Asian Journal of Orthopaedic Research

5(2): 30-48, 2021; Article no.AJORR.65442

Total Knee Arthroplasty- A Review of Emerging Trends in Patient Management and Surgical Practices

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Ikem, Innocent Chiedu, Obafemi Awolowo University, Nigeria.
Reviewers:
(1) Gianluigi Pasta, Fondazione IRCCS Policlinico San Matteo, Italy.
(2) Monish Bami, BLDE University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65442

Review Article

Received 7 December 2020
Accepted 11 February 2021
Published 08 March 2021

ABSTRACT

Background: Osteoarthritis is a chronic, multifactorial, degenerative disorder commonly seen in elderly with predominance for females above the age of 45yrs with largely unknown etiology. With the rising demand for TKA in the foreseeable future, our aim is to assess the emerging trends in patient management and surgical practices for TKA.

Material and Methods: A narrative review of current literature analyzing the patient characteristics, current practices in peri-operative management, methods to control blow loss, pain management and recent advances in TKA.

Results: Literature describes that the prevalence of osteoarthritis of knee along with average BMI and associated comorbidities are on the rise. Emphasis is being laid on blood preservation, including iron therapy, erythropoietin tranexamic acid, low pressure tourniquet, acute normovolemic hemodilution. Multimodal analgesia including pre-emptive analgesia, peri articular injections, peripheral nerve blocks play a major role in pain management. The use of artificial intelligence, Robotics, 3D printing and Computer assisted navigation in TKA in recent years shows a promising future.

Conclusion: Favorable outcomes have been observed with various blood preservation and pain management techniques. TKA remains the forefront of evolution of scientific innovation that have a

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great potential for refining the TKA alignment and biomechanical outcome to subsequently reduce the incidence of TKA revision and improve patient's satisfaction. However, further Level 1 studies are required to assess the long-term outcomes.

Keywords: TKA; erythropoietin; tranexamic acid; normovolemlic haemodilution; multimodal analgesia; pre-emptive analgesia; UKA; computer assisted navigation; soft tissue balancing; robotics; review of literature.

1. INTRODUCTION

Osteoarthritis knee is chronic degenerative disorder, multifactorial in origin characterized by pain during weight bearing, prolonged activity and stiffness experienced after inactivity. It has a prevalence of 22 to 39% in India [1]. The burden of the disease is ever increasing due to ageing population, sedentary lifestyle and increasing obesity. In the USA, primary Total Knee arthroplasty (TKA) rates increased by 170% from 2001-2011, this is further expected to double in the next 10 years [2]. 70,000 knee replacements were performed in 2011 in India alone.

The demand for joint replacement surgeries is set to rise further, so there is urgent need to evaluate the current trends and advancements in the field of primary total knee replacement. The current driving point of research globally is Artificial Intelligence, 3D printing, robotics and better implant design. In terms of patient care, Enhanced recovery after surgery (ERAS) protocols is being adopted, taking total knee replacement progressively towards the status of low morbidity, short stay surgery. Thus, we conducted, a narrative review of the current trends and developments in the field of knee arthroplasty, to aid furthering knowledge on the subject.

2. METHODOLOGY

We conducted a narrative review to assess the current trends and emerging practices in TKA. A PubMed search was conducted for English-language articles published on or before September, 2020. We preferentially included well-designed randomized controlled trials, systematic reviews, and meta-analyses. Where the highest levels of evidence were not yet apparent, we evaluated retrospective and/or observational studies.

2.1 Trends in Patient Characteristics

The prevalence of osteoarthritis has increased to 28.7% in India [3]. Although, there is currently no study on overall demography of patients undergoing total knee arthroplasty in India, globally, joint registries show that women have a higher rate of undergoing TKA than men, females comprised 60.8% of TKAs in 2016 in the American Joint Replacement Registry (AJRR), lowest being 51.6% in New Zealand [4]. The mean age of patients undergoing TKA has increased from 66 to 70.6 years in the past 10 years [5]. A study in the UK showed that the mean body mass index (BMI) of patients undergoing Total knee arthroplasty has significantly gone up from 29.5 kg/m2 to 32.0 kg/m2 [5]. Comorbidity burden has also increased over time in patients undergoing TKA, the prevalence of obesity, obstructive sleep apnea and renal insufficiency has increased by approximately by 10% [6].

