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The painful knee after TKA: a diagnostic algorithm for failure analysis

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Abstract Pain after total knee arthroplasty (TKA) represents a common observation in about 20% of the patients after surgery. Some of these painful knees require early revision surgery within 5 years. Obvious causes of failure might be identified with clinical examinations and standard radiographs only, whereas the unexplained painful TKA still remains a challenge for the surgeon. It is generally accepted that a clear understanding of the failure mechanism in each case is required prior considering revision surgery. A practical 10-step diagnostic algorithm is described for failure analysis in more detail. The evaluation of a painful TKA includes an extended history, analysis of the type of pain, psychological exploration, thorough clinical examination including spine, hip and ankle, laboratory tests, joint aspiration and test infiltration, radiographic analysis and special imaging techniques. It is also important to enquire about the length and type of conservative therapy. Using this diagnostic algorithm, a sufficient failure analysis is possible in almost all patients with painful TKA.
Level of evidence IV.

Keywords Total knee arthroplasty · Pain · Failure · Diagnostic algorithm · Imaging

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Introduction

Despite the clinical success of primary TKA, about 20% of patients after TKA are not satisfied with their outcomes for several reasons [6, 29, 30, 46]. A painful TKA causes a lot of medical, social and some times also legal problems. Although the goal of primary TKA is less pain, better function and long-term survival about 60–80% of all revision surgeries have to be performed during the first 2–5 years after primary implantation [15, 48]. The main reasons for revision surgery includes infection, polyethylene (PE) wear, osteolysis, aseptic loosening, instability and patellofemoral problems [9, 15, 29, 48]. Due to the rapid growing number of primary implantations, the numbers for revision surgery are increasing significantly [8, 18, 27]. The socio-economic effect of this expected revision rates will have a direct influence on the financial burden to the health care systems [28, 35].

There is a consensus in the literature that revision surgery should be performed only, if the causative failure mechanism is well understood [2, 12, 15, 19, 21, 26, 31, 39, 44, 54]. The unexplained painful TKA with no obvious cause on clinical examinations and standard radiographs remains a challenge for the surgeon. These patients are very dissatisfied, suffer on average for more than 1 year of pain, have had a lot of conservative therapy or even a partial/complete revision surgery done, perform 'doctors shopping' and some of them are already chronic pain patients with psychological problems. The diagnosis and failure analysis in these 'mystery knees' [54] with unexplained chronic painful TKAs are very demanding. The aim of this paper is to describe a detailed algorithm to analyse patients suffering from a painful TKA. This systematic algorithm will be discussed with the current literature.

Diagnostic algorithm

Patient collection is performed during the outpatient knee clinic, and most of the patients are referred for second opinion to our institution. All patients underwent a systematic diagnostic algorithm (Table 1). In some difficult cases, which may require numerous clinical and radiographic testings, the diagnostic might be performed having the patient admitted to the hospital. The failure mode, which will be identified prior surgery with the diagnostic algorithm, should be verified during the revision surgery. The standardised diagnostic algorithm can be divided in 10 different steps, which will be described in more detail.

Extended history

All previous surgical reports, laboratory and aspiration results such as cell counts and cultures and previous antibiotic therapy should be available. The type and quality of the obviously failed conservative treatment must be required. All radiographs (even the first X-rays prior surgery) as well as special images (computer tomography, bone scans, MR-imaging and ultrasound) should be available. Furthermore, the social situation (occupation, workers compensation, sick leave, family involvement), sporting activities, expectations, prior psychological consultations and any legal issues must be explored. Patients should also be asked specifically for any history of allergy or chronic regional pain syndrome (CRPS).

Type of pain analysis

There are typical different pain patterns described for painful TKAs [19, 31] (Table 2). Patients must be specifically asked for any episode of swelling, heatness, instability, locking and difficulties during sitting, walking even ground, stair climbing and raising a chair. Time, onset, location, quality and reproducibility of pain should be analysed and might allow some preliminary conclusions to the cause of failure. Furthermore, the typical pain before the primary TKA should be compared to the type of pain after surgery. Active and passive ROM before, immediate after surgery and until now are further important parameters. Additionally, the influence of conservative therapy, painkillers, exercises, stress tests and braces should be explored.

Psychological exploration

Most of these cases are patients suffering from chronic pain with a history of more than 6 months. Any changes in the psychological profile (especially depression), psychological and psychopharmacological therapy should be identified [30]. Every patient with a positive psychological or psychiatric history or patients who are conspicuous in their behaviour should have professional psychological exploration. Furthermore, patients where the clinical findings are not consistent with their complaints should be considered for psychological exploration also.

Table 1 Summary diagnostic steps

1. History	Infection, aspiration, antibiotics, surgery and reports, trauma, allergy, CRPS, symptoms and pain, conservative therapy, X-rays, social background
2. Type of pain	Rest and night, walking even ground, stairs climbing, raising chair
	Anterior or backside knee, full extension or full flexion, starting and loading pain
3. Psychological	Signs of depression and anxiety
	Psychological and psychopharmacological therapy
4. Clinical	Gait, chair and stair test, skin, circulation, muscular atrophy, ROM active and passive
	Patella tracking, stability 0–30–60–90°, soft tissue tests, other joints
5. Infiltration	Intra-articular combined with aspiration
	Extraarticular for trigger points
6. Laboratory tests	WBC, ESR and CRP (IL-6) infection screening
	Extended tests: coagulation, kidney, liver, gout (depending on co-morbidity)
7. Aspiration	Leucocytes and polymorph cells counts
	Cultures with long incubation (14 days)
8. Radiographs	Standard: anterior–posterior and lateral, long-standing full leg, patella axial
	Special: fluoro controlled, stress X-rays 30 and 90°, oblique views, lateral kneeling
9. Special imaging	Ultrasound, bone scans (Tc, leucocyte or gallium)
	Computer tomography (PET scans)
10. Trial therapy	Specific active physiotherapy and physical therapy, painkillers
	Brace, offloading with crutches, taping

