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Periprosthetic acetabular fractures as a complication of total hip arthroplasty

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ABSTRACT

Periprosthetic acetabular fractures are rare but potentially devastating complications of total hip arthroplasty. As the number of total hip arthroplasties performed annually increases, so has the incidence of periprosthetic fractures, with the topic being spotlighted more frequently in the orthopaedic community. There is a particular sparsity of literature regarding periprosthetic acetabular fractures, with periprosthetic femoral fractures after total hip arthroplasty being traditionally far more commonly reported. This article aims to provide an up-to-date review of the epidemiology, risk factors, diagnostic challenges, classifications, and management strategies for periprosthetic acetabular fractures after total hip arthroplasty.

Abbreviations
American Academy of Orthopaedic Surgeons (AAOS)
Computed Tomography (CT)
Continuing Medical Education (CME)
National Joint Registry (NJR)
Periprosthetic fracture (PPF)
Periprosthetic acetabular fracture (PPAF)
Total hip replacements (THRs)
Unified Classification System of Periprosthetic Fractures (UCS)
United Kingdom (UK)
United States of America (USA)

Introduction

Total hip arthroplasty (THA) is universally acknowledged one of the most successful orthopaedic operations and has substantially transformed the treatment of the arthritic hip by relieving pain, restoring hip function, and improving patient quality of life [1,2]. Parallel to the increasing incidence of arthritis, which is attributed to an ageing and more co-morbid population, the number of THAs performed annually has sharply increased in recent years and is projected to continue to increase in both the UK and USA [3–8]. However, as the number of THAs performed grows, on the background of an elderly and more co-morbid patient cohort, so does the number of cases associated with both peri-operative and post-opertaive complications and particularly peri-prosthetic fractures (PPF). Indeed, according to the UK National Joint Registry (NJR) data, there has been a noticeable increase in the yearly incidence of hip revisions due to periprosthetic fractures (PPF) over the past decade. This increase is evident, with numbers rising from 1030 in 2013 to 1172 in 2021 [9]. The rising incidence of these serious injuries represents a growing challenge to orthopaedic surgeons.

This article therefore aims to review the epidemiology, risk factors, diagnostic challenges, classifications, and management strategies for periprosthetic acetabular fracture (PPAF) after THA. The content has been precisely customized to fulfil the criteria of postgraduate examinations and to provide valuable insights within the field.

Epidemiology

PPF after THA is a rare event, with a traditionally reported incidence of 0.4–3.5% [10–13]. Within this range, PPAFs have generally been reported as much rarer than their femoral counterparts, with Haidukewych et al. and Li et al. reporting intra-operative PPAF incidences of 0.4% and 0.49% respectively [11,14]. However, since PPAFs are often difficult to identify intra-operatively, the true incidence may be greater. This hypothesis is supported by two recent studies by Hasegawa et al. and Yun et al., both of whom studied incidences of occult intra-operative PPAFs by performing routine computed tomography (CT) imaging after THA. Both studies reported on cementless acetabular components and defined occult PPAFs as undetectable intra-operatively and on post-operative radiographs. Interestingly, both authors reported an intra-operative PPAF incidence of 0.4% but detected that a further 8.4% and 6.9% of their patient cohorts respectively had occult PPAFs on post-operative CT [15,16]. These two studies blur the traditional division of PPAFs into intra-operative and post-operative. Historically, intra-operative PPAFs have been reported to represent a small proportion of PPAFs but evidence of occult intra-operative PPAFs poses the question as to whether a proportion of post-operative PPAFs are actually a deterioration of an established but undetected intra-operative fracture. Whilst this may obfuscate the true incidences of intra-operative and post-operative PPAFs, there are still distinct aetiologies of intra-operative and post-operative PPAFs. Intra-operative PPAFs can occur at various stages of THA, particularly acetabular reaming, impaction of the acetabular component, and explantation of well-fixed acetabular components in revision THA [11]. Post-operative PPAFs

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broadly occur due to two main reasons: trauma and pathological bone loss due to osteolysis, the latter of which has its own range of underlying aetiologies including debris-induced osteolysis, infection, chronic cup migration, metabolic bone diseases such as Paget's disease, malignancy, and iatrogenic bone removal in revision THA [17]. When considering the aetiologies of these fractures it is helpful to classify them according to patient-specific factors and surgical or implant-specific factors (Table 1).

Patient-specific risk factors

Due to the low reported incidence of PPAFs, there is a scarcity of high patient volume studies to perform statistically rigorous analyses regarding patient-specific risk factors for PPAF. As such, the majority of patient-specific risk factors quoted in the literature are extrapolated from studies regarding periprosthetic femoral fractures.

For example, a large volume retrospective cohort study by Lamb et al. analysed 793,823 primary THAs for risk factors for periprosthetic femoral fractures and identified several risk factors associated with intra-operative fracture [18]. Lamb et al. reported a bi-modal distribution of increased risk of fracture in patients either aged less than 50 years old or more 80 years old. This bimodal distribution is likely to represent a dichotomy in the aetiology of periprosthetic femoral fracture: with younger, more active patients being more likely to sustain high energy trauma; and elderly patients much more likely to have poorer bone stock and quality, combined with an increased likelihood of falls. They also reported increased risk of periprosthetic femoral fracture in patients of female sex, with an American Society of Anaesthesiologists (ASA) grade of 3–5, and any indication for THA other than primary osteoarthritis. Lamb et al. attributed the association between a higher ASA grade and an increased risk of fracture to the likelihood that a higher ASA grade represents underlying co-morbidities that could diminish a patient's bone stock and quality. Patients with more advanced age and more co-morbidities, particularly neurological, diabetic, and cardiorespiratory disease, also have their fracture risk compounded by an increased propensity to fall [15].

Finally, alongside standard pre-operative templating, additional imaging may be helpful to assess for any abnormal bony anatomy, such as thin acetabular walls, protrusio acetabuli, peri-acetabular cysts or dysplastic hips, that may pre-dispose to PPAF. This may include supplementary radiographic views such as Judet views or advanced imaging techniques such as computed tomography (CT) scans [19].

Surgical and implant-specific risk factors

According to the UK NJR, 60.8% of all primary THA in the UK is performed with an uncemented acetabular component, and impaction of said components is a commonly described surgical step that can cause intra-operative PPAF [9]. In fact, Haidukewych et al. reported no PPAFs using cemented acetabular components compared to 21 using uncemented acetabular components in a review of 7121 primary THA procedures [11]. Underreaming and press-fit impaction of uncemented acetabular components, with or without additional screws, remains the most common method of acetabular preparation but is widely reported to be associated with PPAFs [15,19–22]. Overzealous impaction or poor bone quality particularly predispose to PPAFs with this technique, as full seating of an oversized acetabular component requires the native acetabular bone to be subjected to sufficient force to cause plastic deformation upon impaction [22].

Whilst Sharkey et al. reported underreaming as a significant risk factor for PPAF, they also described excessive medialisation of the acetabular component as being associated with PPAF [22]. Both Ivanova et al. and Takigami et al. have also described overreaming and excessive cup medialisation being associated with PPAF in a small number of patients [23,24].

Furthermore, Chitre et al. described a multifactorial increase in risk of PPAF with revision THA compared to primary THA. Patients undergoing revision THA are more elderly, with a higher risk of having osteoporosis, and more likely to have poorer bone stock, particularly depending on the indication for revision [9,25]. Furthermore, explantation of well-fixed acetabular components during revision THA presents a risk of PPAF, particularly if the attempted removal is with sub-optimal technique or equipment [25].

Lastly, both Haidukewych et al. and Davidson et al. also reported a significantly higher risk of intra-operative PPAF with the use of uncemented elliptical compared to uncemented hemispheric acetabular components [11,26]. Given that an elliptical cup has a peripheral flare that is 2 mm larger than its hemispheric counterpart, this risk has been attributed to the increased plastic deformation required to completely seat an elliptical acetabular component.

Table 1
A summary of risk factors for periprosthetic acetabular fractures.

