Evolving indications and reported complications suggest total knee arthroplasty after acute and complex periarticular fractures remains a high-risk operation: a systematic review

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ABSTRACT

Importance Complex periarticular fractures of the knee can be difficult to reconstruct with osteosynthesis, can result in poor function and can lead to increased morbidity and mortality—particularly in the elderly. Primary acute total knee arthroplasty (TKA) is a surgical option which is rarely performed, but thought to have high rates of complication postoperatively.

Objective To investigate the literature regarding optimal patient selection for TKA after acute fracture with particular emphasis on postoperative outcomes and complications.

Evidence review A literature search of the MEDLINE, EMBASE and Cochrane Databases using established methodology for conducting systematic reviews investigating acute TKA after trauma. Two reviewers screened citations using the methodological index for non-randomised studies score to determine inclusion, methodological quality assessment and data extraction.

Findings Eighteen papers met the inclusion criteria; totalling 284 acute arthroplasty procedures. The majority of cases were performed in elderly females and the most common fracture pattern was the Arbeitsgemeinschaft für Osteosynthesefragen type C. Inclusion criteria for acute arthroplasty—whether fracture or patient specific—was poorly defined. Modular, stemmed and highly constrained (condylar or hinged) prostheses were used. Complications were often seen including 44 deaths within 5 years of surgery and three instances of above knee amputation.

Conclusion and relevance Acute knee arthroplasty can be considered as primary management for an acute periarticular fracture in some cases, although patient selection is vital. These patients should also be viewed similar to fractured neck of femur patients and cared for appropriately.

Level of evidence 4.

INTRODUCTION

Periarticular fractures of the knee are a relatively uncommon injury. A significant proportion occur in the elderly and result in significant loss of independence and medical decline. The incidence of periarticular distal femoral fractures has been estimated at 4.5 per 100 000 and 13.3 per 100 000 in the proximal tibia.1 In stable fractures, non-operative treatment with immobilisation and restricted weight bearing can be considered.2 The mainstay of surgical management has been open reduction and internal fixation (ORIF). Intercondylar distal femoral fractures can be treated with blade plate constructs, although in the elderly this is associated with in increased rates of postoperative osteoarthritis (OA).3 In proximal tibial fractures, screws and bone grafting have been employed, but loss of position or fixation is a risk postoperatively.4

An alternative to internal fixation is acute arthroplasty, which was first proposed in a 1982 case report.5 Proponents of this option argue that it allows earlier weight bearing and mobilisation, allows for treatment of complex or unreconstructable fractures and avoids the need for further revision or conversion to arthroplasty.6–9 Previously published results for early total knee arthroplasty (TKA) are encouraging, with low revision rates. However, complications have been reported between 8% and 42%.7 8 10–11 This is in contrast to delayed TKA for post-traumatic OA, where revision rates are between 8% and 20%.12–14 Bohm et al found that long-term TKA for modular tumour prostheses has a 94.4% 20-year survival.

Given the diversity surrounding the management of periarticular fractures of the knee with TKA, the goals of this study were to perform a systematic review of the literature investigating the epidemiology, fracture characteristics, classification...
methods, surgical treatment options, arthroplasty reconstructive techniques and outcomes after joint replacement was used as an initial intervention. In particular, the research question we wished to answer was whether acute TKA is associated with too high rate of complication to make it worthwhile?

METHODS

A systematic review of the English language literature was performed utilising the guidelines as specified by Wright et al and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. This search included the EMBASE, Medline and NHS Evidence Information for Health Databases, as well as the Cochrane Library.

Eligibility criteria

Search terms included (‘Total Knee Arthroplasty’ OR ‘Total Knee Replacement’) AND (‘fracture’ OR ‘injury’). Original scientific papers with a level of evidence of I–IV were included for consideration if any one of the following variables were reported: functional outcomes, complications, postoperative rehabilitation protocols or range of motion results after TKA. Acute arthroplasty was defined where no other form of treatment—whether operative or conservative—was pursued after initial fracture. Exclusion criteria included level V evidence, biomechanical or anatomically based papers, surgical technique reports, cadaveric studies, case reports, podium presentation abstracts and expert opinion. Studies which dealt with TKA in the setting of post-traumatic OA or tumour surgery were also excluded. Duplicate articles were manually identified.