Table 2 Type of pain

Night and rest pain	Infection
	Joint effusion or referred neurogenic
Pain on descending stairs and chair raising	Flexion gap instability
	Femur malrotation
Anterior knee pain	Patella maltracking
	Overuse tendinitis and neurinoma
Posterior knee pain	Posterior soft tissue tightness
	Popliteus tendinitis
Pain on full extension	Anterior soft tissue impingement
	Posterior tightness
Pain on full flexion	Post impingement (offset/osteophytes)
	Patella impingement or tightness
Starting pain	Loose components
	Tibia and/or femur forceps pain
Weight-bearing pain	Unspecific
	Mainly mechanical cause

Clinical examination

The clinical examination should include simple gait pattern analysis, stairs climbing, raising chair test without support and deep knee bending under weight-bearing conditions [19]. Specifically, any limping, pain, locking or instability during these activities must be identified. The neurovascular status as well as muscular imbalances and atrophy of the lower limb should be recognised. Straight leg raising, active and passive ROM, extension and flexion against resistance and patellar tracking tests must be performed. Stability analysis should include medial, lateral and anterior–posterior stability tests in full extension, 30, 60 and 90° of flexion [38]. Testing in full extension is including the dorsal capsule, and testing in 30° of flexion is examining the collateral ligaments only.

Any medial or lateral opening of the joint space (lift-off) of more than 5 mm in the frontal plane should be documented and further distinguished between symmetric or asymmetric instability [41]. The degree of anteroposterior translation provides informations about the sagittal stability. Finally, the patella stability in the mediolateral and craniocaudal direction should be investigated. The different medial, lateral, anterior and posterior soft tissue structures should be examined by palpation and/or functional tests and possible trigger points might be identified. Most of the soft tissues are painful due to overloading or impingement caused by a biomechanical problem in one of the three planes. Examination of the lumbar spine, iliosacral joint, hip, ankle and foot should also be included. Furthermore, chronic regional pain syndrome (CRPS) as a rare cause of a painful TKA must be excluded [13].

Test infiltration

Local anaesthetic injections might help to distinguish between intra- and extraarticular causes of pain. Every chronic painful knee after TKA should be aspirated. In case the fluid does not present macroscopically any typical signs of infection, an intra-articular injection with a local anaesthetic should be performed at the same time. Any intra-articular problem at the interface such as loosening or synovitis should have immediate but temporarily pain relief. Furthermore, painful extraarticular trigger point might be infiltrated with local anaesthesia in order to see whether it will cause pain relief. In knees with clinical suspicious for neuroma, this test infiltration will be diagnostic. Furthermore, two injections at separate times with anaesthetic and placebo can be used to identify patients with secondary gain of the disease.

Laboratory tests

Although almost all laboratory tests are unspecific, standard laboratory tests should include white blood cell count (WBC), erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) in order to exclude infection. The probability of infection is more than 80% when the ESR is more than 30 mm Hg during the first hour and CRP is more than double of normal [10]. Nevertheless, other causes of pathological ESR and CRP have also to be taken into account. It is important to understand that negative laboratory tests do not exclude a low-grade infection [16]. Patients with a positive allergy history might be further tested with specific skin and systemic tests although the clinical relevance seems to be very low [43].

Joint aspiration

All painful knees should be aspirated to exclude infection. The patient must be without any antibiotics for at least 14 days. The aspiration should be performed in a standardised way, under sterile conditions and without any local anaesthesia [16]. Analysis of the cell counts will allow identifying low-grade infections immediately since more than 1.500 leucocytes/μL and more than 65% of polynuclear cells are highly suspicious for an infection [10]. Gram stains are not reliable enough for making a diagnosis. Every aspirate has to go for bacteriological analysis and culture. Depending on the transportation time, specific transport media might be used. The aspirate must be incubated in a standard fashion for at least 14 days [45].

Radiographic analysis

The X-ray examination includes standard and special radiographs. The radiographic analysis should start with a

