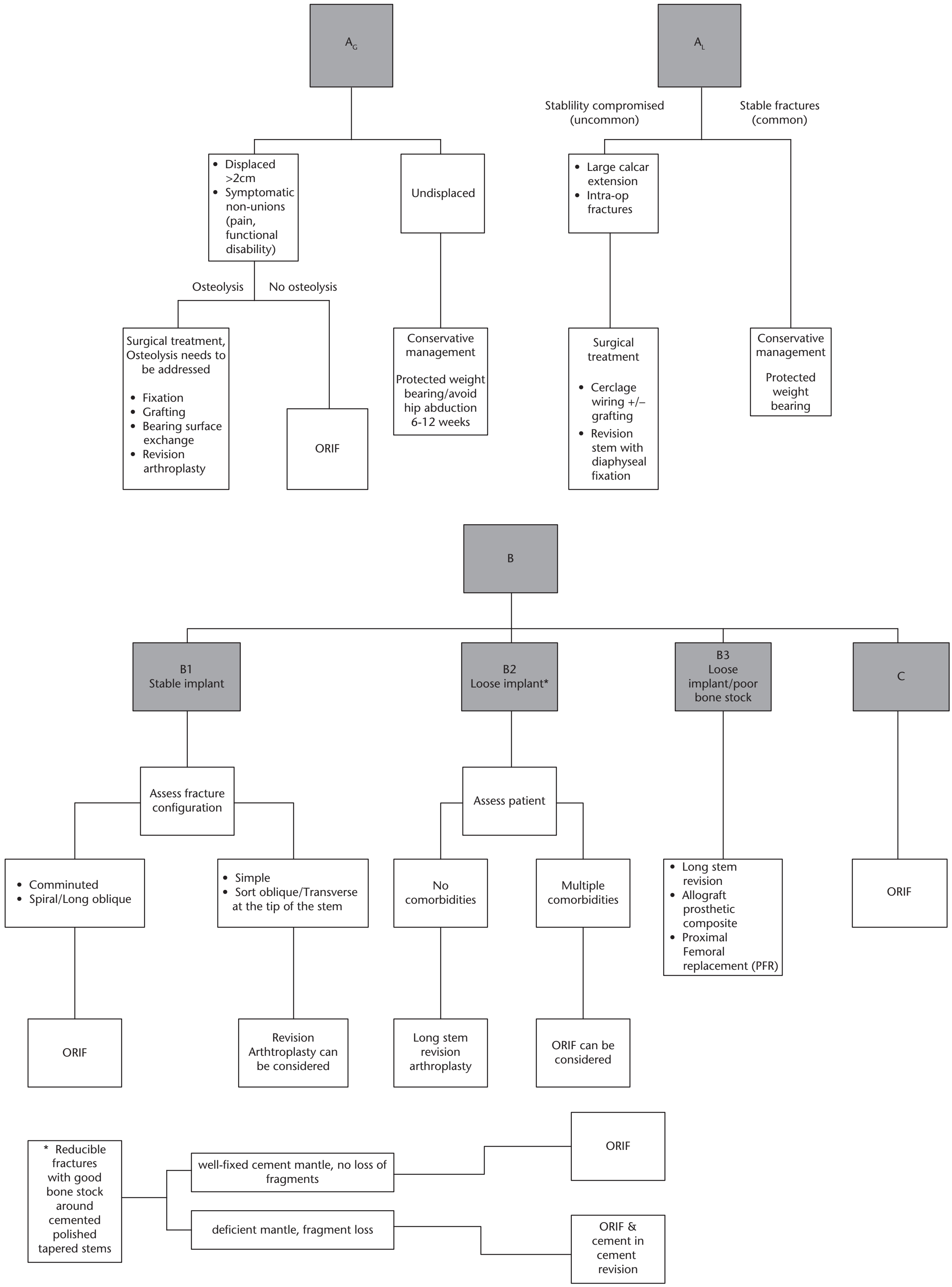

Fig. 9 Algorithm of management for the treatment of periprosthetic fractures.

with a long retrograde plate, and B3 fractures should be mostly treated with augmented revision arthroplasty techniques. Most Type A fractures are still treated conservatively unless underlying osteolysis or an unstable implant (rare) dictate otherwise.

In terms of the principles of PPFs osteosynthesis, MIPO techniques where possible are proven to be beneficial.[62,63] The aim, however, is primarily to reduce the fracture adequately (restore length, axis and rotation). This sometimes leads to open reduction techniques. The plate span width should be at least 2–3 times the fracture length, which for PPFs translates to the use of the longest possible bridging plate in most of our patients. Spreading the screws across the diaphysis to avoid clusters as possible is recommended, which occasionally is difficult when the fracture length is extensive and the available bone stock for adequate screw anchorage limited. Bicortical screw fixation is the default plan, which changes to a combination of unicortical screws and inlay cerclage cables/wires when that is not feasible. Composite solutions for composite problems, including specific fracture types, obesity, low healing potential, difficult interprosthetic fractures, are commonly employed (nail/plate combo, double plating, use of strut grafts).[138,139]

The financial cost of this type of injury has also been investigated and is an important factor. Phillips et al in 2011 found that the mean cost of treatment per patient was £23,649 with the ward cost being responsible for about 80% of the total cost estimated.[2] A further study by Jones et al in 2016 reported a significantly higher cost of about £31,370 per patient. The implant cost was higher in revision surgery patients, but the quicker mobilization led to a reduced hospital stay and overall lower cost.[1] These studies highlighted the fact that it is the rehabilitation period, the complication rates and the total length of stay that mostly affect the overall cost.

PPFs are probably the most challenging of the fragility fractures not only because they present as complex surgical scenarios but also due to the patient's characteristics. These injuries in a frail population do not forgive errors. These procedures should take place following detailed planning, built-for-purpose implants need to be available and strong skills in both trauma and arthroplasty are required. The move towards specializing centres managing these injuries might be a way of providing patients with the best of care and reducing the cost on health services by providing an effective surgical solution and avoiding complications and secondary procedures. More efforts are probably required towards reducing the economic burden for national health structures globally.

The evolution of orthopaedic implants has provided us with more intraoperative surgical options and solutions to deal with these complex injuries, and that applies to both revision implants and fixation devices. The need though remains for even more specially designed implants to address if not all at least the vast majority of PPFs. New concepts of fracture fixation are here, such as plates with far cortical locking (FCL) and active plating.[140,141] In the years to come, we are about to experience their use in clinical practice, and scientific evidence will be required to evaluate the outcomes and the results of these concepts.

Regarding the functional outcomes and the longevity of the implants following revision surgery, the literature still cannot provide robust data for PPFs. The high mortality rates and the sometimes limited follow-up contribute to that. It is crucial that future studies address that issue as these injuries are expected to rise in numbers in the years to come.

Interprosthetic fractures as well as periprosthetic acetabular fractures, even though still uncommon, represent the next upcoming challenge as their numbers are also expected to increase, and more studies around these two topics are required to provide evidence regarding their management.

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