Assessment of methodological quality and statistics

The information extrapolated from identified studies included: patient demographics, mechanism of injury, fracture classification, prosthesis information, time to surgery, postoperative rehabilitation and weight-bearing protocols, functional outcomes, range of motion results and complications. Two independent reviewers examined the articles to determine appropriateness for inclusion. The same authors independently assessed the methodological quality of the data using the methodological index for non-randomized studies (MINORS). MINORS scores were then compared with ensure inter-rater agreement using Cohen’s kappa coefficient. Kappa values of ≤0 were interpreted as indicating no agreement, whereas those 0.01–0.2 indicated non to slight agreement, 0.21–0.4 signified fair agreement, 0.41–0.6 was moderate, 0.61–0.8 substantial and 0.81–1.00 almost perfect agreement.

RESULTS

Our search strategy yielded a total of 1189 articles. After elimination of 393 duplicate articles, a further 270 were excluded after review as they did not reference an acute injury or fracture. One hundred and fifty-eight involved arthroplasty of the knee but not because of acute trauma. Three hundred and forty-one were excluded because they described arthroplasty of a joint other

Figure 1  Search strategy and results.
than the knee. The remaining 27 articles were reviewed in full and a further 9 were excluded based on the same criteria. This yielded a final cohort of 18 papers (figure 1—search strategy and results).

All studies included were case series and classified as level IV evidence, except one which was a case control series. Two reviewers assessed each paper using the MINORS classification and scores were obtained. Excluding the case control series, a mean score of 9.6 was achieved (where 16 is the maximum score for non-comparative studies). Cohen’s kappa coefficients were achieved with a kappa coefficient of 0.78 (95% CI 0.67 to 0.89).

There were a total of 284 TKAs reported over the 18 studies. The majority were performed on elderly patients after low-energy injuries such as falls from a standing height. The range of mean age was between 62 and 87 years and were predominantly performed in females. The presence of OA was inconsistently documented, but appeared to be a factor in decision for arthroplasty over internal fixation in 14 of the papers.

Fracture characteristics and classification were reported in a variety of ways. Five studies focused solely on distal femoral fractures, and these were mostly reported using the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification system. AO type C fractures occurred most commonly. Tibial plateau fractures were the sole focus of three papers, and these were classified with either the AO or the Schatzker classification systems. The remaining studies reported on both femoral and tibial fractures (table 1—fracture characteristics/classification).

A variety of prostheses were used for reconstruction arthroplasty (table 2—prosthetic summary). On the femoral side, stemmed implants were employed in all except one instance. Cement was also used in every instance but the modularity of prostheses was inconsistently documented. Tibial components were also stemmed, modular and cemented in the majority of cases, with six exceptions where a non-stemmed implant was used. Types of constraint employed ranged from cruciate retaining to rotating hinge, although the most common (nine studies) were either condylar constrained or hinged. Additional fixation was occasionally performed either with further internal fixation with plate and screw constructs, cerclage wiring or bone grafting, and reported on in seven studies. Computer navigation was utilised in one study.

Postoperative rehabilitation protocols for the majority recommended full weight bearing immediately after surgery, except in instances of multitrauma, and in one study of eight patients where patients were instructed to partial weight bear for 6 weeks followed by full weight bearing. Continuous passive motion following arthroplasty was employed in only four studies. Only 12 cases of splint or cast immobilisation were reported.

A number of complications were documented in the literature. Overall, there were 44 deaths were reported. Of these, in the immediate perioperative period, 11 (3.8%) occurred following cardiac arrest, venous thromboembolism (VTE), respiratory infection and overwhelming systemic sepsis from periartroplasty joint infection (PJI). Other medical complications reported included gluteal pressure areas, fat embolism during

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Table 1  Summary of papers and fracture characteristics/classification