Patient-specific risk factors	Surgical and implant-specific risk factors
Age (bimodal distribution of either aged less than 50 years old or more 80 years old)	Uncemented acetabular component
Female	Underreaming and press fit impaction of an oversized cup
ASA grade 3–5	Overreaming or excessive cup medialisation
Specific co-morbidities (particularly neurological, diabetic, and cardiorespiratory disease)	Elliptical acetabular cup
Poor bone stock or quality	Any indication for THA other than primary osteoarthritis
Abnormal acetabular anatomy (thin acetabular walls, peri-acetabular cysts, and dysplastic hips)	Revision THA

Diagnosis–intra-operative fractures

As has already been discussed, intra-operative PPAF can be difficult to recognise and there is some emerging literature suggesting that the incidence of intra-operative PPAF is far higher than previously reported due to occult intra-operative fractures [15,16]. As such, a strong clinical suspicion for and awareness of PPAFs is critical to detection of intra-operative PPAFs, particularly at the previously discussed high-risk surgical steps of reaming, impaction, and cup explantation [19]. Diligent pre-operative templating of estimated acetabular component size is useful as any gross deviation from this plan, in either final reamer or cup size, should prompt consideration of and examination for a PPAF [19]. When the correct pre-operatively sized acetabular component is impacted but fails to achieve stability, PPAF should also be suspected and examined for [17,19]. Finally, any difficult cup explantation in revision THA or explantation from poor quality, osteolytic bone warrants examination of the acetabulum for potential occult PPAF.

If there is a suspicion of PPAF intra-operatively, both clinical and radiographic examination is required to assess for PPAF. Acetabular component stability may be carefully assessed using manual pelvic implant stress testing and clinical examination guided by the resultant findings [19]. To complement this, one may acquire intra-operative pelvic radiographs, including anteroposterior and Judet views, the latter for assessment of the acetabular wall and column integrity [19,26,27]. If a fracture is identified, it should be carefully exposed to be visualised in its entirety, so that the fracture may be classified and subsequently managed appropriately [19]. If there is strong clinical suspicion of intra-operative PPAF but no obvious radiographic evidence, one may consider removal of the component to examine the acetabulum directly and advanced post-operative imaging such as CT [28]. Post-operatively, an occult intra-operative PPAF may present as groin pain, reduced range of motion, unexpected leg length discrepancies, or inability to weight bear, and any of these signs should raise suspicion and prompt investigation [17].

Diagnosis–post-operative fractures

True post-operative PPAFs are traditionally divided into two distinct aetiologies: acute traumatic and chronic osteolytic. Clinical signs for either aetiology are the same as discussed for occult intra-operative PPAFs: groin pain, reduced range of motion, unexpected leg length discrepancies, or inability to weight bear. Whilst the onset of clinical symptoms and signs is usually expected to be more insidious in chronic osteolytic PPAFs, this is not always true as acute component migration or fracture propagation on the background of chronic pathology may elicit sudden onset symptoms or signs [28].

Acute traumatic PPAFs are usually non-displaced with a stable fracture pattern but must all be evaluated with extended radiological imaging to assess fracture pattern and implant stability. High energy trauma, displaced fracture, or medially migrated component, particularly if there is a breach of the ilioinguinal line, should be investigated with CT angiography to assess for vascular injury or proximity between fracture or component and the intra-pelvis vasculature [28–31]. Even if there is no vascular injury, displaced traumatic PPAFs often result in pelvic discontinuity, and CT imaging is useful to provide detailed visualisation of fracture pattern and plan for the subsequently necessary revision surgery [28].

As with acute traumatic PPAFs, chronic osteolytic PPAFs require advanced imaging with CT. Due to the underlying pathology, the reduced bone stock and/or quality renders the acetabular component and hemi-pelvis at high risk of instability and/or displacement. Whilst a PPAF or signs of a loose acetabular component (radiolucency around, change in position of, or migration of the acetabular component) may be visible on a plain radiograph, CT is still necessary to evaluate residual bone stock and quality for revision surgery [28]. As with acute traumatic PPAFs, any medially displaced fracture fragments or component should prompt investigation with CT angiography. Any clinical suspicion of underlying peri-prosthetic joint infection should be additionally investigated with blood tests (white cell count, C-reactive protein, and erythrocyte sedimentation rate) and joint aspiration for cell count and culture [32].

Classification

The first proposed classification system of PPAF was by Peterson and Lewallan in 1996, who divided PPAFs into two groups based upon acetabular component stability: type 1 being stable and type 2 unstable [29]. In 1998, Callaghan et al. described the first system that classified PPAFs by anatomical location of the fracture, dividing the acetabulum into four areas: anterior wall, transverse, inferior lip, and posterior wall [33]. Hasegawa et al. proposed a slight adjustment to Callaghan et al.'s classification, by dividing PPAFs into five anatomical locations: (1) medial wall, (2) posterior wall, (3) superolateral wall, (4) anterior wall, and (5) other locations [15].

The most widely established classification system today was proposed by Della Valle et al. in 2003: the modified Paprosky classification. This system has garnered significant popularity as it divides PPAFs by aetiology, stability, and bone stock, which provides useful information to help guide management. The modified Paprosky classification is summarised below in Table 2 [34].

Since 2003, there have been several new classification systems of PPAF described. In 2008, Davidson et al. addended the Vancouver classification of periprosthetic femoral fractures with three types of PPAFs: type I - undisplaced fracture not compromising the stability of reconstruction; type II - undisplaced fracture that may compromise the stability of reconstruction; and type III - displaced fracture [26].

In 2014, Ducan and Haddad proposed unifying classification systems for periprosthetic fractures in each anatomical area into one overarching system: the United Classification System (UCS). PPAFs are represented by the prefix IV.1 and the UCS considers anatomical location of the fracture and stability of the acetabular component [35].

Finally, Pascarella et al. devised a new classification system in 2018 that focused on the timing of fracture and implant stability. Whilst this system boasts the advantages of simplicity and an associated treatment algorithm, it has yet to be widely accepted into clinical practice. The classification system and its treatment algorithm are displayed below in Table 3 [36].

Table 2
The modified Paprosky classification.

Intra-operative during cup insertion	Type 1	1A: Recognised intra-operatively, non-displaced fracture, stable cup
		1B: Recognised intra-operatively, displaced fracture, unstable cup
		1C: Not recognised intra-operatively
Intra-operative during cup removal	Type 2	2A: Less than 50% bone stock loss
		2B: More than 50% bone stock loss
Traumatic	Type 3	3A: stable cup
		3B: unstable cup
Spontaneous	Type 4	4A: Less than 50% bone stock loss
		4B: More than 50% bone stock loss
Pelvic discontinuity	Type 5	5A: Less than 50% bone stock loss
		5B: More than 50% bone stock loss
		5C: Associated with pelvic radiation

Management

The principal objective of PPAF management is to achieve stability of the hemipelvis and acetabular shell. Where surgical revision is indicated, the surgical technique should also be aiming to restore acetabular stability, the anatomical centre of hip rotation, limb length and offset, and achieve stable fixation of the acetabular shell in native bone. The technique required to do so is dependant upon three main factors: timing of the fracture; the stability of the hemipelvis and implant; and the remaining bone stock.

Intra-operative

As already discussed, intra-operative PPAFs are notoriously difficult to detect and rarely reported, so evidence for treatment recommendation is under-powered and largely anecdotal. However, there are a handful of small cohort studies that have some promising results to base provisional treatment algorithms on. In the event that a PPAF is identified intra-operatively after cup impaction, the first factor to consider is implant stability.

Table 3
Periprosthetic acetabular fracture classification by Pascarella et al.

