IntechOpen

Primary Total Knee Arthroplasty

Edited by Alessandro Rozim Zorzi and João Batista de Miranda

PRIMARY TOTAL KNEE ARTHROPLASTY

Edited by **Alessandro Rozim Zorzi**
and **João Batista de Miranda**

Primary Total Knee Arthroplasty
http://dx.doi.org/10.5772/intechopen.68269
Edited by Alessandro Rozim Zorzi and João Batista de Miranda

Contributors

Melvin George, Yavuz Orak, Mahmut Arslan, João Bosco Sales Nogueira, Vittorio Calvisi, Remo Goderecci, Alessandro Paglia, Norman Ciprietti, Dimitrios Nikolopoulos, Ioannis Michos, George Safos, Chih-Wei Chang, Chyun-Yu Yang, Jou-Hwa Wang, Kai-Lan Hsu

Notice

First published in London, United Kingdom, 2018 by IntechOpen
eBook (PDF) Published by IntechOpen, 2019
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, The Shard, 25th floor, 32 London Bridge Street
London, SE19SG – United Kingdom
Printed in Croatia

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Additional hard and PDF copies can be obtained from orders@intechopen.com

Primary Total Knee Arthroplasty
Edited by Alessandro Rozim Zorzi and João Batista de Miranda

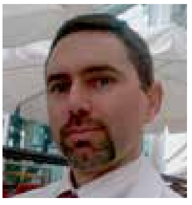
p. cm.

Print ISBN 978-1-78923-142-7

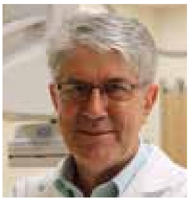
Online ISBN 978-1-78923-143-4

eBook (PDF) ISBN 978-1-83881-302-4

Meet the editors



Alessandro R. Zorzi lives in São Paulo (Brazil), where he works as an orthopedic surgeon and a researcher at the University of Campinas (Unicamp) and Hospital Israelita Albert Einstein. He obtained his MD degree from the Faculdade de Medicina de Ribeirão Preto (University of São Paulo (USP) in 1999 and MSc and PhD degrees from Unicamp. He conducts research in the field of meniscus and cartilage regeneration and in the surgical treatment of osteoarthrosis. He has an interest in scientific divulgation and is the editor of the blog Femur Distal. He is married to Giovana and is the father of Ana Laura and Davi.



Professor João Batista de Miranda is the chairman of the Division of Knee Surgery and Inflammatory Diseases, Department of Orthopedic Surgery, University of Campinas (Unicamp), Brazil. He performs teaching activities with medical students, orthopedic fellows, and postgraduating researchers. He also develops the research and clinical care. He is currently the superintendent of the Unicamp Teaching Hospital. He obtained his PhD degree with an experimental study on bone regeneration and allografts. He has published several scientific articles in international journals and is the coeditor of the book *Bone Grafting* published by IntechOpen.

Contents

Preface

This book presents a compilation of topics related to primary total knee arthroplasty. The chapters cover, in a clear and didactic way, the current themes, written by experts from the area, from different parts of the world. Topics related to the three surgical phases (before surgery, during surgery, and after surgery) are discussed here. This is very important because the surgeon is not a "factory worker." First of all, it is a medicine doctor who has to feel and understand the particularities of each patient.

Demographic studies show an aging population. Osteoarthritis and inflammatory diseases are becoming much more prevalent. In addition, a worldwide epidemic of trauma has led to the need for arthroplasties much more frequently. Therefore, total knee arthroplasty will be an increasingly important subject.

This is the fifth book I have had the pleasure to edit in partnership with the publisher, InTechOpen. I would like to thank the professionals of this pioneering publisher who were among the first ones to realize the importance of sharing their knowledge without barriers, through the system known today as Open Access. To all of you, I would like to express my sincere gratitude especially to the Publishing Process Manager, Ms. Marijana Francetic, of this book who fought hard for it to be completed successfully.

Alessandro Rozim Zorzi, MD, MSc, PhD
Department of Orthopedic Surgery
Campinas State University
São Paulo, Brazil

Professor João Batista de Miranda, MD, PhD
Department of Orthopedic Surgery
Campinas State University
São Paulo, Brazil

Chapter 1

Planning Primary Total Knee Arthroplasties

João Bosco Sales Nogueira,
Leonardo Heráclio do Carmo Araújo and
Marcelo José Cortez Bezerra

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72775

Abstract

Preoperative planning is routinely recommended prior to total knee arthroplasty (TKA). We introduce a methodology for planning TKA based on mechanical alignment. A methodology for planning total knee arthroplasty was discussed among experienced knee surgeons. A rational methodology for planning TKA was stablished and it was setted to an application for mobile devices. It has proved to be useful and revealed accuracy compared to the manual form of preoperative planning. It was able to reduce planning time by more than a half and it was still reliable in measuring the anatomical-mechanical femoral angle (MAFÂ). This chapter introduces a TKA planning method based on mechanical alignment and GAP balancing principles. Kinematic alignment and strategies for soft-tissue balancing in special situations are cited as well.

Keywords: knee surgery, arthroplasty, knee injuries surgery, mobile applications operative time

1. History and introduction

The very first concept of improving knee function was introduced by Verneuil in 1860. He proposed an interposition of soft tissues in order to reconstruct articular surface. Unfortunately, it has led to disappointing results. In the same year, Ferguson resected the entire surface of the knee, which culminated with a better range of motion but lacked stability. In 1958, MacIntosh described a hemiarthroplasty using an acrylic tibial plateau later upgraded by McKeever for a prosthesis made of metal, showing better results.

Guston developed a polycentric prosthesis wich arculates metal to a polyethylene base fixed to the bone by acrylic cement, but the actual concepts used in total knee arthroplasty (TKA) have been established by Freeman in 1973: minimal bone resection; minimal chance of loosening;

minimal debris production; not leaving dead spaces; avoiding long intramedullary stem and intramedullary cement; a standard insertion procedure; minimal range of motion (5–90°); resisting rotation; and resisting excessive movements in any direction.

During the early 1970s, a range of prostheses such as unicondylar, bicondylar, and hinged were used with respect to the patient's preoperative condition and deformity. Since then, a lot of different kinds of implants have been developed following the tendency of maximizing flexion, minimizing wear, and better accommodation of gender and racial anatomic variation. Nowadays, a resurrection of old strategies such as uncemented fixation and partial knee replacement has been noted and minimally invasive approaches are growing respecting the patient's desire of shortening postoperative recovery [1, 2].

This chapter introduces a TKA preoperative planning method based on mechanical alignment and the modified GAP balancing principles. Kinematic alignment (KA) principle, anterolateral approach, and strategies for soft tissue balancing in special situations are cited as well.

2. Biomechanics and templating

The most important surgical technique that affects patient satisfaction and functional outcomes is the correct positioning and alignment of the components. Despite the introduction of computer assisted surgery, patient-specific designs, and kinematic knee alignment, the concept of optimal restoration of alignment still has added controversy on the best approach of planning TKA [3–5].

Most surgeons still agree, and it is traditionally accepted that the alignment of the lower limb should be within 0° ± 3° of the mechanical axis after surgery (measured by the angle formed by the center of the femoral head, the center of the knee, and the center of ankle) [6] (**Figure 1**). By positioning the femoral and tibial components perpendicular to its mechanical axis, there is a balanced distribution of mediolateral forces, not overloading the bone implant interface as well as the bone itself which could lead to loosening of the implant. Furthermore, malalignment causes increased polyethylene wear, leading to osteolysis.

In order to plan a TKA, a preoperative image exam that evidences all reference points is necessary to estimate the anatomical and mechanical axis of the femur and tibia. Since short-leg X-rays do not expose the whole lower limb references, they are not suitable for planning TKA when it is used alone. Long-leg radiograph (LLR) is traditionally used to estimate alignment of the lower limb. It is acquired on weight-bearing films, including the hip, knee, and ankle, with the patella facing forwards. The X-ray beam should be parallel to the articular surface [7]. Although the LLR acquisition is quite standardized, has long track records and it is fairly available, there are concerns about its use, since flexion contractures and rotational malposition could distort the interpretation of the native anatomy [8].

Besides the fact that LLR is quite standardized, has a long track record, and is fairly available, there have been reported concerns about the accuracy when there are flexion contractures and when the position of image acquisition is not neutral, since rotation of the limb could distort the interpretation of native anatomy.

Figure 1. Alignment angle. Measured by the center of the femoral head to center of the knee and center of the ankle. It should be within 0° ± 3°.

2.1. Manual templating

For this instance, we propose a step-by-step methodology for planning TKA based on mechanical alignment, using LLR. We suggest the use of a parchment paper as it avoids scratching the LLR. First, the mechanical axis of the femur (MAF) is defined by connecting a line from the center of the femoral head to the femoral intercondylar notch. Then, the anatomical axis of the femur (AAF) is estimated by connecting a line from the center of the intramedullary femoral canal to the femoral intercondylar notch. The angle formed by the mechanical and anatomical axis of the femur (MAFÂ) is measured, using a protractor. This part of planning has particular importance for those who intend to use intramedullary distal femoral cut guides. Since the femoral stem follows the path of the AAF, the surgeon would know how to accomplish a perpendicular cut to the MAF, by positioning the distal femoral cut guide in a valgus angle to the AAF, referenced by MAFÂ.

After knowing the inclination of the distal femoral cut, the surgeon should evaluate the level of bone resection, anticipating the amount of bone resection. Usually, in a primary TKA, the level of bone resection corresponds to the femoral component thickness (e.g., 9 mm). This step simulates the surgical moment when the surgeon places the distal femoral cut guide onto the distal femoral bone. Using a protractor, the surgeon draws a line perpendicular to the MAF above the first point of the distal femoral bone contact (e.g., 9 mm), from distal to proximal. By doing it, the surgeon could simulate the level and inclination of the distal femoral cut. One should notice that the LLR film does not correspond to real size, being reduced to fit on the film frame. Typically, the amount of reduction in size is reported on the printed film and should be used to make a conversion between film size and actual size.

The same rationality is applied to the tibial bone. The mechanical and anatomical axes are coincident on the tibia, so the mechanical axis of the tibia (MAT) can be defined as a line drawn from the center of the tibial spines to the center of the talus. Mechanical and anatomical axes are usually coincident on the tibia. The mechanical axis of the tibia (MAT) can be defined as a line drawn from the center of the tibial spines to the center of the talus. After defining MAT, tibial cut is planned perpendicular to the MAT. Usually, surgeons plan to cut 8–10 mm below the unworn side of the tibial plateau, but it can be adjusted to best fit the components and balance the knee. So, the surgeon places a line from proximal to distal, at the level desired below the unworn side of the plateau. Still, conversion between LLR size and real size should be adjusted using a mathematical calculation. The whole process of manual templating technique is illustrated in **Figure 2**.

The more parallel the bone cut planes, the less ligament release is necessary. The less parallel the bone cut planes, the more ligament release is necessary. One must note that there is a limit for releasing ligaments. When a great amount of releasing is necessary, the surgeon should consider a more constrained implant, since it could get into a situation called "over resection looseness," when the ligament function capacity is exceeded.

The size of the components can be also estimated during the planning of a TKA. To do it so, the surgeon must have the specific prosthesis templates and should order a short-leg X-ray in an actual size (1:1).

2.2. Digital planning using ATJ® mobile phone application

Despite the fact that manual planning is an affordable method, it lacks portability. The surgeon must have manual tools such as a pencil; an eraser; a protractor; and rulers, big enough to measure the whole LLR film. Besides, the surgeon needs to make mathematical conversions and must comprehend a rational methodology of planning on TKA.

Considering the current computational resources used as tools to support medical practices, the paradigm known as *mHealth*, which consists of the use of mobile computing resources in health, stands out. When applied to favor teaching and learning processes, mobile technologies provide numerous benefits, such as increased resources for student learning, access to

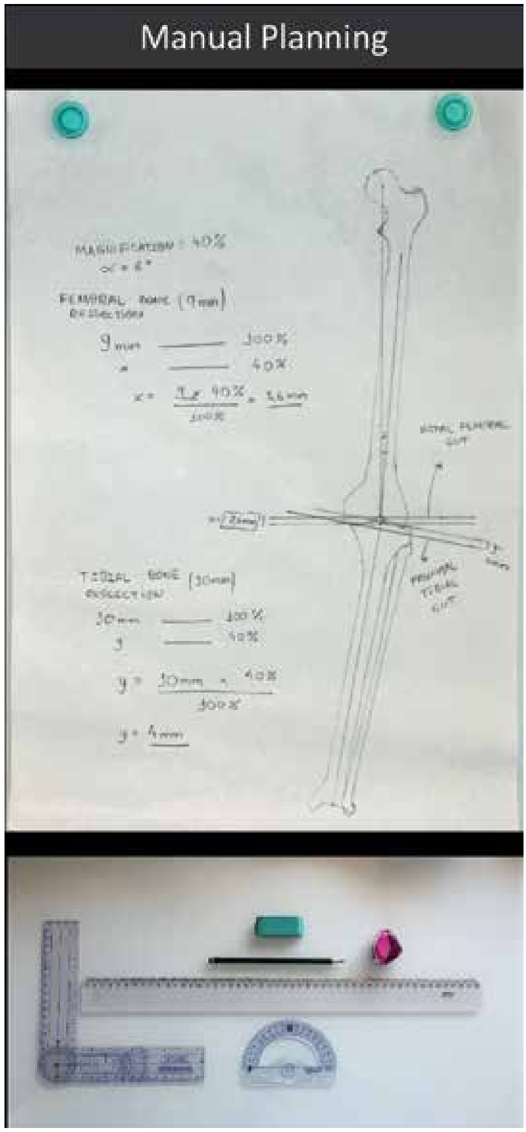


Figure 2. Manual templating. First, the anatomical and mechanical axis of the femur and tibia are defined. MAFÂ is measured by using a protractor. A perpendicular cut is measured from MAF and MAT. To correctly place the bone cut lines, the surgeon must mathematically convert printed LLR film size to real size. To do it, the surgeon needs manual tools such as pencil, eraser, rulers, protector, and goniometer.

textbooks anywhere, anytime, and the provision of resources for the development of innovative teaching methods [9]. By facilitating real-world integration, mobile learning aided by mobile computing (Mobile Learning or m-learning) has created opportunities for development of new teaching strategies in different areas [10].

An interdisciplinary team, involving health and computer science areas, developed an application (ATJ®) that is capable of conducting the surgeon though a step-by-step process (same described

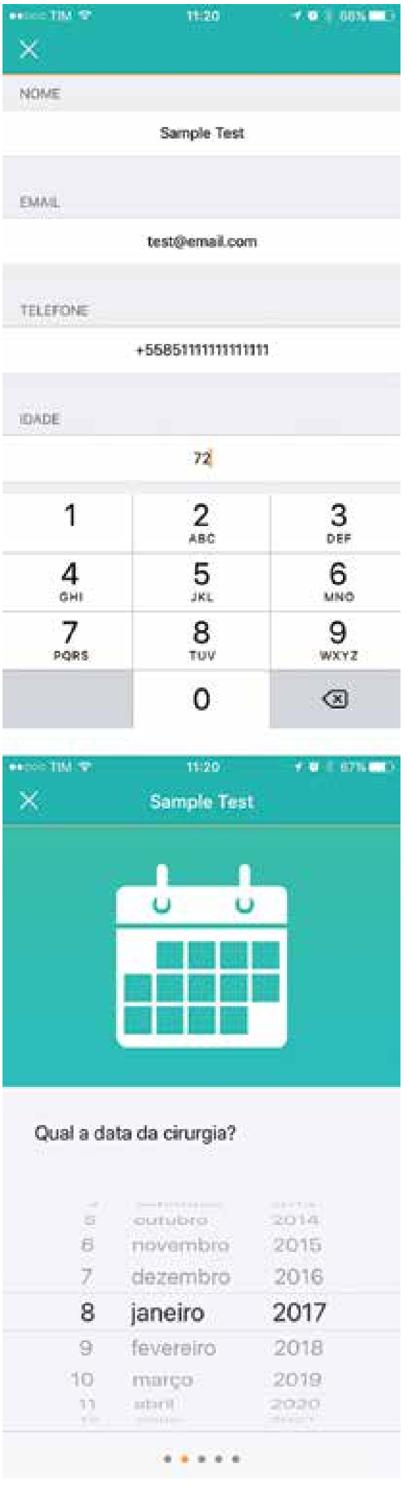


Figure 3. Fields of the medical register. They are available *offline* and *online,* in a cloud host.

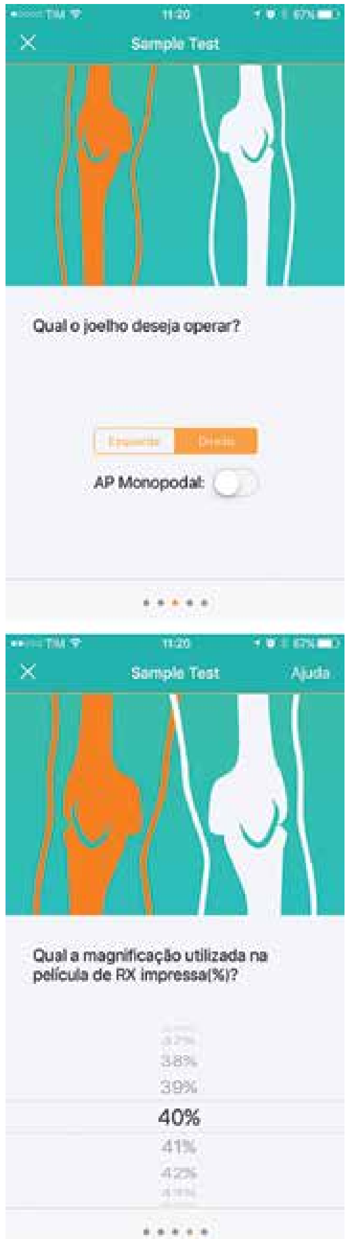


Figure 4. After choosing between the left or right knee, the surgeon must inform the application in which size scale is adopted on LLR. By doing so, the surgeon does not need to make mathematical calculations, since the application is able to convert LLR size to real size.

for manual planning) adapted for digital planning. Besides, explanations about rationality of the methodology and surgical tips on each step of planning were incorporated to the application. It is able to recognize the type of deformity (valgus or varus) and automatically measure MAFÂ. It also suggests soft tissue releases, according to the deformity [11].

Figure 5. The LLR should be uploaded from the device's camera roll or the device's camera can be used to acquire the LLR image (Figure Planning).

Before getting into planning, the surgeon is presented with a video that briefly describes the method used in the application. Fields of registration such as name, email, telephone, age, gender, medical record number, and date are available. The data are stored on the device and in a cloud host. Anytime, wherever the surgeon is, it is possible to access it from any computer if desired (**Figure 3**).

Planning starts by choosing the intended knee to be operated (left or right). After choosing the side, the application inquiries on size scale used on LLR, which is usually informed on LLR margins. This is an important step since the application needs to know the relation between the LLR film size and real size, avoiding the surgeon making mathematical conversions (**Figure 4**).

The LLR can be acquired by two modes: uploading an image from device's camera roll or using the device's camera to photograph the LLR on a negatoscope (**Figure 5**). The application

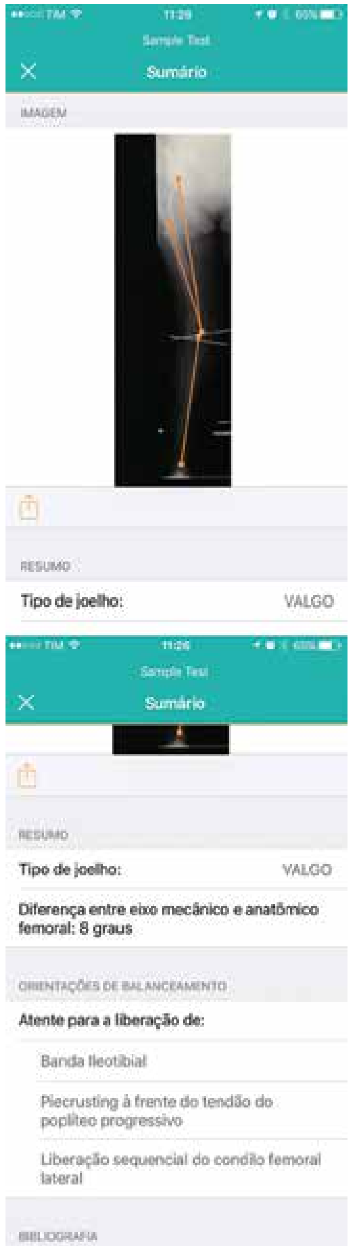


Figure 6. Step-by-step planning process. After defining AAF, MAF, MAFÂ, and MAT, the surgeon should simulate the level and inclination of distal femoral and proximal tibial bone cuts. Application ATJ® is capable of automatically recognizing the knee-type deformity. It also suggests a sequence for ligament releasing.

then takes the surgeon through the whole process of planning by inquiring the surgeon to point references (center of the femoral head, center of the medullary femoral canal, center of the intercondylar notch, center of the tibial spines, and center of the talus). After setting points, the application automatically defines AAF, MAF, MAFÂ, and MAT. It also positions a moveable bone cutting line, perpendicular to MAF and MAT. At the end of the methodology process, it automatically shows the type of deformity, the MAFÂ, and soft tissue releasing sequence (**Figure 6**). Then, scientific references used to build the application are presented.

The application ATJ® has proved to be useful in the context of planning TKA. It has revealed accuracy when measuring the MAFÂ when compared to the manual form of planning. It was also capable of reducing the planning time by more than a half [11, 12].

3. Surgery

3.1. Surgical approaches

A straight anterior skin incision allows exposure for medial and lateral structures and it's the standard skin incision for TKA. Arthrotomy may be done from the medial or lateral side. Anteromedial arthrotomy is the most used approach on TKA and provides excellent exposure of the knee joint (**Figure 7**). After eversion or patella lateral subluxation, the knee is flexed. One must be aware of avulsing off the patellar tendon from the tibial tubercle, if there is too much tension.

Because the most important component of blood supply runs medially, anteromedial approach could affect patellar circulation, and some authors have advocated subvastus and midvastus approaches (**Figure 8**). They are less invasive and can be used specially in moderate knee deformity.

For fixed valgus deformities, the lateral parapatellar approach may be considered. A mild lateral skin incision is made and extended over the lateral border of the tibial tubercle. In the original description, a thin segment of the tubercle is osteotomized with the attached patellar tendon. A medial periosteal hinge is maintained along with the infrapatellar fat pad, which is used for later closer of the lateral retinacula. Some surgeons suggest not to osteotomize the tibial tubercle, turning it into a less invasive approach.

Extended approaches have been described and are very useful in stiff knees and great deformities. Coonse and Adams described a quadriceps turndown. The quadriceps are split down the middle, in an inverted "V" fashion, at about 1 cm above the patella, so the patella could be turned down, allowing the exposure of the joint. Quadriceps snip was described by Insall by an oblique incision at the proximal apex of the quadriceps tendon, at about a 45° angle, directly in line with the fibers of the vastus lateralis. It relaxes the extensor mechanism and protects the tibial tubercle. Tibial tubercle osteotomy enhances exposure and it could be very useful in stiff knees. Tibial crest should be osteotomized 8–10 cm below the tibial tubercle, using the oscillating saw and osteotomes. The shape of osteotomy is trapezoidal, 5-m long, 2-cm wide, and 1.5-cm wide distally. The entire extensor mechanism is then elevated proximally.

Limited approaches are described and could be useful, especially when planning unicompartmental arthroplasties. Limited approaches are part of a traditional extensile approach, and the surgeon tends to use it as he becomes familiar with the surgical technique.

http://dx.doi.org/10.5772/intechopen.72775

Figure 7. Anteromedial approach to the knee. After a medial skin incision, a medial parapatellar arthrotomy is made. It is suitable for most TKA and allows great exposure of the knee joint.

Figure 8. Subvastus approach does not sacrifice the extensor mechanism (blue line) and it is useful specially for minimal invasive approaches. In midvastus approach (red line), the oblique medial vastus is split sharply in line with its fibers, at the level of the superior pole of the patella.

3.2. Surgical theories

3.2.1. Anatomical, mechanical alignment, and gap balance technique

Since the beginning of the implants and instruments, two concepts that guide surgical techniques were established: gap balance and measured resection technique. Universally spread, gap balance surged for cruciate substituting prostheses. Measured resection technique was favored for those who defended cruciate retention implants.

For gap balance technique, either the femur or tibia may be osteotomized first. The main goal is to equalize flexion and extension gaps, most of the time transforming a trapezoidal gap into a rectangular gap (**Figure 9**). For those who favor to start cutting proximal tibial (at about 8–10 mm below the less worn tibial plateau surface), it should be perpendicular to the MAT, and when posterior cruciate ligament (PCL) is sacrificed, the flexion gap opens up a few millimeters more. That situation can implicate in a slightly upper distal femur cut, which can elevate the joint line and bring the patella in a lower position. Distal femoral cut is often parallel to the tibial cut, following the transepicondylar axis. Rotational alignment of the femur is tuned by ligament release or femoral rotation. In a varus knee, when the surgeon opts for

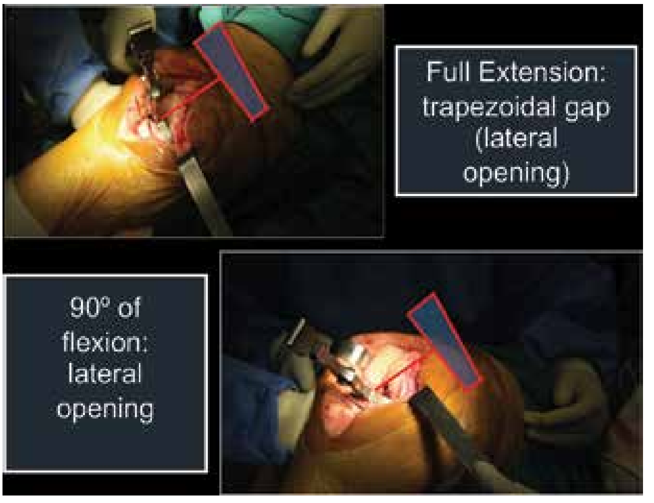


Figure 9. Before ligament releasing, there is usually a trapezoidal gap.

not releasing medial ligaments he usually needs to add external rotation to the femoral cuts. Some references help to establish the appropriate rotation: transepicondylar axis, posterior femoral condyles, Whitside's line (trochlear groove axis), tibial shaft axis, and ligament tension. In some situations, even a small degree of internal rotation could be applied. Before implant is settled, the gap must be rectangular and symmetrical (**Figure 10**).

The measured resection technique aims not to move the joint line position. That situation, in theory, preserves knee's anatomy, sparing the PCL, when possible. Some advocate that preserving the PCL has advantages as it is an important varus/valgus stabilizer of the knee; it can absorb stress; and it can control the movement of rolling back of the femur onto the tibia

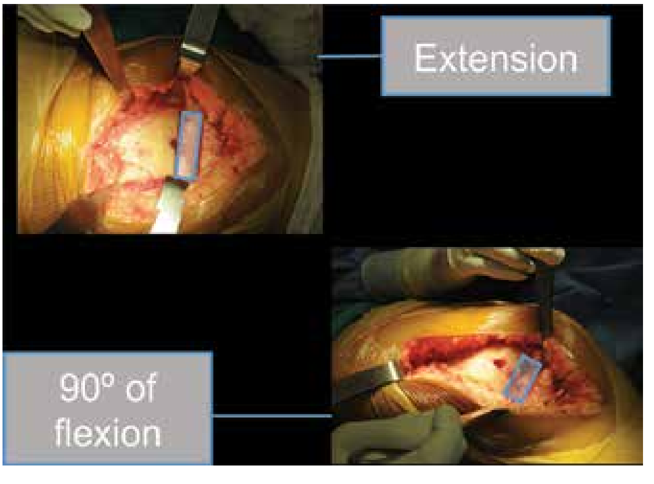


Figure 10. Rectangular gap. Before the implant is set, there must be a rectangular gap.

during flexion. When the ligament is left too tight it could increase posterior stress, causing a movement described by Insall as "open like a book" and "lift-off" of the tibial tray. When the PCL is insufficient, it could cause a paradoxal movement of rolling forward in flexion, limiting flexion by posterior impingement. The tibial cut is made preserving its mild varus and femur cut is made preserving its natural valgus. Equalization of the gaps is not strictly necessary.

During the evolution of the implants some concepts were mixed and the surgeon conquered freedom to make bone cuts a little bit off the outliers. Even for situations when the PCL is preserved, conformed tibial surfaces could be used. Sometimes, the surgeon can choose not to cut the bone perpendicular to the mechanical axis, sparing extensive ligament releases.

3.2.2. Kinematic alignment

The refinement of surgical techniques, implant designs and an individualized tendency of surgical treatment have contributed to resurrection of the discussion about restoration of the native's knee anatomy and preservation of the articular line.

Some authors have noticed that neutral mechanical alignment does not restore biomechanics in a significant part of the population [13–15].

Kinematic Alignment (KA) aims to restore constitutional alignment, ligament tension, and the joint's line level and orientation [16, 17]. Hungerford, Kenna, and Krakow defended a slight varus alignment for the tibia in relation to the MAT. They are considered precursors on KA [18].

According to Howell et al., there are three kinematic knee axis: the primary femoral axis, wich is a transverse axis of femur around which the tibia flexes and extends; the secondary femoral axis, wiich is a traverse axis in the femur around which the patella flexes and extends; and the longitudinal tibial axis, around which the tibia internally or externally rotates on the femur [19] (**Figure 11**). Each axis is parallel or perpendicular to the natural joint line between the femur and tibia throughout the motion arc.

The preoperative plan of a kinematic TKA can be done by using MRI exams in order to estimate chondral and bone erosion [20–22]. These parameters are used to compensate implant's position that should be parallel to the primary and secondary kinematic femoral axis. A patient-specific implant or a conventional implant can be used.

The KA principle is a promising alternative for the execution of TKA. In the centers where it was adopted, the results in the short and medium term were favorable [22], with the premise of restoration of the biomechanics of the knee, which may point to a new paradigm. Nevertheless, studies on durability and long-term function are needed before universal adoption of this new methodology.

Its applicability in patients with a higher degree of bone erosion should also be evaluated cautiously because of the increased risk of malalignment, which may be caused by the difficulty in identifying the references that guide the positioning of the bone cutting guides.

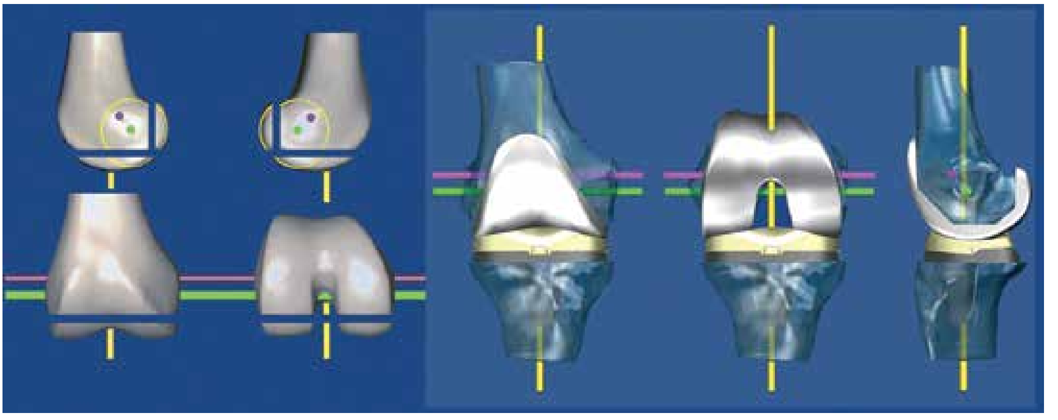


Figure 11. Kinematics axis of the knee (from Howell's studies with authorization).

4. Management of deformities

4.1. Varus deformity

During the arthritic course, there are expected modifications in native alignment and ligament function. Loss of cartilage can create an asymmetrical compartment balance, leading to contracture of soft tissues on the concave side and contralateral loosening on the convex side. As the deformity progresses, these modifications tend to establish into fixed deformities. In varus knees, contraction of medial side involves medial collateral ligament and the whole medial periosteal sleeve, including hamstrings, posteromedial capsule, and PCL. As the deformity progresses, the lateral compartment becomes insufficient, causing abnormal lateral opening and instability.

Instability of the arthritic knee may be viewed as symmetrical or asymmetrical. Symmetrical instability is seen during early arthritis, when there is erosion of cartilage or bone without associated adaptive soft tissue changes. During physical examination, the deformity can be corrected under active reciprocal stress on physical examination. This kind of instability is easily corrected during surgery without needing extensive ligament releasing.

As the deformity progresses it tends to turn into an asymmetrical instability, which is not corrected by active reciprocal stress during physical examination. This kind of fixed deformity occurs when cartilage and bone loss lead to adaptive ligamentous changes. In order to correct this kind of deformity, ligamentous release is mandatory, turning a trapezoidal gap into a rectangular gap. In asymmetrical instabilities, the bone cuts alone are not sufficient to accomplish articular balance.

Instead of only releasing ligaments from the contracted concave side someone could advocate to advance ligament complexes on the convex side, especially when the opposing ligaments are stretched to the point of being incompetent. These authors do not favor ligament advances or reconstructions on the convex side since the functional outcomes have not been acceptable in most series. In such cases, the authors advise considering a more constrained knee design (**Figure 12**).

http://dx.doi.org/10.5772/intechopen.72775

Figure 12. In advanced deformities, when there is great medial bone loss, the surgeon must consider using metal augmentation and more constrained implants.

4.2. Valgus deformity

In the valgus knee, the lateral structures contract, while the medial soft tissues stretch. Differing from varus knees, where the bone erosion occurs more in the tibial bone, in valgus knees most of the bone deformity comes from the femoral side (**Figure 13**). As the deformity progresses it tends to involve the tibial bone and cartilage as well.

Lateral soft tissue structures, including the lateral collateral ligament (LCL), iliotibial band (ITB), and the lateral capsule, contract, while the medial soft tissues stretch. When this

Figure 13. Most part of the bone wear occurs on lateral femoral condyle, although it could involve tibial bone as well.

imbalance becomes permanent it may result in medial thrust during gait. In both varus and valgus deformities, it could be associated with flexion contractures (**Figure 14**).

Krackow has classified valgus deformities into three stages: type I involves lateral femoral bone loss, lateral soft tissue contracture, and intact medial soft tissues; type II adds medial lengthened soft tissues; and type III represents alteration of the proximal tibial joint line, that usually happens as a result of a high tibial osteotomy. As the ITB gets contracted, external rotation is often observed.

Insall and colleagues traditionally recommended releasing lateral capsule, LCL, arcuate ligament, popliteus tendon, lateral femoral periosteum, distal ITB, and the adjacent lateral intermuscular septum from their bone attachments. Some degree of lateral laxity after an extensive lateral release was typically well tolerated. Although extensive release generally corrects the deformity, posterolateral flexion instability may still occur postoperatively. These authors do not favor extensive releasing from bone attachments. Instead, the authors recommend progressively intra-articular liberations ahead of the popliteus tendon, using the pie-crusting technique.