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Journal</th>
<th>Type of study</th>
<th>Level of evidence</th>
<th>No pts</th>
<th>Age mean (range)</th>
<th>Fracture characteristics</th>
<th>AO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell</td>
<td>1992</td>
<td>JBJS Br</td>
<td>case series</td>
<td>IV</td>
<td>14</td>
<td>84 (67–94)</td>
<td>distal femoral</td>
<td>2x33-A1, 2x33-A, 3x33-C1, 7x33-C2</td>
</tr>
<tr>
<td>Wilkes</td>
<td>1994</td>
<td>J Trauma</td>
<td>Case Series</td>
<td>IV</td>
<td>7</td>
<td>77.75 (68–87)</td>
<td>proximal tibial</td>
<td>NS</td>
</tr>
<tr>
<td>Freedman</td>
<td>1995</td>
<td>JOT</td>
<td>case series</td>
<td>IV</td>
<td>2</td>
<td>NS</td>
<td>distal femoral</td>
<td>1x33-A2, 1x33C2</td>
</tr>
<tr>
<td>Yoshino</td>
<td>2001</td>
<td>J Arthroplasty</td>
<td>case series</td>
<td>IV</td>
<td>3</td>
<td>84.7 (83–87)</td>
<td>Mixed - x2 supracondylar + intra-articular extension; x1 intercondylar</td>
<td>NS</td>
</tr>
<tr>
<td>Nau</td>
<td>2003</td>
<td>J Arthroplasty</td>
<td>case series</td>
<td>IV</td>
<td>6</td>
<td>79 (70–90)</td>
<td>Mixed - supracondylar x3, tibial plateau x3</td>
<td>2x33-C2, 1x33-A3, 1x41C2, 1x41C3, 1x41B3</td>
</tr>
<tr>
<td>Rosen</td>
<td>2004</td>
<td>Clin orthop and Rel Res</td>
<td>case series</td>
<td>IV</td>
<td>24</td>
<td>76 (68–85)</td>
<td>distal femoral</td>
<td>1x33-B2, 2x33-C</td>
</tr>
<tr>
<td>Pearse</td>
<td>2005</td>
<td>Injury</td>
<td>case control (cf with ORIF)</td>
<td>III</td>
<td>6</td>
<td>87 (82–92)</td>
<td>distal femoral</td>
<td>2x33-A, 4x33-C</td>
</tr>
<tr>
<td>Appleton</td>
<td>2006</td>
<td>JBJS Br</td>
<td>case series</td>
<td>IV</td>
<td>54</td>
<td>NS</td>
<td>distal femoral</td>
<td>9x33-A3, 45x33-C</td>
</tr>
<tr>
<td>Vermeire</td>
<td>2010</td>
<td>Acta Orthop Belg</td>
<td>case series</td>
<td>IV</td>
<td>12</td>
<td>73 (58–81)</td>
<td>proximal tibial</td>
<td>1x41-B1, 8x41-B3, 3x41-C3</td>
</tr>
<tr>
<td>Malviya</td>
<td>2011</td>
<td>Injury</td>
<td>case series</td>
<td>IV</td>
<td>26</td>
<td>80 (67–92)</td>
<td>Mixed - supracondylar = 11; tibial plateau = 15</td>
<td>2x33A, 2x33B, 7x33C, 1x41A, 1x41B, 2x41C</td>
</tr>
<tr>
<td>Parratte</td>
<td>2011</td>
<td>Orthopaedics + Traumatology</td>
<td>case series</td>
<td>IV</td>
<td>26</td>
<td>80.5 (70–98)</td>
<td>Mixed - x10 distal femoral, x16 = prox tibia</td>
<td>1x33A, 9x33C, 8x41B, 8x41C</td>
</tr>
<tr>
<td>Choi</td>
<td>2013</td>
<td>KSRR</td>
<td>case series</td>
<td>IV</td>
<td>8</td>
<td>76.8 (65–89)</td>
<td>distal femoral</td>
<td>2x33-A1, 1x33-A2, 2x33-B2, 3x33-C1</td>
</tr>
<tr>
<td>Kini</td>
<td>2013</td>
<td>Arch Orthop Trauma Surg</td>
<td>case series</td>
<td>IV</td>
<td>9</td>
<td>73</td>
<td>proximal tibial</td>
<td>6 - Schatzker II, 3 - diaphyseal fracture</td>
</tr>
<tr>
<td>Benazzo</td>
<td>2014</td>
<td>Injury</td>
<td>case series</td>
<td>IV</td>
<td>6</td>
<td>62 (47–76)</td>
<td>Mixed - x4 distal femoral, x2 proximal tibial</td>
<td>2x33-B1, 1x33-C2, 1x33-C3, 2x41-B3</td>
</tr>
<tr>
<td>Boureau</td>
<td>2015</td>
<td>Orthop Traumatol Surg Res</td>
<td>case series</td>
<td>IV</td>
<td>21</td>
<td>79 (68–96)</td>
<td>Mixed - x10 distal femoral, prox tibial x11</td>
<td>2x33-A, 3x33-B, 5x33-C, Schatzker 2=x5, 4=x2, 5=x3, 6=x1</td>
</tr>
<tr>
<td>Haufe</td>
<td>2015</td>
<td>Hindawi</td>
<td>case series</td>
<td>IV</td>
<td>30</td>
<td>78.4 (59–93)</td>
<td>proximal tibial</td>
<td>1x41-B, 17x41-C</td>
</tr>
<tr>
<td>Bettin</td>
<td>2016</td>
<td>JOT</td>
<td>case series</td>
<td>IV</td>
<td>18</td>
<td>77.1 (62–94)</td>
<td>distal femoral</td>
<td>1x41-C, 4x41-B</td>
</tr>
<tr>
<td>Atrey</td>
<td>2017</td>
<td>J Ortho</td>
<td>case series</td>
<td>IV</td>
<td>11</td>
<td>70 (50–102)</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