Timing of fracture	Prosthesis stability	Recommended treatment
1 Intra-operative	a Stable	Conservative treatment / increase primary stability with screws
	a Unstable	ORIF if displacement > 2 cm / acetabular ring with screws/ implant revision
1 Post-operative	a Stable	Conservative treatment/ ORIF
	a Unstable, mobilised simultaneously trauma	Implant revision/ acetabular ring /ORIF
	a Unstable, mobilised before trauma (osteolysis/bone loss)	Implant revision/ acetabular ring /ORIF /bone graft

Stable acetabular component

If the acetabular component is stable, fixation of the cup with additional acetabular screws into both the ilium and ischium and a period of protected post-operative weight bearing is often sufficient [19,22,36,37]. Sharkey et al. reported on nine intra-operatively-identified-PPAFs, six of which were treated with additional acetabular screws. Of the nine recognised fractures, one was revised for periprosthetic infection but none of the other eight patients had undergone revision surgery at a mean follow up of 32 months. In this study, three of the recognised intra-operative PPAFs and four occult intra-operative PPAFS (that were detected on post-operative imaging) either received no treatment or were prescribed a period of modified weight bearing. Of these seven patients who received no extra surgical fixation, one patient (whose fracture was recognised post-operatively and was allowed to fully weight bear) underwent revision arthroplasty for cup migration [22]. However, in a cohort of 43 occult intra-operative PPAFs, who all received no additional treatment or weight bearing precautions, Hasegawa et al. reported that all fractures had achieved radiographic union with no component migration or loosening at 12 months post-operatively. Furthermore, 26 of the 43 patients in this study were followed up beyond five years and all of these patients still had stable components at last follow up [15]. Another study by Yamamuro et al. matched (based on age, sex, body mass index, primary diseases, cup diameter, cup design, and additional dome screw) 38 patients who suffered occult intra-operative PPAF during primary THA with 76 uncomplicated THAs. The intra-operative occult PPAF group received no extra treatment or altered rehabilitation programme and both groups demonstrated radiographic bony ingrowth and ten-year survival rates for cup aseptic loosening and cup failure revision of 100%. Furthermore, there was no statistically significant difference in post-operative Japanese Orthopaedic Association clinical outcomes scores or post-operative complication rates (such as nerve injury, dislocation, heterotopic ossification, iliopsoas impingement, or infection) between the two groups and radiographic follow-up showed no fracture propagation in the PPAF group [38]. Whilst these studies seem to support close monitoring and no modification to post-operative rehabilitation as an appropriate management strategy, Dammerer et al. have reported cases of occult intra-operative PPAFs being associated with revision for aseptic cup loosening and migration. In a retrospective review of 58 occult intra-operative PPAFs, Dammerer et al. described four cases requiring revision for aseptic cup loosening or migration. Interestingly, occult periprosthetic fractures of the medial acetabular wall required revision in three of six fractures detected at this anatomical location. The authors have suggested that further studies investigating occult intra-operative PPAFs by anatomical location, using the Hasegawa classification, may help improve the understanding of which occult PPAFs are at greatest risk of loosening [39].

Unstable acetabular component

If an intra-operatively recognised PPAF is associated with a loose acetabular component, more extensive surgical fixation is required. As already discussed in the diagnosis section of this article, the implanted component must be removed so the fracture can be examined in its entirety. This includes close examination of the anterior and posterior columns and manual stress testing to assess for any pelvic discontinuity [19]. Examination of both pelvic columns may however require greater exposure through additional surgical incisions. Assessment of the posterior column and posterior acetabular wall is easily achievable with a posterior hip approach; however, assessment of the anterior column often requires an additional incision such as the ilio-inguinal, ilio-femoral, modified Stoppa, or Pararectus approach [37,40]. Whilst the ilioinguinal approach provides good anterior acetabular exposure and is relatively atraumatic, the modified Stoppa and Pararectus approaches both provide a good exposure of the pelvic ring [40–43]. Lastly, intra-operative radiographs may be useful to both assess fracture pattern and plan reconstructive strategy [19,26,27].

If significant motion is found at the acetabular columns, traditional plate fixation should be used to achieve stability before attempted re-implantation of a multi-hole revision acetabular component with additional screw fixation. In cases where bone stock is poor, autologous bone graft and porous acetabular augments can be used to aid fixation and promote bony ingrowth. If these revision techniques fail, advanced techniques such as a cup cage construct should be considered. Where any surgical revision or fixation technique is utilised, patients should have an amended period of post-operative restricted weight bearing until imaging confirms signs of fracture healing [19].

Post-operative

Stable acetabular component

As with intra-operative PPAFs, initial evaluation should be of implant and pelvic stability and continuity. An undisplaced fracture with stable implant and hemipelvis may be treated non-operatively with 6–8 weeks of non-weight bearing [36]. This avoids potential complications of surgical revision of PPAF, which include dislocation, infection, wound healing problems, haematoma, neurovascular injury (most commonly superior gluteal vein or sciatic nerve), thromboembolic event, and fat embolism [44]. However, Peterson and Lewallan reported that six out of eight PPAFs that were managed non-operatively required surgery by 20 weeks (two for non-union and four for implant loosening despite fracture healing), leading to Pascarella et al. proposing open reduction and internal fixation (ORIF) as an appropriate alternative treatment option for undisplaced PPAFs with a stable implant (Fig. 1) [29,36]. Two small case series have recently been published that show promising results for ORIF of isolated single column injuries [45,46]. Hickerson et al. reported on five patients who underwent single column ORIF for post-operative PPAF, with no complications (including implant stability and migration) at a mean last follow up duration of 76 months [45]. In addition, Zettl et al. described a minimally invasive ORIF technique used to treat anterior column PPAFs in eight patients. Two patients unfortunately died of unrelated causes (pneumonia and malignancy) within 12 months but none of the remaining six patients required any further revision by 12 months and had a mean Harris hip score of 77. The only complication reported was a lesion of the iliac vein, which was sutured, but caused a considerable transfusion requirement and prolonged ITU stay. There was no residual deficit to the patient from this complication [46].

Unstable acetabular component

Displaced fractures with unstable implants require surgical revision. Choice of surgical technique is dependant on fracture pattern and aetiology. In acute traumatic PPAFs with no pelvic discontinuity, revision strategy is similar to intra-operative PPAFs. If able to provide sufficient stability, ORIF with conventional plating before insertion of a multi-hole revision cup with additional screw fixation is recommended. Where this fails to provide sufficient stability, advanced revision techniques such as Kerboull reinforcement rings, antiprotusio cages and cup-cage constructs can be used [37].

In chronic osteolytic PPAFs, the primary surgical goal is to achieve stability with the restoration of lost bone stock where possible [36]. The surgical technique employed is dependant upon both fracture pattern and extent of osteolysis. Acetabular defects are commonly classified by the American Academy of Orthopaedic Surgeons (AAOS) classification system, that divides acetabular defects into cavitary, segmental, combined cavitary and segmental, pelvic discontinuities, and arthrodesis [47]. This classification of acetabular defects is useful for planning which surgical techniques are likely to be effective in PPAFs with significant osteolysis.