4.3. Flexion contracture

As the degenerative disease progresses, it involves posterior capsule, PCL, and musculotendinous at the posterior aspect of the knee. Bone erosion of posterior femoral condyles and osteophytes may contribute to flexion contracture on arthritis. Despite the fact that some authors understand that postoperative residual flexion contractures are well tolerated, these authors do not favor residual flexion contractures, since residual deformities tend to worsen with time.

Figure 14. Valgus deformity. Contraction of the lateral compartment causes bone erosion and an imbalance of natural kinematics.

After bone cuts, posterior capsule can be released. For those who agree with principles of KA, the preservation of PCL is desirable. That could hamper flexion contracture correction but changing the slope orientation could in part correct that kind of deformity.

Small contractures can be reduced by removal of posterior osteophytes, but posterior capsulotomy is necessary for moderate and severe flexion contractures. These authors advise the resection of PCL when the mechanical alignment theory is chosen.

4.4. Extension contracture

Stiff knees are a challenging situation even for the most experienced knee surgeons. Typically, the techniques described for difficult exposures are necessary. Sometimes, everting the patella is not possible, leading the surgeon only to subluxate it laterally. The soft tissue releases applied for varus and valgus techniques are used and extensive soft tissue release is usually necessary.

4.5. Genu recurvatum

Recurvatum is usually mild and it's treated with under-resection of the distal femoral and proximal tibia. However, in patients with neuromuscular diseases, such as poliomyelitis and Ehler-Danlos, even under-resection and use of thicker components are insufficient to correct recurvatum. For these extreme conditions, the authors recommend the use of constrained prosthesis or hinged implants.

5. Management of bone defects

As osteoarthritis advances, bone defects can distort the natural anatomy of the knee and cause to difficult alignment and implant set.

Figure 15. Peripheral medial bone defect on medial tibial plateau. One must avoid over-resection of the medial tibial plateau as it could fracture proximal fibula. Cancellous bone is insufficient to support the tibial implant.

Contained defects occur from a cyst or a cavity and are treated by filling off the defect or bone cut. One must remember that there is a limit for moving the bone cut level. Augmentation with cement, bone, or metal wedges or blocks should be considered in these cases.

Peripheral defects typically occur in varus knees in the posteromedial plateau and in valgus knees in the distal lateral femur. These kinds of defects are also managed with cement, bone graft, and metal augments. When they occur in tibia, the translation of the tibial tray away from the location of the defect could be sufficient. If not deeper than 10 mm, the defect can be eliminated by resecting the tibia at a lower level until, at a maximum of, 20 mm, but these authors recommend using metal augmentation and intramedullary stems to protect the implant from interface shear forces (**Figure 15**).

6. Choice of implant

There are theoretical concerns when choosing the right implant. For those who choose anatomical and kinematic alignment, the implant tends to reproduce the knee's anatomy and the surgeon should preserve at the most ligaments and the natural inclination of the native's articular line. In such cases, the PCL should be preserved whenever it's possible, since it is a varus/valgus stabilizer, and it can absorb stress.

Anterior cruciate ligament (ACL) plays a role with PCL during knee flexion and extension. As the knee flexes, the femur slides back in tibia (rollback) until a point where the ACL is completely strengthened. As the knee extends, the femur slides forward until a point that the PCL resists this movement. For arthrosis of one compartment, when ALC and PCL are intact, a meniscal-bearing design could be used (e.g., Oxford® unicompartmental prosthesis). As arthrosis progresses, ACL becomes insufficient. When PCL is not sacrificed, the movement of rollback occurs and theoretically, the tibial baseplate should be flat. When PCL is sacrificed, the tibial baseplate should be concave, containing forward and backward motion. However, some of the newer implants now allow PCL sacrifice or retention, regardless the shape of tibial baseplate.

Mobile-bearing designs have increased the sagittal plane conformity which helps to control anteroposterior translation. The increased coronal plane conformity typically presented in mobile-bearing TKA also increases the contact area and lessens contact stresses. These advantages tend to reduce the rate of polyethylene wear. Polyethylene is self-aligned with the femoral component. It reduces the cross-shear stresses and facilitates central patellar tracking. In a fixed-bearing TKA, if the tibial component is left in internal rotation, it moves tibial tuberosity laterally, enhancing the risk of patellar subluxation. Besides, mobile-bearing designs also contribute to diminish the incidence of lateral releasing. Clinically, the fixed-bearing and mobile-bearing TKA systems have performed similarly in outcome studies. These authors favor the use of mobile-bearing designs, especially for younger and higher-demand patients with longer life expectancies.

http://dx.doi.org/10.5772/intechopen.72775

7. Emerging technologies

Patient-specific instruments could be made from preoperative imaging (MRI or CT scans of specific sequences). It could allow the production of manufactured specific cutting guides. These guides are made in respect of the individual anatomy, including osteophytes and bone defects in the correct orientation. It would direct the bone resection before the preplanned knee, avoiding using standard intraoperative cutting guides. Specific guides should require fewer trays of kit, leading to greater operative efficiency, and are expected to reduce operative time and produce more accurate bone cuts. At this point, there are a lot of studies that suggest the use of specific guides with good functional outcomes. Nevertheless, cost-effectiveness still needs to be proven.

Robotic surgery combines navigation with a robot that performs the bony resection, controlled by the surgeon. A preoperative CT scan is used to template the knee. It has a theoretical advantage of not deviating from the defined cutting plane or axes of resection. Despite the appeal that it would reproduce better mechanical axis, additional studies are necessary to justify its use outside the experimental environment before it gets universally used.

8. Conclusion

The restoration of adequate mechanical axes is critical for implant survival. Preoperative planning anticipates surgical difficulties and gives a chance for creating resolutive strategies.

The ATJ® application for mobile phones has proven useful and comes to optimize the surgical planning in TKAs. As it establishes a rational step-by-step process, based on literature, it directs the user to a possible reliable form of surgical planning.

Author details

João Bosco Sales Nogueira[1]*, Leonardo Heráclio do Carmo Araújo[2] and
Marcelo José Cortez Bezerra[3]

*Address all correspondence to: bosco.nogueira@centrodojoelho.com.br

1 Medical School of Federal University of Ceará, Fortaleza, Brazil

2 Hospital Geral de Fortaleza/Santa Casa da Misericórdia de Fortaleza, Fortaleza, Brazil

3 Universidade de Fortaleza/Santa Casa de Fortaleza, Fortaleza, Brazil

References

[1] Scott WN. Insall and Scott Surgery of the Knee. New York: Elsevier; 2012

[2] Ranawat AS, Ranawat CS. The history of total knee arthroplasty. Knee Joint [Internet]. 2012;**26**:699-707. Available from: http://link.springer.com/10.1007/978-2-287-99353-4_63

[3] Donaldson J, Joyner J, Tudor F. Current controversies of alignment. In: Scott WN, editor. Insall and Scott Surgery of the Knee. New York: Elsevier; 2015. pp. 489-494

[4] Yoon J-R, Yang J-H. Satisfactory short-term results of navigation-assisted gap-balancing total knee arthroplasty using ultracongruent insert. Journal of Arthroplasty [Internet]. 2017:1-6. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0883540317308513

[5] Singh AK, Nedopil AJ, Howell SM, Hull ML. Does alignment of the limb and tibial width determine relative narrowing between compartments when planning mechanically aligned TKA? Archives of Orthopaedic Trauma Surgery [Internet]. 2017. Available from: http://link.springer.com/10.1007/s00402-017-2824-6

[6] Deakin AH, Sarungi M. A comparison of variable angle versus fixed angle distal femoral resection in primary total knee arthroplasty. Journal of Arthroplasty [Internet]. 2014;**29**(6):1133-1137. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0883540313008541

[7] Babazadeh S, Dowsey MM, Bingham RJ, Ek ET, Stoney JD, Choong PFM. The long leg radiograph is a reliable method of assessing alignment when compared to computer-assisted navigation and computer tomography. Knee. [Internet]. 2013;**20**(4):242-249. DOI: http://dx.doi.org/10.1016/j.knee.2012.07.009

[8] Wu W, Guo WS, Cheng LM, Liu ZH, Zhang QD, Zhang NF. Individual difference of coronal bowing of femur and its influence on the lower limbs alignment after the total knee arthroplasty. Zhonghua Yi Xue Za Zhi. 2017 Apr 4;**97**(13):1006-1010. DOI: 10.3760/cma.j.issn.0376-2491.2017.13.009. [Article in Chinese; Abstract available in Chinese from the publisher]

[9] Marçal E, Andrade R, Rios R. Aprendizagem utilizando Dispositivos Móveis com Sistemas de Realidade Virtual. RENOTE Revista Novas Tecnologias na Educacao [Internet]. 2005;**3**:1-11. Available from: http://seer.ufrgs.br/renote/article/view/13824

[10] Huang T et al. Total knee arthroplasty in patients with Ranawat type-II valgus arthritic knee with a marked coronal femoral bowing deformity: Comparison between computer-assisted surgery and intra-articular resection. Journal of Orthopaedic Surgery and Research. 2016;**11**:1-9

[11] Nogueira JBS, de Carvalho ACGS, de Barros Filho EM, do Araújo LHC, Bezerra MJC. Planejamento de artroplastia total do joelho através de aplicativo para dispositivos móveis: Relato de caso. Rev Bras Ortop. 2017:1-7

[12] Nogueira JBS, de Carvalho ACGS, de Barros Filho EM, do Araújo LHC, Bezerra MJC, Demange MK. Avaliação de utilidade e acurácia de aplicativo móvel no planejamento de artroplastias totais do joelho. Revista Brasileira Ortopedia [Internet]. 2017:1-9. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0102361616302090

[13] Bellemans J, Colyn W, Vandenneucker H, Victor J. The chitranjan ranawat award. Clinical Orthopaedics and Related Research. 2012;**470**(1):45-53

[14] Nedopil AJ, Singh AK, Howell SM, Hull ML. Does calipered kinematically aligned TKA restore native left to right symmetry of the lower limb and improve function? Journal of Arthroplasty [Internet]. 2017. DOI: https://doi.org/10.1016/j.arth.2017.09.039

[15] McNair PJ, Boocock MG, Dominick ND, Kelly RJ, Farrington BJ, Young SW. A comparison of walking gait following mechanical and kinematic alignment in total knee joint replacement. Journal of Arthroplasty [Internet]. 2017. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0883540317308331%0A; http://www.ncbi.nlm.nih.gov/pubmed/29054726

[16] Howell SM, Howell SJ, Hull ML. Assessment of the radii of the medial and lateral femoral condyles in varus and valgus knees with osteoarthritis. Journal of Bone and Joint Surgery-American Volume [Internet]. 2010;**92**(1):98-104. Available from: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00004623-201001000-00013

[17] Howell SM, Chen J, Hull ML. Variability of the location of the tibial tubercle affects the rotational alignment of the tibial component in kinematically aligned total knee arthroplasty. Knee Surgery, Sport Traumatology, Arthroscopy. 2013;**21**(10):2288-2295

[18] Toksvig-Larsen S, Ryd L, Stentström A, Dansgård F, Jonsson K, Robertson O, et al. The porous-coated anatomic total knee experience. Journal of Arthroplasty [Internet]. October 8, 2017;**11**(1):11-17. DOI: http://dx.doi.org/10.1016/S0883-5403(96)80156-2

[19] Howell SM, Papadopoulos S, Kuznik KT, Hull ML. Accurate alignment and high function after kinematically aligned TKA performed with generic instruments. Knee Surgery, Sport Traumatology Arthroscopy. 2013;**21**(10):2271-2280

[20] Howell SM, Kuznik K, Ghaly R, Hull ML. Does varus alignment adversely affect implant survival and function six years after kinematically aligned total knee arthroplasty? International Orthopaedics. 2015;**39**(11):2117-2124

[21] Nam D, Lin KM, Howell SM, Hull ML. Femoral bone and cartilage wear is predictable at 0° and 90° in the osteoarthritic knee treated with total knee arthroplasty. Knee Surgery, Sport Traumatology Arthroscopy. 2014;**22**(12):2975-2981

[22] Howell SM, Howell SJ, Kuznik KT, Cohen J, Hull ML. Does a kinematically aligned total knee arthroplasty restore function without failure regardless of alignment category? Knee. Clinical Orthopaedics and Related Research. 2013;**471**(3):1000-1007

Cruciate-Retaining Total Knee Arthroplasty

Vittorio Calvisi, Alessandro Paglia,
Norman Ciprietti and Remo Goderecci

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74024

Abstract

The debate over the relative merits of substituting or retaining the posterior cruciate ligament (PCL) in total knee arthroplasty is still ongoing. The potential advantages of PCL preservation are a more natural femoral rollback, the presence of a structure critical for the proprioception, the maintenance of a native central stabilizer of the joint, and low shear stress on the bone-cement interface of the tibial component. Numerous retrospective studies of cruciate-retaining (CR) total knee arthroplasties have demonstrated consistently good clinical results and excellent intermediate and long-term survival. The main criticisms of the surgical technique are that the distal attachment of the PCL is vulnerable to injury and that balancing the PCL can be difficult; based on our experience, surgical tricks will be described to avoid the avulsion of the ligament and they will be discussed the main points to consider when you can find a discrepancy between flexion and extension stability. Based on the current evidence, we conclude that with a standardized technique, this type of implant should be preferred even in those cases where the sacrifice of the cruciate ligament seems to be the easiest way.

Keywords: total knee arthroplasty, cruciate-retaining, posterior cruciate ligament, surgical technique, balancing, advantages

1. Introduction

The main goal of a prosthetic implant is to restore joint function and to eliminate pain. Given the exponential increase in the number of knee arthroplasties, both due to an increase in the average life expectancy and to changes in lifestyle of patients (that maintain a high level of physical activity even at an advanced age), development of prosthetic implants that could reproduce as better as possible the normal knee kinematic and could endure for a long time is the main goal of the developers of these devices; cruciate-retaining total knee replacement (CR-TKR) was introduced to try to achieve these results.

The many reasons for retaining the posterior cruciate ligament (PCL) during total knee replacement (TKR) include improved stability, reduced shear stresses at the fixation interface, improved proprioception, and more efficient gait patterns during level walking and stair climbing; moreover, one of the most commonly cited motives for retaining the PCL is to preserve femoral rollback, which improves extensor efficiency by lengthening the moment arm and improves the range of flexion by minimizing the potential for impingement of the femur on the tibial component, reducing loosening and excessive polyethylene wear.

2. Indications

The classic indications for a PCL retaining total knee arthroplasty (TKA) are fixed flexion of less than 30°, varus less than 20°, and valgus less than 25°; joint subluxation of no more than 1 cm; structurally intact PCL (**Figures 1** and **2**); and technical ability of the surgeon [1].

In our experience, we also use this type of implant even in the revision of a unicompartmental knee replacement caused by an aseptic loosening of the tibial component: with the use of a tibial stem, associated if necessary with an augment, we spare the PCL avoiding the

Figure 1. Anteroposterior view of full-length lower extremity radiographs of a patient suitable for a CR-TKR.

Figure 2. Lateral view of knee radiographs of a patient suitable for a CR-TKR.

intercondylar notch cut: the aim to preserve more bone as possible taking into account that in the vast majorities of cases, these are young patients that will have the risk to require a further revision in the future.

3. Clinical outcomes

Numerous retrospective studies of CR TKAs have demonstrated consistently good clinical results and excellent intermediate and long-term survival [2–5].

While first studies about old generation of CR systems showed systemically a survivorship of 90% at 10 years, new type of implant demonstrated an improved longevity to 96–100% after 10 years. National joint registries are very useful instrument to understand this phenomenon: 14th Annual report of National Joint Registry for England, Wales, Northern Ireland and the Isle of Man updated to December 31, 2016 recounts that from 2003 "More than half of all operations (56.6%) were total knee replacements which were all cemented, unconstrained and fixed, followed by 20.7% which were all cemented, posterior stabilised and fixed… Two-thirds (66.6%) of cemented implants are unconstrained (cruciate-retaining) and have a fixed bearing… The main decline in the type of primary knee surgery carried out has been in the use of all uncemented and hybrid total knee replacements over time…" (less than a third of those figures reported for the year 2003). Analyzing the risk of revisions after primary knee surgery by fixation method and constraint, it reveals how "…Cemented unconstrained, fixed bearing total knee replacement results in lower chances of revision overall compared to other combinations of constraint and bearing used in a cemented fixation of the joint with modular tibial components" and "… Uncemented/hybrid total knee replacements with posterior stabilised constraint and fixed bearings fare worse than their unconstrained bearing equivalents" [6]. Similar results were carried out by the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) 2017 Annual Report: it describes as "…the use of minimally stabilised prostheses has remained relatively constant over the last 10 years. In 2016, these accounted for 67.4% of the three prosthesis types. The use of posterior stabilised prostheses has declined from 32.9% in 2008 to 25.6% in 2016." It also reports that "…Posterior stabilised and medial pivot prostheses have a higher rate of revision compared to minimally stabilised" stating that "…Posterior stabilised prostheses have a higher cumulative incidence of infection…" and "also have a higher cumulative incidence of loosening compared to minimally stabilised prostheses" [7].

Focusing on the differences in clinical outcomes between TKRs with retention versus sacrifice of the PCL, a Cochrane Review published in 2013 by Verra et al. found 17 randomized controlled trials that lead to following conclusion: "… With respect to range of motion, pain, clinical, and radiological outcomes, no clinically relevant differences were found between total knee arthroplasty with retention or sacrifice of the posterior cruciate ligament. Two statistically significant differences were found; range of motion was 2.4° higher in the posterior cruciate ligament sacrificing group, however results were heterogeneous; and the mean functional Knee Society Score was 2.3 points higher in the posterior cruciate ligament sacrificing group…" but "…These differences are clinically not relevant" [8].

More recent meta-analysis obtained the same clinical conclusion [9, 10].

4. Kinematic

Numerous prostheses have been developed to improve the durability and function of TKR and kinematic principles that have been the focus of current implant designs, have been to replicate the native knee's femoral rollback during flexion and the external rotation of the femoral component relative to the tibial component.

In the normal knee, a rolling motion predominates for the first 20° of flexion, which produces a posterior translation of the femoral contact position on the tibia. After 30° flexion, sliding becomes predominant but the net motion remains in the posterior direction [11] and the PCL performs several functions: It guides the rollback of the femoral condyles on the tibial plates during flexion, thus allowing the back portion of the condyles to clear the posterior surface of the tibia at high bending degrees and improving the mechanical efficiency of extensor apparatus; from the point of view of stability, it prevents the posterior subluxation of the tibia on the femur during flexion, with a critical secondary role in stability in varus and valgus with knee flexion [12].

Several studies about CR-TKR evaluated in the past the kinematic of this type of implant: Stiehl et al. in a fluoroscopic analysis showed that CR-TKR "…did not reproduce normal knee Kinematics in any case, but showed a starting point posterior to the tibial midline which translated anteriorly with flexion…" and "…Physiological roll-back has not been demonstrated and its absence is likely to reflect anterior cruciate deficiency, alteration of the normal joint line, or other subtle changes which modify kinematics…" [11]. Similar results were obtained by Dennis et al. in 1998: they found that "…a lack of customary posterior femoral rollback in posterior cruciate-retaining designs, and conversely showing an average anterior femoral translation with knee flexion. Posterior femoral rollback, less than in normal knees, routinely was observed in posterior cruciate substituting total knee arthroplasty, attributed to engagement of the femoral component cam with the tibial post" [13]. However, the same author in a study of 2002, using a standardized technique and a specific new generation implant, found that "the subjects…experienced consistent posterior femoral rollback of the posterior cruciate-retaining total knee arthroplasty" and concluded that "having asymmetric femoral condyles may lead to PFR with increasing knee flexion" [14].

A more recent study by Banks et al. also demonstrated that "…greater axial rotations were associated with complete preservation of the PCL insertion." Definitely, in this study, it was shown a normal axial rotation and a normal condylar translation in CR group, while "cruciate-substituting or post/cam substitution of PCL… exhibited lower ranges of axial rotation and condylar translation than the implant was designed to accommodate."

The key point is that the joint surfaces should be designed to be compatible with normal femoral rollback. Components with different curvature radius of the two condyles allow the femoral component to roll back much more laterally than medially, as on the normal knee. On the tibial side, a slightly flattened design in the sagittal plane makes the best use of the PCL preservation, allowing the femur to roll backward and rotate in a relatively normal way. At the same time, a significant congruity in the frontal plane helps to minimize stress on polyethylene, thus reducing long-term wear [12].

5. Posterior tibial slope

As widely explained by Sierra and Berry when performing a CR-TKR, modest posterior slope (matching patient's native slope between 3 and 7°) may help reduce tension on the PCL and facilitate knee flexion [15]. Posterior tibial slope (PTS) opens the flexion space, and this helps to obtain flexion without PCL recession. However, excessive slope may lead to compromise the insertion point of the PCL into the tibia, which can lead to flexion instability and to reduced or paradoxical femoral rollback reported more frequently in CR than in PS TKR.

One of the last biomechanical discoveries showed as an "increased PTS was associated with biomechanical effects leading to reductions in quadriceps force, contact stress on PF joint, and force on PCL. However, excessive PTS should be avoided to prevent progressive loosening of the TF joint gap due to the reduction of collateral ligament tension during flexion" [16].

A reduced slope can generally lead to lift-off positive test in flexion whose treatment will be extensively described in the technique paragraph.

In conclusion, evaluating the tibial slope is a crucial phase in CR-TKR, since as recently explained by Dae Kyung Bae et al. the steepness of the PTS is one of the main factors that requires the conversion to PS from a CR-type prosthesis [17].

6. Midflexion stability

For a successful TKR, the wide range of movement is not the only objective to achieve, but also joint stability plays a crucial role. During most activities of daily living, the knee is loaded not only in full extension but also in midflexion, and therefore, stability throughout flexion should be considered an important outcome measure. As the PCL is thought to serve as a secondary stabilizer of the knee during varus and valgus stresses, it is likely that the presence of this ligament has some effects on midflexion stability.

In a cadaveric study of 1999, Mihalko observed "…that a major result of posterior cruciate ligament sacrifice is the creation of a larger flexion gap. This result provides insight into relative joint line changes that can occur after posterior cruciate ligament sacrifice…," suggesting… "the need for greater attention to flexion stability when sacrificing the posterior cruciate ligament" [18]. In a 2008 study, Tsuneizumi et al. similarly concluded that "…the PCL kept the knee stable against distal traction force in the flexion position, and sacrifice of this ligament caused joint laxity in different ranges. The increases in the flexion gap after resection of the PCL varied among individuals" [19].

In 2013, Hino et al. focused on stability through the range of movement pinpointing the exact degrees that make differences between CR and PS TKRs stability: "Specifically, CR knees had significantly less laxity in the flexion range of 10 to 30° than PS knees…" demonstrating "…a significant decrease in joint laxity at 120° of flexion for CR-TKRs and in contrast PS TKRs had an increase in joint laxity between 10 and 20° of flexion post-operatively. Overall, CR knees demonstrated less joint laxity than PS knees throughout the whole range of movement." They concluded that "CR knees have less post-operative laxity, especially in deep flexion…" and "...this may be associated with the lower flexion range that could be seen in CR knees" [20].

7. Joint line position

Since restoration of joint line can be difficult in severe osteoarthritic knee with coronal and sagittal plane deformities, many surgeons prefer the use of a PS TKR, which is less sensitive to changes in joint line position: in fact, the level of the reconstructed joint line is one of the main factors that affects the tension of the retained PCL [21]. As reported by Emodi et al. in a cadaveric study "As the joint line was elevated, PCL strain increased at all measured flexion angles above 30°…" and "…the centre of tibio-femoral contact did not change at the flexion angles of 15 and 30°…" but "…at 60, 90 and 105° the tibio-femoral contact centre moved posteriorly with each successive elevation of the joint line." This author also confirmed what already reported in literature that "…Significant decreases in flexion were observed with as little as 2 mm of elevation. Flexion was limited further as the joint line

http://dx.doi.org/10.5772/intechopen.74024

was elevated 4 and 6 mm, and was partially restored following cruciate excision…" and "… The effect of joint line elevation on normalized quadriceps load and patella-femoral contact pressures was observed only at higher flexion angles…" [22].

8. Authors' preferred surgical technique

A standard midline longitudinal approach is performed with medial parapatellar arthrotomy and lateral patellar dislocation; the knee joint is exposed and the Whiteside line and the transepicondylar axis are marked (they are used as femoral rotational landmarks); the intramedullary femoral guide is drilled into the femur; a 9-mm distal femoral bone resection is performed with a valgus angle preoperatively planned (**Figure 3**).

For the tibial side, Hohmann retractors are employed to protect lateral and medial soft tissues (critical structures for a correct balancing); the tibial spine is removed using a surgical saw.

Then through the use of an osteotome, a bone island really closer to the distal insertion of PCL is circumscribed (**Figures 4** and **5**). A pin is placed in front of the PCL defining the anterior side of the island (**Figure 6**); we make use of the extramedullary tibial resection guide to align the tibial mechanical axis; an amount of resection equal to the thickness of the tibial arthroplasty component is measured on the less osteoarthritic plateau and tibial resection is performed bewaring not to get across the lateral and medial sides of marked bone island. The employment of the osteotome is an essential step: it allows to incise the posterior cortex avoiding during the tibial plateau excision the risk of avulsion and subsequent detachment of the PCL.

With these precautions, the tibial plateau is removed (**Figures 7–9**) and the bone island can be carefully shaped through a nibbler to permit the placement of the posterior side of the tibial component (**Figures 10** and **11**).

Figure 3. Distal femur cut: with the angel wing, you can appreciate the minimal resection in order to maintain the level of the joint line position.

Figure 4. Through the use of an osteotome, a bone island is circumscribed.

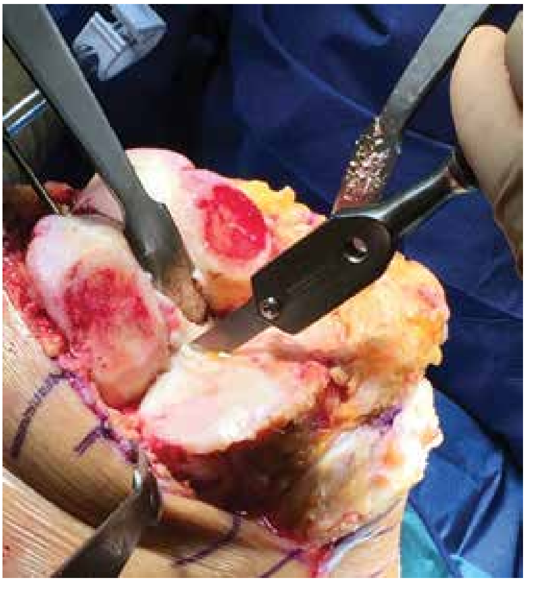


Figure 5. The incision of the posterior cortex necessary to avoid a posterior avulsion.

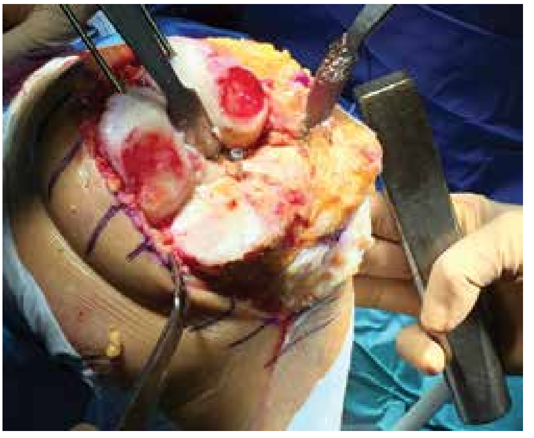


Figure 6. A pin is placed in front of the PCL defining the anterior side of the island.

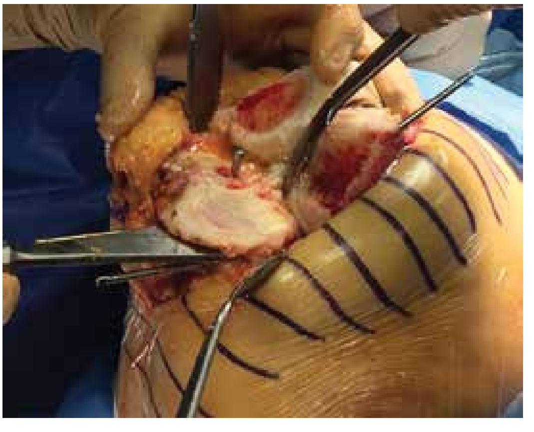


Figure 7. The tibial plateau is detached.

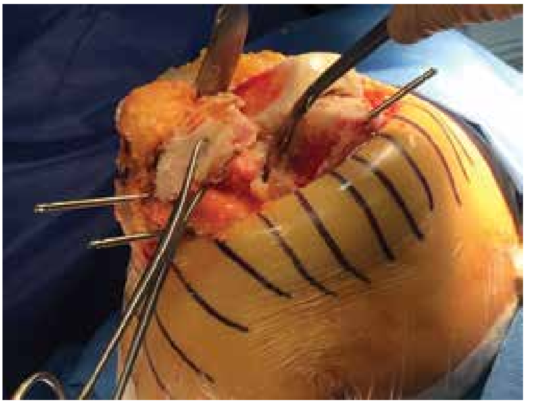


Figure 8. The tibial plateau is removed.

Figure 9. Superior view of the removed plateau.

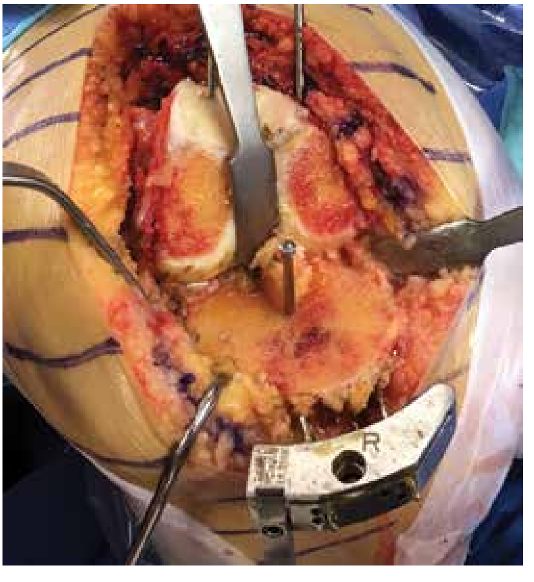


Figure 10. The aspect of the tibial side after the cut with the preservation of the PCL.

The following step, with knee flexed at 90°, is defining the size and the position of the femoral component; we utilize an asymmetric spacer (flexion spacer by Biomet) (**Figure 12**) to perform a posterior condylar femoral resection perpendicular to the Whiteside line and in order to obtain equal medial and lateral gaps and to achieve the same space both in flexion and extension. By posterior referencing, 4-in-1 cutting block (set for the measured implant size and the rotational alignment previously evaluated) is placed and the anterior, posterior, anterior chamfer, and posterior chamfer cuts are performed.

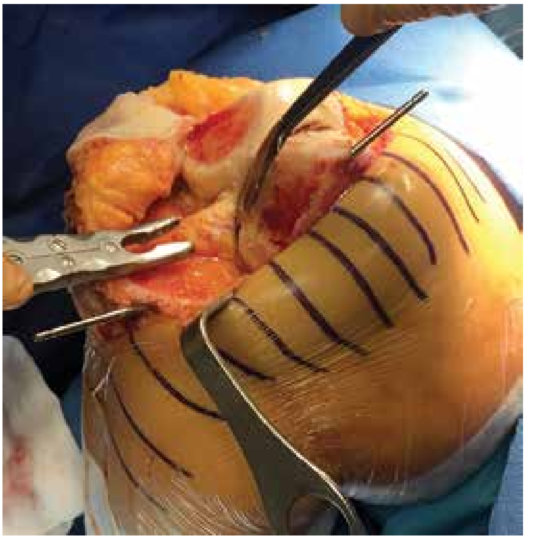


Figure 11. The bone island can be shaped through a nibbler or a Luer.

Through the use of a gap spacer, the alignment and varus or valgus ligamentous balance are always tested both in extension and in flexion. The space between the femoral and the tibial cut surfaces should be within 1–2 mm of each other both in flexion and extension [23].

Figure 12. Balancing the space in flexion through the flexion spacer by Biomet.

When the desired balancing and gaps are achieved, the femoral, tibial, and insert trial components of the correct size are inserted; we check the maximum extension and flexion and then stability and the patellar tracking in the full range of movement; usually, we do not perform patellar resurfacing [24] but just remove osteophytes.

Once the tibial stem hole is created and the preparation procedure is completed, we perform a wash of the joint and then insert definitive cemented components and the polyethylene bearing of the previously evaluated size.

9. Consideration about surgical technique

We think that to improve an already successful procedure, as TKR was well demonstrated to be, we need to look at small details.

In the debate between PS versus CR-TKR, the main reason in favor of PCL sacrifice is that balancing a joint with an intact PCL could be very difficult, especially in case of drastic deformities as severe fixed flexion, varus or valgus angulations more than 20° or considerable joint subluxation: but in these cases, we think that probably PS implant is not the solution since should be preferable the use of a more constrained implant.

We think that the ability of the surgeon is critical to obtain a good CR replacement; technical difficulties lead to a longer learning curve, but using some tips and having cleared all basic science considerations explored in the previous paragraphs, you can achieve good results even in the most difficult cases.

Taking these points into account, the first element to consider is that the goal of the procedure is both to place the TKA in neutral mechanical alignment and to obtain a knee stable in all range of movement. In CR-TKR, the main criticism of the process is the preservation of the PCL and consequent balance of the spaces.

Performing a CR-TKR, the main criticism of the surgical technique is that the distal attachment of the PCL is vulnerable to injury during the tibial resection; the distal attachment of the PCL is located posterior and distal to the tibial plateau, so the application of a protective device on the front is really useful to safeguard it; however, excessive bone resection from the proximal tibia (i.e., greater than 1 cm) or a large posteriorly sloped cut may anyway jeopardize the tibial attachment of the PCL and it has been demonstrated that a pin of minimum 1.7 mm of length ensures a larger margin of safety [25]. In addition, the creation of a bone island with the incision of the posterior cortex is really useful to avoid the avulsion of the ligament during the removal of the plateau.

The second element is that in order to accurately balance the joint, the surgeon can remove less bone from the distal femur (typically matching the thickness of the femoral implant which should be chosen to reproduce the A-P size of the back of native femoral condyles) in comparison to what would be done for a PS TKR (**Figure 7**); due to the retention of the PCL in a CR-TKR, the flexion gap will remain smaller (in a range of 1.8–4.8 mm) than what would be created for a PS implant; therefore, the goal is to keep the extension gap small as well [15].