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intramedullary reaming, persistent hypotension and delirium. The majority of the remaining deaths occurred within 1 year, although loss to follow-up beyond this point is a confounding factor.

Operative complications included persistent haematoma, patella tendon or tibial tubercle avulsion requiring surgical repair, intraoperative fracture and one case of common peroneal nerve palsy. Deep infection requiring return to theatre was recorded in six cases. A variety of microbes were reported. There were eight superficial wound infections that were treated with either oral or intravenous antibiotics and did not require further surgical debridement. In three cases, persistent stiffness necessitated return to theatre for manipulation under anaesthetic. There was only one report of revision arthroplasty, and this occurred after periprosthetic fracture. Above knee amputation (AKA) was reported in three cases; they were the result of dermatomyositis from a heel pressure area, a deep PJI and an ischaemic foot 2 weeks post primary surgery.

Follow-up of patients occurred between means of 6 months and 4.1 years. A variety of functional outcomes scores were employed, with the Knee Society Score (KSS) and Oxford Knee Score (OKS) being the most common. Mean OKS was 38.2 and mean KSS reported over 6 papers was 86.3 with a functional mean score of 53.8. Mean range of flexion was reported between 85° and 118°. Other outcomes measures, such as ability to mobilise or weight bear, pain levels and discharge destination, were infrequently described. Postoperative radiology was performed on all patients, but only four studies included results such as prosthetic malalignment, screw failure or component loosening.
DISCUSSION
The relative advantages of acute TKA after periarticular fracture to the knee are well summarised within the literature. These include concepts such as the ability to mobilise and achieve full weight bearing early, the ability to reconstruct the knee in settings of complex fracture patterns and osteoporosis, avoiding further complex primary arthroplasty surgery in already osteoarthritic joints, and the ability to maintain range of motion in the knee.1011 Patients undergoing ORIF are also commonly frail patients who have to undergo technically demanding and lengthy surgery, and also frequently suffer medical complications such as VTE and PJI.1019 Surgically, failure of fixation and progression of OA can also occur.

To balance these issues, correct patient selection is important. However, few studies documented their inclusion criteria. In all but two studies, the patient’s fitness for surgery was not specified. Pearse’s case controlled series of 12 patients specified an ASA of 2 or less as inclusion criteria,20 while Appleton et al simply described patients as ‘medically fit for anaesthetic’.21 Given the high rates of postoperative complications, fitness for surgery should be detailed in future studies to help determine whether patient inclusion guidelines can be developed. Additionally, given the acuity of fracture as an indication for surgery, it is reasonable to assume that complete optimisation of comorbidities is not possible in these patients.

From a fracture perspective, inclusion criteria for acute TKA was equally poorly specified. While many papers described their periarticular fractures using the AO system, their description of the selection process for arthroplasty over ORIF was not well described; terms such as ‘comminuted or intra-articular fractures’, ‘severe bone loss’ or ‘fracture patterns that were difficult to treat with ORIF’ were used. It is presumed that it was the operating surgeon’s preference in most cases to perform arthroplasty, although this was not specified. Only one study laid out definitive inclusion criteria—AO type C fractures within nine centimetres of the distal femur.20

Despite a perception that only the most comminuted and difficult fractures were treated with TKA, a number of AO type A (extra-articular) fractures were still included in this cohort on both the femoral and tibial side. Although not specifically documented, it is likely that these AO type A fractures had pre-existing OA, which led to the decision for arthroplasty. It appears that the AO system is the most common way to classify these injuries.