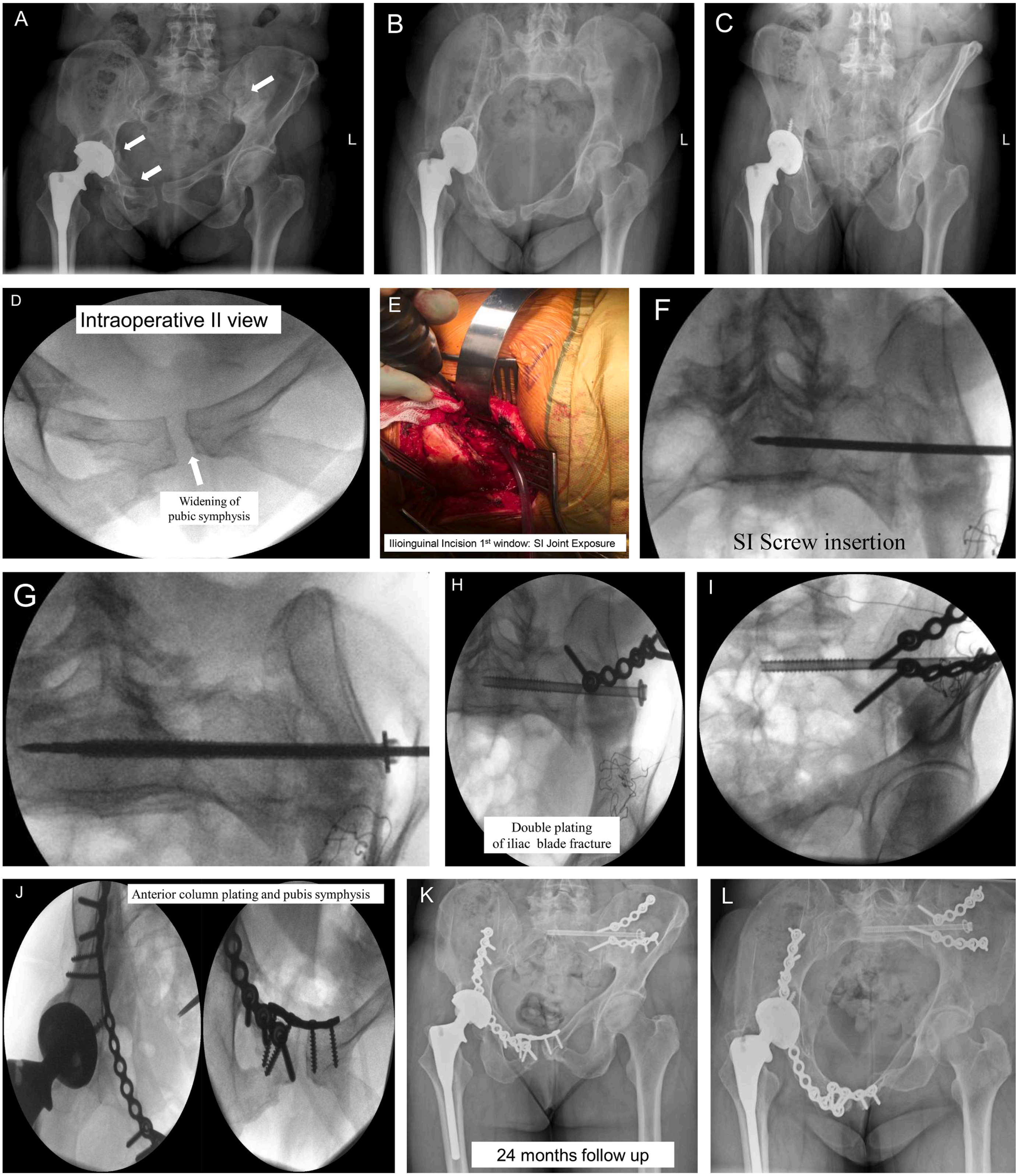

Fig. 1A-F. Anteroposterior (1A), inlet (1B) and outlet (1C) radiographs demonstrating delayed presentation of a complex right periprosthetic fracture in a 58-year-old female patient with disruption of the pelvic ring sustained following a mechanical fall (white arrows). Evidence of instability was clinically apparent as demonstrated using intraoperative image intensifier (II) (1D). Surgical stabilization involved sacroiliac (SI) joint exposure and screw fixation (1E, 1F, 1 G), double plating of the iliac wing fracture (1H, 1I), anterior column plate fixation and stabilization of the pubic symphysis (1 J). Postoperative radiographs at 2-years demonstrate satisfactory union and no migration of the acetabular shell on anteroposterior (1 K), inlet (1 L) and outlet radiographs (1 M).

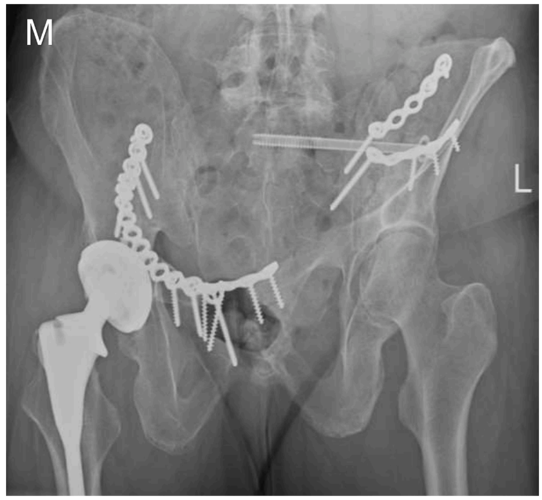

Fig. 1A-F. . (*continued*).

Cavitary acetabular defects do not involve the acetabular rim and so may be treated with morselized bone grafting (preferably autologous) and insertion of a multi-hole revision cup with additional screw fixation [48]. Importantly, the cavitary defect should not exceed 50% of the interface area between implant and host bone, as the literature suggests at least 50% of the implant should contact host bone to prevent implant loosening [49–52].

Unlike cavitary defects, segmental defects include the acetabular rim, reducing the area of native bone available for implant interface and limiting viable bone for additional screw fixation. Minor segmental defects can be managed with porous tantalum augments, Kerboull reinforcement rings and antiprotusio cages [49,53]. Porous tantalum augments are screwed into host bone and unitised with the acetabular component via cementation to both improve interface with native bone and provide additional screw fixation. There is a plethora of literature to support favourable outcomes with porous tantalum augments in revision THA for aseptic loosening, with implant survivorship ranging from 91–97% at mid-term follow up, but little evidence to support their use in PPAFs [54–57]. The theoretical disadvantages of porous tantalum augments in the setting of PPAF are that they provide no fixation across the fracture, do not provide any protection for underlying bone graft, and the unified augment and cup construct must have greater than 50% with viable host bone for reliable osseointegration [58–61].

Two alternative fixation strategies that overcome these limitations are Kerboull reinforcement rings and antiprotusio cages. Securing of either construct to healthy peri-acetabular bone, by cancellous screws through illeal and ischial flanges, alleviates stress forces on an incompetent acetabulum [62,63]. As with porous tantalum augments, there is a sparsity of literature for the use of Kerboull reinforcement rings and antiprotrusio cages in PPAF, but both have been reported with favourable fixation results in revision THA for aseptic loosening. A recent review article by Gibon et al. quoted an implant survival of Kerboull or Kerboull-type reinforcement rings at 53–95% across seven studies, all with a minimum of 5 years follow up [64]. The study reporting a survival of 53% was by Kawanabe et al., who reported that if a bulk allograft was used instead of morselized allograft, implant survival rose to 82% at a mean follow up of 8.7 years [65]. Besides Kawanabe et al., no other study in this systematic review reported an implant survival of below 87% [64]. Another review article by Apato et al. evaluated the outcomes of acetabular cages in revision arthroplasty. They reported a revision free implant survival for Burch-Schneider antiprotusio cages of 94% (375 of 399) at a mean follow up of 5.6 years and of these revisions, 10 were performed for septic loosening. Although only 24 of 399 cases were revised by time of last follow-up, 63 patients (16%) showed clinical or radiographic signs of loosening, suggesting longer term follow up may be prudent to monitor longer term implant survival [66]. These implant survival figures approximate similar literature on the survival of antiprotusio cages in revision arthroplasty, such as studies by Regis et al. and Perka et al. who quote implant survival of 87% (49 of 56) at mean follow up of 11.7 years and 92% (58 of 63) at mean follow up of 5.5 years [67,68]. There are three commonly reported disadvantages of Kerboull reinforcement rings and antiprotusio cages. Firstly, neither effectively integrate into native host bone, as they are made of non-porous, biologically incompatible material [62,63]. Secondly, both techniques require extensive surgical exposure for fixation of the illeal and ischial flanges, which has been reported to be associated with a higher complication rate, particularly neurovascular injury [51,57,69–71]. Finally, although both constructs will provide some fixation across the acetabulum and reduce stress forces through the acetabulum, there are documented cases of implant fatigue failure, particularly when used for pelvic discontinuity [51,71].

Pelvic discontinuity

Pelvic discontinuity is a "distinct form of bone loss, occurring in association with THA, in which the superior aspect of the pelvis is separated from the inferior aspect because of bone loss or a fracture through the acetabulum" [72]. It is a rare complication of THA, with a quoted incidence of 0.9–2.1% [72–74]. As with all PPAF, pelvic discontinuities should be divided into acute and chronic, as the two categories necessitate different management strategies due to the underlying differences in pelvic bone biology and biomechanics [73]. The difference in native pelvic bone biology determines how a surgeon may attempt to re-establish pelvic continuity in these types of injuries.