The third element is about the slope of the tibial cut: posterior slope opens the flexion space and this helps to obtain flexion without PCL recession. Therefore, a modest posterior slope (typically matching the patient's native slope within the range of 3–7°) may help to reduce tension on the PCL and this may facilitate knee flexion. If the extension gap is asymmetrical, it is necessary to perform a ligamentous release in order to obtain a symmetric space, and the gap size finally should be verified with a spacer block. Reflecting on the solution to achieve a symmetrical space in the flexion gap, it is really important to consider what type of instrument we are using: if we get the restoration of a neutral mechanical alignment in extension through the use of an intramedullary device for the femur and an external guide for the tibia, in our experience, the best instrument that helps us to get the correct rotation of femur in flexion is the flexion spacer by Biomet; in fact, it is always referred to the tibial osteotomy (that regardless of surgeon accuracy should be 1° or 2° in valgus or varus deviation) and allows us to reach a parallel cut even in case of a severe lateral condyle hypoplasia thanks to its multiple choice in asymmetrical components (1°, 3°, 4°, 5°, 6°, 8°). Once rotation is obtained, the following step is to determine the depth of the flexion gap. Not only does the flexion gap need to be rectangular (indication of rotation), but it also needs to obtain the same size of the extension gap. Through the use of the flexion spacer, the normal posterior condyle offset is recreated. Then, the depth of the anterior cut is not measured directly but rather determined by the size of the 4-in-1 cutting jig; it may be too shallow (this will cause overstuffing of the patellofemoral joint) or it may be too deep (this will cause notching) [26].

Nevertheless, problems can occur once that bone cuts are performed and trial components are inserted.

A slightly lax PCL is preferable to one that is excessively tight, but an overly lax PCL can result in functional disability secondary to flexion instability. Balance of the PCL should be assessed after correction of any varus or valgus ligamentous imbalance. An excessively tight PCL will result in anterior translation of the tibia from beneath the femur, anterior lift-off of the trial polyethylene from the tibia tray in flexion, and/or displacement of the femoral component in flexion. A useful test of the relative balance of the PCL is the so-called POLO (for PullOut, LiftOff) test introduced by Dr. Richard Scott. In this test, a trial reduction is done with a stemless tibial trial and a curved tibial insert. The PullOut portion of the test is done at 90° of flexion and confirms that the PCL is not too loose if the tibial insert cannot be subluxed (pulled out) anteriorly from beneath the femur. The LiftOff portion is done while putting the knee through a range of motion up to 120° and ensuring that the tibial insert does not look open (lift-off) in flexion, indicating that the PCL is too tight. Scott postulates that if the PCL is not too loose and not too tight, then it must be just right [1].

If the PCL is excessively tight, the tension can be decreased by several techniques. Increased tibial bone resection is only appropriate if the knee is tight in both flexion and extension. If the knee is tight only in flexion, increasing tibial bone resection will leave the knee lax in extension, resulting in symptomatic instability due to hyperextension or excessive varus-valgus play. If the knee is tight only in flexion, the posterior slope of the tibial cut should be assessed. The tibia normally has a 3 to 7°degree posterior slope. The amount of posterior slope cut on the tibia will be dependent on the prosthetic design. Some implants have an inherent posterior slope in the articular geometry and will require less posterior slope than knees with a flat geometry in the sagittal plane. Increasing posterior slope for the tibial resection will relax the PCL. Posterior tibial slope typically should not exceed 10° to avoid risk of injury to the tibial attachment of the PCL. Posterior cruciate recession consists of selective release of the anterior fibers of the PCL from their tibial attachment. Release of the anterior 10–20% of the PCL can often help achieve the correct soft tissue balance. If greater than 75% of the PCL is released, some feel a PCL-substituting prosthesis should be considered. The concern in those cases is that the remaining 25% of the PCL fibers may rupture later with activity, leading to flexion instability. If the PCL is released or absent, the tibial tray should be more conforming because rollback does not occur. Hence, the surgeon should match the constraints of the soft tissue with the inherent constraints of the knee system being used [1].

A knee that is tighter in flexion requires one or a combination of maneuvers that include PCL release, downsloping the tibial resection, downsizing the femoral component, or additional tibial resection with distal advancement of the femoral component. A knee that is tighter in extension is usually corrected merely by added distal femoral resection [1].

10. Conclusion

The most recent literature and National Joint registries confirm that CR-TKR has good clinical results and excellent intermediate and long-term survival.

If in the past many studies argued that CR implant lead to paradoxical kinematic, more recent and relevant studies demonstrated that with new design components and well-standardized technique, the native femoral rollback is better restored with a CR-TKR than with a PS implant. International studies also confirm that the stability in all range of movement can successfully be achieved, and care must be paid to joint line position and posterior tibial slope when performing a CR replacement; in fact, they are two of the main factors that affect the tension of the retained PCL. Less femoral distal cut as possible should be executed to not compromise gap balances between extension and flexion: in fact, the retention of the PCL lead to a smaller space in flexion than what obtained with PCL recession, but if more space is needed in flexion (caused by a too thigh PCL), creating a more sloped tibial cut may help to reduce tension on the PCL-facilitating knee flexion.

The main criticism of the surgical technique is that the distal attachment of the PCL is vulnerable to injury during the tibial resection and the creation of a bone island through the use of an osteotome and a pin in front of the ligament can protect it from a damage that could seriously cause difficulties in balancing; balancing a PCL, especially in case of severe deformities, can be difficult but many tests and solution have been successfully proposed to understand and solve different complex combinations (**Figures 13** and **14**).

We think that performing a CR-TKR is difficult and requires a long learning curve, but at the same time with a standardized technique, it is always possible to prefer this type of implant even in those case wherein many surgeon would prefer a PS implant: considering that more and more young high-demanding patients are subjected to this procedure you should preserve

http://dx.doi.org/10.5772/intechopen.74024

Figure 13. Anteroposterior view of knee radiographs showing successful case of a CR implant.

Figure 14. Lateral view of knee radiographs showing successful case of a CR implant.

as much as possible the ligamentous structures for their physiological function and avoid bone cuts as much as possible (in the CR designs, the creation of the intercondylar notch resection is not required) in the perspective of a possible revision in the future.

Finally, for severe deformities associated with ligamentous laxity, the debate about preserve or resect the PCL is out of place: in these cases, the solution should be finding in a CR or PS TKR but in a more constrained implant.

Author details

Vittorio Calvisi, Alessandro Paglia, Norman Ciprietti and Remo Goderecci*

*Address all correspondence to: remogoderecci@gmail.com

MESVA Department, University of L'Aquila, L'Aquila, Italy

References

[1] Morrey BF, Berry DJ, An K-N, Kitaoka HB, Pagnano MW. Joint Replacement Arthroplasty. 4th centennial ed. Vol. II. Philadelphia: Lippincott Williams & Wilkins, a Wolters Kluwer business; 2011

[2] Buehler KO, EricVenn-Watson, D'Lima DD, Colwell CW Jr. The press-fit condylar total knee system: 8- to 10-year results with a posterior cruciate-retaining design. The Journal of Arthroplasty. September 2000;**15**(6):698-701. DOI: 10.1054/arth.2000.8189

[3] Fetzer GB, Callaghan JJ, Templeton JE, Goetz DD, Sullivan PM, Kelley SS. Posterior cruciate-retaining modular total knee arthroplasty: A 9- to 12-year follow-up investigation. The Journal of Arthroplasty. December 2002;**17**(8):961-966. DOI: 10.1054/arth.2002.34824

[4] Barrington John W, Alexander S, Henrik M, Burke Dennis W. Contemporary cruciate-retaining total knee arthroplasty with a pegged tibial baseplate: Results at a minimum of ten years. JBJS. April 1, 2009;**91**(4):874-878. DOI: 10.2106/JBJS.G.01609

[5] Berger Richard A, Rosenberg Aaron G, Barden Regina M, Sheinkop Mitchell B, Jacobs Joshua J, Galante Jorge O. Long-term followup of the Miller-Galante total knee replacement. Clinical Orthopaedics and Related Research. July 2001;**388**:58-67

[6] 14th Annual report of National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. Prepared by The NJR Editorial Board; Mr Martyn Porter (Chairman, Editorial Board). Available from: http://www.njrreports.org.uk

[7] Association National Joint Replacement Registry (AOANJRR) 2017 Annual Report. David Hale Chairperson. Available from: https://aoanjrr.sahmri.com/annual-reports-2017

[8] Verra WC, van den Boom LGH, Jacobs W, Clement DJ, Wymenga AAB, Nelissen RGHH. Retention versus sacrifice of the posterior cruciate ligament in total knee arthroplasty for treating osteoarthritis. Cochrane Database of Systematic Reviews. 2013;(10. Art. No.: CD004803.). DOI: 10.1002/14651858.CD004803.pub3

[9] Li N, Tan Y, Deng Y, et al. Posterior cruciate-retaining versus posterior stabilized total knee arthroplasty: A meta-analysis of randomized controlled trials. Knee Surgery, Sports Traumatology, Arthroscopy. 2014;**22**:556. DOI: 10.1007/s00167-012-2275-0

[10] Bercik Michael J et al. Posterior cruciate-retaining versus posterior-stabilized total knee arthroplasty. The Journal of Arthroplasty;**28**(3):439-444. DOI: 10.1016/j.arth.2012.08.008

[11] Stiehl JB, Komistek RD, Dennis DA, Paxson RD, Hoff WA. Fluoroscopic analysis of kinematics after posterior-cruciate-retaining knee arthroplasty. Journal of Bone and Joint Surgery (British). 1995;**77-B**:884-889

[12] Insall & Scott—Surgery of the Knee, 5th Edition. Edited by W. Norman Scott. Published with permission of Elsevier Inc.; 2015 Verduci Editore - Roma

[13] Dennis DA, Komistek Richard D, Colwell Clifford E, Ranawat Chitranjan S, Scott Richard D, Thornhill Thomas S, Lapp Mark A. In vivo anteroposterior femorotibial translation of total knee arthroplasty: A multicenter analysis. Clinical Orthopaedics and Related Research. November 1998;**356**:47-57 Symposium: The Papers Presented at the Knee Society Meeting 1998

[14] Bertin KC, Komistek RD, Dennis DA, Hoff WA, Anderson DT, Langer T. In vivo determination of posterior femoral rollback for subjects having a NexGen posterior cruciate-retaining total knee arthroplasty. The Journal of Arthroplasty. 2002;**17**(8):1040-1048

[15] Sierra RJ, Berry DJ. Surgical technique differences between posterior-substituting and cruciate-retaining total knee arthroplasty. The Journal of Arthroplasty. 2008;**23**(7 Suppl):1

[16] Kang K-T, Koh Y-G, Son J, Kwon O-R, Lee J-S, Kwon S-K. Influence of increased posterior tibial slope in total knee arthroplasty on knee joint biomechanics: A computational simulation study. The Journal of Arthroplasty. 2018 Feb;**33**(2):572-579. DOI: 10.1016/j.arth.2017.09.025

[17] Bae DK, Song SJ, Kim KI, et al. Intraoperative factors affecting conversion from cruciate retaining to cruciate substituting in total knee arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy. 2016;**24**:3247. DOI: 10.1007/s00167-015-3971-3

[18] Mihalko WM, Krackow Kenneth A. Posterior cruciate ligament effects on the flexion space in total knee arthroplasty. Clinical Orthopaedics and Related Research. March 1999;**360**:243-250

[19] Tsuneizumi Y, Suzuki M, Miyagi J, Tamai H, Tsukeoka T, Moriya H, Takahashi K. Evaluation of joint laxity against distal traction force upon flexion in cruciate-retaining and posterior-stabilized total knee arthroplasty. Journal of Orthopaedic Science. 2008; **13**:504-509. DOI: 10.1007/S00776-008-1269-8

[20] Hino K, Ishimaru M, Iseki Y, Watanabe S, Onishi Y, Miura H. Mid-flexion laxity is greater after posterior-stabilised total knee replacement than with cruciate-retaining procedures. A computer navigation study. The Bone & Joint Journal. 2013;**95-B**:493-497. DOI: 10.1302/0301-620x.95b4

[21] Ji SJ, Zhou YX, Jiang X, Cheng ZY, Wang GZ, Ding H, Yang ML, Zhu ZL. Effect of joint line elevation after posterior-stabilized and cruciate-retaining total knee arthroplasty on clinical function and kinematics. Chinese Medical Journal. 2015;**128**:2866-2872. DOI: 10.4103/0366-6999.168043

[22] Emodi GJ, Callaghan JJ, Pedersen DR, Brown TD. Posterior cruciate ligament function following total knee arthroplasty: The effect of joint line elevation. The Iowa Orthopaedic Journal. 1999;**19**:82-92

[23] Castelli CC, Falvo DA, Iapicca ML, Gotti V. Rotational alignment of the femoral component in total knee arthroplasty. Annals of Translational Medicine. 2016 Jan;**4**(1):4

[24] Calvisi V, Camillieri G, Lupparelli S. Resurfacing versus nonresurfacing the patella in total knee arthroplasty: A critical appraisal of the available evidence. Archives of Orthopaedic and Trauma Surgery. 2009;**129**:1261. DOI: 10.1007/s00402-008-0801-9

[25] Wood AR, Rabbani TA, Sheffer B, Wagner RA, Sanchez HB. Protecting the PCL during total knee arthroplasty using a bone island technique. The Journal of Arthroplasty. 2017:1-5

[26] Parcells B. Managing Editor. TKA bone cuts. In: Hip and Knee Book. Arthroplasty Education Foundation. February 2017

Methods of DVT Prophylaxis after Total Knee Arthroplasty

Melvin J. George

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73645

Abstract

Postoperative deep-vein thrombosis (DVT), venous thromboembolism (VTE), and pulmonary embolism are few of the most serious complications following total joint arthroplasty. Identification of risk factors and initiation of prophylactic measures are the most important measures to prevent the occurrence of DVT. Several protocols and guidelines are published for DVT prophylaxis in TKA, leaving the surgeon still perplexed. Pharmacological and mechanical prophylaxis methods are used to reduce the risk of postoperative symptomatic deep-vein thrombosis and pulmonary embolism. The use of pharmacological methods is based on a fine balance between their efficacy and the adverse effects associated with them. Each of these agents has their own advantages and disadvantages. Several newer agents are getting approved by FDA for the same. Hence, the choice should be carefully made based on the patient characteristics and risk stratification, and the onset of side effects has to be carefully monitored.

Keywords: DVT, thrombosis, prophylaxis, embolism, postoperative, TKA, joint replacement

1. Introduction

The importance of DVT prophylaxis is well understood from the high incidence of DVT in patients undergoing total knee arthroplasty (TKA). Studies have shown that without any mechanical or pharmacologic prophylaxis, asymptomatic DVT develops in 40–60% of the patients undergoing total hip and knee arthroplasties. Hence, there is a general consensus that these patients require regular prophylaxis even beyond discharge [1]. Venous thrombosis, including deep-vein thrombosis, occurs at an annual incidence of about 1 per 1000 adults and is higher in men than that in women in older age. DVT incidence varies according to the race and ethnicity. Asians have a very low incidence of deep-vein thrombosis due to the preferred vegetarian diet, low prevalence of obesity, hyperlipidemia, and Factor V Leiden mutation. Several meta-analysis studies have shown similar results of low DVT incidence in Asians [2]. Operating surgeon has to minimize the risk of occurrence of this complication and its associated morbidity and mortality. Surgeon's choice of VTE prophylaxis should be based on a balance between safety and efficacy of a particular anticoagulant, with risk stratification of VTE or bleeding. Virchow's triad of events—stasis, vascular endothelial injury, and hypercoagulability, increases the risk of deep-vein thrombosis (DVT). Patients who fulfill two of the three criteria are considered to be high-risk group. Most of the patients undergoing TKA are considered to be at high risk for DVT for the high incidence of endothelial injury during the surgery and the relative stasis during the postoperative period. Well's criteria help us to stratify risk in these patients (**Figure 1**).

Clinical Parameter	
Active cancer (treatment ongoing, or within 6 months or palliative	+1
Paralysis or recent plaster immobilization of lower extremities	+1
Recently bedridden for more than 3 days or major surgery less than 4 weeks prior	+1
Localized tenderness along the distribution of the deep venous system	+1
Entire leg swelling	+1
Calf swelling more than 3 cm compared with asymptomatic leg	+1
Pitting edema (greater than asymptomatic leg)	+1
Previous DVT documented	+1
Collateral superficial veins (nonvaricose)	+1
Alternative diagnosis (as likely or greater than that of DVT)	-2

Pretest probability score calculated from the Wells DVT score can be stratified in either 2 or 3 risk groups. In the 3 risk group, patients with a score of 0 or less are considered low risk, 1-2 are moderate risk, and 3 or greater are high risk. In the 2 risk group, patients are stratified as DVT unlikely (Wells score < 2) or DVT likely (Wells score =2). See Table 2 below.

Figure 1. Well's criteria for DVT risk stratification.

http://dx.doi.org/10.5772/intechopen.73645

Patients without prior clinical suspicion also can develop DVT and fatal pulmonary embolism. Hence, it is therefore important to take appropriate preoperative screening and preventive measures for all these patients and to determine which of them warrant additional prophylaxis. Worldwide accepted guidelines on DVT prophylaxis have been produced by the American College of Chest Physicians (ACCP), American Academy of Orthopedic Surgeons (AAOS), and the National Institute for Health and Clinical Excellence (NICE). But the priority consideration is to diagnose the patients with high risk of developing DVT.

2. Risk factors

The risk factors for the development of DVT can be modifiable or nonmodifiable factors.

Modifiable factors include

- Obesity: it is defined as BMI above 30. Obesity leads to a two- to threefold higher risk of venous thrombosis in men and women. The obese have a further increase in thrombosis risk when they are exposed to other thrombosis risk factors, such as exogenous contraceptive or postmenopausal hormones.
- Homocysteine levels: elevated homocysteine has been consistently reported as a risk factor for venous thrombosis and levels can be reduced with B vitamin supplementation.

Nonmodifiable risk factors include the genetic factors which cause thrombophilic disorders. Protein C, protein S, and antithrombin deficiencies, Factor V Leiden mutation, and increased level of factor V, VII, VIII, IX, XI and von Willebrand factor are a few of the conditions that add up the risk of DVT.

Triggering factors are incidental situations which put patients into high risk of developing DVT, which cannot be avoided but can be tided over.

- Hospitalization—either due to immobility, infection, surgery.
- Surgery/trauma.
- Immobility—due to stasis of blood flow as in cases of plaster casts, bed rest, and paresis of legs due to neurological conditions.
- Cancer—increased risk due to cancer cells activating coagulation and tumors compressing veins causing hemostasis.
- Travel—duration of any form of travel more than 4 h increases the risk by about twofold for several weeks after travel [3].

3. Evaluation

Apart from the history and the classic clinical symptoms and examination findings of pain, tenderness, and swelling of the leg, different techniques are employed to detect even small thrombi in the venous system.

Ultrasound Doppler: it is the most common test used for diagnosing deep-vein thrombosis. It is quick, noninvasive, cheap and patient-friendly.

D-dimer test: the level of D dimer will be elevated in the presence of a blood thrombus.

Venography: this test is indicated if ultrasound does not provide a clear diagnosis. It is an invasive technique whereby a radio-opaque dye is injected into a vein, and then, a radiograph is taken of the leg. The entire pathway of the vein can be identified from the X-ray, and any obstruction somewhere indicates a thrombus.

Impedance plethysmography: changes in venous filling are produced by inflating and deflating the thigh cuff, and electrodes sense the change in blood volume by electrical impedance in the calf veins. A delay indicates that an occlusive thrombus is present in the popliteal or more proximal veins. But this modality is not useful in detecting more proximal DVTs.

Ventilation–Perfusion Scan (V/Q scan): a lung V/Q scan uses a ventilation (V) scan to measure air flow in the lungs and a perfusion (Q) scan to assess the blood flow in the lungs. This will detect even an occult event of pulmonary embolism.

Pulmonary CT angiography: currently, the most commonly used first-choice imaging examination in patients with suspected PE is pulmonary CT angiography [4]. This recommendation is based on high sensitivity and specificity for PE and other clinically important conditions that mimic PE.

But the point of interest is to prevent the occurrence of DVT rather than its detection. All these modalities are used to detect even a minute thrombus occurring in the system. Apart from the identification of high-risk patients, it would be better to screen all these patients for DVT preoperatively. So many studies have been done in this regard in different population using preoperative Doppler screening studies. According to the Scottish Arthroplasty Registry, the incidence of clinically significant VTE within 3 months of TKA is 1.79%, whereas that of fatal PE is 0.15% [5] and the asymptomatic DVT rates are much higher. Therefore, thromboprophylaxis use has been recommended for all patients undergoing TJA in Western population. Many other regional studies have shown that the incidence of DVT in patients undergoing TKA is so less to warrant a regular preoperative Doppler screening. However, it is said that a better modality to detect thrombi would be venography, which is not an appealing invasive procedure.

Numerous guidelines and recommendations suggest the use of various methods of thromboprophylaxis and methods to reduce the risk of development of modifiable factors. Pharmacological and mechanical prophylaxis methods are used, either in isolation or in combination, to reduce the risk of postoperative VTE.

http://dx.doi.org/10.5772/intechopen.73645

4. DVT prophylaxis guidelines

ACCP 2012 guidelines recommend thromboprophylaxis for patients undergoing TJA for a minimum of 10–14 days. They prefer agents like low molecular weight heparin (LMWH), vitamin K antagonist, aspirin, fondaparinux, apixaban, dabigatran, or rivaroxaban. Regular Doppler screening during postoperative period is not recommended. But, prophylaxis is advocated as it is recognized that asymptomatic DVT can produce a fatal PE [6] (**Figure 2**).

Current ACCP Clinical Practice Guidelines for Prevention of VTE After Total Joint Arthroplasty

Recommendation	Grade
In patients undergoing THA/TKA, one of the following agents should be used for a minimum of 10-14 days rather than no antithrombotic prophylaxis:	
LMWH	1B
Fondaparinux	1B
Apixaban	1B
Dabigatran	1B
Rivaroxaban	1B
Low-dose unfractionated heparin	1B
Adjusted-dose vitamin K antagonist	1B
Aspirin	1C
IPCD	1B
For patients undergoing major orthopedic surgery (THA, TKA, hip fracture) and receiving LMWH as VTE prophylaxis, the agent should be started either ≥12 h preop or ≥12 h postop rather than ≤4 h preop or ≤4 h postop.	
In patients undergoing THA/TKA, regardless of the use of IPCD or length of treatment, LMWH should be used in preference to the following alternative agents:	
Fondaparinux	2B
Apixaban	2B
Dabigatran	2B
Rivaroxaban	2B
Low-dose unfractionated heparin	2B
Adjusted-dose vitamin K antagonist	2C
Aspirin	2C
In patients undergoing major orthopedic surgery, VTE prophylaxis should be extended in the outpatient period for up to 35 days from the day of surgery rather than for only 10-14 days.	2B
In patients undergoing major orthopedic surgery, dual prophylaxis with an antithrombotic agent and an IPCD during the hospital stay is recommended.	2C
In patients undergoing major orthopedic surgery with an increased risk of bleeding, an IPCD or no prophylaxis is recommended over pharmacological treatment.	2C
In patients undergoing major orthopedic surgery and who decline or are uncooperative with injections or an IPCD, apixaban or dabigatran should be used (alternatively rivaroxaban or adjusted-dose vitamin K antagonist if apixaban or dabigatran are unavailable) rather than alternative forms of prophylaxis.	1B
In patients undergoing major orthopedic surgery, it is not recommended to use an inferior vena cava filter for primary prevention over no VTE prophylaxis in patients with an increased bleeding risk or contraindications to both pharmacologic and mechanical VTE prophylaxis.	2C
Following major orthopedic surgery, asymptomatic patients do not need Doppler (or duplex) ultrasound screening before hospital discharge.	1B

Abbreviations: ACCP, American College of Chest Physicians; IPCD, intermittent pneumatic compression device; LMWH, low-molecular weight heparin; postop, postoperatively; preop, preoperatively; THA, total hip arthroplasty; TKA, total knee arthroplasty; VTE, venous thromboembolism. Data from Falck-Ytter et al and Lieberman and Pensak.

Figure 2. Highlights of the recent ACCP guidelines for thromboprophylaxis.

The AAOS 2011 guidelines suggest pharmacologic agents and/or mechanical device for the prevention of VTE following joint replacement surgery. They did not recommend any specific agent or duration of thromboprophylaxis. Both guidelines support combined methods of chemoprophylaxis with mechanical device. Also, they discourage the regular Doppler screening for DVT postoperatively [7] (**Figure 3**).

4.1. Methods of thromboprophylaxis

Thromboprophylaxis methods can be broadly divided into three—pharmacological, mechanical, and multimodal measures. Pharmacological measures include early active mobilization, intermittent pneumatic compression device (IPCD), compression stockings, and active ankle pumps. Anticoagulants often used are unfractionated and low molecular weight heparins, vitamin K antagonists, and selective factor Xa inhibitor (e.g., fondaparinux).

4.1.1. Mechanical methods

The most recent amendments to the AAOS, ACCP, and Surgical Care Improvement Project (SCIP) clinical practice guidelines for VTE prophylaxis after total joint arthroplasty now include mechanical compression devices as modalities for VTE prophylaxis. Mechanical compressive devices increase the local blood flow in the lower extremities, decrease the concentration of the

Table 1

Current AAOS Clinical Practice Guidelines for Prevention of VTE After Total Joint Arthroplasty

No.	Recommendation	Grade
1	Recommendation against routine postoperative duplex ultrasonography screening.	Strong
2	Assessing risk of VTE by determining previous VTE events should be considered.	Weak
3	Panel recommends that patients be assessed for known bleeding disorder like hemophilia and for the presence of active liver disease, which further increases risk for bleeding and bleeding-associated complications.	Inconclusive
4	Panel suggests discontinuation of antiplatelet agents (eg, aspirin, clopidogrel) before undergoing elective THA/TKA.	Moderate
5	Panel suggests use of pharmacological agents and/or mechanical compressive devices for VTE prevention in patients undergoing elective THA/TKA.	Moderate
	Panel cannot recommend for or against a specific prophylactic regimen in TKA/THA patients.	Inconclusive
	In the absence of reliable evidence regarding the duration of prophylactic strategies, it is the opinion of the panel that patients and physicians discuss the duration of prophylaxis.	Consensus
6	In the absence of reliable evidence, it is the opinion of the panel that patients undergoing THA/TKA, who have also had a previous VTE, receive pharmacologic prophylaxis and use mechanical compressive devices.	Consensus
7	In the absence of reliable evidence, it is the opinion of the panel that patients undergoing THA/TKA, who also have a known bleeding disorder and/or active liver disease, use mechanical compressive devices for prevention VTE.	Consensus
8	In the absence of reliable evidence, it is the opinion of the panel that patients undergo early mobilization following elective THA/TKA.	Consensus
9	The use of neuraxial (eg, intrathecal, epidural, spinal) anesthesia for patients undergoing elective THA/TKA is recommended to help limit blood loss, although evidence suggests that neuraxial anesthesia does not affect the occurrence of VTE.	Moderate
10	Panel cannot recommend for or against the use of inferior vena cava filters because current evidence does not provide clear guidance about whether inferior vena cava filters prevent embolus in patients undergoing elective THA/TKA who also have a chemoprophylaxis and/or known residual VTE.	Inconclusive

Abbreviations: AAOS, American Academy of Orthopaedic Surgeons; THA, total hip arthroplasty; TKA, total knee arthroplasty; VTE, venous thromboembolism.
Data from Lieberman and Pensak,[illegible] Mont and Jacobs,[illegible] and Lieberman.[illegible]

Figure 3. Highlights of the recent AAOS guidelines for thromboprophylaxis.

activated coagulation factors, and promote lymphatic drainage in adjacent tissues. It avoids the side effects of the anticoagulant drugs such as wound drainage, hematoma, and gastrointestinal and intracranial bleeding and also enhances the effects of anticoagulant.

Early mobilization: it has shown that early mobilization reduces the incidence of DVT in patients undergoing TJA [8]. Patients are encouraged to be mobilized as soon as feasible. These act by increasing the velocity of venous blood flow and preventing stasis as well as decreasing the coagulability of blood by stimulating fibrinolysis. Early mobilization is the simplest, cheapest, and easiest method to prevent DVT after any surgery. The more you mobilize the patient on the first postoperative day, much lesser is the DVT incidence. The incidence reduces by a third in those who mobilize more than 1 m on the first postoperative day, and it reaches zero in those who mobilize more than 5 m [9]. Physical methods can be combined with pharmacological methods also for better control.

Intermittent pneumatic compression device (*IPCD*): inflatable garments are wrapped around the legs, which are intermittently inflated by a pneumatic pump enhancing venous return. Two meta-analyses found that rates of DVT after total knee arthroplasty were much lower with intermittent pneumatic compression devices or LMWH (17–29%) than with aspirin or warfarin (45–53%) [10].

Foot impulse devices (or foot pumps): it increases venous outflow and reduces stasis in immobilized patients. It artificially compresses the venous plexus around the sole, mimicking normal walking and reducing stasis in immobilized patients.

4.1.2. Chemoprophylaxis

Aspirin: it is an inhibitor of the cyclooxygenase enzyme system. It is the most simple and commonly used drug for thromboprophylaxis. It is very cheap, patient compliant and with least side effects. Aspirin inhibits COX1 more than COX2. COX1is chiefly expressed on platelets, which helps in platelet aggregation. Meta-analysis showed that aspirin was effective in reducing the rate of DVT to 30.6% from 48.5% [11]. Conflicting literature exists with regard to the efficiency of aspirin in preventing DVT. Aspirin is inferior to warfarin or LMWH in terms of preventing symptomatic PE or proximal DVT [8]. Also, the rate of complications is very low with the use of aspirin. Pulmonary embolism prevention (PEP) trial [12] which concluded that low-dose aspirin, when taken for 35 days, would result in seven times less symptomatic DVT cases, but three bleeding cases and two nonfatal myocardial infarction per 1000 patients. Studies have shown up to 0.13% developing hematoma and bleeding with warfarin in comparison to 0% with aspirin [13]. Studies have been done comparing the incidence of VTE, PE, proximal DVT, and distal DVT in multimodal prophylaxis methods with aspirin and warfarin. They have showed lower incidence of all types of thromboses with aspirin group [14].

Warfarin: warfarin is a vitamin K antagonist. It has been used extensively for DVT prophylaxis since decades. It was the first oral anticoagulant. However, the usage is restricted by the bleeding risk, potential drug interaction, and requirement for constant monitoring (INR). Warfarin inhibits the maturation of vitamin k-dependent coagulation factors in the coagulation cascade. Multitude of studies has been carried out comparing the efficacy of warfarin and LMWH. Majority of them showed LMWH was a more effective agent to prevent DVT formation ($P < 0.05$), but no difference to warfarin in preventing symptomatic events including PE [15]. Though regular INR monitoring is needed with warfarin, it significantly reduced the incidence of DVT when compared to aspirin but less effective than LMWH [11].

Low molecular weight heparins (*LMWHs*): another widely used drug is low molecular weight heparin (LMWH). LMWHs are fragments of heparin produced by chemical or enzymatic depolymerization. LMWH has the highest efficacy in terms of preventing VTE. Few available ones are enoxaparin, dalteparin, and tinzaparin. Among these three, only two (enoxaparin and dalteparin) are indicated in major orthopedic surgery [16]. The ACCP recommends the use of LMWH in preference to other agents [17]. With the use of LMWH, the rate of fatal PE is reduced to 0.04% (from 0.16%), but the rate of clinically significant bleeding increased from 1.67% to 2.22% [18]. Its advantages are predictability, dose-dependent plasma levels, no need for regular monitoring, a long half-life and less bleeding for a given antithrombotic effect, low risk of immune-mediated thrombocytopenia, and heparin-induced osteoporosis.

Novel oral anticoagulants: since 2000, newer oral anticoagulants were introduced, collectively known as novel oral anticoagulants. They inhibit specific steps in the coagulation pathway. New oral anticoagulants include two classes of drugs—direct thrombin inhibitors and factor Xa inhibitors. Factor Xa inhibitors are mainly rivaroxaban and apixaban. They act by binding to the active site of factor Xa, thus inhibiting the interaction with its substrate. Dabigatran is the first FDA-approved direct thrombin inhibitor. Another DTI—Ximelagatran—was introduced but had to be withdrawn from market in 2006 as the FDA-denied approval (**Figure 4**).

The advantages of these agents are rapid onset of action, predictable anticoagulant response, no need for monitoring, wider therapeutic index, fewer drug–drug and drug-food interactions, reduced or comparable rates of thrombosis, bleeding, and other adverse events, and being orally administered, it is convenient and compliant. Many studies have come up with conflicting conclusion regarding these molecules.

Figure 4. The new oral anticoagulants and their mode of action.

http://dx.doi.org/10.5772/intechopen.73645

Rivaroxaban: these US FDA-approved drugs were launched after four phase III trials. Studies showed that these groups of drugs showed to be more effective than LMWH in reducing overall VTE incidence and mortality rate in TKA patients with no additional risk of bleeding [19, 20]. But most of the large-scale studies have shown increased risk of bleeding with rivaroxaban when compared to LMWH even though statistically not significant. Apart from the drug reactions and risk of bleeding, these have drug interactions with NSAIDs which the treating surgeon has to be aware of (**Figure 5**).

Apixaban: it is another class of DTI with similar mechanism of action as of dabigatran. It exerts minimal impact on PT, INR, and aPTT. American College of Cardiology (ACC) and American Heart Association (AHA) in 2011 released a focused update recommendation on dabigatran vs. warfarin comparison which stressed its use as an alternative to warfarin in patients with increased risk of developing deep vein thrombosis.

Dabigatran: it is a direct thrombin inhibitor which cleaves both free and fibrin-bound thrombin. FDA investigated the rates of GI bleed and intracranial hemorrhages with dabigatran and warfarin and initially concluded that they both showed similar results. But a similar trial in Europe (RE-ALIGN trial) was stopped as the dabigatran users showed higher incidence of strokes, heart attacks, and thrombosis on prosthetic heart valves. Hence, it is not advised in patients with renal/hepatic impairment or prior history of GI bleeds or recent ulcers.

Creatine Clearance (mL/min)	>50	50-30	29-15	<15 or HD
Atrial fibrillation	20 mg po daily	15 mg po daily		Avoid use
Postoperative thromboprophylaxis	10 mg po daily **Knee:** 12-14 days **Hip:** 35 days	10 mg po daily, use with caution	Avoid use	Avoid use
Treatment of PE/VTE	15 mg twice daily x21 days, then 20 mg po daily	Use with caution	Avoid use	Avoid use
Secondary Prophaxis for PE/VTE	20 mg po daily	Use with caution	Avoid use	Avoid use

Figure 5. Figure showing the characteristics of rivaroxaban.