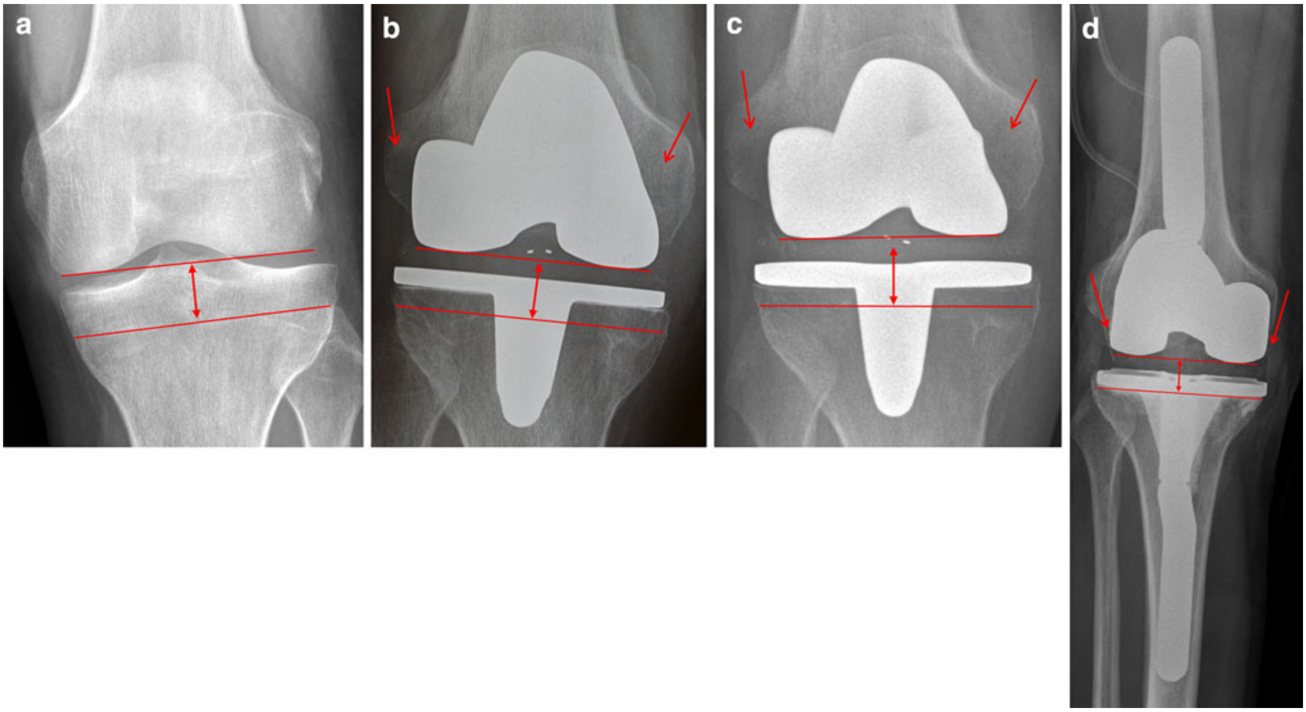

Fig. 1 Standardised fluoroscopic controlled short anterior–posterior radiographs for analysing medial–lateral positioning, underhang or overhang (*arrows*), joint line analysis (*lines*), PE thickness, interface and bony defects; **a** contra lateral non-operated knee; **b** after primary surgery 05/2009 no obvious problems except some femur underhang (*arrows*) and suspicion for femur malrotation; **c** after partial femur revision 05/2010 uncemented tibia component still well fixed and femur component with increased underhang (*arrows*), still suspicion for malrotation, raised joint line for 5 mm and increased PE thickness; **d** after full revision with stem augmentation 01/2011 correction of femur size and rotation as well as joint line using 5-mm distal blocks (*arrows*)

standardised anterior–posterior and lateral view (Figs. 1, 2).[1] Together with the OR report, the type of implant can be identified on these two radiographs including constraint, conformity and mobility of inlay. The specific design might have an influence on the cause of pain and symptoms of the patients and is an important factor for failure analysis. Furthermore, any bony defects, fracture, osteosynthesis material, osteolysis, loosening lines, malposition and overhang or underhang of the components might be identified. Using the pre-operative anterior–posterior and lateral radiographs for comparison with the post-operative X-rays, the appropriate size of the femoral component, posterior offset, patella height and joint line can be identified easily. As an alternative, the contra lateral standard anterior–posterior and lateral X-ray of the non-replaced knee might be helpful (Fig. 2). A long leg (three joint) weight-bearing anterior–posterior view is necessary to analyse the femoral and tibial mechanical alignment in the frontal plane according to Paley [23, 36] (Fig. 3).

For further analysis, some special radiographs might be necessary. A fluoroscopic controlled view parallel to the interfaces in both planes (Figs. 1 and 2) and specific oblique views for the femoral component [32] might help to clearly identify loosening lines and/or osteolysis. A special weight-bearing axial patella view in 45° of knee flexion helps to analyse patella tracking (Fig. 4) and is superior to the non-weight-bearing standard axial views [3]. In patients with limited flexion, a special lateral kneeling view under weight bearing can help to indentify posterior (less offset) and anterior impingement (patella baja) problems (Fig. 5). The functional stress radiographs in 30 and 90° of flexion

[1] Figures 1, 2, 3, 4, 5, 6, 7 and 8 show a representative case with painful TKA: 49 year old active police men, distal tibia fracture in 1980, scope 03/2008, primary TKA (mobile rotating platform) in 05/2009 for posttraumatic OA, post operative ROM 0-0-120° but disturbed gait, instability, recurrent effusion, pain during stair climbing and raising a chair, progression of pain. In 05/2010 isolated femur component revision for femur malrotation; post operative further progression of symptoms with limited flexion and walking distance. Referred to our institution, infection excluded, secondary depression, lost his job, massive disturbed gait, 50% quadriceps atrophy, multiple knee trigger points, but no signs for CRPS, limited flexion 0–0–80° with pain at max flexion, typical lateral flexion gap instability but no patella maltracking or anterior-posterior instability. In 01/2011 complete revision using a standard revision system and fix bearing PS with correction of femur malrotation, restoring posterior offset and lowering joint line. At 3 months post operative outcome is good with flexion 0–0–120°, stable knee, little swelling, normal gait and residual pain only, still working on muscular atrophy and not yet able to go back in his job.