Acute pelvic discontinuity is usually either traumatic, following a fall, or iatrogenic, from underreaming and press fit impaction of an oversized component or overreaming. On the background of good bone stock, these fractures are usually apposable after implant removal and have good potential for biological healing and union [73]. As such, acute pelvic discontinuity may be treated with the same treatment algorithm as unstable post-operative PPAFs with good bone stock, provided the hemipelvis can be sufficiently stabilised (Fig. 2). In a case series of eight patients with acute pelvic discontinuity treated with posterior column ORIF and uncemented cup insertion, Rogers et al. reported fracture union and 100% revision-free survivorship at a mean 34 months follow up [73]. Furthermore, Martin et al. reported 80% revision-free survivorship and healing of the discontinuity in 74% of patients with the same technique [75].

In contrary, chronic pelvic discontinuity occurs progressively due to pathological osteolysis of periacetabular bone. The underlying pathology often renders the remaining bone sclerotic and non-vascularised with overlying fibrous tissue. This not only makes visual identification of PPAFs difficult but leaves the residual native bone stiff with limited potential for biological healing and union [53,76]. Consequently, management strategy focuses not on bony re-apposition and restoration of biological pelvic continuity but on reconstruction with durable, stable implants that are resistant to migration and fatigue failure.

Cup-cage constructs were first described by Hanssen and Lewallen in 2005 and have since become a popular treatment strategy for chronic pelvic discontinuity [77,78]. Cup-cage constructs benefit multimodal fixation methods, through both osseointegration of the trabecular uncemented cup and ilio-ischial fixation spanning the discontinuity from the overlying cage. There is a wealth of literature describing successful medium-term results of cup-cage constructs, including two systematic reviews by Malahias et al. and Wang et al. [79,80]. Malahias et al. reported a construct survival rate of 91.9% (158 of 172) and a revision rate of 8.1% (14 of 172) for the acetabular component, at a varied mean follow up of between 32–72 months. Presented causes for revision surgery were dislocation (6.4%; 11 of 172), periprosthetic joint infection (4.1%; 7 of 172), aseptic loosening (3.5%; 6 of 172), and periprosthetic fracture (1.2%; 2 of 172) [79]. Wang et al. reported similar figures from a cohort of 232 patient, with a mean follow up period of 48.9 months: presenting a revision rate of 8% and a complication rate of 20% [80]. Similarly to Malahias et al., Wang et al. reported

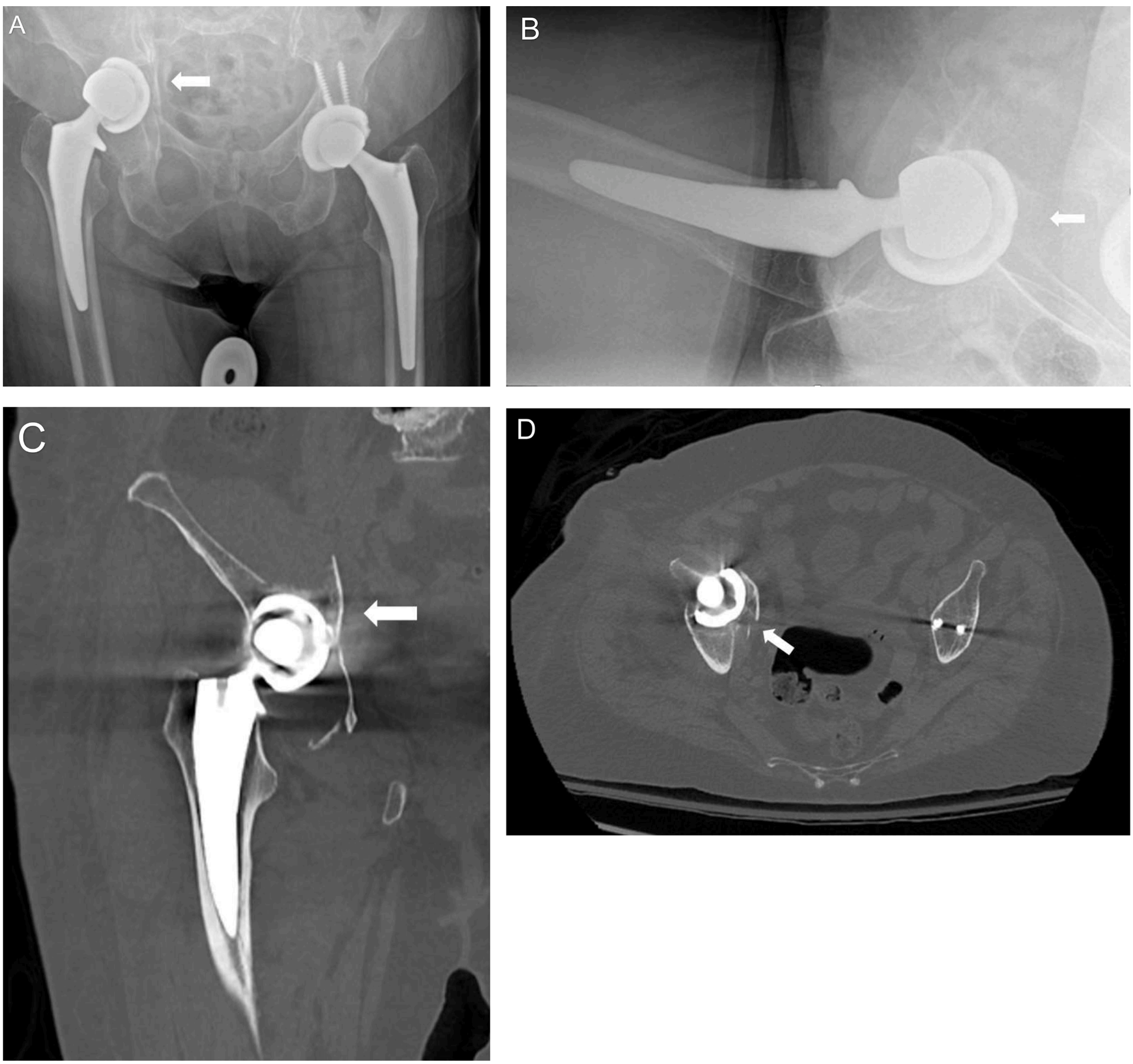

Fig. 2A-F. Anteroposterior and lateral radiographs (2A and 2B) demonstrating a right periprosthetic acetabular fracture (white arrow) with an acutely displaced shell and evidence of pelvic discontinuity sustained following a mechanical fall. Coronal (2C) and axial CT scan sequences (2D) further illustrate the fracture pattern which was revised using the double cup arthroplasty technique (2E and 2F).

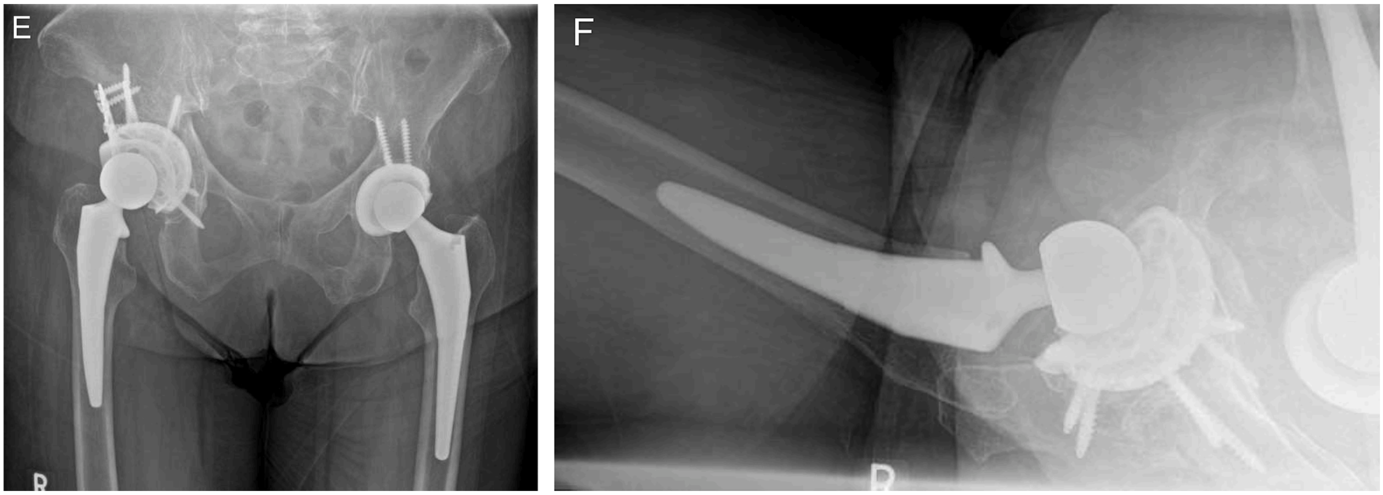

Fig. 2A-F. . (*continued*).