2.2 Current Practices in Peri-Operative Management of TKA Patients

Globally ERAS guidelines are being adopted for elective arthroplasties with focus on adequate patient optimization preoperatively and early mobilization and rehabilitation post operatively, allowing early discharge, reducing patient morbidity and hospital costs. This includes the focus areas of reducing blood loss, controlling pain, efficient rehabilitation (Figs. 1-3).

2.2.1 Control of blood loss

Currently increased attention is being given to management of peri-operative blood loss in patients undergoing primary TKA. Minimizing blood loss can reduce postoperative pain, increase ease of rehabilitation, reduce hospital costs, infection rates and length of hospital stay [7].

2.2.1.1 Pre-operative

Pre-Operative anemia (<13 g/dL for males, <11g/dL for females) is one of the strongest indicators of transfusion requirement in patients undergoing TKA (Fig. 1). Munoz et al. found the prevalence of Anemia in the population undergoing non cardiac surgeries to be around 75% [8]. Baron et al. [9]. demonstrated that peri-operative anemia is linked to poor surgical outcome, greater risk of infection and higher mortality [9]. Hence correction of anemia in the preoperative period is essential for good outcomes.

2.2.1.2 Iron therapy

Iron therapy is a cheap and effective strategy to correct preoperative anemia. Oral iron therapy for 3 to 6 months preoperatively, is effective in increasing postoperative hemoglobin and in reducing the need of blood transfusion or Intravenous IV) erythropoietin [10]. Oral Iron therapy is a cheap and easily adaptable strategy in a developing country like India, but its use is limited by its gastrointestinal side effects. Intravenous Iron is as effective as opal iron in increasing hemoglobin levels, but some studies have linked intravenous iron with increased risk of post-operative infections [8]. Thus, Iron supplementation is recommended in patients with preoperative anemia (Fig. 1).

2.2.1.3 Erythropoietin

Intravenous Erythropoietin is another modality that can be used in patients not responding to iron therapy or patient with anemia of chronic disease. Erythropoietin is currently used for orthopaedic surgeries in two different regimens. It can either be administered 300U/kg 10 days before surgery, on day of surgery and 4th day post operatively, or 600U/kg subcutaneously days 21, 14, 7 before surgery and on day of surgery [11,12]. However, its use is limited due to high cost and increased risk of thromboembolism [12].

2.2.2 Intraoperative

2.2.2.1 Tranexamic acid

Use of tranexamic acid has significantly reduced the need for Allogenic blood transfusion and intra operative blood loss without increasing the risk of thromboembolic events (Fig. 2) [13]. Tranexamic acid (TXA) can be given by oral, intravenous and topical routes. A meta-analysis by Chen et al [14]. found that topical TXA was equally as effective as systemic TXA and patients who had received TXA had 0.39 relative risk of receiving blood transfusion as compared to those who didn't receive TXA (Table 1) [14]. A randomized controlled trial by Nielsen et al. [15], concluded that Intravenous and intra-articular Tranexamic acid reduced blood loss by 37% as compared to Intravenous tranexamic acid alone both at post-operative day 1 and day 2 [15]. Intravenous tranexamic acid is contraindicated in patients with previous cardiac surgery or venous thromboembolism (VTE).

Though there is still no global consensus or guidelines regarding the dosage or route of administration of TXA. Two randomised controlled trials by Lei et al. [16] and Zhang et al. [17], found that a 6 dose regimen of tranexamic acid, with first dose of 60mg/kg before incision, followed by five doses of 1g TXA given at 3,6,12,18,24 hours after first dose, reduced peri-operative blood loss significantly as compared to Low dose 20 mg/kg regimen and two dose regime, In addition the six dose regimen also significantly reduced levels of inflammatory markers like FDP, D-dimers, IL-6 and consumption of analgesics, without affecting coagulation parameters and without increasing the risk of thrombotic events (Table 1) [17,16] .

Thus, a combination of Intra-articular and intravenous tranexamic acid or a 6-dose regimen can be adapted to improve patient outcomes.