4.1.3. Multimodal methods

Combining mechanical and pharmacological prophylaxis enables greater reduction of the risk of DTV. It also reduces the dosage of anticoagulants and thus the risk of bleeding, and achieves the same or even better thromboprophylaxis than monotherapy. Classifying patients into low or high risk of developing VTE is advocated. Low-risk patients received aspirin and intermittent calf compression, whereas high-risk patients received LMWH or warfarin and intermittent calf compression. All patients have to be mobilized within 24 h of surgery.

Few studies have advocated less potent pharmacological agents for low-risk patients and more potent agents for high-risk patients as the results showed negligible incidence of DVT, PE, and wound hematoma in both the groups [21]. Few recent studies show superior effects for aspirin in multimodal thromboprophylaxis when compared to warfarin [13, 14, 22].

4.1.4. Concerns with thromboprophylaxis

The risks associated with thromboprophylaxis are mainly hemorrhage, wound hematoma, persisting wound drainage, failure of wound healing, risk of infection, and blood loss requiring transfusion. One of the main drawbacks of initiating thromboprophylaxis is the high incidence of major bleeding, reaching up to 4–7.9% [23]. More potent the prophylactic agent, more the incidence. Oral agents hence have lower bleeding rates [15]. A study on 290 patients post-TJA using 10-day course of inj. enoxaparin 30 mg twice daily showed high incidence of 3–5% of readmission, re-exploration, and prolonged hospitalization for wound drainage and bleeding [24]. There were increased rates of return to the operating room for wound complications, wound drainage for more than 7 days, and incidence of symptomatic DVT in 3.8% patients and nonfatal PE in 1.3% patients. Parvizi et al. reviewed 78 septic failure cases that underwent revision and showed a direct correlation between excessive anticoagulation and development of periprosthetic infection [25]. The occurrence of such complications after elective TJA due to the use of prophylactic agents is heartbreaking to most surgeons.

Also, timing of initiation of the prophylaxis is also debated. Two schools of thought are initiation of LMWH 12 h preoperative and 12 h postoperative. Earlier initiation of prophylaxis has shown greater efficacy in preventing DVT but also causes a higher incidence of bleeding. The decision about which agent and when to initiate chemoprophylaxis should be based on the balanced efficacy-bleeding ratio of the prophylactic agents [26].

There is still no consensus on the duration of the use of prophylaxis too. The recently released new AAOS guidelines do not provide a specific duration for prophylaxis [27]. Earlier ACCP guidelines advocated a minimum of 10 days of prophylaxis, with extended prophylaxis up to 35 days. AAOS advised different duration for different agents: LMWH/fondaparinux for 7–12 days and aspirin/warfarin for 6 weeks. Extended prophylaxis with only LMWH was effective post THA, but not TKA [28].

5. Current trend

Ideal DVT prophylaxis method still remains an enigma. The choice is based on patient characteristics and surgeon's experience. Aspirin is recognized as a primary chemoprophylactic agent with the adaptation of the recent ACCP guidelines by the Surgical Care Improvement Project (SCIP). They strongly endorse risk stratification for VTE prophylaxis and opined that aspirin will become the mainstay of prevention of VTE for the majority of patients after TJA. Thus, we could optimize outcomes for our patients, by preventing the feared VTE while limiting bleeding complications that can occur with other aggressive anticoagulants [29]. Identifying and stratifying the patients at risk for DVT remains a challenge. As a general consensus, it is taken that patients post TJA can receive aspirin as thromboprophylaxis without much risk. But, those patients at very high risk may need more potent agents and careful monitoring [30].

Further research is needed to identify patients at major risk and probability of VTE and bleeding. The current clinical guidelines provide an orthopedic surgeon with more latitude, and choices of VTE prophylaxis without emphasis on aggressive chemical, and often unneeded prophylaxis. The key to determining the appropriate chemical prophylaxis for patients is to balance safety and efficacy while minimizing bleeding. Modern arthroplasty surgeons advocate early postoperative mobilization and use of mechanical prophylaxis in combination with chemoprophylaxis according to the risk stratification, which of course seems to be a reasonable safer approach.

Author details

Melvin J. George

Address all correspondence to: johnirimpenz@yahoo.co.in

Sree Narayana Institute of Medical Sciences, Kochi, Kerala, India

References

[1] Liberman JR, Hsu WK. Prevention of venous thromboembolic disease after total hip and knee arthroplasty. Current concepts review. Journal of Bone and Joint Surgery. American Volume. 2005;**87**:2097-2112

[2] Kanchanabat B, Stapanavatr W, Meknavin S, Soorapanth C, Sumanasrethakul C, Kanchanasuttirak P. Systematic review and meta-analysis on the rate of postoperative venous thromboembolism in orthopaedic surgery in Asian patients without thromboprophylaxis. The British Journal of Surgery. 2011;**98**:1356-1364

[3] Cannegieter SC, Doggen CJ, van Houwelingen HC, Rosendaal FR. Travel-related venous thrombosis: Results from a large population-based case control study (MEGA study). PLoS Medicine. 2006 Aug;**3**(8):e307

[4] Mayo J, Thakur Y. Pulmonary CT angiography as first line imaging for PE: Image quality and radiation dose considerations. American Journal of Roentgenology. 2013;**200**:522-528

[5] Howie C, Hughes H, Watts AC. Venous thromboembolism associated with hip and knee replacement over a ten-year period: A population-based study. Journal of Bone and Joint Surgery. British Volume (London). 2005;**87**:1675-1680

[6] Kume H, Inoue Y, Mitsuoka A, Sugano N, Morito T, Muneta T. Doppler ultrasonography-aided early diagnosis of venous thromboembolism after total knee arthroplasty. European Journal of Vascular and Endovascular Surgery. 2010;**40**(5):664-668

[7] Kim K-I, Kang D-G, Khurana SS, Lee S-H, Cho Y-J, Bae D-K. Thromboprophylaxis for deep vein thrombosis and pulmonary embolism after total joint arthroplasty in a low incidence population. Knee Surgery & Related Research. 2013;**25**(2):43-53

[8] Husted H, Otte KS, Kristensen BB, Orsnes T, Wong C, Kehlet H. Low risk of thromboembolic complications after fast-track hip and knee arthroplasty. Acta Orthopaedica. 2010;**81**:599-605

[9] Chandrasekaran S, Ariaretnam SK, Tsung J, Dickison D. Early mobilization after total knee replacement reduces the incidence of deep venous thrombosis. ANZ Journal of Surgery. 2009;**79**:526-529

[10] Westrich GH, Haas SB, Mosca P, Peterson M. Meta-analysis of thromboembolic prophylaxis after total knee arthroplasty. Journal of Bone and Joint Surgery. British Volume (London). 2000;**82**:795-800

[11] Freedman KB, Brookenthal KR, Fitzgerald RH Jr, Williams S, Lonner JH. A meta-analysis of thromboembolic prophylaxis following elective total hip arthroplasty. The Journal of Bone and Joint Surgery. American Volume. 2000;**82**:929-938

[12] Prevention of pulmonary embolism and deep vein thrombosis with low dose aspirin: Pulmonary Embolism Prevention (PEP) trial. Lancet. 2000;**355**(9212):1295-1302

[13] Ibrahim J, Raphael EH, Tischler RH, Richard H, Rothman WJ, Hozack JP. Aspirin: An alternative for pulmonary embolism prophylaxis after Arthroplasty? Clinical Orthopaedics and Related Research. 2014;**472**(2):482-488

[14] Vulcano E, Gesell M, Esposito A, et al. Aspirin for elective hip and knee arthroplasty: A multimodal thromboprophylaxis protocol. International Orthopaedics (SICOT). 2012;**36**(10):1995-2002

[15] Fitzgerald RH Jr, Spiro TE, Trowbridge AA, Gardiner GA Jr, Whitsett TL, O'Connell MB, et al. Prevention of venous thrombo-embolic disease following primary total knee arthroplasty. A randomized, multi-center, open-label, parallel-group comparison of enoxaparin and warfarin. The Journal of Bone and Joint Surgery. American Volume. 2001;**83**(6):900

[16] Merli GJ, Groce JB. Pharmacological and clinical differences between low-molecular-weight-heparins. Implications for prescribing practice and therapeutic interchange. Physical Therapy. 2010;**35**:95-105

[17] Falck-Ytter Y, Francis CW, Johanson NA, Curley C, Dahl OE, Schulman S, Ortel TL, Pauker SG, Colwell CW Jr. Prevention of VTE in Orthopedic Surgery Patients. Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;**141**(2 Suppl):e278S-e325S

[18] Dhanasekara Raja P, Natesan R, George M, Kanakeshwar RB, Rajasekaran S. Multimodal thromboprophylaxis for total hip and knee arthroplasty: Understanding the when and how. Asian Journal of Arthroplasty. 2017;**2**(1):20-23

[19] Eriksson BI, Borris LC, Friedman RJ, Haas S, Huisman MV, Kakkar AK, et al. Rivaroxaban vs enoxaparin for thromboprophylaxis after hip arthroplasty. The New England Journal of Medicine. 2008;**358**:2765-2775

[20] Lassen MR, Ageno W, Borris LC, Lieberman JR, Rosencher N, Bandel TJ, et al. Rivaroxaban vs enoxaparin for thromboprophylaxis after total knee arthroplasty. The New England Journal of Medicine. 2008;**358**:2776-2786

[21] Dorr LD, Gendelman V, Maheshwari AV, Boutary M, Wan Z, Long WT. Multimodal thromboprophylaxis for total hip and knee arthroplasty based on risk assessment. The Journal of Bone and Joint Surgery. American Volume. 2007;**89**:2648-2657

[22] Vulcano E, Gesell M, Esposito A, Valle AGD. Aspirin for elective hip and knee arthroplasty: A multimodal thromboprophylaxis protocol. International Orthopaedics. 2012;**36**(10):1995-2002

[23] Sachs RA, Smith JH, Kuney M, Paxton L. Does anticoagulation do more harm than good? A comparison of patients treated without prophylaxis and patients treated with lowdose warfarin after total knee arthroplasty. Journal of Arthroplasty. 2003;**18**:389-395

[24] Burnett RS, Clohisy JC, Wright RW, McDonald DJ, Shively RA, Givens SA, Barrack RL. Failure of the American College of Chest Physicians-1A protocol for lovenox in clinical outcomes for thromboembolic prophylaxis. The Journal of Arthroplasty. 2007;**22**:317-324

[25] Parvizi J, Ghanem E, Joshi A, Sharkey PF, Hozack WJ, Rothman RH. Does "excessive" anticoagulation predispose to periprosthetic infection? The Journal of Arthroplasty. 2007;**22**(6, Suppl 2):24-28

[26] Kwong LM, Muntz JE. Thromboprophylaxis dosing: The relationship between timing of first administration, efficacy, and safety. American Journal of Orthopedics (Belle Mead, N.J.). 2002;**31**(11 Suppl):16-20

[27] Mont MA, Jacobs JJ, Boggio LN, Bozic KJ, Della Valle CJ, Goodman SB, Lewis CG, Yates AJ Jr, Watters WC 3rd, Turkelson CM, Wies JL, Donnelly P, Patel N, Sluka P, AAOS. Preventing venous thromboembolic disease in patients undergoing elective hip and knee arthroplasty. The Journal of the American Academy of Orthopaedic Surgeons. 2011;**19**:768-776

[28] Eikelboom JW, Quinlan DJ, Douketis JD. Extended-duration prophylaxis against venous thromboembolism after total hip or knee replacement: A meta-analysis of the randomised trials. Lancet. 2001;**358**:9-15

[29] Mont MA, Hozack WJ, Callaghan JJ, Krebs V, Parvizi J, Mason JB. Venous thromboemboli following total joint arthroplasty: SCIP measures move us closer to an agreement. The Journal of Arthroplasty. 2014;**29**(4):651-652

[30] Parvizi J, Huang R, Raphael IJ, Arnold WV, Rothman RH. Symptomatic pulmonary embolus after joint arthroplasty: Stratification of risk factors. Clinical Orthopaedics. 2014;**472**(3):903-912

Chapter 4

Primary Total Knee Arthroplasty in Valgus Deformity

Nikolopoulos Dimitrios, Sagos George and
Michos Ioannis

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74114

Abstract

Proper limb and component alignments as well as soft tissue balance are vital for the longevity and optimal long-term outcomes of total knee arthroplasty (TKA). The majority of orthopedic surgeons agree that the total arthroplasty procedure in valgus knees with a deformity of more than 10° is technically demanding and may prove challenging. At the time of operation, the bone and soft tissue abnormalities that should be corrected make accurate axis restoration, correct component positioning and joint stability attaining a difficult task. Specific pathologic anatomic changes associated with valgus knee should be understood preoperatively and estimated so as to select the proper surgical method, to enhance component position and to restore soft-tissue balancing. The purpose of this chapter is to consider all the valgus knee anatomical variations, to analyze the best preoperative planning and to evaluate the type of implant, constrained or not. Lastly, it will also be underlying the current main approaches and techniques to be proposed in the literature for both bone cuts and soft tissue management of valgus knees and if minimally invasive techniques can be performed in severe deformed knees.

Keywords: valgus, knee, arthroplasty, lateral approach, medial approach

1. Introduction

Angular deformities around the knee joint necessitate special consideration to restore normal alignment during total knee arthroplasty (TKA). In the region of 10–15% of patients requiring a primary TKA present with a valgus deformity (VD), the accurate correction of which still poses a challenge [1]. Excessive preoperative malalignment predisposes to a greater risk of failure compared to well-aligned knees [2]. For this reason, the restoration of the normal mechanical axis of the knee and the balance of the surrounding soft tissues have to be observed to be important for the final outcome of knee replacement operations [2–5]. Thus, the severely valgus deformed knees are associated with a worse outcome when compared with their varus counterparts [5].

The etiologic parameters of knee VD are different and multifactorial from congenital to secondary such as primary osteoarthritis. More specifically, inflammatory arthritis (rheumatic diseases), primary osteoarthritis, posttraumatic arthritis (as a result of a tibial malunion, physeal arrest, or tibial plateau fracture), or overcorrection from a high tibial osteotomy for a preexisting varus deformity are the main etiologies in adults with [2, 6]. However, a significant percentage of adults with lateral compartment arthritis and concomitant VD represents unresolved physiologic valgus deformed knees. Infrequently, persistence of genu valgus from childhood may exist secondary to metabolic disorders, such as rickets and renal osteodystrophy [7]. Overwhelmingly, the most common etiology of VD knees is primary osteoarthritis and secondly rheumatoid arthritis and posttraumatic arthritis, whereas other inflammatory disorders and osteonecrosis are scarce etiologies based on the main clinical series that utilized TKA in the last two decades [1–5, 8–16].

The valgus deformity is sustained by anatomical variations divided into bone remodeling and soft tissue contraction/elongation, and usually it is a combination of primary or secondary bone and soft-tissue abnormalities. These include contracted lateral capsular and ligamentous structures, lax medial structures, and acquired or preexisting bony anatomic deficiencies. This constellation of pathology makes attaining soft-tissue balance when the knee is returned to physiologic alignment extremely difficult [2, 4, 6]. More specifically, the contracted structures are the iliotibial band (ITB), the lateral collateral ligament (LCL), the popliteus tendon, and the posterolateral capsule (PLC). Rarely, the lateral head of the gastrocnemius and the long head of the biceps femoris are affected. Some authors also further described a posterior cruciate ligament (PCL) alteration in valgus knees, but in the literature its influence in maintaining the deformity is not universally accepted [2]. The stabilizing structures on the medial side of the knee are attenuated. Unlike its varus counterpart, bone tissue variations consist of lateral cartilage erosion, lateral condylar hypoplasia and metaphyseal femur remodeling, while the tibial plateau is usually less affected [2, 3, 8–10]. The described deformities can lead to a tibial external rotation and to a patellar lateral subluxation tendency [11].

In 2005, Ranawat described three grades of VD [1]. More specifically, in Grade-I (80%), the deformity is less than 10° and is passively correctable, whereas it is characterized by an intact medial collateral ligament (MCL). In Grade-II (15%), the axis deviation ranges between 10° and 20°, whereas the MCL is elongated but functional; and in Grade-III (5%), the axis deviation is more than 20°. All the medial stabilizing elements are typically not functional so a constrained implant usually is required [1, 10].

Understanding the specific pathologic anatomic changes associated with the valgus knee is a prerequisite so as to select the proper surgical method, to optimize component position and restore soft-tissue and gap balance [17]. Over the last 20 years, numerous approaches and soft-tissue procedures have been proposed to perform TKA in VD with the purpose to restore and maintain the limb's anatomical axis. In this chapter, we overview the most common approaches, we analyze the different techniques of succeeding anatomical axis restoration and soft tissue and gap balance, and lastly we present the literature up-to-date long-term results.

http://dx.doi.org/10.5772/intechopen.74114

2. Clinical examination and preoperating planning

Total knee arthroplasty (TKA) with valgus release is indicated when both mechanical and pharmacological nonoperative treatment modalities for end-stage degenerative joint disease have failed to relieve pain. The major contraindication to TKA is infection, and relative contraindications include young age, high activity level, and obesity [18]. Clinical evaluation and radiological assessment are extremely important as part of the TKA preoperating planning.

2.1. Knee physical examination

Patients with end-stage degenerative joint disease and valgus knee deformity have significant pain, limitation of daily living activities, increasing angular deformity, and increasing instability. In mild to severe VD, there is important ROM limitation, and in many cases night pain awakes the patient.

During standard physical examination for end-stage degenerative knee disease, the orthopedic physician should assess the patient's overall alignment both in the supine and weight-bearing positions, and the gait should be observed, in order to identify other dynamic instabilities (**Figure 1**). Both sagittal deformity (as fixed flexion contracture or recurvatum) and rotational deformity must be attended. Furthermore, the knee range of motion should be measured; the

Figure 1. Valgus left knee in standing position.

extensor mechanism status and the patellofemoral joint should be evaluated and measured [2, 6, 11].

In addition, preoperative clinical examination plays a major role for the orthopedic surgeon to determine whether the deformity is fixed, correctable or unstable. The knee should be further evaluated for anteroposterior laxity, coronal and sagittal deformity, and mediolateral instability [3]. It is very crucial to assess if VD is fixed (Ranawat Grade III) or still reducible (Ranawate Grade II or I). In fixed deformity, the lateral structures are tight and in contrast the medial ligaments are partially continent. As a consequence, in these deformities, when the lateral soft tissue release is fulfilled, the remaining laxity requires the usage of constrained prosthesis. In contrast, in a reducible deformity, soft tissue release is less invasive, and a standard unconstrained prosthesis could be used. The orthopedic surgeon would lastly perform a neurovascular examination to differentiate a possible lumbosacral or vascular disease [2, 9–11].

2.2. Radiographic evaluation

After the clinical assessment, the mandatory preoperative planning radiographs of three classic views of the affected knee are: standing anteroposterior, lateral (profile), and sunrise (**Figure 2**). The limb axis deviation measurement with long film standing views or CT-scan with anterior

Figure 2. Anteroposterior X-ray in standing position for measuring valgus deviation.

orientation of the patella is very useful and important [3]. It has been mentioned that rotation up to 20° has little effect on the measurement of the femorotibial axis deviation [19].

Based on our experience, in cases of serious bone stock deficiency, a knee computer tomography will be helpful. Attention should be paid to lateral distal femoral hypoplasia, posterior femoral condyle erosion and metaphyseal remodeling both of the femur and tibia, which can lead to malalignment or malrotation of the femoral component and which could be better measured with CT. The patellofemoral joint may also be partially dislocated.

The anteroposterior and lateral X-ray views would further aid to evaluate the amount of osseous resection needed to correct deformities without leading to knee instability. A precise knee profile view is helpful for assessing the tibial slope, and the height of the patella (alta or baja) based on the Insall-Salvati ratio. In addition, the 30° flexion patellofemoral view will help to evaluate if patella is centered in troxilia (centered, subluxation, luxation) [2, 11, 20].

In order to measure the VD level and plan the amount of surgical correction (templating), a weight-bearing long leg X-ray view is fundamental so as to evaluate the lower limb alignment (mechanical and anatomical axis) (**Figure 3**). Stress radiographs or fluoroscopic examination may be used to determine the amount of medial instability [2]. A baseline electromyogram should be made for patients presenting with symptoms such as hypoesthesia, dysesthesia, and paresthesia that may be attributed to lumbosacral disease [2, 11].

2.3. Templating

In the radiographic weight-bearing anteroposterior view of the knee, a template of bone cuts should be performed in consideration with the prosthesis type and design that will be implanted in the candidate for TKA. Two lines are drawn: one line on the tibial anatomical axis and afterward a perpendicular one at the level of the lateral tibial plateau. In that way, the surgeon will have an indication for the tibial resection [2, 4]. Firstly, the femoral anatomical axis is drawn and secondly the line with the desired amount of remaining valgus (usually 3°) at the level of the intercondylar notch [4]. The orthopedic surgeon should also observe the

Figure 3. Anteroposterior X-rays in standing position of Valgus knees in different grades.

posterior capsule's presence of osteophytes, on the knee X-ray lateral view. Lastly, the lateral view can be further used for sizing the femoral component and for locating the entry point of the femoral canal [1, 11, 17].

2.4. Component selection

During preoperating planning, the orthopedic surgeon selects the implant. The selection should be carried out based on the clinical evaluation and the radiological measurements, but the final decision should be taken during the operation and after the knee bone cuts and soft-tissue balancing. That is why valgus knee surgeons always have plane A and plane B in the prosthesis selection (constrained component, VVC or classical), especially in severe deformed knees.

Preferably, in proper restored soft-tissue balancing, a minimally constrained component can be implanted. Nevertheless, if significant deformity necessitates posterior cruciate ligament (PCL) sacrifice for soft-tissue balancing, the majority of surgeons agree that a more constrained posteriorly stabilized (PS) component must be used [6]. PS knee components provide some degree of posterior stabilization as well as protection against posteromedial, posterolateral, straight medial, or straight lateral translation, but it will not protect against residual medial laxity, which is one of the major considerations in achieving proper balance in VD knees [9, 10, 18].

The debated issue between posterior-stabilized (PS) and cruciate-retaining (CR) implants in VD is that the PCL is often contracted and it may limit the deformity correction [10, 21]. It is true that in specific cases, the deformity correction with an intact PCL may be difficult to be obtained, as the PCL is a secondary stabilizer [22, 23]. Above and beyond, the PS design is more stable than a CR one due to the post-cam mechanism, and the PS design allows greater lateralization of the femoral and tibial components that improves the patella tracking and minimizes the necessity performing a lateral retinacula release [1, 2]. For these reasons, in VD knees, some orthopedic surgeons prefer a contracted PCL with a PS design as simplest as to stabilize it by using a CR implant [6].

McAuley et al. also presented that CR implants could be used in a wide range of VD osteoarthritic knees and that survival is improved when the LCL and/or the popliteus tendon are preserved. Release of both the PCL and popliteus is one of the two factors that made revision resulting from wear, osteolysis, or instability more likely, whereas, release of both the LCL and popliteus increased the likelihood of revision by 19.9 times due to more mediolateral laxity [24].

A debated issue is the amount of constraint needed to balance a VD knee. Favorito et al. proposed that the surgeons should resist the temptation, if possible, of a more highly constrained prosthesis. Although a highly constrained component may be necessary in difficult revision cases, they are infrequently necessary for primary arthroplasties [6]. In severe VD knees, the problem is that the PCL may be stretched or elongated, which means nonfunctional and these knees require either an ultra-congruent (VVC or hinged) or PC component.

Additionally, in extremely deficient lateral femoral condyle valgus knees, the usage of component augmentation blocks may be required. That is because the lateral femoral condyle may have had little or no distal femoral bone resected or, similarly, little to no bone resected from the chamfer and posterior cuts; then component augmentation blocks may be required

[4, 6]. Nevertheless, if press-fit femoral component is being performed, then as long as native bone is resting on the medial-posterior side of the chamfer cuts, then the remaining lateral defect can be filled with autograft bone taken from other cuts during the procedure [1, 6].

3. Surgical approach and technique

In order to understand and perform the valgus knee operative procedure, the orthopedic surgeons should consider that the lateral stabilizers are of two types: (1) the lateral collateral ligament (LCL) and the popliteal tendon who insert near the flexion-extension axis and act in both knee extension and flexion and (2) the fascia lata, the posterolateral articular capsule (PLC), the biceps and the external gastrocnemius muscles who insert remotely with respect to the axis and act only in extension [17, 25].

Many and various protocols of progressive step-wise release have been proposed during the last two decades, and as a consequence, the sequence of the lateral release remains controversial. In 2003, the SOO (*Societe d'Orthopedie de l'Ouest*—Western France Orthopedics) Society presented a classification system of four types of valgus knee, with increasing surgical difficulty to be distinguished from Type I to IV. More specifically, in Type I valgus knees, the deformity can be completely reduced, without medial laxity, and with no particular problems whereas a medial approach is possible. In case of course of patellar dislocation, a lateral approach is recommended. In Type II valgus knees, the deformity is totally or partially irreducible, nonetheless without medial laxity, and is the most frequent; and lateral release is required. In Type III, the deformity is reducible, but with medial distension laxity, and then the medial laxity should be managed. Lastly, in Type IV, the deformity is irreducible, with medial distension laxity, and a combination of Types II and III problems [25].

3.1. Anterolateral approach

Keblish [11] was the first, in 1991, to recommend a lateral capsular approach for TKA in the valgus knee, and the technique was refined by Buechel [25]. It has been proved unpopular because it is considered to be technically more demanding as elevation of the tibial tubercle was also recommended. On the other hand, Whiteside in 1993 [27] and Bulki et al. in 1999 showed the outcome in VD knees with lateral approach and tibial tubercle osteotomy (TTO) [28]. The disadvantage of this approach is the TTO, which is necessary for eversion of the patella. In 1998, Fiddian et al. presented a modified lateral capsular approach with repositioning of vastus lateralis in VD knee arthroplasties with very good results [29].

A longitudinal incision along the lateral border of the quadriceps muscle was described by Keblish [11], always taking care to leave 1 cm of the lateral retinaculum, from the junction between the vastus lateralis and the quadriceps tendon to the patella, through 50% of the tendon. In difficulty of the lateral closure, it was proposed two different tricks to be facilitated. On the one hand, approximation of the infrapatellar fat pad to the patellar ligament; and on the other hand, separation of the vastus lateralis from the rectus femoris, followed by suturing together the two tendons in a staggered position [11].

In the anterolateral approach, as described in detail by Nikolopoulos et al. [4, 17], a straight midline skin incision is followed by a lateral parapatellar capsulotomy. The ITB is next elevated from Gerdy's tubercle. Also, in order to medially displace the patella, TTO is performed laterally, leaving the soft tissues intact medially. The TTO length measures 5–6 cm, whereas proximally, at the upper part of the patellar tendon insertion, the transverse part of the osteotomy prevents proximal migration. The tibial tubercle is hinged medially, hence offering a wide exposure of the joint surface (**Figure 4**).

Tibial resection is done—directing the level of the cut perpendicular to its longitudinal axis. After removal of the osteophytes, especially in the lateral tibial plateau, a resection must always be performed from 6 to 8 mm in the medial compartment (**Figure 5**). In cases of severe bony deformity of the tibial plateau, no bone may be resected on the lateral side so as medial over-resection or malaligned cuts to be avoided [2].

The distal femoral cut is done in 3° of valgus in relation to the femoral axis. The distal femoral cut at 3° only, instead of 5–7° that applies in varus knees, protects against under-correction. A slightly more varus result has been proposed during TKA for VD to counteract any tendency for the knee to shift back into valgus [11]. In order to avoid elevation of the joint line, caution should be taken so as the lateral femoral condyle not to be over-resected [4]. In severe VD of the distal femur, Rossi et al. proposed [2] no lateral condyle distal femoral resection or minimal (1–2 mm) resection. Also the femoral resection in the medial condyle should be no more than 10 mm (usually 7–8 mm). The surgeon should also pay attention to the lateral condylar hypoplasia in VD that can determine a great intra-rotation of the components if a posterior reference is used [2]. Both the AP axis of Whiteside and the epicondyle axis are used to assess and confirm the orientation of the femoral cut [3, 4]. Arima et al., taking into consideration this aspect, utilized the usage of the anteroposterior axis so as to give the proper femoral rotation in valgus anatomy [30]. In cases of severe trochlear dysplasia, the Whiteside line is extremely difficult to be identified, so the epicondylar axis or parallel to the tibial cut technique must be used to assess a correct femoral rotation [2].

At this phase, especially for tight knees in flexion, the sub-periosteal POP and LCL elevation from the epicondyle is performed. In tight knees, PLC release could be performed in both flexion and extension. During closure, the tibial tuberosity is generally fixed to its original position or slightly more medially in cases that the patella tends to track laterally and dislocate.

Figure 4. Surgical procedure of the tibial tubercle osteotomy stages (TTO).

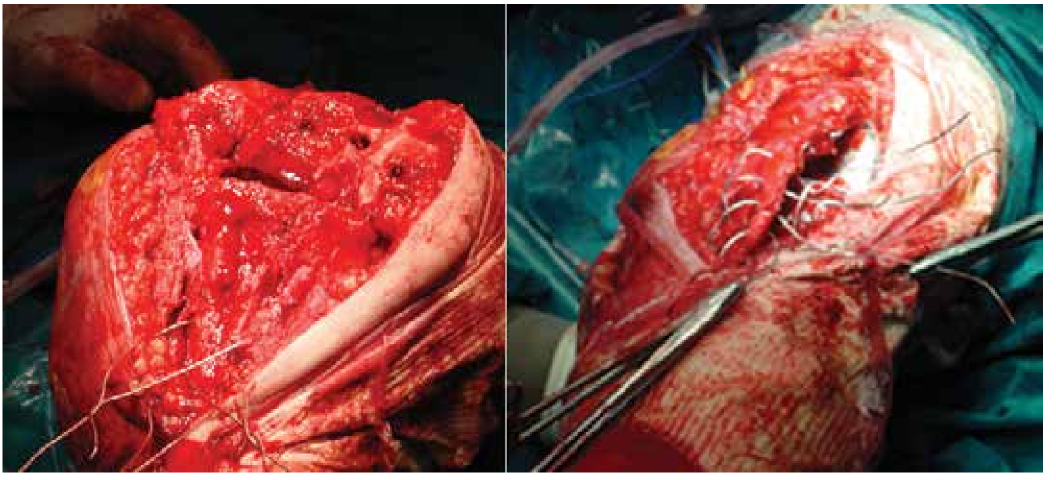


Figure 5. During operation, fixing the tibial tuberosity osteotomy with three loops.

Therefore, tibial tubercle transfer is necessary for satisfactory alignment. Tibial tubercle fixation can be performed even with two 4.5 mm cortical screws or with three wire loops (preferred). The oblique direction of the wire loops offers better resistance to proximal directed forces [4]. Patellar tracking was finally checked with the "no-thumb" test.

The main reasons and advantages considered of the group of orthopedic surgeons [1–4] preferring the anterolateral procedure are mainly three. Firstly the lateral release, as part of the approach, is usually necessary in VD knees and it does not seriously impair the extensor mechanism vascular supply as in medial arthrotomy. Secondly, the lateral approach facilitates the release of the lateral contracted elements, offering better surgical view and lastly the possibility to medicalize the tubercle if required improves the patella tracking [2, 4].

3.2. Anteromedial approach

The anteromedial is the standard approach being used commonly all these decades by the surgeons in the VD knees and with no contraindications [1–6]. A straight midline skin incision is performed, followed by a standard medial parapatellar arthrotomy. The tibial and femoral bone cuts followed the same technique as the one described in the anterolateral approach. In order to achieve optimal soft tissue balancing, as contracture of the ITB is noted with the knee in full extension, release is performed by elevation from Gerdy's tubercle or fractional lengthening with multiple stab wounds. An additional release includes the LCL from the distal part of the femur and popliteus [4]. In most cases with mild to severe VD, release of the posterolateral capsule is performed. The PLC is released either from the distal part of the femur, with the knee in flexion, using a curved osteotome; or with the knee in full extension, fractionally lengthening by means of multiple stabs punctures ("pie crust" technique) [1, 32]. Finally, lateral retinacular release is required to facilitate patellofemoral tracking. Tracking of the extensor mechanism is again evaluated with use of the appropriate lift-off test [3, 4].

The main disadvantage of the medial approach is that it is more difficult to reach the postero-lateral corner during the lateral soft tissue release. For this reason, sometimes a TTO is necessary. Additionally, in cases that a medial parapatellar approach is combined with a lateral release, patellar vascular damage has been described [26].

3.3. Soft tissue balancing

3.3.1. Lateral soft tissue

It is accepted worldwide that the lateral structure release is necessary in VD knees. Nevertheless, there is an open debate on the subject of the best sequence and the best technique to perform those releases. In the abovementioned part, our experience was presented [3, 4], in accordance with the main ideas of other researchers [11, 26–29, 31–34]. In that part, the literature different proposals for soft tissue balancing of the retracted lateral structures of VD knees would be analyzed. More specifically, the releases should be performed with the knee extended and by using lamina spreaders to check the tension of the medial and lateral compartments. After each release, evaluation of the alignment and the stability of the knee should be performed in order to achieve a symmetrical rectangular extension and flexion gaps with the spacer block in situ [2, 35].

First, Krackow et al. presented in type I valgus knees the release of the ITB and the LCL, followed by the PLC, POP and the lateral head of the gastrocnemius muscle (when necessary) [10]. In type II valgus deformities, a medial ligamentous reconstruction was also proposed, either proximal or distal advancement of the medial ligament mechanism according to the surgeon's preference. Buechel presented simultaneously a sequential three-step lateral release for correcting fixed VD knees during TKA, which included firstly elevation of the ITT from Gerdy's tubercle, secondly the LCL and PT, and lastly the entire periosteum of the fibular head. Ligament balancing was achieved when the knee was aligned in both the frontal and sagittal planes with a medial and lateral opening of 2–3 mm when forced valgus and varus stress were applied at 5° of flexion.

Ranawat et al. described a stepwise technique in which the first structure to be released was the PCL; and afterward, a PLC intra-articular release by using an electrocautery at the level of the tibial cut surface. The ITB is released when necessary with multiple "inside-out" stab incisions as well as the LCL. These multiple transverse stab incisions, the so-called "pie-crusting" technique, are performed a few centimeters proximal to the joint line of the ITB with a no. 15 surgical blade, lengthens as necessary the lateral side. On the contrary, the POP is normally preserved [1]. Clarke et al. [36] and Aglietti et al. [37] performed the pie-crust technique with excellent results. It is believed that the pie-crusting technique reliably corrects moderate to severe fixed valgus deformities with a low complication rate and reasonable mid-term results. The multiple punctures reduce the risk of posterolateral instability allowing gradual stretching of the lateral soft tissues and preserving the popliteus tendon [36]. Nevertheless, one of the disadvantages of this technique is the potential risk of peroneal nerve lesion [1, 36, 37]. In a cadaveric study, Bruzzone et al. observed that the nerve is at overall risk during the release of the PLC, in the triangle defined by the POP, the tibial cut surface and the most posterior fibers of the ITB ("danger zone"), but not during the pie-crusting of the ITB ("safe zone") [38].