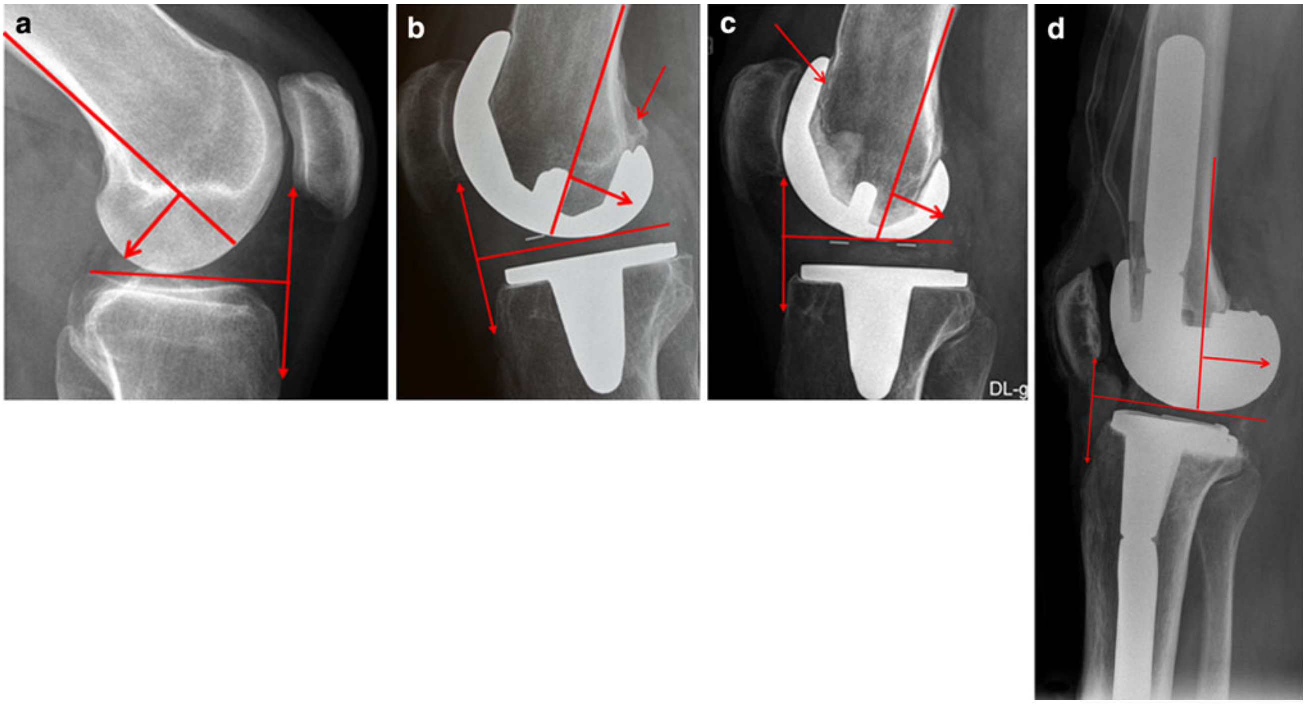

Fig. 2 Standardised fluoroscopic controlled short lateral radiographs for analysing anterior–posterior positioning, interface, bony defects, joint line, patella height (*lines*), femur posterior offset (*lines*), size and osteophytes, tibia slope and size; **a** contra lateral non-operated knee; **b** after primary surgery 05/2009 no obvious problems except the cement less femur one size too small with reduced posterior offset (*arrow*) and some posterior osteophytes left (*arrow*), patella height, tibia size and slope normal (3° for this design); **c** after partial revision of the femur 05/2010 cemented femur two sizes too small with no posterior offset (*arrow*), anterior undercutting (*arrow*), slight extension positioning (10°) and some radiolucent lines, but no clinical or radiographic signs of loosening (implant at risk), patella with relative (5 mm elevated joint line) and absolute (3 mm shorting of ligament) baja position (*lines*); **d** after full revision with stem augmentation 01/2011 reconstruction of posterior offset (*arrow*) and joint line, tibia size and slope normal (7° for this system)

in the frontal plane are very helpful to document frontal instability or asymmetry of the extension and flexion gaps (Fig. 6) [50]. Anterior–posterior stress X-rays might be helpful to quantify instability in the sagittal plane also.

Special imaging techniques

These images include ultrasound, computer tomography (CT) and special bone marrow imaging techniques and are necessary in selected cases only. For more details and interpretation of these special imaging techniques, we refer to the special literature, as this will go beyond the scope of this review [49]. Using ultrasound soft tissue inflammation (bursitis or tendinitis), ruptures as well as soft tissue tumours might be diagnosed very elegant. A few CT slices using a specific protocol allow an exact analysis of the axial alignment in patients with clinical suspicion for malrotation of the femur and/or tibia component (Fig. 7) [25, 40, 51]. In cases with very severe bony defects, a special CT scan can be performed also. Conventional tomography might be an attractive alternative for these cases with less radiation dose. Bone marrow imaging studies include different types of bone scans and the new positron emission tomography (PET) technique. These special bone marrow images are another puzzle piece for differential diagnosis, but should not be performed as a routine [22].

Trial conservative therapy

Every painful TKA without any obvious reason for failure (infection, fracture, implant breakage, clear loosening and/or severe osteolysis) should have an intensive trial of conservative therapy for at least 3 months including pain control with painkillers and physical therapy. The physiotherapy should specifically focus on the underlying problem and cause of pain. This programme needs to be explained to the patient to allow him to understand the necessity of this trial therapy [47]. Most of these patients show muscular atrophy and/or imbalances, which should be addressed also. Daily home exercises and training programmes in combination with braces and other supporting devices should be performed [47].