2.2.2.2 Tourniquet use

Another method of controlling intra operative blood loss is the use of tourniquet (Fig. 2). Use of tourniquets helps in decreasing intra-operative blood loss, increasing the efficacy of cementing, better visualization of surgical field. Over the last few years there has been an increased focus on the complications of tourniquet use. According to a recent meta-analysis conducted by Cai et al [18]. The use of tourniquet reduced intra operative blood loss and operating time but had no effect on total blood loss and the risk of DVT [18,19]. Previous studies by Zheng et al [20]. and Wakankar et al [21]. showed that patients with TKA performed under tourniquet had lesser early ROM and more pain as compared to patients who underwent tourniquet less TKA, though patient outcomes at 1 year were similar in both the groups [20,21]. However, a recent randomized controlled trial by Ayik et al [22]. Showed no difference in Isokinetic muscle strength of knee flexors and extensors, Knee ROM and functional score at 1 month and 3 months post operatively, with and without tourniquet use [26]. A prospective double-blinded randomized controlled trial by Goel et al [23]. Also found that Tourniquet use was associated with lesser requirement of blood transfusions, greater ease of visualization of surgical field, and there were no significant differences in post-operative ROM and pain scores [23]. No difference in cement penetration was found with and without tourniquet use [24]. Tourniquet use is also linked to increased cement mantle thickness under the tibial component [25].

The use, advantages and disadvantages of tourniquet are still under debate and further studies are required to evaluate their importance; however, the frequency and pattern of use varies based on surgeon's preference.

Newer strategies such as Fibrin Sealants and bipolar sealers are still under investigation and no significant added benefit has been found apart from increased costs [26–28]. A meta-analysis by Wang et al. (2014), showed that fibrin sealants were safe and effective as a method of haemostasis in patients undergoing TKA [26]. The main components of fibrin sealant are Factor XIII, fibrinogen and some anti fibrinolytic agents, which achieve local hemostasis by replicating the last step of the coagulation cascade. Saltzmann et al. (2014) in a review, reported that bipolar sealers produced coagulation at a lower temperature than standard electrocautery and thus caused less tissue charring, less tissue necrosis and decreased the duration of surgery, the disadvantages were high cost and thermal spread [27]. Bipolar devices achieve hemostasis by radiofrequency energy, which denature the vessel wall's elastin and collagen.

2.3 Acute Normovolemic Hemodilution

Acute normovolemic hemodilution (ANH) is another strategy currently being employed to combat intra-operative losses. In ANH a certain amount of autologous blood is collected right before the surgery, an equal volume of crystalloid is then added to this (Fig.3). This is then transfused intra operatively or post operatively when the need for allogenic blood transfusion arises. This method reduces the erythrocyte loss for the same amount of blood volume lost [29]. ANH has emerged as a cheap alternative in a resource deprived setting like India where there is a general shortage of blood products. It can reduce the need for allogenic blood transfusions, risk of transfusion transmitted infections [30].

2.3.1 Post-operative

2.3.1.1 Suction drains

Use of closed suction drainage system is common place amongst orthopaedic surgeons in India despite conflicting supporting clinical evidence. Suction Drains theoretically prevent joint hematoma and exudation and thus lead to lesser pain and wound complications [31]. Patients with drains following TKA have been reported to have a higher hemoglobin drop and higher transfusion rates [32]. However, patients with drain placed post operatively were found to have better Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores and range of motion (ROM) at 6 months post operatively [31]. Cheung et al [33]. Found that low pressure suction drains (350mmHg) resulted in lesser drop in hemoglobin and lesser requirement for transfusion as compared to high pressure suction drains (600mm Hg), without increasing rate of complications or affecting the functional outcome [33].

The incidence of bacterial colonization increases significantly after 24 hrs of drain placement, Drinkwater et al. [34], reported that surgical drains should be removed ideally within the first 24hrs post operatively to reduce the occurrence of drain related infections [34].

A retrospective analysis by Agarwala et al [35]. Reported that clamping the drain for 4 hrs post operatively caused tamponade and significantly reduced blood loss from the drain [35]. Though the use of drains post TKA is still controversial, based on current evidence, A low pressure drain placed for a short duration improves patient outcomes and can be practiced as per surgeon's preference and patient characteristics [36].