As the LCL is the tightest more common structure, then it is the first structure to be released according to Favorito et al. The next sequential release follows is the POP (an important structure for rotational and valgus stability in flexion), the PLC, the femoral insertion of the LHG and, finally, the ITB [6].

Whiteside described a sequence of soft tissue release based on the anatomic function of ligaments in flexion and extension consistently. A ligament attached to the femur near the epicondyles, so near the axis through which the tibia rotates and the knee flexes and extends, has an important role in flexion stability. Conversely, a ligament attached far away from the epicondyle is more important for the extension knee stability. Thus, for knees that are tight in flexion and extension, the LCL and POP tendon are released. For those knees that remain tight only in extension, ITB release is needed. Posterior capsular release is performed only when necessary for persistent lateral ligament tightness [39].

In 1999, Krackow and Mihalko published a cadaveric study that assessed the amount of correction achieved in each step of release, comparing it in flexion and extension. The sequences on the one hand were ITB, POP, LCL, and LHG; and on the other hand LCL, POP, ITB, and LHG. They evaluated the amount of correction at 0°, 45°, and 90° of flexion. The results showed that the greatest varus rotation occurred once all structures were released, with the LHG origin last in both groups. The largest increase occurred after the LCL release. Then it is hypothesized that in severe VD, the LCL should be released first; and POP and ITB should be used afterward to grade the release [40].

Boyer et al. emphasized the purpose of the lateral approach in valgus knee arthroplasty, as it allows the automatic ITB division and elevation from the Gerdy's tubercle to be taken in continuity with the anterior compartment fascia and release of the attachments of the lateral part of the femur. More specifically in tight knees in extension, firstly the ITB was released. Afterwards, if additional releases are needed, a tight PLC was detached from the posterior condyles or transected at the level of the tibial cut from PCL insertion to the posterolateral corner. Release of the gastrocnemius and the biceps tendon should be considered in cases that the result was not sufficient. If the spacer introduced, then the ligament release stops to prevent varus laxity. [41].

In 2002, Brilhault et al. described an alternative technique for lateral structure release in association with a lateral parapatellar approach [42]. More specifically, a sliding osteotomy of the femoral LCL and POP insertions is done and the resulting bone block is mobilized and placed more distally. Bremer et al. presented in their study excellent result without any conversion to semi-constrained or constrained knee prosthesis [43]. Mullaji and Shetty described a more accurate repositioning of the epicondyle, after releasing the PLC and the ITB, with the use of a computer-navigated system [44]. Computer navigation while performing lateral femoral epicondylar osteotomy allows precise, controlled, quantitative lengthening of lateral structures, and restoration of optimum soft tissue balance and alignment [45].

3.3.2. *Medial soft tissue*

Krackow et al. analyzed that in Grade II VD knees, the MCL may not be completely functional and a residual medial laxity is poorly tolerated postoperatively. In these conditions, the authors suggested tightening the medial ligamentous structures, particularly if the PCL has been retained

[44]. A small bone plug with the attached insertion of the PCL, and the PLC is removed from the tibia and moved distally, securing it with transosseous sutures. In this technique, the MCL is tightened by moving a bone block distally with its tibial insertion [45].

The advancement of the MCL from the epicondyle or a division and imbrication in order to tighten it can be performed in conjunction with the use of constrained condylar prosthesis [6].

3.4. Clinical results

Accurately restoring the mechanical axis (MA) of the limb, aligning components, and properly balancing soft tissue—as already mentioned—are vital for the long-term success of TKA [1–6]. In the last three decades, a number of different surgical techniques have been described for TKA, in severe valgus deformed knees [1–6, 9–11, 18, 31–34]. The distal femoral cut at 3° only, instead of 5–7° that applies in varus knees, protects against under-correction. A slightly more varus result has been proposed during TKA for VD to counteract any tendency for the knee to shift back into valgus [31]. Miyasaka et al. in their 10- to 20-year follow-up study presented successful bony alignment in 75% of cases by having a postoperative valgus alignment between 2° and 7° [22].

Above and beyond, on the subject of ligament balancing, there is no consensus regarding the sequence in which the lateral elements should be released in valgus knees. Starting with Insall et al. [46], in 1979, who described a soft-tissue balancing technique in which the ITB was divided transversely above the joint line, while the lateral aspect of the capsule, the LCL and the POP tendon were detached from the lateral femoral condyle [9, 46]. The excellent or good results referred was 93%; with limited posterior subluxation (<3%) and 3.6% reoperation rate in 5 years [45] and 6.7% in 12 years [47].

Afterward, other researchers such as Keblish [11], Buechel [26] and Fiddian [27] recommended a lateral approach with or without TTO. Keblish preferred lateral approach in VD knees as it has a better view; it is direct, anatomical and more "physiological" technique according to his opinion that maintains soft-tissue integrity. In 79 cases, Keblish performed the "lateral release" as part of the approach and concluded that the patellofemoral tracking and alignment stability were optimized and medial blood supply preserved. Clinical experience also showed the approach to be more esthetic and the results objectively superior, that is why the lateral approach was recommended as the "approach of choice" for fixed VD in TKA. In that difficult group of patients, there were good to excellent scores in 94.3% of cases; whereas knee stability was enhanced with the use of nonconstrained prostheses [11].

Furthermore, Buechel recommended the lateral approach with TTO in order to regain neutral alignment in VD of up to 90° and then to correct the fixed external tibial rotation deformity [26]. Fiddian et al. performed the lateral approach with repositioning of vastus lateralis at closure, with good to excellent results in 25 cases. The knee ROM and VD restoration were achieved in all the 25 cases; apart from two cases that developed 10° and 15° of fixed flexion deformity. With the repositioning of vastus lateralis at the end, the normal patellofemoral tracking was also restored [29].

Whiteside proposed the sequential releases of the ITB, POP, LCL and the lateral head of gastrocnemius; and tibial tubercle transfer when the Q angle was >20° [27]. He referred mean valgus angle at 7° after surgery; but with no alignment or varus-valgus stability deterioration during the 6-year follow-up period. Nevertheless, in greater than 25° VD, knees had a tendency for increased posterior laxity. Lastly, Whiteside presented patellar subluxation and dislocation in less than 1% in the study [27].

Conversely, Krackow [10, 40, 45] and Healy [48] recommended medial soft-tissue advancement or reconstruction combined with lateral release. To be more specific, Krackow and Mihalko [40] studied in cadavers the flexion-extension joint gap changes after lateral structure release for VD correction in TKA and concluded that in severe valgus deformities, the LCL should be considered first for release and the POP and ITB be used to grade the release. In their series of 99 TKA, the Grade I VD knees (based on Ranawat classification) were treated with lateral release versus the Grade II VD knees which were treated with ligament reconstruction procedures on the medial side. The 72% of the patients referred excellent results whereas 18% good, 7% fair, and 2% poor [45]. Healy et al. presented, in Grade II VD knees, lateral ITB release in combination with proximal MCL advancement with bone plug recession, with fully stable and functional ROM at 4–9 years follow-up [48].

Apart from Krackow cadaveric study, extremely interesting results published in 2001 by Peters et al. who studied the flexion-extension gap symmetry during sequenced release of the lateral structures in VD knees. It is concluded that complete release of the ITB at the joint line had a more profound effect on the extension than the flexion gap. On the contrary, complete release of the LCL/POP from the femur more profoundly affected the flexion than the extension gap; both of these release steps produced gap increases that were significant (7–12 mm). Selective fractional lengthening of the ITB, the PLC, and the POP tendon alone produced smaller magnitudes of correction, which more symmetrically affected flexion-extension gaps [49].

Above and beyond, in 2004, Politi and Scott referred, good-to-excellent results in TKAs with VD >15°, and achieved soft tissue balance, with a lateral cruciform retinacular release, and without LCL and POP release in 32 out of 35 cases [50]. In the remaining three cases, the extension gap balancing was achieved by adding, apart from the lateral cruciform retinacular release, the LCL and POP partial release. No further prosthetic constraint was necessary following these releases, and these knees have remained clinically stable at their latest mean 3.4-year follow-up despite the partial release of the LCL and its contribution to flexion gap stability [50].

Stern et al. accomplished ligamentous balancing in TKAs with VD >10°, with sequential releases from the lateral side of the femur and without MCL reconstruction, achieving 91% of good-to-excellent results. The postoperative axis alignment was 5–9° valgus [31]. Likewise, Laurencin et al. reviewed TKAs with 25° VD, where lateral retinacular release was accompanied by sequential lateral release achieving postoperative anatomic alignment between 0° and 10° valgus, in 96% patients [51].

In 2014, Chalidis et al. presented the results of 57 Grade II VD knees that underwent a primary TKA via lateral parapatellar approach with a global step-cut "coffin" type TTO over a 10-year period. Postoperatively, there was a significant improvement in knee extension, flexion, Knee Society Pain and Function Scores and WOMAC Osteoarthritis Index. Congruent patellar tracking was observed in all cases. So, the researchers concluded that lateral approach in combination with TTO is an effective technique for noncorrectable valgus deformed knee in TKA [52].

Brilhault et al. also proposed in 2002 an interesting balancing way for VD knees by treating 13 patients with fixed VD of the knee with a semi-constrained TKA combined with advancement of the LCL by means of a lateral femoral condylar sliding osteotomy [42]. At follow-up of mean 4.6 years, the mean Knee Society Score improved from 32 to 88 and the functional score from 45 to 73 conversely. The mean tibiofemoral angle was corrected from 191° to 180°. There was no postoperative tibiofemoral or patellar instability and, in most knees, distal transposition of the lateral femoral condyle achieved satisfactory stable alignment [42].

Hadjicostas et al. used computer navigation in severe VD (>20°) knees in combination with an osteotomy of the lateral femoral condyle. The correct mediolateral balancing of the extension gap was confirmed by the navigation system during the operation time and before the final fixation of the lateral femoral condyle. The 15 knees were corrected to a mean of 0.5° of valgus (0–2°), with excellent mid-term results referred by the authors. Lastly, flexion of the knee statistical significantly also improved to a mean of 105° (90–130°) postoperatively, and the mean Knee Society score improved from 37 (30–44) to 90 points (86–94) [53].

As a consequence, the "outside-in" or the "inside-out" technique has been proposed by different surgeons with similar results, such as Keblish, Murray, Stern, Buechel [4, 8, 9, 11, 26, 29, 31]. Likewise, the "pie crust" technique has also been proposed by Ranawat as an alternative way of knee balance, plus Clarke through the taut PLC or ITB with the knee fully extended [36, 37, 54]. If the lateral release cannot sufficiently stabilize flexion and extension gaps, then the medial side of the joint should be addressed, in an effort to limit the degree of lateral soft-tissue release [4, 6]. Several techniques have been similarly described for successfully and safely "tightening" the incompetent MCL [10, 40, 48].

Taking into consideration firstly that many surgeons find it difficult to correct a VD by using a conventional alignment guiding system without also using a constrained implant; and secondly that a marked coronal femoral bowing deformity is easily missed [55, 56]. Huang et al. proposed, in 2016, that the use of a computer-assisted surgery (CAS) for an intra-articular bone resection is effective for increasing the accuracy and reproducibility of limb and component alignment with fewer outliers [55]. Both intra-articular bone resection and CAS are beneficial in Ranawat arthritic type-II VD knees with marked coronal femoral bowing deformity as with a rather high prevalence has been reported in Japan, China, Korea, India, Taiwan, Singapore, and Turkey. The marked coronal bowing deformity alters the relationship between the MA and anatomical axis (AA) of the femur, thereby affecting the postoperative MA and the placement of the femoral component [55, 56]. The most important Huang's et al. study finding was that CAS was more efficacious than intra-articular resection for facilitating a properly reconstructed MA, femoral component placement, and restoration of the joint-line in TKA on patients with marked coronal femoral bowing deformity. Nevertheless, CAS did not yield a better clinical outcome at a mean follow-up of 60.2 months [55].

3.5. The advantages of the anterolateral approach and the lateral balancing versus hazards of anteromedial approach

The medial parapatellar release arthrotomy though suggested as a standard procedure in a varus knee does not represent the optimal approach in a severe and technically demanding VD knee [4]. That is because the release of lateral patellar retinaculae is necessitated in most VD cases in order to prevent patellar instability. The latter as accompanied with medial capsulotomy results in significant impairment of the knee extensor mechanism's blood supply [57]. Though if the knee joint is approached via a lateral parapatellar arthrotomy, release of the lateral retinaculae is integrated in the approach and patella vascularity is preserved as the medial side stays undisturbed [4, 10, 57]. Laurencin reported 12% of patella avascular necrosis in medial parapatellar approach for TKA in combination with extensive lateral retinacular release [51]. Miyasaka also reported only one case out of 108, in which a patella fracture occurred 3 years after surgery which was believed to be secondary due to avascular necrosis [31]. In Nikolopoulos et al. series, no patella fracture or avascular necrosis was observed [3, 4].

Very important also in the knee extensor mechanism is the scar tissue due to previous knee's surgical operations. More specifically, scar tissue from previous tibial osteotomy makes patella's eversion problematic, and there is always a hazard for patellar ligament avulsion by forceful intraoperative retraction. Therefore, in order to protect the knee extensor mechanism, additional surgical techniques are needed either proximally (V-Y quadricepsplasty or "quadriceps snip") [58, 59] or distally to the patella with TTO [4, 6, 28, 34, 60–63]. We believe that the eversion of the patella is easily performed when a TTO is added to the lateral approach in primary TKA with severe valgus deformity, offering excellent view [4].

Likewise, in a lateral capsulotomy, the extensor mechanism is displaced medially, and as the tibia rotates internally, offers an excellent exposure of the contracted lateral structures, thus facilitates their adjustment. This encourages more conservative releases and significantly, discourages unnecessary steps that may create instability [4, 11]. In contrast in the medial approach, the lateral displacement of the extensor mechanism increases the external tibial rotation, pushing the contracted PLC away from the operative field and consequently technical difficulties in balancing the valgus knee [11]. Analyzing the literature on the subject of TTO, it has been valuated as a highly beneficial and safe procedure in achieving gentle eversion of the patella [4, 6, 28, 35, 60–63]. Besides, it prevents tibia internal rotation during patellar eversion, which may simplify proper positioning of the tibial component in severe valgus knees [4, 10, 63].

Furthermore, in a medial approach, the patella tracking is less than optimum and postoperative patellar problems are more common [10, 11, 27]. In opposition, the patellar tracking in a lateral approach is assured with the self-centering movement of the quadriceps-patellar tendon mechanism [11, 27]. In cases where a TTO is added, alignment of the extensor mechanism can be improved or adjusted when required, as osteotomy fixation at the end of the operation allows medial transfer of the patellar tendon insertion, eliminating in that way the postoperative patellar maltracking [4, 11]. In Nikolopoulos et al. series [3, 4], no patellar instability

Figure 6. Severe valgus deformity (A). Full correction after the operation (B).

was observed postoperatively in the group of lateral parapatellar arthrotomy combined with TTO, as we had the chance to release the soft tissues easily and to transfer the tuberosity medially in two cases, succeeding the optimal quadriceps-patella tendon balance [4].

Burki et al. observed good results in 88% of their cases by applying TTO as part of lateral approach in revision valgus TKAs. No complications were reported from the osteotomy side, apart from one case complicated with anterior tibial compartment syndrome [28]. We also presented one case in our series [3]. Burki et al. hypothesized that TTO may traumatize the anterior tibial compartment; that is why it was recommended as a standard procedure the release of the anterior tibial fascia with several longitudinal incisions [28]. The length of the osteotomized tubercle in our series were 5 cm [3, 4] versus 7 cm in Burki series [28]. That was with the purpose of avoiding tibial fractures. Piedade had 8.7% of TTO fractures and tibial plateau fissures [63]. Consequently, consideration needs to be given to the size of the bony fragment and the quality of the fixation with respect to achieving sound consolidation of the osteotomy [4].

The results in valgus knees arthroplasties with medial parapatellar capsulotomy have been inferior to those of varus knees with significant deformity [5]. Karachalios et al. mentioned the residual VD in these knees with arthroplasty did not result in early component failure, but was associated with a worse clinical outcome [5]. The literature on the other hand refers 70–78% of full restoration of the anatomical axis in valgus knees [2, 5, 6, 9]. Incomplete axis restoration has been linked with impaired clinical outcome [4, 5]. Conversely, the authors using lateral parapatellar capsulotomy have reported better results in terms of anatomical axis correction and also in terms of clinical performance [11, 26, 64]. Besides, in cases with moderate or severe VD, an excellent decision with very good results is the use of a PCL-sparing prosthesis as Krackow et al. [10] showed.

Last of all, it is very important to resume the results of the open debate: "which approach leads to better outcome?" The recent studies which compare standard medial parapatellar approach versus lateral parapatellar with TTO showed the following:

(a) Nikolopoulos et al. [4] reported no statistically significant differences in terms of clinical results, on the groups of lateral approach combined with TTO vs. a standard medial approach (**Figures 6** and **7**). Nevertheless, in the lateral approach group, a valgus deviation occurred in 9% of the patients compared to 32% in the medial one [4].

Figure 7. Profile standing position knee X-ray. Oblique direction of the wire loops for resistance to upwards pulling forces and step at the upper part of osteotomy, preventing the proximal migration.

(b) Hirschmann et al. showed that the lateral parapatellar approach with TTO leads to at least comparable functional results and less pain after TKA at 2 years follow-up. The burning question for the researchers, however, remained if this can outweigh the higher risk of early complications and revisions [36].

(c) Sekiya et al. [35] reported the clinical and radiological results in two randomized groups of patients (medial vs. lateral without TTO) after performing a TKA in valgus knees. They found no significant differences in ROM between the groups, but better postoperative flexion was mentioned in the lateral group.

Hay et al. had randomly divided 32 patients into two groups, the one in which the lateral subvastus approach combined with a TTO was performed and the other with the medial parapatellar approach. No significant differences were found between the groups in the parameters of clinical outcome, as the ROM, the VAS score, the Western Ontario McMasters University Osteoarthritis index, and the KSS at 2-year follow-up. It was found significant better patellar tracking in the group of lateral subvastus approach combined with TTO. Due to complications related with TTO and longer surgical time (10–15 min) in the lateral approach, the researchers did not support its routine use of the except for the patients in whom problems with patellar tracking were anticipated [65].

4. Complications

Several complications have been reported in valgus knee arthroplasties. More specifically, Favorito et al. [6] presented in a review article the main complications referred in the literature. The most commonly reported complications are tibiofemoral instability (2–70%), recurrent valgus deformity (4–38%), postoperative motion deficits which requires manipulation under anesthesia (1–20%), wound problems (superficial or deep infection) (4–13%), patellar stress fracture or osteonecrosis (1–12%), patellar tracking problems (2–10%), and peroneal nerve palsy (1–4%) [1, 2, 4, 8, 10]. Nikolopoulos et al. also referred one case of a 5 mm proximal migration of the osteotomized fragment occurred which was stabilized with screws only, without the use of wire loops. However, this did not affect the final outcome, despite breakage of one screw (**Figure 8**) [3].

One more very important complication after TKA for VD that has been cited is the peroneal nerve palsy. Due to the femorotibial axis deformation and the elongation of the lateral side, the nerve is stretched and is placed at risk for indirect injury via traction or induced ischemia [4, 6, 23]. Other indirect mechanisms of injury may include compression or crushing from tight dressings [66]. Also, the "pie crust" technique as part of the lateral release when is used puts the peroneal nerve in hazard, so greater deal of safety concern should be accomplished [28, 36, 38]. According to the literature, Idusuyi and Morrey [67] reported 32 postoperative peroneal nerve palsies in more than 10,000 consecutive TKAs. Ten out of the 32 palsies had 12° or more of preoperative VD. The lengthening of the lateral aspect during lateral stabilizer release and subsequent traction to the peroneal nerve presumably caused the palsy. That is

http://dx.doi.org/10.5772/intechopen.74114

Figure 8. Profile Knee X-ray. Fixation with screws only: Six weeks post-op, slight proximal migration of tubercle, with one screw broken.

why our recommendation is generally patients' careful evaluation for palsy symptoms postoperatively. If peroneal nerve palsy type symptoms are discovered, the knee should be flexed to relax the tension that is effectively being placed on the nerve. There are no objective guidelines or data to support the efficacy of any immediate surgical intervention [67].

5. Conclusion

TKA is a well-established procedure and has proven to be durable and effective for the treatment of advanced arthritis of the knee joints; however, the long-term follow-up in VD arthritic knees was relatively inferior to those of varus counterparts. The main reason for poor prognosis is the difficulty to achieve good soft-tissue balance during the operation, and this is the challenge for every orthopedic surgeon in knee arthroplasties. In this chapter, we analyzed in detail the valgus knee philosophy, the approaches and surgical techniques proposed both for bone cuts and soft tissue management analyzing in detail the pros and cons of each proposed technique. The surgeon in valgus knee should more confidently achieve soft tissue balancing, resulting in better load distribution and enhancing component stability and longevity.

Conflict of interest

None.

Notes/thanks/other declarations

None.

Author details

Nikolopoulos Dimitrios[1*], Sagos George[1] and Michos Ioannis[2]

*Address all correspondence to: drdnikol@hotmail.com

1 Orthopaedic Department, Central Clinic of Athens, Greece

2 D Orthopaedic Department, Asklepion Voulas General Hospital, Voula, Greece

References

[1] Ranawat AS, Ranawat CS, Elkus M, Rasquinha VJ, Rossi R, Babhulkar S. Total knee arthroplasty for severe valgus deformity. The Journal of Bone and Joint Surgery. American Volume. 2005;**87**:271-284

[2] Rossi R, Rosso F, Cottino U, Dettoni F, Bonasia DE, Bruzzone M. Total knee arthroplasty in the valgus knee. International Orthopaedics. 2014;**38**(2):273-283

[3] Apostolopoulos AP, Nikolopoulos DD, Polyzois I, Nakos A, Liarokapis S, Stefanakis G, et al. Total knee arthroplasty in severe valgus deformity: Interest of combining a lateral approach with a tibial tubercle osteotomy. Orthopaedics & Traumatology, Surgery & Research. 2010;**96**(7):777-784

[4] Nikolopoulos DD, Polyzois I, Apostolopoulos AP, Rossas C, Moutsios-Rentzos A, Michos IV. Total knee arthroplasty in severe valgus knee deformity: Comparison of a standard medial parapatellar approach combined with tibial tubercle osteotomy. Knee Surgery, Sports Traumatology, Arthroscopy. 2011;**19**(11):1834-1842

[5] Karachalios T, Sarangi PP, Newman JH. Severe varus and valgus deformities treated by total knee arthroplasty. Journal of Bone and Joint Surgery (British). 1994;**76**:938-942

[6] Favorito PJ, Mihalko WM, Krackow KA. Total knee arthroplasty in the valgus knee. The Journal of the American Academy of Orthopaedic Surgeons. 2002;**10**:16-24

[7] White GR, Mencio GA. Genu valgum in children: Diagnostic and therapeutic alternatives. The Journal of the American Academy of Orthopaedic Surgeons. 1995;**3**:275-283

[8] Murray PB, Rand JA. Symptomatic valgus knee: The surgical options. The Journal of the American Academy of Orthopaedic Surgeons. 1993;**1**:1-9

[9] Elkus M, Ranawat CS, Rasquinha VJ, Babhulkar S, Rossi R, Ranawat AS. Total knee arthroplasty for severe valgus deformity: Five to fourteen-year follow-up. The Journal of Bone and Joint Surgery. American Volume. 2004;**86**:2671-2676

[10] Krackow KA, Jones MM, Teeny SM, Hungerford DS. Primary total knee arthroplasty on patients with fixed valgus deformity. Clinical Orthopaedics. 1991;(273):9-18

[11] Keblish AP. The lateral approach to the valgus knee. Surgical Technique and analysis of 53 cases with over two year follow-up evaluation. Clinical Orthopaedics and Related Research. 1991;**271**:52-62

[12] Satish BR, Ganesan JC, Chandran P, Basanagoudar PL, Balachandar D. Efficacy and mid-term results of lateral parapatellar approach without tibial tubercle osteotomy for primary total knee arthroplasty in fixed valgus knees. The Journal of Arthroplasty. 2013; **28**(10):1751-1756

[13] Rajgopal A, Dahiya V, Vasdev A, Kochhar H, Tyagi V. Long-term results of total knee arthroplasty for valgus knees: Soft-tissue release technique and implant selection. Journal of Orthopaedic Surgery (Hong Kong). 2011;**19**(1):60-63

[14] Radulescu R, Badila A, Japie I, Ciobanu T, Manolescu R. Primary total knee arthroplasty in severe valgus knee. Journal of Medicine and Life. 2013;**6**(4):395-398

[15] Girard J, Amzallag M, Pasquier G, Mulliez A, Brosset T, Gougeon F, Duhamel A, Migaud H. Total knee arthroplasty in valgus knees: Predictive preoperative parameters influencing a constrained design selection. Orthopaedics & Traumatology, Surgery & Research. 2009;**95**(4):260-266

[16] Ang CL, Fook S, Chia SL, Chin PL, Lo NN, Yeo SJ. Unconstrained arthroplasty in type II valgus knees: Posterior stabilized or cruciate retaining? Knee Surgery, Sports Traumatology, Arthroscopy. 2014;**22**(3):666-673

[17] Nikolopoulos D, Michos I, Safos G, Safos P. Current surgical strategies for total arthroplasty in valgus knee. World Journal of Orthopedics. 2015;**6**(6):469-482

[18] Lombardi AV Jr, Dodds KL, Berend KR, Mallory TH, Adams JB. An algorithmic approach to total knee arthroplasty in the valgus knee. The Journal of Bone and Joint Surgery. American Volume. 2004;**86-A**(Suppl 2):62-71

[19] Swanson KE, Stocks GW, Warren PD, Hazel MR, Janssen HF. Does axial limb rotation affect the alignment measured in deformed limbs? Clinical Orthopaedics. 2000;**371**: 246-252

[20] Robbins GM, Masri BA, Garbuz DS, Duncan CP. Preoperative planning to prevent instability in total knee arthroplasty. The Orthopedic Clinics of North America. 2001; **32**(4):611-626

[21] Mihalko WM, Miller C, Krackow KA. Total knee arthroplasty ligament balancing and gap kinematics with posterior cruciate ligament retention and sacrifice. American Journal of Orthopedics (Belle Mead NJ). 2000;**29**(8):610-616

[22] Matsuda Y, Ishii Y, Noguchi H, Ishii R. Varus-valgus balance and range of movement after total knee arthroplasty. Journal of Bone and Joint Surgery. British Volume (London). 2005;**87**:804-808

[23] Mihalko WM, Krackow KA. Anatomic and biomechanical aspects of pie crusting posterolateral structures for valgus deformity correction in total knee arthroplasty: A cadaveric study. The Journal of Arthroplasty. 2000;**15**:347-353

[24] McAuley JP, Collier MB, Hamilton WG, Tabaraee E, Engh GA. Posterior cruciate-retaining total knee arthroplasty for valgus osteoarthritis. Clinical Orthopaedics and Related Research. 2008;**466**(11):2644-2649

[25] Williot A, Rosset P, Favard L, Brilhault J, Burdin P. Total knee arthroplasty in valgus knee. Orthopaedics & Traumatology, Surgery & Research. 2010;**96S**:S37-S42

[26] Buechel FF. A sequential three-step lateral release for correcting fixed valgus knee deformities during total knee arthroplasty. Clinical Orthopaedics. 1991;**260**:170-175

[27] Whiteside LA. Correction of ligament and bone defects in total arthroplasty of the severely valgus knee. Clinical Orthopaedics. 1993;(288):234-245

[28] Burki H, Knoch M, Heiss C, Drobny T, Munzinger U. Lateral approach with osteotomy of the tibial tubercle in primary TKA. Clinical Orthopaedics. 1999;**362**:156-161

[29] Fiddian NJ, Blakeway C, Kumar A. Replacement arthroplasty of the valgus knee. A modified lateral capsular approach with repositioning of vastus lateralis. The Journal of Bone and Joint Surgery. American Volume. 1998;**80**(5):859-861

[30] Arima J, Whiteside LA, McCarthy DS, White SE. Femoral rotational alignment, based on the anteroposterior axis, in total knee arthroplasty in a valgus knee. A technical note. The Journal of Bone and Joint Surgery. American Volume. 1995;**77**(9):1331-1334

[31] Stern SH, Moeckel BH, Insall JN. Total knee arthroplasty in valgus knee. Clinical Orthopaedics. 1991;(273):5-8

[32] Miyasaka KC, Ranawat CS, Mullaji A. 10- to 20-year follow-up of total knee arthroplasty for valgus deformities. Clinical Orthopaedics and Related Research. 1997;**345**:29-37

[33] Sekiya H, Takatoku K, Takada H, Sugimoto N, Hoshino Y. Lateral approach is advantageous in total knee arthroplasty for valgus deformed knee. European Journal of Orthopaedic Surgery and Traumatology. 2014;**24**(1):111-115

[34] Hirschmann MT, Hoffmann M, Krause R, Jenabzadeh RA, Arnold MP, Friederich NF. Anterolateral approach with tibial tubercle osteotomy versus standard medial approach for primary total knee arthroplasty: Does it matter? BMC Musculoskeletal Disorders. 2010;**11**:167

[35] Matsueda M, Gengerke TR, Murphy M, Lew WD, Gustilo RB. Soft tissue release in total knee arthroplasty. Cadaver study using knees without deformities. Clinical Orthopaedics and Related Research. 1999;**366**:264-273

[36] Clarke HD, Fuchs R, Scuderi GR, Scott WN, Insall JN. Clinical results in valgus total knee arthroplasty with the "pie crust" technique of lateral soft tissue releases. The Journal of Arthroplasty. 2005;**20**(8):1010-1014

[37] Aglietti P, Lup D, Cuomo P, Baldini A, De Luca L. Total knee arthroplasty using a pie-crusting technique for valgus deformity. Clinical Orthopaedics and Related Research. 2007;**464**:73-77

[38] Bruzzone M, Ranawat A, Castoldi F, Dettoni F, Rossi P, Rossi R. The risk of direct peroneal nerve injury using the Ranawat "inside-out" lateral release technique in valgus total knee arthroplasty. The Journal of Arthroplasty. 2010;**25**(1):161-165

[39] Whiteside LA. Selective ligament release in total knee arthroplasty of the knee in valgus. Clinical Orthopaedics and Related Research. 1999;**367**:130-140

[40] Krackow KA, Mihalko WM. Flexion-extension joint gap changes after lateral structure release for valgus deformity correction in total knee arthroplasty: A cadaveric study. The Journal of Arthroplasty. 1999;**14**(8):994-1004

[41] Boyer P, Boublil D, Magrino B, Massin P, Huten D, Guepar Group. Total knee replacement in the fixed valgus deformity using a lateral approach: Role of the automatic iliotibial band release for a successful balancing. International Orthopaedics. 2009;**33**(6):1577-1583

[42] Brilhault J, Lautman S, Favard L, Burdin P. Lateral femoral sliding osteotomy lateral release in total knee arthroplasty for a fixed valgus deformity. Journal of Bone and Joint Surgery. British Volume (London). 2002;**84**(8):1131-1137

[43] Bremer D, Orth BC, Fitzek JG, Knutsen A. Briard's sagittal sliding osteotomy of the lateral condyle in total knee arthroplasty of the severe valgus knee. Operative Orthopädie und Traumatologie. 2012;**24**(2):95-108

[44] Mullaji AB, Shetty GM. Lateral epicondylar osteotomy using computer navigation in total knee arthroplasty for rigid valgus deformities. The Journal of Arthroplasty. 2010;**25**(1):166-169

[45] Krackow KA, Holtgrewe JL. Experience with a new technique for managing severely overcorrected valgus high tibial osteotomy at total knee arthroplasty. Clinical Orthopaedics and Related Research. 1990;(258):213-224

[46] Insall JN, Scott WN, Ranawat CS. The total condylar knee prosthesis. A report of two hundred and twenty cases. The Journal of Bone and Joint Surgery. American Volume. 1979; **61**(2):173-180

[47] Vince KG, Insall JN, Kelly MA. The total condylar prosthesis. 10- to 12-year results of a cemented knee replacement. Journal of Bone and Joint Surgery. British Volume (London). 1989;**71**(5):793-797

[48] Healy WL, Iorio R, Lemos DW. Medial reconstruction during total knee arthroplasty for severe valgus deformity. Clinical Orthopaedics. 1998;**356**:161-169

[49] Peters CL, Mohr RA, Bachus KN. Primary total knee arthroplasty in the valgus knee: Creating a balanced soft tissue envelope. The Journal of Arthroplasty. 2001;**16**(6):721-729

[50] Politi J, Scott R. Balancing severe valgus deformity in total knee arthroplasty using a lateral cruciform retinacular release. The Journal of Arthroplasty. 2004;**19**(5):553-557

[51] Laurencin CT, Scott RD, Volatile TB, Gebhardt EM. Total knee replacement in severe valgus deformity. The American Journal of Knee Surgery. 1992;**5**:135-139

[52] Chalidis BE, Ye K, Sachinis NP, Hawdon G, McMahon S. Lateral parapatellar approach with tibial tubercle osteotomy for the treatment of non-correctable valgus knee osteoarthritis: A retrospective clinical study. The Knee. 2014;**21**(1):204-208

[53] Hadjicostas PT, Soucacos PN, Thielemann FW. Computer-assisted osteotomy of the lateral femoral condyle with non-constrained total knee replacement in severe valgus knees. Journal of Bone and Joint Surgery. British Volume (London). 2008;**90**(11):1441-1445

[54] McNabb DC, Kim RH, Springer BD. Instability after total knee arthroplasty. The Journal of Knee Surgery. 2015;**28**(2):97-104

[55] Huang TW, Chuang PY, Lee CY, Lin SJ, Huang KC, Shen SH, Tsai YH, Lee MS, Hsu RW. Total knee arthroplasty in patients with Ranawat type-II valgus arthritic knee with a marked coronal femoral bowing deformity: Comparison between computer-assisted surgery and intra-articular resection. Journal of Orthopaedic Surgery and Research. 2016;**11**(1):88

[56] Huang TW, Hsu WH, Peng KT, Hsu RW, Weng YJ, Shen WJ. Total knee arthroplasty with use of computer-assisted navigation compared with conventional guiding systems in the same patient: Radiographic results in Asian patients. The Journal of Bone and Joint Surgery. American Volume. 2011;**93**:1197-1202

[57] Wetzner SM, Bezrch JS, Scott RD, Bierbaum BE, Newberg AH. Bone scanning in the assessment of patellar viability following knee replacement. Clinical Orthopaedics. 1985; (199):215-219

[58] Coonse K, Adams JD. A new operative approach to the knee joint. Surgery, Gynecology & Obstetrics. 1943;**77**:344-347

[59] Garvin KL, Scuderi G, Insall JN. Evolution of the quadriceps snip. Clinical Orthopaedics and Related Research. 1995;**231**:131-137

[60] Dolin MG. Osteotomy of tibial tubercle in total knee replacement. A technical note. The Journal of Bone and Joint Surgery. American Volume. 1983;**65**:704-706

[61] Whiteside LA, Ohl MD. Tibial tubercle osteotomy for exposure of the difficult total knee arthroplasty. Clinical Orthopaedics and Related Research. 1990;(260):6-9

[62] Wolff AM, Hungerford DS, Krackow KA, Jacobs MA. Osteotomy of the tibial tubercle during total knee replacement. The Journal of Bone and Joint Surgery. American Volume. 1989;**71**:848-852

[63] Piedade SR, Pinaroli A, Servien E, Neyret P. Tibial tubercle osteotomy in primary total knee arthroplasty: A safe procedure or not? The Knee. 2008;**15**:439-446

[64] Insall JN, Easley ME. Surgical techniques and instrumentation in total knee arthroplasty. In: Insall JN, Scott WN, editors. Surgery of the Knee. 3rd ed. New York NY: Churchill Livingstone; 2001. pp. 1717-1738

[65] Hay GC, Kampshoff J, Kuster MS. Lateral subvastus approach with osteotomy of the tibial tubercle for total knee replacement: A 2 year prospective, randomised, blinded controlled trial. Journal of Bone and Joint Surgery. 2010;**92B**:862-866

[66] Rose HA, Hood RW, Otis JC, Ranawat CS, Insall JN. Peroneal-nerve palsy following total knee arthroplasty: A review of The Hospital for Special Surgery experience. The Journal of Bone and Joint Surgery. American Volume. 1982;**64**:347-351

[67] Idusuyi OB, Morrey BF. Peroneal nerve palsy after total knee arthroplasty: Assessment of predisposing and prognostic factors. The Journal of Bone and Joint Surgery. American Volume. 1996;**78**:177-184

Chapter 5

Tourniquet Use in Total Knee Arthroplasty

Kai-Lan Hsu, Chih-Wei Chang, Chyun-Yu Yang and Jou-Hua Wang

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73644

Abstract

The use of an intraoperative tourniquet for total knee arthroplasty (TKA) is a common practice. Although it provides clear filed and ideal cementation during surgery, issues regarding the effectiveness, drawbacks and complications are still investigated. This review was conducted to evaluate the role of tourniquet in TKA through a comprehensive literature search was done in PubMed Medicine, Embase, and other internet database. Debating issues, including the blood loss, operation time, alignment, compromised wound healing, quadriceps weakness and timing of release were furtherly examined. Based on our prior work and the general consensus that the tourniquet should be set with the lowest pressure and for the least ischemic time possible, we recommend early tourniquet release right after the closure of extensor mechanism in the TKAs without drainage.