Discussion

A diagnostic algorithm had been described, which allows a step-by-step approach in the chronic painful knee after

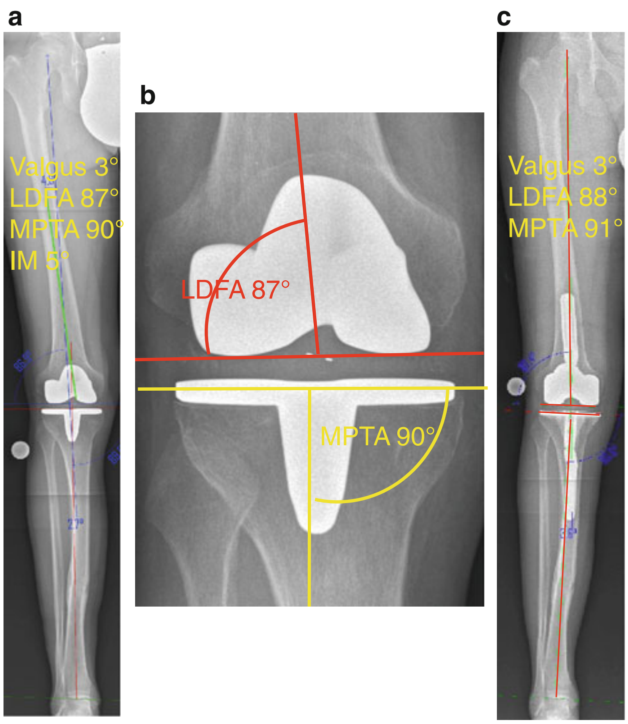

Fig. 3 Standardised full leg (hip–knee–ankle) weight-bearing X-ray for deformity analysis including mechanical axis femur and tibia, medial proximal tibia angle (MPTA), lateral distal femur angle (LDFA), varus/valgus deformity and IM-correction angle; **a** after partial revision 05/2010 good alignment with valgus 3°, LDFA 87°, MPTA 90° and IM 5°; **b** shows magnification of **a** with LDFA and MPTA; **c** after full revision 1/2011 with normal alignment (valgus 3°, LDFA 88° and MPTA 91°)

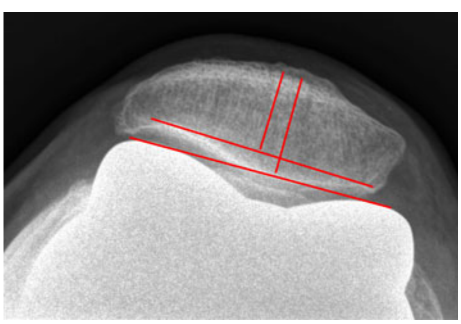

Fig. 4 Patella axial view under weight-bearing condition for analysing of patella tracking (tilting and shifting) and implant position (if replaced) shows after partial revision 05/2010 a non-replaced patella with slight lateral shifting, but no tilting or maltracking (*lines*) and only slight OA with typical compensation of femur malrotation by the mobile bearing

TKA with no obvious causes of failure. These ‘mystery knees’ are a challenge for the surgeon, but devastating for the patient. This diagnostic algorithm had been successfully used for 5 years in our department in more than 300 cases. Some preliminary results of 100 consecutive cases had been reported recently [24]. About 30% of all these patients did not want to have revision surgery. These

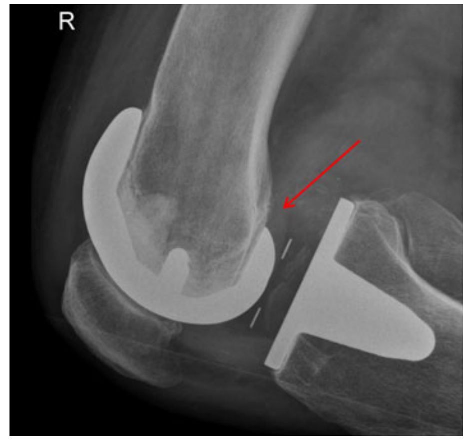

Fig. 5 Special lateral view under weight-bearing condition in maximum flexion for analysing anterior and/or posterior impingements shows after partial revision 05/2010 posterior soft tissue impingement of the rotating platform and the dorsal capsule/femur shaft (*arrow*) representing the cause of the painful limited flexion after revision surgery

patients were divided in a subgroup who showed improvement of their symptoms after conservative therapy, and their residual pain was acceptable. In the other subgroup, the symptoms and the loss of quality of live were not bad enough for these patients to take the risk of a revision surgery. In about five per cent of all painful TKA, no clinical relevant failure could be identified. About 15% of patients needed psychological therapy before surgery could be performed. Finally, in about 65% of all cases, revision surgery had to be performed due to loss of quality of life as the main indication for surgery [24]. To the best of our knowledge, our preliminary data present the first failure analysis outcome where rotational and frontal malalignment were routinely examined with long full leg radiographs and CT scans. It is therefore not surprising that the three main early failure modes in our serious were malrotation of the components (54%), frontal malalignment (41%) and instability or stiffness (36%). Furthermore, in 50% of the revision cases, two ore more reasons for implant failure caused the painful TKA. Based on these results, the entire algorithm should be used in all patients to identify all possible co-factors for pain and failure.