dislocation, aseptic loosening, infection, and nerve injuries to be the most common complications [79,80]. Cup-cage constructs also show credible survival beyond these relatively short follow up periods. Martin et al. reported a 100% construct survival in a cohort of 27 patients at a minimum of 5 year follow up, whilst Amenabar et al. presented a 93% and 85% construct survival at 5 and 10 years respectively, in a retrospective review of 67 patients [75,78]. However, as highlighted by the two aforementioned systematic reviews, the risk of complications is not insignificant. The risk of dislocation is substantial with a cup-cage construct as the trabecular uncemented cup must be placed relatively vertical and retroverted to allow engagement of the ischial flange of the overlying cage. When the articulating acetabular component is then cemented into the construct in the traditional anteverted position, there is significant risk of anterior impingement and care must be taken intra-operatively to mitigate this risk [76]. Furthermore, there is a documented risk of sciatic nerve injury with ilio-ischial cages if the ischial flange is either not slotted into bone or is slotted into particularly osteolytic bone, with Goodman et al. reporting a sciatic nerve injury rate of 6.6% (4 of 61) in a retrospective review of acetabular reconstruction with ilio-ischial rings [81]. In 2017, Sculco et al. described a novel construct design intended to mitigate this risk: the half cup-cage construct. The ischial flange is removed from the cage to mitigate the risk of sciatic nerve injury, which resulted in no cases of sciatic nerve injuries from a cohort of 27 compared to two cases from a control group of 30 patients treated with full cup-cage constructs. Interestingly the construct does not appear to show the expected drop-off in stability, at mean follow up of 4.6 years, with a revision-free survival of 96% compared to 83% in the full cup-cage control group [82].

Pelvic distraction is a relatively new technique, first described by Sporer et al. in 2012 [83]. Instead of compressing the fracture edges, sequentially larger reamers are used until bleeding, healthy bone is reached on either side of the fracture line. A tantalum uncemented acetabular shell, 6–8 mm larger than the last reamer, is then implanted (whilst the hemipelvis is being distracted) to engage healthy bone on either side of the fracture and is secured by additional screw fixation. The pelvic distraction achieves initial stability and use of a porous acetabular implant promotes long-term stability via osseointegration. Whilst there is a scarcity of literature regarding this novel technique, initial evidence suggests promising outcomes. In 2018, Sheth et al. supplemented Sporer et al.'s initial cohort of 20 patients with 12 of their own, to present findings on 32 patients treated with acetabular distraction over a mean follow up of 62 months [83,84]. Sheth et al. reported only one patient (3%) requiring revision for aseptic loosening but two patients who suffered neurovascular injury. The authors posited that over distraction may have placed excessive stress onto adjacent neurovascular structures [84]. In addition, Bingham et al. later reported on 31 patients treated with pelvic distraction, from a cohort of 162 patient requiring surgical treatment of pelvic discontinuity. The authors presented an implant survivorship of 97% for aseptic loosening at 2 years with 90% of implants showing radiographic osseointegration at follow up [85].

Where bone loss is too severe to seat a cup-cage construct or uncemented jumbo cup by pelvic distraction, one can consider a custom tri-flange acetabular implant. Pre-operative CT scans of a patient are reconstructed into a three-dimensional model of a patients hemipelvis, complete with bone defects, from which a patient-specific tri-flanged titanium implant is created. The custom construct is designed to restore a patient's anatomical hip joint centre of rotation and allow for implant fixation with screw placement into healthy bone. Initial reports of short- and medium-term outcomes in the literature suggest excellent implant survival but significant complication rates. The aforementioned systematic review by Malahias et al. also reported on a cohort of 95 cases using custom tri-flange implants over a follow up period ranging from 30 to 123 months. The overall revision-free survival rate of these components was 95.8% (91 of 95), with component revisions being due to aseptic loosening, recurrent dislocations and two case of periprosthetic joint infection. However, the all-cause re-operation rate in this systematic review was 28%, with 17 cases of dislocation (17.9%), 6 cases of periprosthetic joint infection (6.3%), 3 cases of periprosthetic fracture (3.2%), and 1 case of aseptic loosening (1.1%) [79]. Furthermore, both Matar et al. and Christie et al. reported an implant survival of 100% in 17 and 86 patients at mean follow up times of 3.6 years and 53 months, respectively [86,87]. However, Christie et al. described six patients (7.8%) requiring re-operation for dislocation [87]. Although the reported rate of dislocation is high across the literature for custom tri-flange implants, there is hope that the growing popularity of dual mobility cups may help to mitigate this risk in the future [88].

Continuing medical education (CME) summary points

- PPAFs are a rare but potentially devastating consequence of THA. They are often clinically difficult to identify intra- and post-operatively, so a surgeon must maintain a high index of suspicion, particularly during difficult cup impaction or in patients with unexplained post-operative pain or leg length discrepancy.
- Acute PPAFs may be managed conservatively if the acetabular implant is stable, or with ORIF and acetabular revision if the acetabular implant is unstable.
- Treatment of chronic PPAFs must prompt detailed examination of fracture pattern and bone stock before selecting the complex surgical

revision technique necessary to re-establish a stable hemipelvis and acetabular component.
- Whilst initial literature suggests promising survivorship of complex acetabular reconstructions, these techniques are associated with significant complication rates, particularly dislocation, and further research is required to illuminate the long-term results.

CME Viva Question 1What risk factors for periprosthetic acetabular fractures do you know?Risk factors for periprosthetic acetabular can be patient, technique or implant related.

1 Systemic patient factors
  a Osteoporosis, decreased preoperative mobility
  b Neurological conditions (e.g. Parkinson's, Stroke) leading to "frequent falls"
  c Trauma
2 Local patient factors
  a Infection
  b Osteolysis (e.g., poly wear, Metal on metal hip)
  c Irradiation
  d Tumour
3 Surgical and implant factors
  a Overreaming during acetabular preparation (large cup small acetabulum)
  b Cup impaction following underreaming (>2 mm)
  c Blunt reamers
  d Elliptical or porous tantalum cups

Recommended referencesSharkey PF, Hozack WJ, Callaghan JJ, Kim YS, Berry DJ, Hanssen AD, LeWallen DG. Acetabular fracture associated with cementless acetabular component insertion: a report of 13 cases. J Arthroplasty. 1999 Jun;14(4):426-31. doi: 10.1016/s0883-5403(99)90097-9. PMID: 10428222.Beckers G, Djebara AE, Gauthier M, Lubbeke A, Gamulin A, Zingg M, Bastian JD, Hannouche D. Acetabular Peri-Prosthetic Fractures-A Narrative Review. Medicina (Kaunas). 2022 May 1;58(5):630. doi: 10.3390/medicina58050630. PMID: 35630047; PMCID: PMC9143047.Mahoney CR, Garvin KL. Periprosthetic acetabular stress fracture causing pelvic discontinuity. Orthopedics. 2002 Jan;25(1):83-5. doi: 10.3928/0147-7447-20020101-23. PMID: 11811249.**CME Viva Question 2What are known complications of periprosthetic acetabular fractures?**

1 Pelvic discontinuity

Pelvic discontinuity is a rare complication of periprosthetic acetabular fractures and is associated with 0.9% of acetabular revisions. It is more common in women and patients with rheumatoid arthritis or severe osteoporosis.

1 Implant loosening and migration

Failure to identify periprosthetic acetabular fractures intraoperatively, especially when involving the medial wall or posterior column, can lead to early loosening and failure.Fractures considered stable radiologically or clinically/ intraoperatively are often treated conservatively. However, these implants often tend to migrate, leading to undesired cup orientation. Revision rates can therefore reach up to 80%, with 38% in the first year.