Keywords: tourniquet, total knee arthroplasty, ischemic, blood loss, timing

1. Introduction

Total knee arthroplasty (TKA) is associated with substantial postoperative blood loss for which blood transfusion might be necessary. Various strategies to hemostasis had been proposed, including the use of tourniquet during surgery. The use of tourniquet was believed to help reduce intraoperative blood loss [1–4], provide better visualization, save operative time [4, 5], and facilitate the cementing quality and other surgical procedures. However, some conflicting results were reported regarding blood loss and fixation of cemented [6–8]. Furthermore, certain drawbacks were mentioned after the use of tourniquet, including thigh pain, nerve palsy, ischemia [9], soft tissue damage, thromboembolic complications [10], decrease muscle strength [11], and knee range of motion (ROM) [3]. In spite of the common use of tourniquet in orthopedic surgeries, the role of tourniquet in TKA remains controversial, and some surgeons suggested that tourniquet is not necessary [12, 13].

To reduce the aforementioned drawbacks, adjunctive measures such as skin protection [14], elastic cuff [15], and reducing cuff pressure [16, 17] are frequently taken while applying the tourniquet during TKAs. Recently, early deflation of tourniquet has drawn increasing attention. Since most surgeons use tourniquet to facilitate the procedure mainly, there are no need for prolonged use of tourniquet. Various timings of deflation have been proposed in the literature, such as deflating tourniquet after cementing the implants [18–20], after closure of arthrotomy [21], or immediately after wound closure [22]. However, no consensus has been achieved to date.

To clarify the role of tourniquet in TKA, a comprehensive review was therefore conducted. An extensive search as well as review of the related literature regarding the tourniquet use was performed. This review focused on:

1. Effectiveness of tourniquet use in TKA.
2. Safety and complications of tourniquet use in TKA.
3. Effect of early deflation of tourniquet.

2. Search of literature

Our review team completed the search of electronic databases, including the Cochrane Central Register of Controlled Trials (2010), PubMed Medline (1966 to May 2011), and Embase (1980 to May 2011). We used the following search terms and Boolean operators: (tourniquet) AND (knee OR arthroplasty OR joint replacement). We also searched the reference lists of the relevant articles for any further associated studies. The criteria for inclusion were (1) reports dealing with patients undergoing primary TKA and (2) studies about tourniquet use. After reviewing the titles and abstracts of the studies, we determined if the study was appropriate for retrieval. The retrieved literature was completely reviewed. A consensus about the content of this review article was reached throughout series of discussion.

3. Intraoperative tourniquet use

3.1. Blood loss

Whether or not a tourniquet can reduce blood loss in total knee arthroplasty is still being debated in the literature. Although intraoperative blood loss was significantly less in the tourniquet group in the present study, there is often a substantial hidden or unmeasured blood loss in TKA. Some authors claimed that a tourniquet is effective for reducing blood loss [1, 2, 23], but others did not agree. Numerous studies reported no significant difference in the amount of blood loss with or without tourniquet use [24, 25], and others even suggested that the use of tourniquet induces more blood loss [26, 27].

There are some parameters commonly used to evaluate the blood loss of the surgery. Directly measured items include *the intraoperative blood loss* and *the transfusion rate. Measurable total blood loss*, the summation of intra- and postoperative blood loss, is determined by the increasing weight of soaked gauze added the amount of postoperative drainage. *Calculated total blood loss*, which is always regarded as true total blood loss, was measured by Hb and Hct levels before and after surgery.

In the research model of meta-analysis, some authors suggested that the use of tourniquet did not affect total blood loss [3, 5, 8, 28], which was opposed by Alcelik et al. [29]. However, Alcelik et al. [29] estimated total blood loss simply based on the measurable blood loss while overlooking the hidden blood loss. Thus, the evidence available indicates that tourniquet indeed significantly reduce the intraoperative blood loss rather than the total blood loss.

3.2. Operation time

The application of a tourniquet in TKA was believed to afford a relative bloodless surgical field, facilitating time saving. However, the critical timing of deflation should be mentioned regarding the operation time. The pooling data showed significantly shortened surgical duration in the tourniquet group once the tourniquet was released after wound closure and compressive dressing [2, 27, 30]. In comparison, early release of the tourniquet right after cementing the prosthesis for hemostasis would prolong the operation time for troublesome oozing [5, 20, 31–34]. Thus, the studies with early release of tourniquet did not correlate with significant shortened operation time [23, 24, 26].

3.3. Alignment and stability

A tourniquet use is believed to improve the visualization of anatomical structures [35] due to better control of intraoperative bleeding. However, this advantage does not necessarily promise the improved implant position or surgical accuracy. Stetzelberger et al. [36] found that the mechanical leg alignment, the joint line level, and the patellar height could be accurately reconstructed with and without the tourniquet use.

On the other hand, an inflated tourniquet could alter the patellofemoral tracking [28] and may give the impression of an enhanced lateral tracking because of an increased lateral retinacular tension [37, 38]. Some authors recommend the deflation of the tourniquet prior to a lateral release to avoid unnecessary interventions. However, Matsui et al. [39] found that there is low clinical relevance even tourniquet deflation significantly improved the patellofemoral tracking and it is reliable to test intraoperative congruity a tourniquet in place.

There is a lack of data available in the literature whether the use of a tourniquet increases implant fixation in TKA. Radiostereometric analysis (RSA) has been used to investigate the influence of the tourniquet on implant fixation, but no difference was found [40, 41]. Recently, Pfitzner et al. found that the use of a tourniquet in primary TKA increased the tibial cement mantle thickness [42], which could increase implant stability and survival [43].

3.4. Risk of thrombosis

The use of a tourniquet can be an important issue but still controversial regarding the formation of deep vein thrombosis (DVT) after TKA. Abdel-Salam and Eyres [44], Mori et al. [10], and Tai et al. [5] reported an increased incidence of DVT with the use of a tourniquet in TKA, but Wakankar et al. [35] and Fukuda et al. [23] both reported that the incidence of DVT was not related to the use of a tourniquet. However, these studies vary in diagnostic tool, race, and the presentation of symptoms.

The length of tourniquet time (ischemic duration) is another factor affecting the risk of thrombosis. Bin Abd Razak et al. [45] and Chung et al. [46] reported that the rate of DVT appeared to be associated with prolonged tourniquet time, probably due to a long period of venous stasis and damage to calcified vessels. Early deflation of tourniquet is also found to decrease the risk of DVT [18, 47].

Although most DVTs were asymptomatic, an asymptomatic postoperative DVT is associated with an increased risk of the late development of the post-thrombotic syndrome [48, 49]. Thus, patients with an asymptomatic DVT should be monitored carefully.

3.5. Complication related to wound healing

Wound condition after TKA is important for the prevention of periprosthetic infection [50, 51]. Delay in wound healing is associated with deep infection, which leads to the arthroplasty failure [52].

The use of a tourniquet is associated with a higher incidence of postoperative wound problems [3, 5, 28, 44], including significant hematoma, wound oozing, skin blistering, bruising, necrosis, and superficial wound infection requiring antibiotics treatment. Circulatory stasis caused by tourniquet inflation may worsen the local soft tissue condition [5]; furthermore, reactive hyperemia and activation of fibrinolytic cascade after tourniquet release increase the tissue pressure and local inflammation [3, 53], all of which lead to tissue hypoxia and subsequently compromised wound healing.

3.6. Thing pain, weakness, and postoperative recovery

For patients who undergo tourniquet-controlled TKA, thigh pain is a very common complaint during the early postoperative period. Performing TKA without a tourniquet could reduce postoperative thigh pain in several literature [1, 3, 12, 13], but the benefit declines with time and becomes insignificant different at follow-ups longer than 6 months.

Compromised knee motion after tourniquet use has also been mentioned in some literature [35, 40, 44]. The possible reasons are as follows: (1) using a tourniquet may injure the nerve and the skeletal muscle, even causing rhabdomyolysis [40, 54] and (2) increased postoperative pain would limit the patient's ability to perform postoperative training [40, 55].

Considering the acting and involving region of tourniquet, quadriceps weakness is a hallmark of TKA [56, 57], though few studies investigated this issue. Abdel-Salam and Eyres observed a quicker ability to achieve a straight leg raise maneuver in whom a tourniquet was not used [44]. Dennis et al. [11] also reported the diminished strength of quadriceps during the first 3 months after TKA using a tourniquet. However, no significant difference of knee-extension strength 48 h after surgery was reported by Harsten et al. [58].

Long-term effect of tourniquet use on the postoperative ROM is still debating. Ledin et al. [40] reported that the ROM was 11° greater in the non-tourniquet group after 2-year follow-up, but Abdel-Salam and Eyres [44] and Liu et al. [13] found no difference in knee flexion after 1-year follow-up.

4. Timing of tourniquet release

To reduce the ischemic duration and the incidence of complications aforementioned, some surgeons suggested the early release of tourniquet. The different timings of tourniquet deflation include immediately after wound closure [22], after a tight arthrotomy closure [21] and mostly after the implantation of the prostheses [18, 20, 32].

Although there were some reviewing articles related to the timing of tourniquet release in TKA, the results varied. For blood loss, Huang et al. [59] and Zan et al. [47] suggested that tourniquet release before wound closure for hemostasis wound significantly increase not only total measured blood loss but also calculated blood loss. Zhang et al. [31] found that releasing tourniquet before wound closure could increase only total blood loss. However, Tie et al. [60] reported no significant difference existed in calculated blood loss nor total blood losses. To analyze the blood loss in detail, intraoperative blood loss may contribute to most of increased blood loss. Releasing tourniquet before wound closure theoretically could ensure a better view of hemostasis, and patients would have better blood conservation. Nevertheless, fibrinolytic activity rises after the release of an arterial tourniquet [61], contributing to the higher perioperative blood loss. In addition, it was impossible to find all bleeding sources, especially the oozing spots. These are the reasons why total blood loss is higher when tourniquet is released before wound closure in some reviewing article.

Several studies demonstrated that releasing tourniquet before wound closure had a decreased risk of postoperative complications such as wound complications [22], deep infection, DVT [31], and so on [47, 60, 62]. Although there is no significant difference in some meta-analysis [18, 59], it had a trend that releasing tourniquet before wound closure could decrease the incidence rate of major complication.

5. Pressure

Clinical and experimental studies supported a positive correlation between the degree of neuromuscular injury and the amount of pressure or the ischemia duration. Olivecrona et al. [16]

reported a higher cuff pressure increase risks of tourniquet-related postoperative complications. Despite various pressures being used in different studies, the general consensus is that the tourniquet should be employed at the lowest pressure and for the least ischemic time possible to avoid complications. In some published studies [17, 34, 53, 63], cuff pressures, ranging from 300 to 350 mm Hg, have been reported.

To reduce the cuff pressure, some surgeons preferred the setting of cuff pressure on the basis of the systolic blood pressure plus a margin of 100 mmHg [34], and less early postoperative pain has been reported [64]. Meanwhile, another common method, twice of the systolic pressure, has also been adopted [65]. Besides, based on the fluctuating systolic pressure, improved devices with timely automated measurement of limb occlusion pressure have been investigated to reduce the cuff pressure [16].

6. Authors' preference

For the past decade, the authors focused on the effects of a tourniquet in TKA. In a meta-analysis [5], we found that using tourniquet in TKA may save time without evident hemostatic benefits. Then, a prospective, randomized, controlled trial was therefore conducted to clarify the effect of tourniquets in TKA. Reduced operative time, reduced intraoperative blood loss, and prevented excessive inflammation and muscle damage were obtained in the tourniquet-controlled TKAs [1]. Further, to save unnecessary ischemic duration, an effective hemostasis via a tamponade by the closed arthrotomy without drainage was used. Not only the shortened ischemic time but also better earlier functional recovery was obtained at early postoperative follow-ups [21]. Currently, although tourniquet is routinely used in our daily practice of TKAs, timely release as well as low cuff pressure is stressed based on the awareness of the risks of thromboembolism and other aforementioned complications.

Author details

Kai-Lan Hsu[1,2], Chih-Wei Chang[1,2,3]*, Chyun-Yu Yang[1,3] and Jou-Hua Wang[1]

*Address all correspondence to: u7901064@yahoo.com.tw

1 Department of Orthopaedic Surgery, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

2 Department of Biomedical Engineering, College of Engineering, National Cheng Kung University, Tainan, Taiwan

3 Bone and Joint Center, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

References

[1] Tai TW, Chang CW, Lai KA, Lin CJ, Yang CY. Effects of tourniquet use on blood loss and soft-tissue damage in total knee arthroplasty: A randomized controlled trial. The Journal of Bone and Joint Surgery American Volume. 2012;**94**(24):2209-2215

[2] Vandenbussche E, Duranthon LD, Couturier M, Pidhorz L, Augereau B. The effect of tourniquet use in total knee arthroplasty. International Orthopaedics. 2002;**26**(5):306-309

[3] Zhang W, Liu A, Hu D, Tan Y, Al-Aidaros M, Pan Z. Effects of the timing of tourniquet release in cemented total knee arthroplasty: A systematic review and meta-analysis of randomized controlled trials. Journal of Orthopaedic Surgery and Research. 2014;**9**:125

[4] Yi S, Tan J, Chen C, Chen H, Huang W. The use of pneumatic tourniquet in total knee arthroplasty: A meta-analysis. Archives of Orthopaedic and Trauma Surgery. 2014;**134**(10):1469-1476

[5] Tai TW, Lin CJ, Jou IM, Chang CW, Lai KA, Yang CY. Tourniquet use in total knee arthroplasty: A meta-analysis. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA. 2011;**19**(7):1121-1130

[6] Yin D, Delisle J, Banica A, Senay A, Ranger P, Laflamme GY, et al. Tourniquet and closed-suction drains in total knee arthroplasty. No beneficial effects on bleeding management and knee function at a higher cost. Orthopaedics & Traumatology, Surgery & Research: OTSR. 2017;**103**(4):583-589

[7] Ejaz A, Laursen AC, Jakobsen T, Rasmussen S, Nielsen PT, Laursen MB. Absence of a tourniquet does not affect fixation of cemented TKA: A randomized RSA study of 70 patients. The Journal of Arthroplasty. 2015;**30**(12):2128-2132

[8] Smith TO, Hing CB. Is a tourniquet beneficial in total knee replacement surgery? A meta-analysis and systematic review. The Knee. 2010;**17**(2):141-147

[9] Ejaz A, Laursen AC, Kappel A, Jakobsen T, Nielsen PT, Rasmussen S. Tourniquet induced ischemia and changes in metabolism during TKA: A randomized study using microdialysis. BMC Musculoskeletal Disorders. 2015;**16**:326

[10] Mori N, Kimura S, Onodera T, Iwasaki N, Nakagawa I, Masuda T. Use of a pneumatic tourniquet in total knee arthroplasty increases the risk of distal deep vein thrombosis: A prospective, randomized study. The Knee. 2016;**23**(5):887-889

[11] Dennis DA, Kittelson AJ, Yang CC, Miner TM, Kim RH, Stevens-Lapsley JE. Does tourniquet use in TKA affect recovery of lower extremity strength and function? A randomized trial. Clinical Orthopaedics and Related Research. 2016;**474**(1):69-77

[12] Ejaz A, Laursen AC, Kappel A, Laursen MB, Jakobsen T, Rasmussen S, et al. Faster recovery without the use of a tourniquet in total knee arthroplasty. Acta Orthopaedica. 2014;**85**(4):422-426

[13] Liu D, Graham D, Gillies K, Gillies RM. Effects of tourniquet use on quadriceps function and pain in total knee arthroplasty. Knee Surgery & Related Research. 2014;**26**(4):207-213

[14] Olivecrona C, Tidermark J, Hamberg P, Ponzer S, Cederfjall C. Skin protection underneath the pneumatic tourniquet during total knee arthroplasty: A randomized controlled trial of 92 patients. Acta Orthopaedica. 2006;**77**(3):519-523

[15] Lee OS, Lee MC, Han HS. Efficacy and safety of a new elastic tourniquet cuff in total knee arthroplasty: A prospective randomized controlled study. Biomedical Engineering Online. 2017;**16**(1):102

[16] Olivecrona C, Ponzer S, Hamberg P, Blomfeldt R. Lower tourniquet cuff pressure reduces postoperative wound complications after total knee arthroplasty: A randomized controlled study of 164 patients. The Journal of Bone and Joint Surgery American Volume. 2012;**94**(24):2216-2221

[17] Olivecrona C, Blomfeldt R, Ponzer S, Stanford BR, Nilsson BY. Tourniquet cuff pressure and nerve injury in knee arthroplasty in a bloodless field: A neurophysiological study. Acta Orthopaedica. 2013;**84**(2):159-164

[18] Zan P, Mol MO, Yao JJ, Fan L, Yang D, Liu K, et al. Release of the tourniquet immediately after the implantation of the components reduces the incidence of deep vein thrombosis after primary total knee arthroplasty. Bone & Joint Research. 2017;**6**(9):535-541

[19] Steffin B, Green-Riviere E, Giori NJ. Timing of tourniquet release in total knee arthroplasty when using a postoperative blood salvage drain. The Journal of Arthroplasty. 2009; **24**(4):539-542

[20] Kvederas G, Porvaneckas N, Andrijauskas A, Svensen CH, Ivaskevicius J, Mazunaitis J, et al. A randomized double-blind clinical trial of tourniquet application strategies for total knee arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA. 2013;**21**(12):2790-2799

[21] Chang CW, Lan SM, Tai TW, Lai KA, Yang CY. An effective method to reduce ischemia time during total knee arthroplasty. Journal of the Formosan Medical Association. 2012;**111**(1):19-23

[22] Heller S, Chen A, Restrepo C, Albert E, Hozack WJ. Tourniquet release prior to dressing application reduces blistering following total knee arthroplasty. The Journal of Arthroplasty. 2015;**30**(7):1207-1210

[23] Fukuda A, Hasegawa M, Kato K, Shi D, Sudo A, Uchida A. Effect of tourniquet application on deep vein thrombosis after total knee arthroplasty. Archives of Orthopaedic and Trauma Surgery. 2007;**127**(8):671-675

[24] Aglietti P, Baldini A, Vena LM, Abbate R, Fedi S, Falciani M. Effect of tourniquet use on activation of coagulation in total knee replacement. Clinical Orthopaedics and Related Research. 2000;**371**:169-177

[25] Katsumata S, Nagashima M, Kato K, Tachihara A, Wauke K, Saito S, et al. Changes in coagulation-fibrinolysis marker and neutrophil elastase following the use of tourniquet

during total knee arthroplasty and the influence of neutrophil elastase on thromboembolism. Acta Anaesthesiologica Scandinavica. 2005;**49**(4):510-516

[26] Tetro AM, Rudan JF. The effects of a pneumatic tourniquet on blood loss in total knee arthroplasty. Canadian Journal of Surgery. 2001;**44**(1):33-38

[27] Li B, Wen Y, Wu H, Qian Q, Lin X, Zhao H. The effect of tourniquet use on hidden blood loss in total knee arthroplasty. International Orthopaedics. 2009;**33**(5):1263-1268

[28] Jiang FZ, Zhong HM, Hong YC, Zhao GF. Use of a tourniquet in total knee arthroplasty: A systematic review and meta-analysis of randomized controlled trials. Journal of Orthopaedic Science: Official Journal of the Japanese Orthopaedic Association. 2015;**20**(1): 110-123

[29] Alcelik I, Pollock RD, Sukeik M, Bettany-Saltikov J, Armstrong PM, Fismer PA. Comparison of outcomes with and without a tourniquet in total knee arthroplasty: A systematic review and meta-analysis of randomized controlled trials. The Journal of Arthroplasty. 2012; **27**(3):331-340

[30] Nishiguchi M, Takamura N, Abe Y, Kono M, Shindo H, Aoyagi K. Pilot study on the use of tourniquet: A risk factor for pulmonary thromboembolism after total knee arthroplasty? Thrombosis Research. 2005;**115**(4):271-276

[31] Zhang P, Liang Y, He J, Fang Y, Chen P, Wang J. Timing of tourniquet release in total knee arthroplasty: A meta-analysis. Medicine. 2017;**96**(17):e6786

[32] Christodoulou AG, Ploumis AL, Terzidis IP, Chantzidis P, Metsovitis SR, Nikiforos DG. The role of timing of tourniquet release and cementing on perioperative blood loss in total knee replacement. The Knee. 2004;**11**(4):313-317

[33] Hersekli MA, Akpinar S, Ozkoc G, Ozalay M, Uysal M, Cesur N, et al. The timing of tourniquet release and its influence on blood loss after total knee arthroplasty. International Orthopaedics. 2004;**28**(3):138-141

[34] Ishii Y, Matsuda Y. Effect of the timing of tourniquet release on perioperative blood loss associated with cementless total knee arthroplasty: A prospective randomized study. The Journal of Arthroplasty. 2005;**20**(8):977-983

[35] Wakankar HM, Nicholl JE, Koka R, D'Arcy JC. The tourniquet in total knee arthroplasty. A prospective, randomised study. The Journal of Bone and Joint Surgery British Volume. 1999;**81**(1):30-33

[36] Stetzelberger V, Obertacke U, Jawhar A. Tourniquet application during TKA did not affect the accuracy of implant positioning: A randomized clinical trial. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA. 2017

[37] Husted H, Toftgaard Jensen T. Influence of the pneumatic tourniquet on patella tracking in total knee arthroplasty: A prospective randomized study in 100 patients. The Journal of Arthroplasty. 2005;**20**(6):694-697

[38] Komatsu T, Ishibashi Y, Otsuka H, Nagao A, Toh S. The effect of surgical approaches and tourniquet application on patellofemoral tracking in total knee arthroplasty. The Journal of Arthroplasty. 2003;**18**(3):308-312

[39] Matsui Y, Shintani K, Okajima Y, Matsuura M, Nakagawa S. The effect of tourniquets on patellofemoral joint congruity during total knee arthroplasty. Journal of Orthopaedic Science: Official Journal of the Japanese Orthopaedic Association. 2016;**21**(5):630-634

[40] Ledin H, Aspenberg P, Good L. Tourniquet use in total knee replacement does not improve fixation, but appears to reduce final range of motion. Acta Orthopaedica. 2012; **83**(5):499-503

[41] Molt M, Harsten A, Toksvig-Larsen S. The effect of tourniquet use on fixation quality in cemented total knee arthroplasty a prospective randomized clinical controlled RSA trial. The Knee. 2014;**21**(2):396-401

[42] Pfitzner T, von Roth P, Voerkelius N, Mayr H, Perka C, Hube R. Influence of the tourniquet on tibial cement mantle thickness in primary total knee arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA. 2016;**24**(1):96-101

[43] Peters CL, Craig MA, Mohr RA, Bachus KN. Tibial component fixation with cement: Full-versus surface-cementation techniques. Clinical Orthopaedics and Related Research. 2003;**409**:158-168

[44] Abdel-Salam A, Eyres KS. Effects of tourniquet during total knee arthroplasty. A prospective randomised study. The Journal of Bone and Joint Surgery British Volume. 1995;**77**(2):250-253

[45] Bin Abd Razak HR, Binte Abd Razak NF, Tan HA. Prevalence of venous thromboembolic events is low in Asians after Total knee arthroplasty without chemoprophylaxis. The Journal of Arthroplasty. 2017;**32**(3):974-979

[46] Chung LH, Chen WM, Chen CF, Chen TH, Deep LCL. Vein thrombosis after total knee arthroplasty in asian patients without prophylactic anticoagulation. Orthopedics. 2011; **34**(1):15

[47] Zan PF, Yang Y, Fu D, Yu X, Li GD. Releasing of tourniquet before wound closure or not in total knee arthroplasty: A meta-analysis of randomized controlled trials. The Journal of Arthroplasty. 2015;**30**(1):31-37

[48] Wille-Jorgensen P, Jorgensen LN, Crawford M. Asymptomatic postoperative deep vein thrombosis and the development of postthrombotic syndrome. A systematic review and meta-analysis. Thrombosis and Haemostasis. 2005;**93**(2):236-241

[49] Siragusa S, Beltrametti C, Barone M, Piovella F. Clinical course and incidence of post-thrombophlebitic syndrome after profound asymptomatic deep vein thrombosis. Results of a transverse epidemiologic study. Minerva Cardioangiologica. 1997;**45**(3):57-66

[50] Garbedian S, Sternheim A, Backstein D. Wound healing problems in total knee arthroplasty. Orthopedics. 2011;**34**(9):e516-e518

[51] Vince K, Chivas D, Droll KP. Wound complications after total knee arthroplasty. The Journal of Arthroplasty. 2007;**22**(4, Suppl 1):39-44

[52] Galat DD, McGovern SC, Larson DR, Harrington JR, Hanssen AD, Clarke HD. Surgical treatment of early wound complications following primary total knee arthroplasty. The Journal of Bone and Joint Surgery American Volume. 2009;**91**(1):48-54

[53] Clarke MT, Longstaff L, Edwards D, Rushton N. Tourniquet-induced wound hypoxia after total knee replacement. The Journal of Bone and Joint Surgery British Volume. 2001; **83**(1):40-44

[54] Appell HJ, Gloser S, Duarte JA, Zellner A, Soares JM. Skeletal muscle damage during tourniquet-induced ischaemia. The initial step towards atrophy after orthopaedic surgery? European Journal of Applied Physiology and Occupational Physiology. 1993;**67**(4):342-347

[55] Kumar N, Yadav C, Singh S, Kumar A, Vaithlingam A, Yadav S. Evaluation of pain in bilateral total knee replacement with and without tourniquet; a prospective randomized control trial. Journal of Clinical Orthopaedics and Trauma. 2015;**6**(2):85-88

[56] Mizner RL, Petterson SC, Snyder-Mackler L. Quadriceps strength and the time course of functional recovery after total knee arthroplasty. The Journal of Orthopaedic and Sports Physical Therapy. 2005;**35**(7):424-436

[57] Stevens-Lapsley JE, Balter JE, Kohrt WM, Eckhoff DG. Quadriceps and hamstrings muscle dysfunction after total knee arthroplasty. Clinical Orthopaedics and Related Research. 2010;**468**(9):2460-2468

[58] Harsten A, Bandholm T, Kehlet H, Toksvig-Larsen S. Tourniquet versus no tourniquet on knee-extension strength early after fast-track total knee arthroplasty; a randomized controlled trial. The Knee. 2015;**22**(2):126-130

[59] Huang Z, Ma J, Zhu Y, Pei F, Yang J, Zhou Z, et al. Timing of tourniquet release in total knee arthroplasty. Orthopedics. 2015;**38**(7):445-451

[60] Tie K, Hu D, Qi Y, Wang H, Chen L. Effects of tourniquet release on total knee arthroplasty. Orthopedics. 2016;**39**(4):e642-e650

[61] Harvey EJ, Leclerc J, Brooks CE, Burke DL. Effect of tourniquet use on blood loss and incidence of deep vein thrombosis in total knee arthroplasty. The Journal of Arthroplasty. 1997;**12**(3):291-296

[62] Barwell J, Anderson G, Hassan A, Rawlings I. The effects of early tourniquet release during total knee arthroplasty: A prospective randomized double-blind study. The Journal of Bone and Joint Surgery British Volume. 1997;**79**(2):265-268

[63] Noordin S, McEwen JA, Kragh JF Jr, Eisen A, Masri BA. Surgical tourniquets in orthopaedics. The Journal of Bone and Joint Surgery American Volume. 2009;**91**(12):2958-2967

[64] Worland RL, Arredondo J, Angles F, Lopez-Jimenez F, Jessup DE. Thigh pain following tourniquet application in simultaneous bilateral total knee replacement arthroplasty. The Journal of Arthroplasty. 1997;**12**(8):848-852

[65] Liu HY, Guo JY, Zhang ZB, Li KY, Wang WD. Development of adaptive pneumatic tourniquet systems based on minimal inflation pressure for upper limb surgeries. Biomedical Engineering Online. 2013;**12**:92

Pain Management

Yavuz Orak and Mahmut Arslan

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74296

Abstract

Postoperative pain is caused by neuronal damage that occurs during the surgical procedure and the stimulation of the nociceptors. In postoperative period, total knee arthroplasty (TKA) is painful, and pain management is quite difficult. The main purpose of postoperative pain relief is to reduce the pain of the patient, to contribute to the healing process, to shorten the length of hospital stay, and to reduce hospital costs. Techniques such as intravenous analgesia, epidural analgesia, and peripheral nerve blocks are used to prevent postoperative pain. In addition, oral and parenteral analgesics, patient-controlled analgesia (PCA), nerve blocks, and periarticular injection methods are used as multimodal analgesia methods. Pain scales such as visual analogue scale (VAS), verbal descriptive scale (VDS), and numerical rating scale (NRS) are used as the standard methods in the evaluation of pain of patients. Systemic opioids, nonsteroidal anti-inflammatory drugs, and local anesthetics are used for postoperative analgesia. Preemptive analgesia, defined as analgesia initiated prior to surgical incision, and multimodal analgesia have been shown to reduce opioid consumption associated with high complication rates. Postoperative pain management should be planned considering the clinical characteristics of the patient, experience of the anesthetist, and clinical facilities. Early postoperative analgesia reduces systemic complication rates and improves early rehabilitation, patient satisfaction, and quality of life.

Keywords: pain management, analgesia, preemptive analgesia, multimodal analgesia, regional analgesia techniques, drug therapy

1. Introduction

According to the definition made by the International Organization for Research on Aging (IASP), pain is a sensorial, emotional, unpleasant sensation about someone's past experiences, whether they are connected to an organic gown or not, starting from anywhere in the body.

2. Classification of pain

1. Acute pain: it is a type of pain that starts suddenly, has a nociceptive nature, has tissue damage, shows a close relationship with the cause of the lesion in terms of location, time, and intensity, and gradually disappears as the healing progresses [1, 2]. The most common types of acute pain are posttraumatic, postoperative, and obstetric pain [3].
2. Superficial (cutaneous) pain: it is type of a pain that occurs against nociceptive stimuli that occur in skin, subcutaneous tissue, and mucous membranes.
3. Deep somatic pain: it is a pain that is usually caused by muscle, tendon, joint receptors or bones, which is blunt and cannot be localized.
4. Visceral pain: it is a pain originated from the deterioration of functions of their tissue (parietal pleura, pericardium, and peritoneum).
5. Chronic pain: it is defined as acute pain that begins as acute pain and lasts for 1–6 months [4].

3. Pain pathways

In order for a stimulus to be perceived as pain, it is necessary to go through four different physiological processes:

a. Transduction; at the end of the nerve is the stage where the stimulus is converted into electrical activity.
b. Transmission; it is the spread of electrical activity throughout the nervous system.
c. Modulation; changes in nociceptive transmission.
d. Perception; interaction with the individual's psychology and subjective emotional experiences.

4. Postoperative pain in total knee arthroplasty

Postoperative pain is caused by neuronal damage that occurs during the surgical procedure and the stimulation of the nociceptors. In postoperative period, total knee arthroplasty (TKA) is painful and pain management is quite difficult. The main purpose of postoperative pain relief is to reduce the pain of the patient, to contribute to the healing process, to shorten the length of hospital stay, and to reduce hospital costs.

Techniques such as intravenous analgesia, epidural analgesia, and peripheral nerve blocks are used to prevent postoperative pain. In addition, oral and parenteral analgesics, patient-controlled analgesia, nerve blocks, and periarticular injection methods are used as multimodal analgesia method. Systemic opioids, nonsteroidal anti-inflammatory drugs, and local anesthetics are frequently used for postoperative analgesia.

Pain scales such as visual analogue scale (VAS), verbal descriptive scale (VDS), numerical rating scale (NRS) are used as standard methods in the evaluation of pain of patients.

Total knee arthroplasty (TKA) is known to be a very painful orthopedic procedure [5]. For this reason, effective pain control is important to optimize the rehabilitation process in order to ensure patient satisfaction, hospital stay, and cost reduction [6]. However, the difficulty of postoperative pain management after TKA is to maintain adequate motor function with adequate analgesia. The patient is informed about the surgery to be performed before the operation, and a training program and the physical preparation are recommended. Patients undergoing preoperative exercise and training showed significant improvements in function, quadriceps strength, and duration of stay. After the surgical intervention is performed, the patient can continue the rehabilitation program to speed up the healing process in the home under the supervision of a physiotherapist. Rehabilitation therapy depends on many factors such as patient characteristics, prosthesis characteristics, and postoperative complications.

More than 1.1 million joint arthroplasty (TJA) are performed annually in the USA, and more than 700,000 of them are primary TKA [7, 8].