Several reviews had been published on how to deal with the painful TKA and how to perform an appropriate failure analysis [2, 12, 15, 19, 21, 26, 31, 39, 44, 54]. There is a consensus in all of these reviews that revision surgery should not be performed without the exact knowledge about the cause of failure. Revision surgery just because of pain will have a large likelihood of bad outcome. Bader et al. [2] mentioned the possible scientific and legal consequences of general failure analysis, which may also allow early identification of design-related problems. For the failure analysis in painful TKA, every author has used a

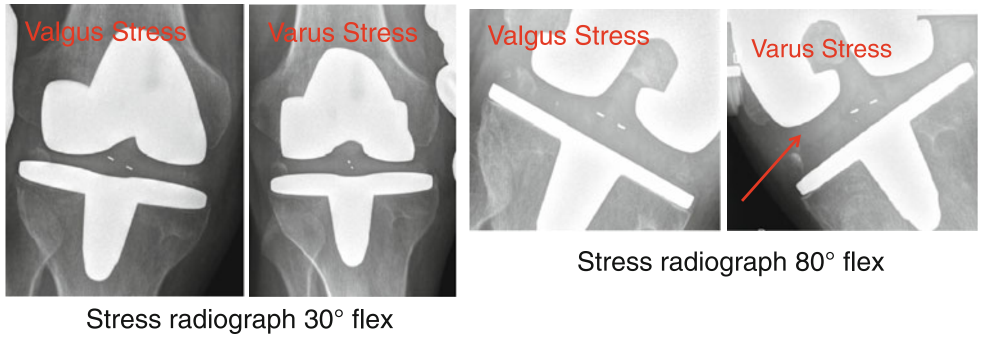

Fig. 6 Special varus/valgus stress radiographs in 30 and 90° flexion for analysing instability in extension and flexion gaps shows after partial revision in 05/2010 a symmetric and balanced extension gap and significant lateral lift off in maximum flexion of 80° (*arrow*) representing the cause of the painful lateral flexion instability, which was aggravated by the mobile bearing also

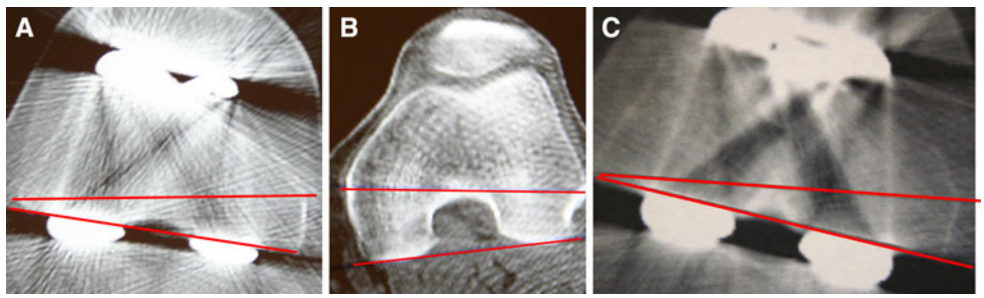

Fig. 7 Special CT scan for analysing rotational positioning of femur and tibia component with surgical epicondylar line, posterior condylar line and posterior condylar angle; **a** shows after primary TKA 5/2009 internal malrotation of 8° (tibia rotation perfect not shown); **b** Interestingly, the CT of the non-operated right knee shows extensive femur external rotation with 9° posterior condylar angle (femur maltorsion syndrome); **c** shows after partial revision of the femur 5/2010 still internal femur malrotation of 7°

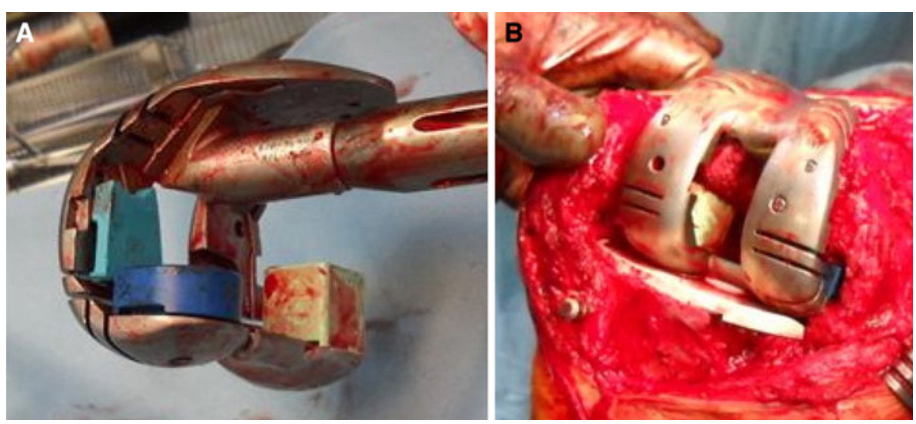

Fig. 8 Intra-operative pictures during full revision 01/2011; **a** shows the trial component with posterior (lateral 20 mm and medial 10 mm) and distal 5 mm augments; **b** shows the trial component in place with a balanced flexion gap after correction of posterior offset and rotation

different approach. Vince [54] described 9 causes of failure such as septic and aseptic loosening with or without osteolysis, tibiofemoral instability, patellar complications, component malrotation, structural failure of the implant, arthrofibrosis, sepsis, extensor mechanism failure, fracture and the ‘mystery knee’ without any diagnosis. He pointed out that revision surgery should always correct all failures; otherwise, there is a high risk to simply ‘repeat surgery’ and make the similar mistakes again [54]. The failure analysis has been distinguished between extrinsic and intrinsic factors by Mandalia et al. [31]. The extrinsic factors included hip, neurological, vascular, bursitis, fracture, tendinitis, heterotopic ossification, psychological disorders and other causes (foot and ankle and systemic diseases). The intrinsic factors included infection, instability, malalignment, soft tissue impingement, arthrofibrosis, wear (with osteolysis and aseptic loosening), recurrent haemarthrosis and extensor mechanism problems. Gonzalez and Mekhail [19] proposed a four-step algorithm including the history with different types of pain, physical examination, radiographic studies and laboratory analysis. They described in more detail the evaluation of the clinical history and physical examination of the patient.