2.3.1.2 Limb positioning

Post operative limb position has also been found to affect the blood loss resulting from the surgery. Overall, it has been found that keeping the operated knee in flexion of up to 60-90 degrees, with hip flexed and limb elevated reduces the blood loss, drain output, need for transfusions and need for analgesia and is associated with a better ROM at 3 months post operatively, but overall long terms outcomes are similar as with the patients with limb extended post operatively [37,38].

2.4 Pain Management in Total Knee Replacement

Pain management is an essential part of Total Knee Replacement regimens as adequate pain control improves outcomes by increasing patient satisfaction and increasing the ease of rehabilitation (Fig. 4). Recently a multimodal approach is being adopted to control pain following TKA, as compared to the use a single modality of analgesia previously (Fig.5). This has reduced the consumption of narcotic analgesics and has improved patient outcomes [39].

2.4.1 Pre-emptive analgesia

Pain management in TKA starts pre-operatively. Pre-emptive analgesia is an anti-nociceptive measure started before the patient undergoes surgery, to reduce post-operative pain. It aims to reduce central and peripheral hypersensitivity, to reduce hyperalgesia post operatively and reduce the need for narcotics and other analgesics [40,41]. A double blind randomized controlled trial by Lubis et al [42]. Showed that a pre-emptive analgesia with a combination of celecoxib 400mg and pregabalin 150mg given 1 hour before surgery reduced post-operative morphine consumption significantly and allowed early mobilization, without any significant side effects [42].

2.4.2 Periarticular injections

Another recent area of interest emerging in TKA pain management is the use of periarticular injections intra-operatively. The agents used in peri articular injections typically include local anesthetics, non-steroidal anti-inflammatory drugs (NSAIDS), opioids and corticosteroids optionally (Table 2) [43].Though currently there is no consensus on the specific drug cocktail to be used for peri articular injections, the one common finding is that periarticular analgesia immediately before closure, reduces post-operative Visual Analogue Scale (VAS) scores, requirement of opiates, increases early ROM and decreases the length of hospital stay (Table 2) [44]. Most of the recommended regimens include a local anesthetic agent ropivacaine or bupivacaine, with ketorolac, morphine and an optional steroid [45]. The efficacy of periarticular injection can be increased by combining it with a femoral nerve block. A Peri articular injection is better than a femoral nerve block in controlling the early post-operative pain but the femoral nerve block functions to control the rebound pain once the effect of peri articular injection wears off [46]. Periarticular injection with a femoral nerve block has been found to be more efficacious than the commonly used epidural analgesia in terms of pain control, early ROM and reduced complications like hypotension and urinary retention [47].

Thus, the current need is to adopt a multi modal approach including pre-emptive analgesia, neuraxial anesthesia, peri articular injections, peripheral nerve blocks, patient controlled anesthesia using local anesthetics, opiates, NSAIDS, steroids for better patient outcomes following TKA [48].

2.5 Current Trends in Rehabilitation after Total Knee Arthroplasty

Rehabilitation protocols form an important part of TKA management. Current trends are moving towards adopting digital orthopedics, this has been accelerated due to the ongoing COVID-19 pandemic.

As a part of the ERAS pathway, it has been found that preoperative patient education and physiotherapy improves post-operative patient compliance with the physiotherapy regimen and also improves functional scores [49].

Currently Tele-rehabilitation protocols are being adopted globally and have emerged as a useful modality in view of the pandemic [50]. Tele-rehabilitation has been found comparable to usual after care in terms of quality of life, pain and functional scores [51]. New technologies that are emerging in TKA rehabilitation are virtual reality assisted physiotherapy which has been found to be as effective as conventional physiotherapy. It can used to administer physiotherapy remotely [52,53]. Wearable sensor technology is also being used to monitor patient rehabilitation remotely. Smart watches and fitness trackers can be used to monitor step count, weight, physiological parameters, gait analysis, analgesic intake and help track real-time data and guide patient management. Innovative tracking devices are available that can be worn around operated or diseased joints to enable continuous monitoring of activity data—including range of motion, ambulation, exercise compliance, and wound-site temperature trends [53,54].