5. Pathophysiological changes caused by postoperative pain in the organism

Acute postoperative pain that is poorly treated is associated with both physiological and psychological functions in the body [2, 9–11], which are as follows:

- Cardiovascular system: coronary ischemia, myocardial infarction
- Pulmonary system: hypoventilation, decreased vital capacity, pulmonary infection
- Gastrointestinal system: reduced motility, ileus, nausea, vomiting
- Renal system: increases in urinary retention and sphincter tone, oliguria

There are negative effects on the muscular system, on the coagulation system, on the wound healing, and on the immune system. Finally, poorly controlled pain after surgery may impair sleep and have negative psychological effects, such as demoralization and anxiety.

6. Postoperative pain treatment/management methods

1. Regional analgesia techniques and multimodal analgesia
2. Drug therapy
3. Nonpharmacological techniques
4. Preemptive analgesia
5. Patient education

6.1. Regional analgesia techniques and multimodal analgesia

Despite improvements in pain management, approximately half of TKA (total knee arthroplasty) patients develop severe pain in the early postoperative period. Excessive tissue damage and complex innervation in TKA make pain control difficult. Femoral nerve, sciatic nerve, and obturator nerve are involved in the innervation of the knee joint. In major surgeries, such as TKA, changes occur in the endocrine system and central, peripheral, and sympathetic nervous systems. If postoperative analgesia is not achieved adequately, systemic responses induced by the surgery increase and serious risks may occur to the patients.

Conventional methods such as parenteral opioids, epidural analgesia, and femur blocks have been widely used to remove the pain associated with TKA [12]. In addition, the fascia iliaca block has recently been used more frequently to reduce the pain associated with TKA [13]. Comparing general anesthesia with neuraxial anesthesia in the patients with TKA, the risk of perioperative complications was significantly reduced in patients undergoing neuraxial anesthesia [14]. In another study, the risk of short-term complications in patients with TKA was higher in patients receiving general anesthesia than in patients receiving neuraxial anesthesia [15]. Neuraxial anesthesia was associated with the reduction of major complications. A recent meta-analysis has shown that there is a significant decrease in the incidence of postoperative surgical site infection in neuraxial anesthesia when compared to general anesthesia and neuraxial anesthesia in the patients with TKA and total hip arthroplasty (THA) [16]. The use of peripheral nerve block (PNB) also reduced the need for postsurgical critical care services [17].

Multimodal analgesia techniques are often used in the “fast-track” recovery protocols to improve pain relief. Mixture of local anesthetics and anti-inflammatory and opioid analgesics for periarticular infiltration has been used in the multimodal protocols. It can improve the pain score, reduce the total perioperative opioid consumption, enhance the early mobilization, and increase the patient satisfaction [18]. Several multimodal analgesics have been developed in clinical practice [19, 20] and paracetamol, nonsteroidal anti-inflammatory drugs (NSAIDs), opioids, ketamine [21], alpha-2 adrenergic agonists [22], and corticosteroids have been used [23].

Periarticular drug injection is an attempt to apply a low-concentration, high-volume local anesthetic solution to the joint capsule and periarticular surrounding tissues to provide postoperative analgesia [24]. When used as a part of a multimodal analgesic protocol in patients undergoing TKA, femoral nerve blockade has been shown to reduce narcotic consumption and improve postoperative pain scores [25]. However, periarticular infiltration is usually insufficient to provide adequate analgesia in the anterior direction of the knee [26]. Periarticular infiltration analgesic protocols that infiltrate anterior, posterior, and medial compartments of the knee are reported to only last between 6 and 12 h [27]. Prolonged motor blockade, quadriceps muscle weakness, difficulty ambulating, and postoperative falls limit the utility of femoral nerve block (FNB) in the “fast track” rehabilitation protocols [28, 29]. In a study, Fascia iliaca block effectively reduced the amount of morphine used after TKA in the first 24 h. This study shows that the fascia iliaca block provides the same level of analgesia with the use of less morphine compared with the periarticular injection [30]. However, the fascia iliaca block requires as much as 40–50 mL of volume to achieve an effective result [31]. In another study, the analgesic efficacy of the fascia iliaca block was compared to the femur nerve block in the guideline of ultrasonography and no difference was found in VAS scores and opioid consumption [32]. The sciatic nerve block (SNB) is used in addition to FNB for complete analgesia after TKA. In a systematic review, SNB administered as a supplement to FNB has shown that it does not provide adequate analgesic activity [33]. Studies with larger patient groups showed a significant reduction in postoperative opioid consumption, less opioid-induced adverse effects, and significantly lower resting and dynamic pain scores [34–38]. Adductor channel block was also studied. In the meta-analysis study performed, there was no significant difference in pain control and morphine consumption between the adductor canal bloc (ACB) and the femoral nerve block (FNB) group. However, it was observed that ACB provided faster postoperative mobilization ability without reduction of analgesia in patients undergoing TKA [39]. Another study conducted after TKA to compare the efficacy of single-shot adductor canal block (SACB) and postoperative continuous adductor canal block (CACB) placement and showed that CACB was superior to SACB for analgesia control but ambulation ability, success rate, early functional recovery, and treatment-related side effects were similar [40]. Different studies have shown that ACB and FNB have similar motor function recovery, strength ratings, and quadriceps muscle strength at postoperative 24 and 48 h in TKA patients [41, 42].

6.2. Drug therapy

TKA operation is one of the most painful orthopedic procedures [43]. For this reason, it is difficult to provide adequate analgesia with a single drug or method. Multimodal analgesia methods will be more appropriate to reduce side effects and provide pain control. Multimodal analgesia is defined as providing more effective pain control by the combined use of various analgesic drugs and techniques that may have additive or synergistic effects targeting different pain mechanisms in the peripheral and/or central nervous system [44].

In multimodal pain management, patient education, preemptive oral medications, regional anesthesia methods, peripheral nerve blocks, local infiltrations, and postoperative rehabilitation are included. Most of the side effects seen in analgesia treatment are due to the parenteral opioid. One of the main goals of multimodal analgesia is to reduce the need for opioids.

6.2.1. Nonsteroidal anti-inflammatory drugs

Tissue inflammation in TKA surgery triggers the production of PGs that play a role in acute postoperative pain. NSAIDs reduce central sensitization by inhibiting central and peripheral prostaglandin synthesis. It may be effective for 2 weeks when inflammation continues in the postoperative period. Ketorolac is a nonselective COX inhibitor and has oral, parenteral, ophthalmic, and nasal forms. It is used in moderate and severe postoperative pain management after major surgeries [45]. It reduces opioid consumption when used as a part of multimodal pain management [46]. The use of NSAIDs can cause gastritis or peptic ulcer formation and impair platelet aggregation, renal function, and wound healing. For this reason, there are concerns about their use in the perioperative period. Preemptive use of selective COX-2 (cyclooxygenase) inhibitors (celecoxib and rofecoxib) has been shown to reduce postoperative pain scores in the knee surgeries [47]. The use of selective COX2 inhibitors in TKA surgeries has been shown to reduce opioid consumption, provide early onset of physical rehabilitation, and reduce nausea and vomiting [48]. Similarly, diclofenac or ketorolac administered in a single dose in joint arthroplasty patients reduced morphine consumption by 29% compared to placebo [49].

6.2.2. Paracetamol

It is nonopioidand and non-NSAID analgesic. It inhibits prostaglandin synthesis in the CNS and plays a role in preventing central sensitization. There is a minimal effect on peripheral PG synthesis. Unlike NSAIDs, the anti-inflammatory effect is poor, and there are no negative effects on platelet function and gastric mucosa. It has been shown that 1 g intravenous paracetamol provides rapid and effective analgesia in major orthopedic surgeons [50]. Paracetamol can be administered 1 g/day four times. When combined with paracetamol and NSAIDs, better analgesia is achieved when both drugs are used alone [51].

6.2.3. Glucocorticoids

Glucocorticoids have strong anti-inflammatory effects. Corticosteroids are thought to be an important component because of their local anti-inflammatory effects and their ability to reduce the local stress response in the operation [52]. There have been many studies on corticosteroids, and conflicting evidence has been obtained about their benefits [53–58]. Some studies have shown that postoperative pain is improved with corticosteroids [53–56] but other studies do not benefit [57, 58]. In another study, postoperative pain level was lower in the corticosteroid group than that in the noncorticosteroid group in first 24 h [59]. In a meta-analysis, dexamethasone, a long-acting glucocorticoid, has been shown to reduce postoperative pain and opioid consumption [60]. In one study, it was shown that preoperative single dose iv 40 mg dexamethasone reduced dynamic pain scores [61]. Another study showed that dexamethasone administered as a part of multimodal analgesia in 269 patients undergoing TKA reduced postoperative pain and bulimia and did not increase wound complications [62]. In contrast to these studies, patients with a periarticular injection with high- and low-dose corticosteroids were compared and found no improvement in postoperative pain level [58]. Surgical techniques such as the surgical approach and the use of pneumatic turniken may be effective on early postoperative pain [63, 64]. One of the most commonly used corticosteroids for periarticular injection is methylprednisolone [52, 57, 65–67].

6.2.4. Opioids

Opioids have been used to provide analgesia and relieve anxiety for centuries. Opioid receptors are found in many regions of the CNS. These receptors are located in the central nervous system, cerebral cortex, hypothalamus, thalamus, midbrain extrapyramidal area, substantia gelatinosa, and sympathetic preganglionic nerves. Places with the highest concentration of these receptors are structures and pathways associated with pain [68].

The first opioid receptors were found in 1973. Later, endogenous opioids were found. There are four types of receptors. These include mu (μ), kappa (k), sigma (s), and delta (d) receptors. Opioids show their effect by linking their receptors.

1. Mu (μ) receptors: specific morphine agonist. It is stimulated by morphine and is responsible for supraspinal analgesia.
2. Kappa (k) receptors: they are responsible for spinal analgesia and sedation.
3. Sigma (s) receptors: responsible for dysphoria and hallucinations.
4. Delta (d) receptors: beta-endorphin and encephalin are specific agonists. It is influential on motor integration and urine function.

Classification of opioids:

1. Natural opioids: phenanthrene derivatives: codeine, morphine, and thebaine. Benzylisoquinoline derivatives: papaverine.
2. Synthetic opioids: phenylpiperidine derivatives (fentanyl, sufentanil, and meperidine), benzomorphan derivatives (pentazocine and phenazocine), diphenylpropyl or methadone derivatives (methadone and d-propoxyphene), and morphinan derivatives (levorphanol).
3. Semisynthetic opioids: dihydromorphone/morphinone, heroin, and thebaine derivatives (etorphine).

Morphine contains the basic properties of the majority of the structures of the opioids. The effects of morphine in the central nervous system, analgesia, euphoria and sedation. The most important effect of morphine on the central nervous system therapeutically is analgesia.

Analgesia provided by systemic opioids often accompanies side effects such as sedation, nausea, pruritus, urinary retention, and constipation. However, they continue to be an important part of severe postoperative pain management [69]. They can be used intramuscularly, intravenously, orally, rectally, sublingually, subcutaneously, epidurally, or intrathecally. If patients are able to use the oral route, oral administration is recommended. Side effects of oral opioids are less frequent and are mostly related to the gastrointestinal system. Intravenous patient-controlled analgesia (PCA) should be preferred if the parenteral route is used. Intravenous opioid PCA is recommended for bolus application with appropriate lock interval without basal infusion. In the postoperative period, it is usually administered via intravenous PCA for the first 24–48 h and then is used as oral agents [44]. Oral opioids have immediate release and controlled release forms [70]. Rapid-release patients are effective in the treatment of moderate and severe postoperative pain, but are impractical because they need to be reapplied every 4 h. Since postoperative pain is continuous at the beginning, analgesics should be used regularly especially in the first 24 h. Long-acting oxymorphone and oxycodone have been shown to be effective in postoperative analgesia in TKAs [71, 72]. Especially morphine and fentanyl are frequently used for postoperative analgesia in TKA cases. The application of intrathecal morphine and fentanyl is very effective in postoperative pain control. In a study conducted, 0.2 mg and 0.3 mg intrathecal morphine administration was shown to be effective for postoperative analgesia [73]. Other studies have been done to support this study. The use of 0.5 mg intrathecal morphine has been shown to be more reliable and more effective than injections of 0.2 mg [74].

Intrathecal morphine is less hydrophobic than other opioids, has a longer duration in the cerebrospinal fluid, and provides very good postoperative analgesia [75]. On the other hand, another study reported that morphine should not be used even in small doses due to these side effects [76]. Opioids are known to produce more effective and long-lasting anesthesia when used with local anesthetics. Opioids are known to produce more effective and long-lasting anesthesia when used with local anesthetics [77, 78]. In a study of TKA cases, we compared the use of intrathecal morphine and fentanyl for postoperative analgesia and found that fentanyl provided more effective postoperative analgesia [79]. Long-acting opioids (LAO) are often used for malignant, nonmalignant, and different pain treatments. A lot of work about LAO (oxycodone, morphine) has been done in this regard. In a study on LAO, there was a decrease in pain while there was an increase in vomiting and sedation [80]. After the use of LAO (oxycodone), the rehabilitation of patients was found to be better in TKA cases [81]. In the studies performed, intravenous PCA and oxycodone were compared and there was no difference in pain [82], and no difference in pain after LAO (oxycodone) used after total joint arthroplasty [83].

6.2.5. Gabapentinoids (gabapentin and pregabalin)

Gabapentin has been shown to be effective in the treatment of herpetic neuralgia, neuropathic pain [84], and diabetic neuropathy [85]. These anticonvulsant drugs, which have been used for a long time in the management of chronic pain, have started to be used in acute postoperative analgesia in recent years. They may cause side effects such as sedation and dizziness. It has been shown that administration of pregabalin (300 mg preoperatively and 150–50 mg twice daily for the first 14 days postoperatively) reduces the incidence of opioid consumption and neuropathic pain development after TKA [86]. We also have studies showing that postoperative analgesia is reduced after the application of preoperative gabapentin and pregabalin in lower extremity surgeons [87, 88]. Another study has shown that gabapentin effectively reduces postoperative narcotics consumption and pruritus incidence [89]. In another meta-analysis trial, the use of pregabalin shows that it could improve pain control at 24 and 48 h with rest, reduce morphine consumption, and improve knee flexion level, as well as reduce nausea, vomiting, and pruritic event rate. However, pregabalin increased the incident rate of dizziness after total knee arthroplasty (TKA) and total hip arthroplasty (THA) but could not improve the pain control at 72 h with rest [90].

6.2.6. Ketamine

Ketamine is used by anesthetists for sedation and general anesthesia. With the detection of the N-methyl-D-aspartate receptor's role in nociceptive pain transmission and central sensitization, ketamine has begun to be used as a potential antihyperalgesic agent. Subanesthetic low doses of ketamine provide significant analgesic efficacy without psychomimetic side effects [45]. Low-dose ketamine has no adverse effects on respiratory and cardiovascular system and does not cause nausea-vomiting, urinary retention and constipation or postoperative ileus. In patients receiving TKA, low-dose ketamine infusion has been shown to reduce morphine consumption postoperatively (3 μg/kg per minute intraoperatively and 1.5 μg/kg per minute for 48 h) [91].

6.3. Nonpharmacological techniques

There have been many studies on surgical techniques and equipment, but most have had no or limited effect on postoperative analgesia. These studies focused on drains, surgical approaches, tourniquet use, prosthetic types, and reshaping of the patellar surface. A comparison of cooling and compression techniques with the control group showed that postoperative pain and morphine consumption were reduced [92]. The efficacy of TENS administration in postoperative analgesia after TDP was not demonstrated [93]. The results of cryotherapy are contradictory. The potential benefits of cryotherapy in a meta-analysis are not clinically significant [94]. Routine use is therefore not recommended.

6.4. Preemptive analgesia

Analgesics are administered before painful stimulation to prevent peripheral and central sensitization. Preemptive analgesia inhibits peripheral sensitization and central sensitization. It should also prevent inflammatory and neuropathic pain types [95]. Local anesthetic infiltration, regional anesthesia methods, and drugs (NMDA receptor antagonists, opioids, COX-2 inhibitors, nonsteroidal anti-inflammatory drugs (NSAID), and local anesthetics) can be used for preemptive analgesia. According to a study, preemptive analgesia is statistically significant, although not clinically significant [96]. When preemptive analgesia is administered, it should be considered as a method of pathological pain as well as physiological conventional perioperative analgesia [97]. Preemptive analgesia is an effective method in clinical practice for the approach to postoperative pain involving incisional and inflammatory injury [98].

Drugs used in preemptive analgesia:

1. Local anesthetics
2. Nonsteroidal anti-inflammatory drugs (NSAIDs)
3. COX-2 inhibitors
4. Opioids
5. NMDA receptor antagonists

6.5. Patient education

There are two major components of pain perception: the sensory discriminative component and the motivational affective component [99]. Emotional component is targeted with patient education. Patients and their relatives are informed, and their anxiety is reduced by eliminating their fears about the unknown; the realistic goals are identified, and a relationship is established with patients and their relatives; the patient satisfaction increases, and the pain scores decrease [100].

7. Conclusion

In TKA, many methods are proposed and used for postoperative pain management. There are many factors that affect postoperative pain management. The age of the patient, the experience of the surgeon, the technical conditions, and the method used are some of these. Taking all these factors and literature into consideration, the use of multimodal analgesia techniques is recommended.

Systemic medications for postoperative analgesia after TKA:

1. Paracetamol
2. NSAIDs
    a. Celecoxib
    b. Ibuprofen
    c. Naproxen
    d. Ketorolac
3. Ketamine
4. Gabapentinoids
    a. Gabapentin
    b. Pregabalin
5. Glucocorticoids
6. Opioids
    a. Morphine
    b. Fentanyl
    c. Hydromorphone
    d. Hydrocodone
    e. Tramadol
    f. Extended-release oxycodone
    g. Extended-release morphine

8. Key rules in knee rehabilitation

1. Bone-bond stability is a prerequisite for optimal knee function recovery [101, 102].
2. Postsurgery rehabilitation program should be started early.

http://dx.doi.org/10.5772/intechopen.74296

3. During the rehabilitation program, unbalanced and full weight should not be allowed until a normal range of motion and walking pattern is achieved.
4. The development of reflex inhibition in the extensor or flexor mechanisms should be recognized early and must be struggled in the appropriate modalities.
5. The operated and unoperated extremities should be strengthened together.
6. For the success of the rehabilitation program, orthopedic surgeon, physical medicine and rehabilitation specialist, physiotherapist, occupational therapist, nurse, and the social team of service specialists need to communicate well.

Author details

Yavuz Orak* and Mahmut Arslan

*Address all correspondence to: dryavuzorak@hotmail.com

Anesthesiology and Reanimation Department, Faculty of Medicine, Kahramanmaras Sutcu Imam University, Kahramanmaraş, Turkey

References

[1] Ferrante FM, Vadebonconer TR. Postoperative Pain Management. 2nd ed. New York: Churchill Livingstone Inc.; 1993. pp. 485-518

[2] Carr DB, Goudas IC. Acute pain. Lancet. 1999;**353**:2051

[3] Basbaum AI, Jessel T. The perception of pain. In: Kandel ER, Schwartz J, Jessel T, editors. Principles of Neuroscience. New York: Appleton and Lange; 2000. p. 472

[4] Craig AD, Bushnell MC, Zhang ET, Blomqvist A. A thalamic nucleus specific for pain and temperature sensation. Nature. 1994;**372**:770-773

[5] Gerbershagen HJ, Aduckathil S, van Wijck AJM, Peelen LM, Kalkman CJ, Meissner W. Painintensityon the first day after surgery:A prospective cohort study comparing 179 surgical procedures. Anesthesiology. 2013;**118**(4):934-944

[6] Liu SS, Wu CL. The effect of analgesic technique on postoperative patient-reported outcomes including analgesia: A systematic review. Anesthesia and Analgesia. 2007; **105**(3):789-808

[7] Hall MJ, DeFrances CJ, Williams SN, Golosinskiy A, Schwartzman A. National hospital discharge survey: 2007 summary. National Health Statistics Reports. 2010:1-20, 24

[8] Ethgen O, Bruyere O, Richy F, Dardennes C, Reginster JY. Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. The Journal of Bone and Joint Surgery. American Volume. 2004;**86**:963-974

[9] Breivik H. Postoperative pain management: Why is it difficult to show that it improves outcome? European Journal of Anaesthesiology. 1998;**15**(6):748-751

[10] Joshi GP, Ogunnaike BO. Consequences of inadequate postoperative pain relief and chronic persistent postoperative pain. Anesthesiology Clinics of North America. 2005; **23**(1):21-36

[11] Kehlet H. Multimodal approach to control postoperative pathophysiology and rehabilitation. British Journal of Anaesthesia. 1997;**78**(5):606-617

[12] Galimba J. Promoting the use of periarticular multimodal drug injection for total knee arthroplasty. Orthopaedic Nursing. 2009;**28**:250-254 [quiz 255]

[13] Brisbane Orthopaedic & Sports Medicine Centre Writing Committee, McMeniman TJ, McMeniman PJ, Myers PT, Hayes DA, Cavdarski A, et al. Femoral nerve block vs fascia iliaca block for total knee arthroplasty postoperative pain control: A prospective, randomized controlled trial. The Journal of Arthroplasty. 2010;**25**:1246-1249

[14] Memtsoudis SG, Sun X, Chiu YL, et al. Perioperative comparative effectiveness of anesthetic technique in orthopedic patients. Anesthesiology. 2013;**118**:1046-1058

[15] Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S, Callaghan JJ. Differences in short-term complications between spinal and general anesthesia for primary total knee arthroplasty. The Journal of Bone and Joint Surgery. American Volume. 2013;**95**:193-199

[16] Chang CC, Lin HC, Lin HW. Anesthetic management and surgical site infections in total hip or knee replacement: A population-based study. Anesthesiology. 2010;**113**:279-284

[17] Memtsoudis SG, Stundner O, Rasul R, et al. Sleep apnea and total joint arthroplasty under various types of anesthesia: A population-based study of perioperative outcomes. Regional Anesthesia and Pain Medicine. 2013;**38**:274-281

[18] Lamplot JD, Wagner ER, Manning DW. Multimodal pain management in total knee arthroplasty: A prospective randomized controlled trial. The Journal of Arthroplasty. 2013;**29**:329-334

[19] Chan E-Y, Fransen M, Sathappan S, Chua NHL, Chan Y-H, Chua N. Comparing the analgesia effects of singleinjection and continuous femoral nerve blocks with patient controlled analgesia after total knee arthroplasty. Journal of Arthroplasty. 2013;**28**(4):608-613

[20] Chang CB, Cho W-S. Pain management protocols, peri-operative pain and patient satisfaction after total knee replacement: A multicentre study. The Journal of Bone & Joint Surgery—British Volume. 2012;**94**(11):1511-1516

[21] Adam F, Chauvin M, Du Manoir B, Langlois M, Sessler DI, Fletcher D. Small-dose ketamine infusion improves postoperative analgesia and rehabilitation after total knee arthroplasty. Anesthesia and Analgesia. 2005;**100**(2):475-480

[22] Blaudszun G, Lysakowski C, Elia N, Tram'er MR. Effect of perioperative systemic $\alpha 2$ agonists on postoperative morphine consumption and pain intensity: Systematic review and meta-analysis of randomized controlled trials. Anesthesiology. 2012;**116**(6):1312-1322

[23] Lunn TH, Kristensen BB, Andersen LØ, et al. Effect of high-dose preoperative methylprednisolone on pain and recovery after total knee arthroplasty: A randomized, placebocontrolled trial. British Journal of Anaesthesia. 2011;**106**(2):230-238

[24] Ng FY, Ng JKF, Chiu KY, Yan CH, Chan CW. Multimodal periarticular injection vs continuous femoral nerve block after total knee arthroplasty: A prospective, crossover, randomized clinical trial. The Journal of Arthroplasty. 2012;**27**:1234-1238

[25] Paul JE, Arya A, Hurlburt L, et al. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: A meta-analysis of randomized controlled trials. Anesthesiology. 2010;**113**:1144-1162

[26] Sanna M, Sanna C, Caputo F, Piu G, Salvi M. Surgical approaches in total knee arthroplasty. Joints. 2013;**1**:34-44

[27] Andersen L, Kehlet H. Analgesic efficacy of local infiltration analgesia in hip and knee arthroplasty: A systematic review. British Journal of Anaesthesia. 2014;**113**:360-374

[28] Sharma S, Iorio R, Specht LM, Davies-Lepie S, Healy WL. Complications of femoral nerve block for total knee arthroplasty. Clinical Orthopaedics and Related Research. 2010;**468**:135-140

[29] Kandasami M, Kinninmonth AW, Sarungi M, Baines J, Scott NB. Femoral nerve block for total knee replacement—Aword of caution. The Knee. 2009;**16**:98-100

[30] Bali C, Ozmete O, Eker HE, Hersekli MA, Aribogan A. Postoperative analgesic efficacy of fascia iliaca block versus periarticular injection for total knee arthroplasty. Journal of Clinical Anesthesia. 2016 Dec;**35**:404-410. DOI: 10.1016/j.jclinane.2016.08.030 Epub 2016 Oct 14

[31] Range C, Egeler C. Fascia Iliaca compartment block: Landmark and ultrasound approach. http://www.frca.co.uk/Documents/193%20Fascia%20Iliaca%20compartment%20 block.pdf

[32] Kong M, Guo R, Chen J, Li P, Wu Z. Arandomized study to compare the analgesic efficacy of ultrasound-guided block of fascia Iliaca compartment or femoral nerve after patella fracture surgery. Cell Biochemistry and Biophysics. 2015;**72**:567-570

[33] Abdallah FW, Brull R. Is sciatic nerve block advantageous when combinedwithfemoralnerveblockfor postoperativeanalgesiafollowing total knee arthroplasty? A systematic review. Regional Anesthesia and Pain Medicine. 2011;**36**:493-498

[34] Wegener JT, van Ooij B, van Dijk CN, et al. Value of single-injection or continuous sciatic nerve block in addition to a continuous femoral nerve block in patients undergoing total knee arthroplasty: A prospective, randomized, controlled trial. Regional Anesthesia and Pain Medicine. 2011;**36**:481-488

[35] Pham Dang C, Gautheron E, Guilley J, et al. The value of adding sciatic block to continuous femoral block for analgesia after total knee replacement. Regional Anesthesia and Pain Medicine. 2005;**30**:128-133

[36] Morin AM, Kratz CD, Eberhart LH, et al. Postoperative analgesia and functional recovery after total-knee replacement: Comparison of a continuous posterior lumbar plexus (psoas compartment) block, a continuous femoral nerve block, and the combination of a continuous femoral and sciatic nerve block. Regional Anesthesia and Pain Medicine. 2005;**30**:434-445

[37] Hunt KJ, Bourne MH, Mariani EM. Single-injection femoral and sciatic nerve blocks for pain control after total knee arthroplasty. The Journal of Arthroplasty. 2009;**24**:533-538

[38] Abdallah FW, Chan VW, Gandhi R, et al. The analgesic effects of proximal, distal, or no sciatic nerve block on posterior knee pain after total knee arthroplasty: A double-blind placebo-controlled randomized trial. Anesthesiology. 2014;**121**:1302-1310

[39] Gao F, Ma J, Sun W, Guo W, Li Z, Wang W. Adductor canal block versus femoral nerve block for analgesia after total knee arthroplasty a systematic review and meta-analysis. Clinical Journal of Pain. April 2017;**33**(4)

[40] Shah NA, Jain NP, Panchal KA. Adductor canal blockade following total knee arthroplasty-continuous or single shot technique? Role in postoperative analgesia, ambulation ability and early functional recovery: A randomized controlled trial. The Journal of Arthroplasty. 2015;**30**:1476-1481

[41] Kim DH, Lin Y, Goytizolo EA, et al. Adductor canal block versus femoral nerve block for total knee arthroplasty: A prospective, randomized, controlled trial. Anesthesiology. 2014;**120**:540-550

[42] Memtsoudis SG, Yoo D, Stundner O, et al. Subsartorial adductor canal vs femoral nerve block for analgesia after total knee replacement. International Orthopaedics. 2015; **39**:673-680

[43] Buvanendran A, Fiala J, Patel KA, Golden AD, Moric M, Kroin JS. The incidence and severity of postoperative pain following inpatient surgery. Pain Medicine. 2015;**16**:2277-2283

[44] Chou R, Gordon DB, de Leon-Casasola OA, et al. Management of postoperative pain: A clinical practice guideline from the American Pain Society, the American Society of Regional Anesthesia and Pain Medicine, and the American Society of Anesthesiologists' Committee on Regional Anesthesia, Executive Committee, and Administrative Council. The Journal of Pain. 2016;**17**:131-157

[45] Kopp SL, Børglum J, Buvanendran A, Horlocker TT, Ilfeld BM, Memtsoudis SG, Neal JM, Rawal N, Wegener JT. Anesthesia and analgesia practice pathway options for total knee arthroplasty: An evidence-based review by the American and European Societies of regional anesthesia and pain medicine. Regional Anesthesia and Pain Medicine. 2017;**42**(6):683-697

[46] Dorr LD, Raya J, Long WT, Boutary M, Sirianni LE. Multimodal analgesia without parenteral narcotics for total knee arthroplasty. The Journal of Arthroplasty. 2008;**23**:502-508

[47] Reuben SS, Bhopatkar S, Maciolek H, Joshi W, Sklar J. The preemptive analgesic effect of rofecoxib after ambulatory arthroscopic knee surgery. Anesthesia and Analgesia. 2002; **94**:55-59

[48] Buvanendran A, Kroin JS, Tuman KJ, Lubenow TR, Elmofty D, et al. Effects of perioperative administration of a selective cyclooxygenase 2 inhibitor on pain management and recovery of function after knee replacement: A randomized controlled trial. JAMA. 2003;**290**:2411-2418

[49] Alexander R, El-Moalem HE, Gan TJ. Comparison of the morphine-sparing effects of diclofenac sodium and ketorolac tromethamine after major orthopedic surgery. Journal of Clinical Anesthesia. 2002;**14**:187-192

[50] Sinatra RS, Jahr JS, Reynolds LW, Viscusi ER, Groudine SB, Payen-Champenois C. Efficacy and safety of single and repeated administration of 1 gram intravenous acetaminophen injection (paracetamol) for pain management after major orthopaedic surgery. Anesthesia. 2005;**102**:822-831

[51] Ong CK, Seymour RA, Lirk P, Merry AF. Combining paracetamol (acetaminophen) with nonsteroidal antiinflammatory drugs: A qualitative systematic review of analgesic efficacy for acute postoperative pain. Anesthesia and Analgesia. 2010;**110**:1170-1179

[52] Parvataneni HK, Shah VP, Howard H, et al. Controlling pain after total hip and knee arthroplasty using a multimodal protocol with local periarticular injections: A prospective randomized study. The Journal of Arthroplasty. 2007;**22**(suppl 2):33-38

[53] keuchi M, Kamimoto Y, Izumi M, et al. Effects of dexamethasone on local infiltration analgesia in total knee arthroplasty: A randomized controlled trial. Knee Surgery, Sports Traumatology, Arthroscopy. 2014;**22**:1638-1643

[54] Sean VW, Chin PL, Chia SL, et al. Single-dose periarticular steroid infiltration for pain management in total knee arthroplasty: A prospective, double-blind, randomised controlled trial. Singapore Medical Journal. 2011;**52**:19-23

[55] Yue DB, Wang BL, Liu KP, Guo WS. Efficacy of multimodal cocktail periarticular injection with or without steroid in total knee arthroplasty. Chinese Medical Journal. 2013;**126**:3851-3855

[56] Kwon SK, Yang IH, Bai SJ, Han CD. Periarticular injection with corticosteroid has an additional pain management effect in total knee arthroplasty. Yonsei Medical Journal. 2014;**55**:493-498

[57] Christensen CP, Jacobs CA, Jennings HR. Effect of periarticular corticosteroid injections during total knee arthroplasty. A double-blind randomized trial. Journal of Bone and Joint Surgery. American Volume. 2009;**91-A**:2550-2555

[58] Chia SK, Wernecke GC, Harris IA, et al. Peri-articular steroid injection in total knee arthroplasty: A prospective, double blinded, randomized controlled trial. The Journal of Arthroplasty. 2013;**28**:620-623

[59] Tsukada S, Wakui M, Hoshino A. The impact of including corticosteroid in a periarticular injection for pain control after total knee arthroplasty. Bone & Joint Journal. 2016;**98-B**:194-200

[60] De Oliveira GS Jr, Almeida MD, Benzon HT, McCarthy RJ. Perioperative single dose systemic dexamethasone for postoperative pain: A meta-analysis of randomized controlled trials. Anesthesiology. 2011;**115**(3):575-588

[61] Kardash KJ, Sarrazin F, Tessler MJ, Velly AM. Single-dose dexamethasone reduces dynamic pain after total hip arthroplasty. Anesthesia and Analgesia. 2008;**106**:1253-1257

[62] Koh IJ, Chang CB, Lee JH, Jeon YT, Kim TK. Preemptive low-dose dexamethasone reduces postoperative emesis and pain after TKA: A randomized controlled study. Clinical Orthopaedics and Related Research. 2013;**471**:3010-3020

[63] Matsueda M, Gustilo RB. Subvastus and medial parapatellar approaches in total knee arthroplasty. Clinical Orthopaedics and Related Research. 2000;**371**:161-168

[64] Ejaz A, Laursen AC, Kappel A, et al. Faster recovery without the use of a tourniquet in total knee arthroplasty. Acta Orthopaedica. 2014;**85**:422-426

[65] Tsukada S, Wakui M, Hoshino A. Pain control after simultaneous bilateral total knee arthroplasty: A randomized controlled trial comparing periarticular injection and epidural analgesia. Journal of Bone and Joint Surgery: American Volume. 2015;**97-A**:367-373

[66] Yadeau JT, Goytizolo EA, Padgett DE, et al. Analgesia after total knee replacement: Local infiltration versus epidural combined with a femoral nerve blockade: A prospective, randomised pragmatic trial. Bone & Joint Journal. 2013;**95-B**:629-635

[67] Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: A modification of CDC definitions of surgical wound infections. Infection Control and Hospital Epidemiology. 1992;**13**:606-608

[68] Reisine T, Pasternak G. Opioid analgesics and antagonists. In: Hardman JG, Limbard LE, editors. Goodman and Gilman's the Pharmacologic Basis of Therapeutics. 9th ed. New York: McGraw-Hill; 1996. p. 521

[69] Pulos N, Sheth N. Perioperative pain management following total joint arthroplasty. Annals of Orthopedics and Rheumatology. 2014;**2**(3):1029

[70] Azam MQ, Sadat-Ali M, Bader A. Pain management in knee arthroplasty: An overview. International Journal of Surgery Research and Practice. 2015;**2**:035

[71] Ahdieh H, Ma T, Babul N, Lee D. Efficacy of oxymorphone extended release in postsurgical pain: A randomized clinical trial in knee arthroplasty. Journal of Clinical Pharmacology. 2004;**44**:767-776