Vince et al. [55] described also the possible cause of instability that might be due to the lack of correct balancing during primary surgery, component malalignment, late ligamentous insufficiency, extensor mechanism problems, inappropriate prosthetic design or purely surgical errors. Bong and Di Cesare [5] separated the cause of stiffness after TKA in patients-related factor and technical-related factors. The patient-related factors included severe obesity, low compliance, intolerance to pain and failed physiotherapy. The technical factors included overstuffing of the patella, mismatch of the flexion and extension gaps, inaccurate ligament balancing, component malposition, oversized components, excessive tightening of the extensor mechanism and joint line elevation. Gustke [21] focused on the important role of analysing the joint line position preoperatively. He pointed out that in revision surgery even with more constraint implants a clinical relevant instability might persist if the joint line is not corrected. Porteous et al. [42] have demonstrated the clinical relevance of restoring the joint line. They included 114 revision cases and found a significantly better outcome when the joint line was preserved within 5 mm. This was the case in 64% of the cases only. Distal femoral augments might be required much more frequently than expected.

There is a consensus in the literature that the exploration should always start with an extended history, sufficient clinical examination, standard laboratory tests and standard radiographs [2, 12, 15, 19, 21, 24, 26, 31, 54]. According to our experience, this will allow to find a preliminary diagnosis in about 80% of the cases. Gonzalez and Mekhail [19] described in their review also that a summation of physical findings, radiographs and laboratory studies generally allows making a diagnosis. Especially, the above described extended history is time consuming and some times difficult, but the previous operation reports, laboratory tests and radiographs are very helpful. In some cases, failure analysis will not be possible without this information. There is a controversy if further more cost-intensive evaluations will be necessary in all cases as cost-effectiveness is an issue especially in the American literature [1, 26]. In our experience, all further diagnostic steps should either be used to confirm or redefine the preliminary diagnosis. The quality, time course and type of pain must correlate well with the clinical and imaging findings [19]. To proof this correlation, a full understanding of the failure mechanism is required. Especially, in well-fixed implants, which do not show any failure on standard radiographs, the documentation of the failure mechanism on further special imaging techniques might have legal consequences also.

Most of these patients have a history of chronic pain with a high incidence of psychological problems [30, 46]. It is very important for the patient that his complaints are taken seriously by the surgeon. In most of the patients, once the cause of pain has been explained, the acceptance for the situation will increase. Nevertheless, patients suffering on mental problems such as depression or psychosomatic distress should not be operated before these problems are under control [30].

The clinical picture of a painful knee after TKA may significantly vary. Nevertheless, there are some typical clinical patterns described [19, 31] (Table 2). Furthermore, for the different extraarticular soft tissue structures, specific tests are available. In complex cases with soft tissue involvement and suspicious of an overloading syndrome, a specialist for physical medicine and conservative therapy might be consulted [47]. The intra- and extraarticular symptoms are related to the disturbed biomechanics of the knee and needs a full understanding of the type of prosthesis (constraint, conformity, mobile or fixed bearing) and the biomechanical consequences of the failure mechanism(s). For example, the common cause of internal malrotation of the femur component in an otherwise well-balanced knee will show a symmetric extension gap and painful lateral lift of with an asymmetric flexion gap. There might be two different types of patients [25]: The type A patient can always flex the knee perfectly immediately after surgery. However, this patient complains of instability and anterior knee pain during stair descending or raising a chair. The type B patient could never flex more than 70–80° and complains about pain in the medial compartment. Despite intensive physiotherapy and even mobilisation under anaesthesia, this knee will end up with painful limited ROM or even a stiff knee. In our experience, primary arthrofibrosis is a very rare disease (<1%). In almost all cases, arthrofibrosis is a secondary phenomenon of a chronic low-grade infection and/or mechanical problems [25].

About 1–2% of painful TKAs show a CRPS, and it is important to identify them by their atypical symptoms of burning skin pain, trophic changes and neurovascular disturbances [13]. Surgery is contraindicated in these patients and guanethidine or sympathicus blockade in combination with a specific physiotherapy might improve the symptoms. In rare cases, a secondary revision surgery is necessary after the CRPS is under control, because otherwise the existing mechanical problem will further trigger the CRPS.

Skin allergy to metal components of the implant (nickel, cobalt and chrome) is a common observation in this age group (5–10% of females and 3–5% of males) [43]. Allergy to components of the bone cement is much more rare [53]. So far, correlation of these skin allergies to any clinical problem with the implant is not well understood [43]. In our experience, the incidence of allergy-related problems is very low (less 1%), but at least in some countries, allergy has legal consequences for the surgeon [43]. On the other hand, we see many patients (about 15%) where the skin allergy test was positive after surgery and they are referred falsely as painful TKA's related to this allergy.