Stemmed, modular and cemented implants were almost always employed. Although it has not been investigated in the literature, Bohm et al argued for intramedullary alignment jigs to be used to allow for stemmed implants.10 Rotating hinge implants were most commonly utilised, and this likely reflects the difficulty in achieving adequate soft tissue balancing in patients whose collateral ligament integrity may be compromised by trauma, or with pre-existing alignment issues in arthritic knees. However, with increased constraint there is known increased risk of implant loosening in osteoporotic bone.22 Furthermore, additional fixation was occasionally, including plate and screw constructs or cerclage wiring, and this may reflect the desire of the operating surgeon to provide additional stability to the prosthesis or the fracture pattern.

Outcomes after surgery are difficult to compare. There was only one case control series comparing acute TKA with a Stemmore implant to ORIF.20 Results were mixed, with the TKA group achieving better return to independent walking, and quicker rehabilitation and knee flexion; the ORIF group needed fewer transfusions, had reduced pain and better overall OKS’s. Other papers reported a range of outcomes scores with mean KSS between 78 and 90.2. These are difficult to interpret as there are a number of case series only. Conversion of failed ORIF to TKA for non-union or postoperative OA was considered by exclusion criteria but may nonetheless be a factor in the choice to perform acute arthroplasty. Post ORIF, in the elderly, non-union rates have been reported at 20% and complications as high as 40%.21 Additionally, the results of delayed TKA after femoral fracture and failed fixation are poor compared with primary surgery.24 It is not known how this compares to acute primary TKA after trauma.

Both medical and surgical complications are a significant risk to these patients and seemed to be underemphasised in many papers. The rate of perioperative mortality in patients undergoing acute arthroplasty is difficult to quantify in the low numbers identified in this paper but is relatively consistent with other large studies which have assessed perioperative mortality in patients who undergo hip hemiarthroplasty, with 90-day survival rates calculated at 96.3%.23 Medium-term outcomes were assessed by Appleton et al and they found a 41.1% 12-month mortality, with a median survival of 1.7 years in a survival analysis of 54 patients.21 This high mortality rate may affect the lower reported rate of revision arthroplasty.10

AKA and catastrophic PJI requiring return to theatre and revision occurred far more readily than in either primary or revision (elective) arthroplasty surgery. ORIF of the distal femur in the geriatric population is also prone to complications and mortality after ORIF of periarticular fractures has been reported at 4.5% at 30 days26 and 18% at 1 year.27 Ultimately, it must be remembered that these patients are often extremely frail and medically unwell. It is not unreasonable to consider them in the same light as fractured neck of femur patients, where treatment under a geriatric team is considered best practice, and the decision for non-operative treatment made from a palliative and end of life care perspective.24

After reviewing the literature in our systematic review, our recommendations for the treatment of patients with complex periarticular fractures of the knee are as follows:
1. Patient selection is vital, although there is limited evidence of which specific risk factors lead to complications. Patients should only be selected if their overall perioperative risk for complex arthroplasty is assessed from a holistic perspective.
2. Future series should report strict operative and medical indications for surgery, as well as clearly defined fracture characteristics/classification.
3. Relative indications include AO type C fractures and type A (with existing OA) if considered non-reconstructable with internal fixation, and osteoporosis.
4. Often higher levels of constraint such as condylar constrained or hinged implants will be required.
5. A postoperative management protocol should be developed similar to those for fractured neck of femur patients, with a multidisciplinary approach including specialist orthogeriatric input.

CONCLUSION
Complex periarticular fractures of the knee can be treated with acute TKA. However, patient selection from a fitness for surgery and fracture pattern perspective is pertinent as there are a number of reported and serious complications. Surgically, high constraint and additional fixation should be considered. Finally, these patients should be viewed as similar to fractured neck of
femur patients, and they should be treated by the full geriatric multidisciplinary team in the perioperative setting.

**Contributors** All three authors were involved in all four criteria as per the ICMJE guidelines: substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not required.

**Provenance and peer review** Not commissioned; externally peer reviewed.

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