[72] Cheville A, Chen A, Oster G, McGarry L, Narcessian E. A randomized trial of controlled-release oxycodone during inpatient rehabilitation following unilateral total knee arthroplasty. Journal of Bone and Joint Surgery. American Volume. 2001;**83-A**(6):915

[73] Rathmell JP, Pino CA, Taylor R, Patrin T, Viani BA. Intrathecal morphine for postoperative analgesia: A randomized, controlled, dose-rangingstudyafterhipandknee arthroplasty. Anesthesia and Analgesia. 2003;**97**(5):1452-1457

[74] Gupta A. Update on intra-articular analgesia. Techniques in Regional Anesthesia and Pain Management. 2003;**7**(3):155-160

[75] Andrieu G, Roth B, Ousmane L, et al. The efficacy of intrathecal morphine with or without clonidine for postoperative analgesia after radical prostatectomy. Anesthesia and Analgesia. 2009;**108**(6):1954-1957

[76] Gürkan Y, Canatay H, Özdamar D, Solak M, Toker K. Spinal anesthesia for arthroscopic knee surgery. Acta Anaesthesiologica Scandinavica. 2004;**48**(4):513-517

[77] Bailey PL, Stanley TH. Pharmacology of intravenous narcotic aneshhetics. In: Miller RP, editor. Anesthesia. New York, NY, USA: Churchill Livingstone; 1986. pp. 745-797

[78] Gustafsson LL, Hallin ZW. Spinal opioid analgesia. A criticalupdate. Drugs. 1988;**35**(6): 597-603

[79] Kilickaya R, Orak Y, Balci MA, Balci F, Unal I. Comparison of the effects of intrathecal fentanyl and intrathecal morphine on pain in elective total knee replacement surgery. Pain Research & Management. 2016;**2016**:3256583

[80] Musclow SL, Bowers T, Vo H, Glube M, Nguyen T. Long-acting morphine following hip or knee replacement: A randomized, double-blind, placebo-controlled trial. Pain Research and Management. 2012;**17**(2):83-88

[81] Cheville A, Chen A, Oster G, McGarry L, Narcessian E. A randomized trial of controlled-release oxycodone during inpatient rehabilitation following unilateral total knee arthroplasty. The Journal of Bone and Joint Surgery. American Volume. 2001;**83**:572-576

[82] Illgen R, Pellino T, Gordon D, Butts S, Heiner J. Prospective analysis of a novel long-acting oral opioid analgesic regimen for pain control after total hip and knee arthroplasty. The Journal of Arthroplasty. 2006;**21**:814-820

[83] Kerpsack J, Fankhauser R. The use of controlled-release versus scheduled oxycodone in the immediate postoperative period following total joint arthroplasty. Orthopedics. 2005;**28**:491-494

[84] Rosner H, Rubin L, Kestenbaum A. Gabapentin adjunctive therapy in neuropathic pain states. The Clinical Journal of Pain. 1996;**12**:56-58

[85] Backonja M, Beydoun A, Edwards KR, et al. Gabapentin for the symptomatic treatment of painful neuropathy in patients with diabetes mellitus: A randomized controlled trial. Journal of the American Medical Association. 1998;**280**:1831-1836

[86] Buvanendran A, Kroin JS, Della Valle CJ, Kari M, Moric M, Tuman KJ. Perioperative oral pregabalin reduces chronic pain after total knee arthroplasty: A prospective, randomized, controlled trial. Anesthesia and Analgesia. 2010;**110**:199-207

[87] Orak Y, Gunes Y, Bicer S, Ozcengiz D. The effect of gabapentin on postoperative pain and opioid-related side effects in patients undergoing combined spinal-epidural anaesthesia (a preliminary study). Clinical and Experimental Medical Sciences. 2013;**1**(6):251-261

[88] Türktan M, Orak Y, Yasemin G, Sunkar Biçer Ö, Güleç E, Hatipoğlu Z, Burgut R. The effect of pregabalin on postoperative pain in the patients undergoing lower extremity surgery. Turkiye Klinikleri Journal of Anesthesiology. 2014;**12**(1):26-30

[89] Han C, Li X-d, Jiang H-g, Ma J-x, Ma X-l. The use of Gabapentin in the management of postoperative pain after total knee arthroplasty. A PRISMA-compliant meta-analysis of randomized controlled trials. Medicine. 2016;**95**:23

[90] Li F, Ma J, Kuang M, Jiang X, Wang Y, Lu B, Zhao X, Sun L, Ma X. The efficacy of pregabalin for the management of postoperative pain in primary total knee and hip arthroplasty: A meta-analysis. Journal of Orthopaedic Surgery and Research. 2017;**12**:49. DOI: 10.1186/s13018-017-0540-0

[91] Cengiz P, Gokcinar D, Karabeyoglu I, Topcu H, Cicek GS, Gogus N. Intraoperative low-dose ketamine infusion reduces acute postoperative pain following total knee replacement surgery: A prospective, randomized double-blind placebo-controlled trial. Journal of the College of Physicians and Surgeons–Pakistan. 2014;**24**:299-303

[92] Webb JM, Williams D, Ivory JP, Day S, Williamson DM. The use of cold compression dressings after total knee replacement: A randomized controlled trial. Orthopedics. 1998;**21**:59-61

[93] Angulo DL, Colwell CW Jr. Use of postoperative TENS and continuous passive motion following total knee replacement. Journal of Orthopaedic and Sports Physical Therapy. 1990;**11**:599-604

[94] Adie S, Kwan A, Naylor JM, Harris IA, Mittal R. Cryotherapy following total knee replacement. Cochrane Database of Systematic Reviews. 2012;**9**:CD007911

[95] Craig TH. Multimodal postopertive pain management. American Journal of Health-System Pharmacy. 2004;**61**:4-10

[96] Niv D, Lang DE, Devor M. The effect of preemptive analgesia on subacute postoperative pain. Minerva Anestesiologica. 1999;**65**:127-140

[97] Kissin I. Preemptive analgesia. Anesthesiology. 2000;**93**:1138-1143

[98] Katz J. Preemptive analgesia: Evidence, current status and future direction. European Journal of Anaesthesiology. 1995;**12**:8-13

[99] Melzac R, Casey KL. Sensory, motivational and central control determinants of pain. In: Kenshalo DR, editor. Skin Senses. New York: Springfield, IL; 1968. pp. 423-435

[100] Giraudet-Le Quintrec JS, Coste J, Vastel L, Pacault V, Jeanne L, et al. Positive effect of patient education for hip surgery: A randomized trial. Clinical Orthopaedics and Rela ted Research. 2003:112-120

[101] Demir H. Diz Artroplasti Rehabilitasyonu. Erciyes Tıp Derg. 2002;**24**:194-201

[102] Zeni JA Jr, Snyder-Mackler L. Early postoperative measures predict 1- and 2-year outcomes after unilateral total knee arthroplasty: Importance of contralateral limb strength. Physical Therapy. 2010;**90**:43-54

Chapter 7

Fast Track Surgery Program in Knee Replacement

Jou-Hua Wang, Chih-Wei Chang, Yi-Chen Chen,
Chyun-yu Yang and Kai-Lan Hsu

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74026

Abstract

A Fast-track (FT) program, a well-established approach for patients undergoing selective operations, aims at enhanced post-operative recovery. It was first introduced by Professor Henrik Kehlet in 1990s and was applied in colorectal surgery. With the increasing elderly population as well as the increasing incidence of osteoarthritis, the rapid growth of requirement of joint arthroplasties is to be expected. Therefore, many orthopedic teams have applied related principles to their daily practice of total knee arthroplasty to accelerate rehabilitation with lower mortality and morbidity, and to optimize patient satisfaction. The program is a multimodal and multidisciplinary standardized care. Various caring specialties are involved to fulfill the goals of the fast-track program; the basic members include anesthetists, surgeons, pain specialist, physiotherapists, nurses and even medical physicians. In general, the strategy consists of five strands: careful patient selection, improving preoperative care, minimizing perioperative stresses, decreasing postoperative discomfort, and improving postoperative recovery. Through full understanding of these strands and concepts, a comprehensive, perioperative care is thus constructed. This review article gives reader an overall concept of fast track surgery in total knee replacement surgery. A comprehensive search in English literature, including case series, associate randomized controlled trials and systematic reviews were performed using the PubMed databases in 2017 December.

Keywords: fast-track, total knee arthroplasty, multimodal, enhanced recovery, perioperative care

1. Introduction

A Fast-track (FT) program, or more precisely named enhanced recovery after surgery (ERAS) is a well-established approach for patients undergoing selective operations that target enhanced

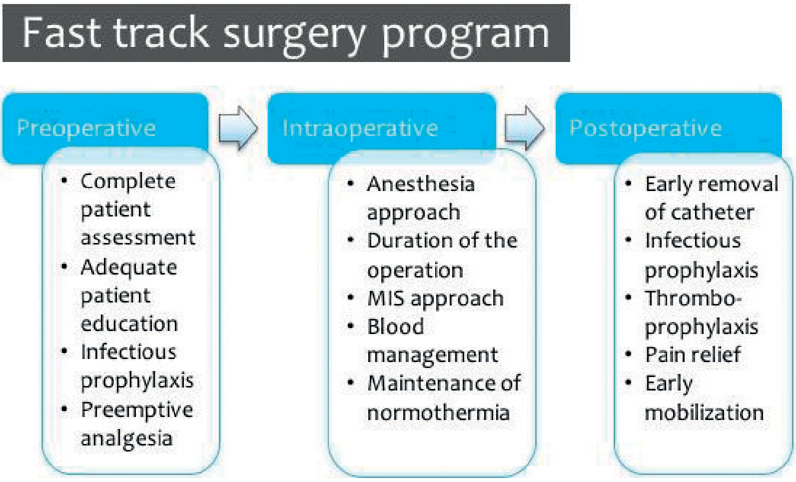


Figure 1. Algorithm of fast track TKA surgery.

post-operative recovery [1, 2]. FT refers to a standardized, evidence-base and multimodal strategy to surgery [3]. It aims at early recovery, early discharge with better prognosis and less complications. Outpatient surgical pathways even go one step further and aim for same day of admission and discharge of the patient undergoing selective operations.

This concept was pioneered by Professor Henrik Kehlet in the early 1990s and firstly applied in the colorectal surgery [4]. It is then expanded to many surgical fields, e.g., gynecologic, urologic, cardiovascular or orthopedic surgery. Over the past decades, it has been proven an effective and beneficial program for not only patients but also surgeons as well as the health insurance system.

As increasing elderly population and increasing incidence of osteoarthritis, the growth of requirement of knee arthroplasty is to be expected [5]. However, the difficulty in economic health care along with increasing financial pressure has reinforced the necessity of putting FT into the focus. An increasing number of knee surgeons have already introduced fast track surgery for patients undergoing knee arthroplasty. It is carried out by the fast track team which composed of anesthetists, surgeons, pain specialist, physiotherapists, and nurses [6].The main strategy consists of five strands: careful patient selection, improving preoperative care, minimizing perioperative stress, decreasing postoperative discomfort, and improving postoperative recovery, thus leading to potentially lower mortality and morbidity as well as optimizing patient satisfaction. To make the FT program and related approaches easily-understood, we classified it into 3 phases according to the proceeding of operation: the pre-, intra- and post-operative management. (**Figure 1**).

2. Preoperative management

The challenge for the patients begins with the initial consultation and the decision to undergo total knee arthroplasty (TKA). It is important to select appropriate candidates and optimize every facet of their condition [7]. There are several key factors that should be considered to minimize the risks of complications and comorbidities [8].

2.1. Preoperative patient assessment

The preoperative assessment should always start with a thorough history taking. Patients often reported pain, functional deficit, or other instability symptoms. The location, duration, severity, character, alleviating and aggravating factors should be obtained in detail. The patients' baseline activity level and past medical history including underlying systemic disease, surgical history, anesthetic history, allergic history, social history and current medication should be recorded. Identification of the unfavorable conditions such as preoperative anemia or coagulopathy is important to reduce the potential complications and comorbidities. Also, previous surgical and non-surgical treatment should be documented. Patient's occupation, leisure hobbies and expectation toward surgical outcomes are inquired.

Complete physical examination is mandatory, including gait observation, inspection, palpation, measurement of range of motion, contractures and ligament stability. Gait observation is mainly looking for the presence of antalgic gait pattern and the requirement of walking aids. Inspection of the patients includes skin change, swelling, and associated deformity of the knee. Following palpation should identify the area of tenderness, severity of effusion, crepitus and patellar tracking. Measurement of range of motion, contractures and ligament stability are also needed.

2.2. Preoperative patient education

Adequate patient education is required to prevent patients or their family from holding unrealistic expectation. Surgeon should notify patients of what will happen during their inpatient stay, associated risks and the postoperative recovery plan. Some educational class illustrating the whole procedure and related impacts are therefore arranged for the candidates for TKA. In addition, the identification of assistive care companion at home is important to clarify the availability and ability of nursing after discharge, leading to the reduced anxiety of the patients for the coming surgical interventions. Through sufficient patient education and discussion, less anxiety with enhanced patient compliance could be expected [9].

2.3. Preoperative preparation

2.3.1. Infectious prophylaxis

One of the great challenge for orthopedic surgeon was avoiding the prosthetic joint-associated infections [10]. Several patients' preoperative conditions are considered as risk factors for increasing the rate of infection after TKA. Risk factors include old age, poor nutritional status, extreme body mass index, smoking, rheumatoid arthritis or diabetes mellitus [11–13]. Previous histories of trauma, steroid injection, or infection elsewhere in the body are also associated with increasing rates of infection. According to the Surgical Care Improvement Project initiated in 2004, rate of wound infections was reduced by the administration of prophylactic antibiotics. Current literature suggested that systemic administration of prophylactic antibiotics should be given within 60 min of surgical incision [14].

2.3.2. Preemptive analgesia

Analgesia given prior to surgery is assumed to prevent peripheral and central sensitization. Preemptive medications such as NSAIDs, COX-2 inhibitors, and the neuropathic agent gabapentin and pregabalin have all shown promising result in reducing the magnitude and duration of postoperative pain [15]. However, the optimal dose, timing of administration, and whether there is potential benefit of continuing the analgesics during operation remain debating issues.

3. Intraoperative management

With the revolutionary advances in the surgical and anesthetic fields, many surgical procedures are now routinely performed on outpatient basis. Currently, with the combination of multiple strategies that target at minimizing surgical stress, many orthopedic surgeons are now applying the concepts of fast track program to their clinical practice. Fast track knee arthroplasty or even outpatient joint arthroplasty is increasingly performed. To reach the goal of fast track, there are 5 major strategies to be aware of: anesthesia approach, duration of the surgical procedure, minimally invasive surgical approach, blood management, and the maintenance of normothermia.

3.1. Anesthesia approach

The potential impact of different types of anesthetic technique administered during TKA on postoperative outcome remains controversial. Different anesthesia approaches may affect the incidence of surgical site infection, urinary retention, and also pose different impact on medical cost. There are two anesthetic techniques that are often used in TKA, general anesthesia and spinal anesthesia. In current literature, spinal anesthesia is a more recommended anesthetic approach as it is associated with more favorable postoperative outcomes, lower complication rate and lower 30-day mortality. Patients receiving spinal anesthesia are observed to experience shorter length of hospital stay, lower rate of pulmonary embolism, pneumonia, cerebrovascular events, acute renal failure and the need for blood transfusion [16, 17].

Regional anesthesia also plays a role in fast track program. Peripheral nerve blocks such as femoral nerve blocks and adductor canal blocks are often used in TKA in assistance with spinal or general anesthesia. It is assumed that peripheral nerve blocks provide supplemental anesthesia and analgesia effect during the perioperative and postoperative periods. Reported benefits include shorter length of hospital stay, less opioid consumption and earlier participation in physical therapy [18–20]. Reduced risk of hypotension and urinary retention were also observed in patients receiving regional anesthesia comparing with patients receiving epidural anesthesia.

Local infiltration anesthesia (LIA) has been gaining focus in recent years, as several well-conducted studies had indicated the potential benefits postoperatively [21, 22]. LIA consists of a mixture of medications that include long-acting anesthetic, NSAIDs and epinephrine. Regimen varies from institution to institution. It is injected to the posterior capsule, collateral ligaments, capsular incision, quadriceps muscle tendon, and the adjacent subcutaneous tissues. Significant reduction in opioid consumption, improvement in pain VAS score and patient satisfaction are observed in patients receiving LIA [21, 22].

3.2. Duration of the surgical procedure

The duration of the surgical procedure should be minimized as short as possible. However, the delay in operation duration is frequently reported with revision surgeries, the use of computer navigation and inexperienced surgeons. Prolonged operative time may be highly associated with the increase rate of surgical site infection, deep wound infection and other associated complications [23].

3.3. Minimally invasive surgical approach

Minimally invasive approach for total knee arthroplasty was introduced in 1990s, and popularized in recent 10 years. The minimally invasive approach allowed smaller wound incision, less soft tissue trauma, less invasion to muscle, especially vastus medialis obliquus (VMO). Minimally invasive approach has transformed from conventional parapatellar approach, and later converted to sub-vastus approach, which boasted no invasion to VMO, and had less soft tissue damage during the procedure. However, with VMO preserved the surgical field clearance decrease and may lead to difficulties in prosthesis sizing, and placement. Mini-midvastus approach was then introduced, and was shown to have similar outcomes comparing to sub-vastus approach [24, 25].

Through minimal invasive approach, extensor muscles were maximally preserved. Large scale of RCTs showed the better short-term outcomes including better knee flexion/ extension torque, faster days to raise leg, greater range of motion, higher in knee society score (KSS), less total estimated blood loss and less postoperative pain [26, 27]. However, minimal invasive approach may also contribute to longer tourniquet time and operating time, as well as wound complication. In term of long term outcomes and longevity, there is still insufficient evidence to declare that minimal invasive approach had long term advantages over conventional total knee arthroplasty.

3.4. Blood management strategy

Perioperative blood loss of TKA can be significant. It could lead to resultant anemia which leads to further need of blood transfusion associated morbidity and mortality [28]. Therefore, it is always an important issue to avoid massive blood loss during and after TKA procedure.

During TKA, a pneumatic tourniquet is commonly used to provide clear surgical field and significantly reduces blood loss and surgical time [29]. However, no significant difference was shown for postoperative knee-extension strength, hemoglobin level, pain, nausea, length of hospital stay, and local swelling.

Antifibrinolytic agents such as tranexamic acid (TXA) decreased the rate of fibrinolysis and therefore stabilizes fibrosis clot [30]. It can be administrated by oral, intra-venous, intramuscular, or intra-articular. Current literature had shown the effect of reducing blood loss, less reduction of postoperative hemoglobin and less swelling with strong evidence [31–33]. In addition, there's no increased risk for deep vein thrombosis (DVT) among related studies.

3.5. Maintenance of normothermia

Maintenance of intraoperative normothermia (defined as a condition of normal core body temperature around 36.5 to 37.5°C) is recommended in current surgical guidelines (AHRQ, WHO, and SCIP) in order to minimize the incidence of complications. Although most surgical guidelines recommend maintaining patients in a normothermia status, the role is still controversial and unclear as these guidelines are often based on limited evidence outside the field of orthopedics. Several studies have suggested that perioperative hypothermia may increase perioperative blood loss, transfusion rate, risk of surgical site infection or the incidence of cardiovascular morbidities.

Patients who underwent general anesthesia or experienced longer operating time were at higher risk of who developing hypothermia. However, some studies showed the contrary result. Even though hypothermia increases the amount of estimated blood loss, it did not increase transfusion rate, postoperative complications, length of hospital stay or the rate of 30-day readmission [34]. In general, it is still recommended that patients' core temperature should be constantly monitored throughout the operation to maintain normothermia status.

4. Postoperative management

The goal of postoperative management is to enhance recovery and encourage patients to participate in physical rehabilitation soon after surgery. To optimize outcome and prognosis, multiple evidence-based principles of postoperative care are required.

4.1. Traditional care principles

Recent studies do not recommend the routine insertion of drain, nasogastric tube, or urinary catheter after surgery, as these tubes limit the patients to their early mobilization and ambulation [35].

4.2. Infectious prophylaxis

Postoperative prophylactic antibiotics are often used, but the duration was recommended no longer than 24 hours postoperatively [14].

http://dx.doi.org/10.5772/intechopen.74026

4.3. Thromboprophylaxis

Patients who undergo TKA are at high risk of venous thromboembolism(VTE) as the incidence of symptomatic and asymptomatic VTE is 10% and 40–60%, respectively [36, 37]. After admission, a complete assessment of VTE risk is performed. Thromboprophylaxis measures include general, mechanical and pharmacological strategies. General thromboprophylaxis including avoidance of dehydration, early mobilization and lower limb range of motion exercises are applied to patients at any risk. Mechanical thromboprophylaxis including stockings or intermittent pneumatic calf compression are used during operation. While pharmacological strategies, for instance, low molecular weight heparins should be started 6 to 12 hours after surgery [38].

4.4. Pain relief

TKA is often associated with moderate to severe postoperative pain during the early postoperative period. Effective pain management following total knee arthroplasty is critical for which enables early mobilization, ambulation and even patients' satisfaction via the reduced adverse physiological and psychological responses [39, 40].

In traditional clinical practice, opiates play a major role in postoperative pain management. However, despite the strong analgesic effect of opiates, there are a number of associated adverse effects, e.g., nausea, vomiting, or risk of addiction. The associated adverse effects could further delay the recovery of the patients and increase the overall healthcare expenditure. Current literatures recommend the application of opioid sparing regimen with multimodal analgesics. It was proven to provide adequate pain control and avoidance of opioid-related adverse effects. Combination analgesics such as paracetamol, NSAIDs, COX-2 inhibitors, neuropathic medication or NMDA antagonist block different pathways of pain to optimize analgesic efficacy [41]. Combination therapy also reduces the required dose of individual medication which further lowers the incidence of medication adverse events. Other alternative modalities such as cryotherapy, through the application of cool water to the surgical site or transcutaneous electrical nerve stimulation (TENS) are also taken into consideration, as studies have shown to reduce the acute pain after surgery [42, 43].

4.5. Ambulation and exercise

Early ambulation and exercise should be valued as an important part of the fast track program as it provides a range of health benefits [44]. Current literature suggests that rehabilitation and physical therapy initiated on the day of surgery. Early mobilization potentially prevents complications such as venous thromboembolism, atelectasis, urinary tract infection, stroke,…, etc., [45]. Furthermore, it was reported by related studies to reduce length of hospital stay, post-operative morbidity and mortality, improved patient satisfaction, and reduced VTE and its sequelae [45, 46].

5. Authors' experience

As the most cost-effective surgical intervention for arthritic knee, TKA has become the daily practice of many orthopedic surgeons. Based on the supportive literature and our past experiences in establishment of clinical pathway, we believe the concepts and approaches of fast-track program (or enhanced recovery after surgery) are patient-friendly and practical. We found it a great idea to integrate various caring specialties to construct a comprehensive program throughout the perioperative duration.

Within a decade, we had shortened the length of stay of our patients from 12 days to less than a week using only part of the aforementioned recommendations in FT program, though more elder patients and unchanged criteria of discharge. In our institution, better recovery and satisfaction are to be expected after the completion of detailed preoperative education and evaluation.

6. Conclusion

In conclusion, fast track program represents a multimodal and multidisciplinary standardized care which aimed at early mobility, early discharge with better prognosis and less complications. By combination of preoperative, intraoperative, and postoperative strategies, the synergistic effects are shown to improve peri-operative outcomes. Decreasing length of hospital stay, complications, and overall medical costs can be expected. For a well-established surgical intervention as TKA, FT program provides benefits for the patients with their earlier recovery, early discharge with better prognosis and less complications. Further, the approaches of FT program will keep up with continued understanding of perioperative pathophysiology, improved care and evidence-based interventions.

Acknowledgements

This work was supported by National Cheng Kung University Hospital (Grant number NCKUH-10609007) and National Cheng Kung University (Grant number NCKU-FD104008). We also acknowledge the technical assistance from Ms. Mei-Hui Shieh, and Yu-Chieh Chen.

Conflict of interest

Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

http://dx.doi.org/10.5772/intechopen.74026

Author details

Jou-Hua Wang[1], Chih-Wei Chang[1,2,3]*, Yi-Chen Chen[4], Chyun-yu Yang[1,2] and Kai-Lan Hsu[1,3]

*Address all correspondence to: u7901064@yahoo.com.tw

1 Department of Orthopaedic Surgery, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

2 Bone and Joint Center, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

3 Department of Biomedical Engineering, College of Engineering, National Cheng Kung University, Tainan, Taiwan

4 Department of Nursing, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

References

[1] Wilmore DW, Kehlet H. Recent advances: Management of patients in fast track surgery. BMJ: British Medical Journal. 2001;**322**(7284):473

[2] Rasmussen LS, Jørgensen CC, Kehlet H. Enhanced recovery programmes for the elderly. LWW; 2016

[3] Kehlet H, Wilmore DW. Evidence-based surgical care and the evolution of fast-track surgery. Annals of Surgery. 2008;**248**(2):189-198

[4] Kehlet H. Fast-track colorectal surgery. The Lancet. 2008;**371**(9615):791-793

[5] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. JBJS. 2007;**89**(4):780-785

[6] Kehlet H, Wilmore DW. Fast-track surgery. British Journal of Surgery. 2005;**92**(1):3-4

[7] Mathijssen NM, Verburg H, van Leeuwen CC, Molenaar TL, Hannink G. Factors influencing length of hospital stay after primary total knee arthroplasty in a fast-track setting. Knee Surgery, Sports Traumatology, Arthroscopy 2016;**24**(8):2692-2696

[8] Kort NP, Bemelmans YF, van der Kuy PHM, Jansen J, Schotanus MG. Patient selection criteria for outpatient joint arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy 2017;**25**(9):2668-2675

[9] McDonald S, Page MJ, Beringer K, Wasiak J, Sprowson A. Preoperative education for hip or knee replacement. The Cochrane Library. 2014

[10] Zmistowski B, Karam JA, Durinka JB, Casper DS, Parvizi J. Periprosthetic joint infection increases the risk of one-year mortality. JBJS. 2013;**95**(24):2177-2184

[11] Bongartz T, Halligan CS, Osmon DR, et al. Incidence and risk factors of prosthetic joint infection after total hip or knee replacement in patients with rheumatoid arthritis. Arthritis Care & Research. 2008;**59**(12):1713-1720

[12] Bozic KJ, Lau E, Kurtz S, et al. Patient-related risk factors for periprosthetic joint infection and postoperative mortality following total hip arthroplasty in Medicare patients. JBJS. 2012;**94**(9):794-800

[13] Ong KL, Kurtz SM, Lau E, Bozic KJ, Berry DJ, Parvizi J. Prosthetic joint infection risk after total hip arthroplasty in the Medicare population. The Journal of Arthroplasty. 2009;**24**(6): 105-109

[14] Dale WB, Peter MH, Workgroup SIPGW. Antimicrobial prophylaxis for surgery: An advisory statement from the National Surgical Infection Prevention Project. Clinical Infectious Diseases. 2004;**38**(12):1706-1715

[15] Lee JK, Chung K-S, Choi CH. The effect of a single dose of preemptive pregabalin administered with COX-2 inhibitor: A trial in total knee arthroplasty. The Journal of Arthroplasty. 2015;**30**(1):38-42

[16] Park YB, Chae WS, Park SH, Yu JS, Lee SG, Yim SJ. Comparison of short-term complications of general and spinal anesthesia for primary unilateral total knee arthroplasty. Knee surgery & related research. 2017;**29**(2):96

[17] Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S, Callaghan JJ. Differences in short-term complications between spinal and general anesthesia for primary total knee arthroplasty. JBJS. 2013;**95**(3):193-199

[18] Lund J, Jenstrup M, Jaeger P, Sørensen A, Dahl J. Continuous adductor-canal-blockade for adjuvant post-operative analgesia after major knee surgery: Preliminary results. Acta Anaesthesiologica Scandinavica. 2011;**55**(1):14-19

[19] Jenstrup M, Jaeger P, Lund J, et al. Effects of adductor-canal-blockade on pain and ambulation after total knee arthroplasty: A randomized study. Acta Anaesthesiologica Scandinavica. 2012;**56**(3):357-364

[20] Macfarlane AJ, Prasad GA, Chan VW, Brull R. Does regional anesthesia improve outcome after total knee arthroplasty? Clinical Orthopaedics and Related Research®. 2009;**467**(9):2379

[21] Busch CA, Shore BJ, Bhandari R, et al. Efficacy of periarticular multimodal drug injection in total knee arthroplasty: A randomized trial. JBJS. 2006;**88**(5):959-963

[22] Spangehl MJ, Clarke HD, Hentz JG, Misra L, Blocher JL, Seamans DP. The Chitranjan Ranawat Award: Periarticular injections and femoral & sciatic blocks provide similar pain relief after TKA: A randomized clinical trial. Clinical Orthopaedics and Related Research®. 2015;**473**(1):45-53

[23] Peersman G, Laskin R, Davis J, Peterson M, Richart T. Prolonged operative time correlates with increased infection rate after total knee arthroplasty. HSS Journal. 2006;**2**(1):70-72

[24] Tria AJ, Scuderi GR. Minimally invasive knee arthroplasty: An overview. World journal of orthopedics. 2015;**6**(10):804

[25] Bonutti PM, Mont MA, McMahon M, Ragland PS, Kester M. Minimally invasive total knee arthroplasty. JBJS. 2004;**86**(suppl_2):26-32

[26] Dabboussi N, Sakr M, Girard J, Fakih R. Minimally invasive total knee arthroplasty: A comparative study to the standard approach. North American Journal of Medical Sciences. 2012;**4**(2):81

[27] Cheng T, Liu T, Zhang G, Peng X, Zhang X. Does minimally invasive surgery improve short-term recovery in total knee arthroplasty? Clinical Orthopaedics and Related Research. 2010;**468**(6):1635-1648

[28] Hart A, Khalil JA, Carli A, Huk O, Zukor D, Antoniou J. Blood transfusion in primary total hip and knee arthroplasty. Incidence, risk factors, and thirty-day complication rates. J Bone Joint Surg Am. 2014;**96**(23):1945-1951. DOI: 10.2106/JBJS.N.00077[published. [Online First: Epub Date]

[29] Tai T-W, Lin C-J, Jou I-M, Chang C-W, Lai K-A, Yang C-Y. Tourniquet use in total knee arthroplasty: A meta-analysis. Knee Surgery, Sports Traumatology, Arthroscopy. 2011; **19**(7):1121-1130

[30] Pilbrant Å, Schannong M, Vessman J. Pharmacokinetics and bioavailability of tranexamic acid. European Journal of Clinical Pharmacology. 1981;**20**(1):65

[31] Wong J, Abrishami A, El Beheiry H, et al. Topical application of tranexamic acid reduces postoperative blood loss in total knee arthroplasty: A randomized, controlled trial. JBJS. 2010;**92**(15):2503-2513

[32] Charoencholvanich K, Siriwattanasakul P. Tranexamic acid reduces blood loss and blood transfusion after TKA: A prospective randomized controlled trial. Clinical Orthopaedics and Related Research. 2011;**469**(10):2874-2880

[33] Ishida K, Tsumura N, Kitagawa A, et al. Intra-articular injection of tranexamic acid reduces not only blood loss but also knee joint swelling after total knee arthroplasty. International Orthopaedics. 2011;**35**(11):1639-1645

[34] Frisch NB, Pepper AM, Rooney E, Silverton C. Intraoperative hypothermia in total hip and knee arthroplasty. Orthopedics. 2017;**40**(1):56-63

[35] Feroci F, Lenzi E, Baraghini M, et al. Fast-track colorectal surgery: Protocol adherence influences postoperative outcomes. International Journal of Colorectal Disease. 2013; **28**(1):103-109

[36] Warwick DJ, Whitehouse S. Symptomatic venous thromboembolism after total knee replacement. Journal of Bone and Joint Surgery. British Volume (London). 1997;**79**(5):780-786

[37] Stulberg BN, Insall J, Williams G, Ghelman B. Deep-vein thrombosis following total knee replacement. An analysis of six hundred and thirty-eight arthroplasties. JBJS. 1984;**66**(2): 194-201

[38] Geerts WH, Bergqvist D, Pineo GF, et al. Prevention of venous thromboembolism: American College of Chest Physicians evidence-based clinical practice guidelines. Chest journal. 2008;**133**(6_suppl):381S-453S

[39] Husted H, Lunn TH, Troelsen A, Gaarn-Larsen L, Kristensen BB, Kehlet H. Why still in hospital after fast-track hip and knee arthroplasty? Acta Orthopaedica. 2011;**82**(6):679-684

[40] Wu CL, Raja SN. Treatment of acute postoperative pain. The Lancet. 2011;**377**(9784):2215-2225

[41] Jiang J, Teng Y, Fan Z, Khan MS, Cui Z, Xia Y. The efficacy of periarticular multimodal drug injection for postoperative pain management in total knee or hip arthroplasty. The Journal of Arthroplasty. 2013;**28**(10):1882-1887

[42] Ni S-H, Jiang W-T, Guo L, et al. Cryotherapy on postoperative rehabilitation of joint arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy. 2015;**23**(11):3354-3361

[43] Rakel BA, Zimmerman MB, Geasland K, et al. Transcutaneous electrical nerve stimulation for the control of pain during rehabilitation after total knee arthroplasty: A randomized, blinded, placebo-controlled trial. PAIN. 2014;**155**(12):2599-2611

[44] Jakobsen TL, Kehlet H, Husted H, Petersen J, Bandholm T. Early progressive strength training to enhance recovery after fast-track total knee arthroplasty: A randomized controlled trial. Arthritis Care & Research. 2014;**66**(12):1856-1866

[45] Epstein NE. A review article on the benefits of early mobilization following spinal surgery and other medical/surgical procedures. Surgical Neurology International. 2014;**5** (Suppl 3):S66

[46] Husted H, Otte KS, Kristensen BB, Ørsnes T, Wong C, Kehlet H. Low risk of thromboembolic complications after fast-track hip and knee arthroplasty. Acta Orthopaedica. 2010; **81**(5):599-605

*Edited by Alessandro Rozim Zorzi
and João Batista de Miranda*

This book presents a compilation of topics related to primary total knee arthroplasty. The chapters cover, in a clear and didactic way, the current themes, written by experts from the area, from different parts of the world.

Topics related to the three surgical phases (before surgery, during surgery, and after surgery) are discussed here. This is very important because the surgeon is not a "factory worker." First of all, it is a medicine doctor who has to feel and understand the particularities of each patient.

Demographic studies show an aging population. Osteoarthritis and inflammatory diseases are becoming much more prevalent. In addition, a worldwide epidemic of trauma has led to the need for arthroplasties much more frequently. Therefore, total knee arthroplasty will be an increasingly important subject.

Published in London, UK

IntechOpen

ISBN 978-1-83881-302-4
9 781838 813024