After history and clinical examination, every knee should have routine laboratory testing [1, 4, 10, 16, 17, 20]. Unfortunately, for infection diagnosis, a negative laboratory test (including WBC, ESR and CRP) is not excluding a low-grade infection. About 10% of these negative cases with the typical clinical symptoms might have an infection [4, 10, 17, 20]. New markers like IL-6 will be helpful in combination with CRP and might further increase the accuracy of laboratory tests to rule out infection [4, 7]. Nevertheless, infection is mainly a clinical diagnosis, and every painful TKA remains an infected case until it is proven that it is not infected.

A standardised joint aspiration remains the 'golden standard' for infection diagnosis, and it allows germ identification and culture also [16]. According to the latest guidelines of the AAOS [10], aspiration of the knee should be performed only if laboratory tests (ESR and/or CRP) are positive. In contrast to these new guidelines, some authors and we recommend to routinely aspirate any painful TKA with clinical suspicion for infection or prior revision surgery to exclude infection [11, 16, 19]. The accuracy of a highly standardised aspiration and incubation technique for infection diagnosis is around 90%, but depending on the quality of aspiration and incubation time, a wide range from 58 to 100% had been published [16]. It is of utmost importance that the aspiration and/or biopsies must be cultured for 14 days, otherwise about 30% of the low-grade infections might be missed [45]. In combination with cell counts (>1,500 leucocytes/μL—range 1,100–3,000) and neutrophil differential (>65%—range 64–80%), the accuracy of joint aspiration will be further increased [10]. Nevertheless, diagnosis of a low-grade infection will never be 100%. An accuracy of 100% has been shown in cases when several standardised tissue probes were taken prior to surgery. However, this requires surgical intervention under anaesthesia and can be recommended in selected cases only [16]. On the other hand, standardised 4–6 tissue probes should be taken for bacteriological and histological examinations during all revision surgeries, even if the pre-revision workup has shown no infection [10]. Intra-operative gram stains cannot be recommended anymore, whereas intra-operative frozen sections can still be helpful [10]. PCR (polymerase chain reactions) have shown to be very sensitive, but cannot be used for culture and therefore are not standard for diagnostic at the moment [33]. For excluding tuberculosis, a PCR test might be helpful.

Most of the problems can be identified on standard radiographs (anterior–posterior and lateral views). To get high quality radiographs, a fluoroscopic controlled technique is very helpful (Figs. 1, 2). The simple comparison with the natural knee before surgery or with the contralateral non-operated knee will allow to identify the interfaces, joint line, patella height, slope, positioning of the components and posterior offset (Figs. 1, 2). The standardised full leg (hip–knee–ankle) weight-bearing radiograph (full extension and neutral rotation) is necessary to analyse the mechanical axis and to exclude deformities in the frontal plane (Fig. 3), [40]. For example, a valgus placed femoral component might be responsible for patella maltracking although the overall alignment is normal due to varus tibia component placement. The clinical significance of the overall mechanical alignment is currently under debate [37], but most of the authors consider malalignment of more than 4–5° of the mechanical axis as a major cause of early failures due to asymmetric overloading of the implant interface and increased PE wear [14, 24, 40, 48, 55]. The further described special and functional radiographs might be necessary to understand the pathology and to document the clinical diagnosis. Furthermore, special views are helpful for functional examination of the patellofemoral joint including patella maltracking (weight-bearing axial view) [3] (Fig. 4) and posterior or anterior impingement (lateral weight-bearing kneeling view) (Fig. 5).

Unfortunately, rotational positioning of the components cannot be diagnosed on radiographs only. On fluoroscopic controlled anterior–posterior views in neutral rotation, the malrotation might be suspected (Fig. 1), but cannot be used for diagnosis. Furthermore, the proposed special radiographic kneeling views for determining femur rotation have not shown to be accurate enough in our experience [52]. The special CT scan remains the 'golden standard' for rotational diagnosis of the components [25, 34, 40, 51]. Nevertheless, an accurate protocol has to be performed; otherwise, the rotational positioning might not be identified or will not be correct [51]. The usage of bone scan is discussed very controversially in the literature [19, 31, 49]. In our experience, a 'pattern recognition' of all three bone scan phases might be helpful. As the unspecific radionuclide pattern will show the 'footprint' of the mechanical problem in most of the cases, the bone scan might verify the clinical diagnosis with overload of soft tissue structures or bone interfaces. Furthermore, a negative bone scan will nearly exclude any problem at the bone-implant interface or surrounding soft tissues. This might be helpful in patients with secondary gain of the disease.

The final indication for revision surgery should be based on a failed intensive conservative therapy and the loss of quality of live for the patient only. All patients without obvious cause of failure should have at least 3 months of a trial-specific conservative therapy before revision surgery will be performed [47]. This will not only allow confirming the diagnosis but also gives the patient confidence for further decision-making.

Conclusion

Understanding all the cause(s) of failure(s) in painful TKAs is important before performing any revision surgery. In this review, the concept of a step-by-step diagnostic algorithm is described in more detail for painful TKAs. This includes extended history, type of pain analysis, psychological exploration, clinical examination, test infiltration, laboratory tests, joint aspiration, radiographic analysis, special imaging and trial conservative therapy. Using this diagnostic algorithm in almost all cases, a sufficient failure analysis is possible, which is the prerequisite for a successful revision surgery in patients with painful TKA.

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