1 Non-union and pain

Aside from cup loosening, non-union and pain has been a common cause for revision surgery following a trial of non-operative management.

1 Risks associated with revision surgery
  a Dislocation
  b Infection, wound healing problems, haematoma
  c Vascular injury (Superior gluteal vein)
  d Neurological injury (Sciatic nerve)
  e Thromboembolic event, fat embolism

Recommended referencesBabis GC, Nikolaou VS. Pelvic discontinuity: a challenge to overcome. EFORT Open Rev. 2021 Jun 28;6(6):459-471. doi: 10.1302/2058-5241.6.210022. PMID: 34267936; PMCID: PMC8246102.Dammerer D, Putzer D, Glodny B, Petersen J, Arrich F, Krismer M, Biedermann R. Occult intra-operative periprosthetic fractures of the acetabulum may affect implant survival. Int Orthop. 2019 Jul;43(7):1583-1590. doi: 10.1007/s00264-018-4084-7. Epub 2018 Aug 10. PMID: 30097730.Callaghan JJ, Kim YS, Pederson DR, Brown TD. Periprosthetic fractures of the acetabulum. Orthop Clin North Am. 1999 Apr;30(2):221-34. doi: 10.1016/s0030-5898(05)70077-8. PMID: 10196424.Russell GV Jr, Nork SE, Chip Routt ML Jr. Perioperative complications associated with operative treatment of acetabular fractures. J Trauma. 2001 Dec;51(6):1098-103. doi: 10.1097/00005373-200112000-00014. PMID: 11740260.**CME Viva Question 3What do you understand by pelvic discontinuity?**Pelvic discontinuity is defined as a dissociation of the superior and inferior aspects of the pelvis caused by a defect traversing the anterior and posterior columns of the acetabulum.What is the goal in managing pelvic discontinuity in the setting of periprosthetic acetabular fractures?The goal is to achieve rigid fixation of the acetabular component to the pelvis and to stabilise the hemipelvis. This can be achieved by using the acetabular component to bridge and

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stabilize the superior and inferior pelvis.What reconstruction options do you know?Several reconstruction methods including multi-hole cups, metal augments, anti-protrusion cages, hemispherical cups combined with plate fixation (ORIF), cup-cage constructs, acetabular distraction and custom triflange implants have been described. Outcomes have shown to be best in patients with good bone stock and absence of segmental or cavitary bone loss.What if reconstruction cannot be achieved?In cases where reconstruction cannot be achieved (e.g., poor bone stock, infection), removal of implants, healing of the dissociation and staged revision can be planned.In low demand patients, salvage procedures such as resection arthroplasty ("Girdlestone" procedure) can be considered.Recommended referencesBabis GC, Nikolaou VS. Pelvic discontinuity: a challenge to overcome. EFORT Open Rev. 2021 Jun 28;6(6):459-471. doi: 10.1302/2058-5241.6.210022. PMID: 34267936; PMCID: PMC8246102.Horberg JV, Bailey JR, Kay K, Allan DG. Staged Total Hip Arthroplasty: A Novel Technique in Managing Native and Periprosthetic Acetabular Insufficiency. Arthroplast Today. 2021 May 31;9:78-82. doi: 10.1016/j.artd.2021.04.014. PMID: 34136608; PMCID: PMC8180963.Berry DJ, Lewallen DG, Hanssen AD, Cabanela ME. Pelvic discontinuity in revision total hip arthroplasty. J Bone Joint Surg Am. 1999 Dec;81(12):1692-702. doi: 10.2106/00004623-199912000-00006. PMID: 10608380.**CME Viva Question 4Are you aware of any classification systems of periprosthetic acetabular fractures which include recommendations for treatment?**Classification systems that describe pelvic ring injuries, such as the Young-Burgess, AO or Tile classification, do not consider periprosthetic fractures, whilst other classification systems such as Callaghan et al. or Hasegawa et al. are descriptive and do not correspond to therapeutic algorithms.Corresponding to the Vancouver classification of periprosthetic femoral fractures Duncan and Haddad proposed the "Unified Classification System of Periprosthetic Fractures" which shows a high inter- and intra-observer reliability and can be applied across the musculoskeletal system. This classification system can also offer guidance in managing periprosthetic acetabular fractures.**The Unified Classification System of Periprosthetic Fractures (UCS)Type A:** Apophyseal or extra-articular/periarticularAvulsion fracture of anterior inferior (AIIS) and superior (ASIS) iliac spine or ischial tuberosity**Type B:** Bed of the implant or around the implant**B1**: Stable well-fixed implant (non-operative management)**B2**: Loose implant, adequate bone stock (uncomplicated revision)**B3**: Loose implant, severe bone loss (complex reconstruction or salvage procedure)**Type C:** Clear of the implantIlium or pubic rami fracture**Type D:** Dividing the pelvis between implantsPelvic fracture with bilateral THR**Type E:** Each of 2 bones supporting one joint replacementFractured acetabulum and femur**Type F:** Facing a joint replacementFracture of the acetabulum following hemiarthroplastyFurther classification systems that offer guidance in managing periprosthetic acetabular fractures have been postulated by Paprosky and Della Valle as well as Pascarella et al. and are based on the timing of fracture, implant stability and bone loss.Recommended referencesDuncan CP, Haddad FS. The Unified Classification System (UCS): improving our understanding of periprosthetic fractures. Bone Joint J. 2014 Jun;96-B(6):713-6. doi: 10.1302/0301-620X.96B6.34040. PMID: 24891568. Della Valle CJ, Momberger NG, Paprosky WG. Periprosthetic fractures of the acetabulum associated with a total hip arthroplasty. Instr Course Lect. 2003;52:281-90. PMID: 12690856.**CME Viva Question 5Can you name different surgical treatment options for UCS (Unified Classification System) Type B fractures and their corresponding indications?**Revision cupIn case of isolated anterior or posterior wall fractures, where the acetabulum is either contained or containment can be achieved by medialisation, simple cup revision without additional ORIF will achieve stable fixation.ORIF posterior/anterior column and revision cupIf containment cannot be achieved, stabilisation of the posterior column via Kocher-Langenbeck approach and respective the anterior column via an anterior approach, and subsequent cup implantation using press-fit technique is required.Cranial socket revision cup with flange and iliac pegAnterior column fractures with or without posterior hemitransverse/ T-fracture components can be stabilised with a cranial socket revision cup with flange and iliac peg allows stable fixation of the cup to the ilium. This technique does not necessitate anterior column plating and can be done via a single approach with minimal surgical trauma.Porous acetabular cups +/- metal augmentsIn acute pelvic discontinuity and good one stock ORIF and highly porous tantulum cups show good primary and secondary stability and good outcomes.Antiprotrusio cageAntiprotrusio cages, often in combination with bone grafting or porous metal augments, are used in pelvic discontinuity. Flanges that engage in the ilium, ischium and/or pubis via multiple screws. These constructs provide a large surface area and span bone defects, distribute load, can incorporate large bone grafts and resist migration of the cemented liner.Cup-cage constructWith this technique a large uncemented porous metal cup, which functions as a large structural allograft, is implanted in the acetabulum and stabilised with an overlying antiprotrusio cage. This is used in the setting of a large or uncontained bone defect.Acetabular distractionAcetabular distraction technique is used in chronic pelvic discontinuity. Following debridement and reaming the superior and inferior hemipelvis is distracted and the cup (6-8 mm larger than the last reamer) positioned. This achieves good initial stability which can be improved further with superior and inferior screws. This technique relies on a certain flexibility of the pelvis. Custom triflange implantsCustom triflange implants are used to address chronic discontinuity with excessive bone loss. These titanium and often porous or hydroxyapatite coated implants consist of an iliac, ischial and pubic flange. Multiple screws through all three flanges achieve good stability, and the custom nature of this implant

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allows to restore the anatomical centre of rotation.Recommended referencesBabis GC, Nikolaou VS. Pelvic discontinuity: a challenge to overcome. EFORT Open Rev. 2021 Jun 28;6(6):459–471. doi: 10.1302/2058–5241.6.210022. PMID: 34267936; PMCID: PMC8246102.Berry DJ. Antiprotrusio cages for acetabular revision. Clin Orthop Relat Res. 2004 Mar;(420):106-12. doi: 10.1097/00003086-200403000-00015. PMID: 15057085.de Ridder VA, Pape HC, Chana-Rodríguez F, Boudissa M, Claudia G, Fabian S, Steven H, Tina H, Konstantinos T, Zoe D. Managing periprosthetic fractures: perspectives on periprosthetic pelvic fractures. OTA Int. 2023 Mar 28;6(1 Suppl):e266. doi: 10.1097/OI9.0000000000000266. PMID: 37006450; PMCID: PMC10064643.

SBA Question 1What is the main advantage of sole revision arthroplasty (revision of cup only) for periprosthetic fractures of the acetabulum, when compared to posterior column open reduction internal fixation (ORIF) with cup revision?

1 Increased surgical trauma
2 Decreased risk of secondary hip dislocations
3 Staged revision
4 Dual-incision technique

Correct answer: 2Where a stable pelvis with containment of the acetabulum can be achieved with sole revision arthroplasty, a single approach without release of external rotators leads to lower rates of secondary hip dislocations.Incorrect answers:1. A Kocher-Langenbeck approach, for ORIF of the posterior column, requires detachment of the external rotators and typically leads to increased surgical.3. and 4. Both, sole revision arthroplasty and posterior column ORIF with cup revision can be performed via single incision in one stage.Recommended referencesde Ridder VA, Pape HC, Chana-Rodríguez F, Boudissa M, Claudia G, Fabian S, Steven H, Tina H, Konstantinos T, Zoe D. Managing periprosthetic fractures: perspectives on periprosthetic pelvic fractures. OTA Int. 2023 Mar 28;6(1 Suppl):e266. doi: 10.1097/OI9.0000000000000266. PMID: 37006450; PMCID: PMC10064643.**SBA Question 2Following implantation of an uncemented cup during primary total hip replacement, you notice an undisplaced fracture of the posterior wall. The cup appears well fixed, and the acetabulum contained. What is the best next step in managing this patient?**

1 Removal of implant and revision to jumbo cup
2 Removal of implant, reconstruction of posterior wall and hemispherical cup
3 Retention of implant and supplemental screws
4 Removal of implant, bone grafting and hemispherical cup

Correct answer: 3Undisplaced fractures with a stable cup can be treated conservatively. However, despite the implant being stable on testing with a cup introducer, supplemental screws are recommended. These should be placed anterior and posterior to the fracture line, with bicortical posterior screws. Sometimes this can warrant a multi-hole cup. A close follow-up is recommended.Incorrect answers:1. Jumbo cups (>62mm in women and >66mm in men) are usually reserved for revision surgery and are helpful in restoring the anatomic centre of rotation.2. and 4. Pelvic reconstruction or bone grafting are not indicated in the presence of a stable cup. Recommended referencesBenazzo F, Formagnana M, Bargagliotti M, Perticarini L. Periprosthetic acetabular fractures. Int Orthop. 2015 Oct;39(10):1959-63. doi: 10.1007/s00264-015-2971-8. Epub 2015 Aug 27. PMID: 26311511.Acharya M, Elnahal WA. Strategies of management of traumatic periprosthetic acetabular fractures around a pre-existing total hip arthroplasty. J Clin Orthop Trauma. 2020 Nov-Dec;11(6):1053–1060. doi: 10.1016/j.jcot.2020.10.033. Epub 2020 Oct 17. Erratum in: J Clin Orthop Trauma. 2021 Aug 05;21:101558. PMID: 33192009; PMCID: PMC7656486.**SBA Question 3A 70-year-old man presents following a fall. He did undergo total hip replacement 5 years ago and reports a previously well-functioning hip. A CT scan shows a transverse acetabular fracture with medial migration of cup. The femoral component appears to be well fixed. The patient does not have any significant past medical history. Which treatment are you offering the patient?**

1 Toe touch weightbearing and close follow up
2 Acetabular revision with jumbo cup
3 Removal of implant and staged reconstruction with anterior and posterior plate fixation
4 Acetabular revision with cup-cage construct

Correct Answer: 4A transverse fracture of the acetabulum involves both columns and, like pelvic discontinuity, can lead to significant instability. A cup-cage construct with a porous metal acetabular component with inset cage fixes and stabilises the proximal and distal fragment.Incorrect Answers:

1 Conservative management will unlikely achieve a satisfactory outcome in this case.
2 Jumbo cups are unlikely to achieve stable fixation in the setting of bi-columnar instability.
3 Both column reconstruction and plating via an anterior and posterior approach is unlikely necessary in this scenario.

Recommended referencesArvinte D, Kiran M, Sood M. Cup-cage construct for massive acetabular defect in revision hip arthroplasty- A case series with medium to long-term follow-up. J Clin Orthop Trauma. 2020 Jan-Feb;11(1):62-66. doi: 10.1016/j.jcot.2019.04.021. Epub 2019 Apr 25. Erratum in: J Clin Orthop Trauma. 2020 Nov-Dec;11(6):1175. Erratum in: J Clin Orthop Trauma. 2021 Aug 05;21:101556. PMID:

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32001986; PMCID: PMC6985017.**SBA Question 4What are the advantages of anti-protrusio cages in acetabular revision?**

a Restoration of cup containment
b Bridging of acetabular defects
c Restoration of column stability
d Minimises fracture progression
e Protects large bone grafts

1 a, b, c
2 a, b, c, d, e
3 d, e
4 b, c, d, e

Correct answer: 2Antiprotrusio cages, often in combination with bone grafting or porous metal augments, are used in pelvic discontinuity. Flanges that engage in the ilium, ischium and/or pubis via multiple screws. These constructs provide a large surface area and distribute load, span bone defects and provide columnar stability, restore containment and prevent liner migration, allow incorporation of large bone grafts.Incorrect answers: 1, 3, 4Restoration of cup containment, bridging of acetabular defects, restoration of column stability, minimising fracture progression and protection of large bone grafts are all advantages of antiprotrusio cages. Recommended referencesBerry DJ. Antiprotrusio cages for acetabular revision. Clin Orthop Relat Res. 2004 Mar;(420):106–12. doi: 10.1097/00003086-200403000-00015. PMID: 15057085.**SBA Question 5A 75-year-old patient presents with severe pain in his right hip following a fall. Imaging including CT shows a non-comminuted transverse fracture with medial migration of a pressfit acetabular cup. How would you classify this fracture according to the Unified Classification System?**

1 B1
2 B2
3 C
4 F

Correct answer: 2Imaging suggests a loose implant. In the presence of likely adequate bone stock this would be considered a Type B2 fracture.Incorrect answers: 1, 3, 4,The Unified Classification System of Periprosthetic Fractures (UCS)Type A: Apophyseal or extra-articular/periarticularAvulsion fracture of anterior inferior (AIIS) and superior (ASIS) iliac spine or ischial tuberosityType B: Bed of the implant or around the implantB1: Stable well-fixed implant (non-operative management)B2: Loose implant, adequate bone stock (uncomplicated revision)B3: Loose implant, severe bone loss (complex reconstruction or salvage procedure)Type C: Clear of the implantIlium or pubic rami fractureType D: Dividing the pelvis between implantsPelvic fracture with bilateral THRType E: Each of 2 bones supporting one joint replacementFractured acetabulum and femurType F: Facing a joint replacementFracture of the acetabulum following hemiarthroplastyRecommended referencesDuncan CP, Haddad FS. The Unified Classification System (UCS): improving our understanding of periprosthetic fractures. Bone Joint J. 2014 Jun;96-B(6):713-6. doi: 10.1302/0301-620X.96B6.34040. PMID: 24891568.

Ethical approval

This was not required for this article.

Authors' contributions

T Al-Jabri: Designed the article layout, drafted, edited and approved the manuscript.
AJ Hart: Designed the article layout, edited and approved the manuscript.
MJ Wood: Drafted, edited and approved the manuscript.
A Zaghloul: edited and approved the manuscript.
B Lanting: edited and approved the manuscript.
PV Giannoudis: edited and approved the manuscript.

Consent for publication

Not applicable.

Declaration of Competing Interest

The authors declare that they do not have any competing interests.

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