2.6 Changing Trends in Surgical Practice

2.6.1 Uni-compartmental knee arthroplasty

The acceptance of unicompartmental knee replacement (UKA) is increasing worldwide with varying utilization rates ranging from 5.2% in Canada to 9.2% in the UK [55]. The AJRR is the only joint registry reporting a decrease in the use of UKA, decreasing from 5.1% in 2014 to 3.2% in 2016 [4]. UKA is gradually becoming the preferred option when osteoarthritis is confined to one compartment. Initially there were some apprehensions about this implant due to some reports suggesting lower survival rates. However, newer studies have shown a 10-year survival rate of >95% with newer generation implants [56]. UKA is currently considered for unicompartmental Osteoarthritis (OA) or femoral avascular necrosis with intact patello-femoral and lateral compartments. Contraindication for UKA has been pre-existing patello-femoral joint degeneration and anterior cruciate ligament (ACL) deficiency. The most common cause of failure was loosening of the components followed by progressive degeneration in the non-replaced components and then by polyethylene wear [56]. UKA is simpler, has a short learning curve , recovers quicker and there are various advantages such as small incision, minimal soft tissue resection, shorter operative time, less blood loss, less chances of infection, better bone stock conservation (important consideration for future conversion to total knee replacement), option to convert to bicondylar replacement if there is involvement of opposite compartment, rapid and more predictable recovery, more post-operative range of motion and overall higher patient satisfaction (Table 3) [57].

Data from 3 randomized controlled trials showed no difference in operative times. Between TKA and UKA, though all of the studies showed a significantly shorter duration of hospital stay for UKA as compared to TKA [58]. The rate of complications like myocardial infarction, cerebrovascular accidents, venous thromboembolism were significantly lesser with UKA than TKA [59]. Better functional scores and pain scores were obtained after UKA than TKA, but revision rates were higher for UKA, however, the rate is similar for both in high volume centres. However, the use of this modality depends on shared decision making with the patients, based on prospective advantages and disadvantages.

2.7 Computer Assisted Navigation in Surgery

The main aim of a TKA is to alleviate pain and improve patient functionality. The success rates of this procedure are high but technical errors remain a major cause of implant failure and patient dissatisfaction [60]. Mason et al [61]. Reported that greater than +/- 3 degrees of mal-alignment in the mechanical axis accounted for more than 30% of TKA providing undesirable results [61]. This need for better alignment, more accurate cuts, implant positioning and soft tissue balancing has driven the development of computer assisted navigation in total knee replacement over the past decade.

Navigation assisted Total Knee Arthroplasties have been reported to have better radiological alignment as compared to conventional TKAs. Multiple meta-analyses have shown that navigated TKA have better alignment in coronal and sagittal plan, and better restoration of mechanical axis, that lie within the limit of 3 degrees as compared to conventional TKA [62,63].

Although navigation systems have been in place for the past 15 years, numerous meta-analysis and systematic reviews have been conducted comparing the outcome of conventional TKA with Navigation assisted TKA. Most of the studies reported that in spite of superior radiological outcomes, patient outcomes showed no difference in midterm and long term follow up, though the implant survival was slightly greater in navigation assisted TKA, this wasn't found to be statistically significant [64–66]. The overall similar results in terms of patient outcomes outweigh the benefit of better radiological alignment due to increased costs to the patient, increased surgical times. The American Association of Orthopedic Surgeons (AAOS) in their guidelines for treating osteoarthritis of the knee does not advocate the routine use of navigation assisted TKA due to no benefits in terms of outcomes or complications [67].

2.7.1 Portable accelerometer based navigation systems

Recently, accelerometer base portable navigation systems have been introduced to combine the benefits of a Large console computer assisted navigation with TKA with conventional instrumentation. Accelerometer based navigation systems are less invasive and can be used with conventional extra-medullary jigs [68]. They offer the benefit of reduced cost, lesser surgical time and greater ease of use. However similar to computer assisted, imageless, large console navigation systems, they improve the radiological alignment as compared to conventional TKA but no significant difference in patient outcomes has been found in short and mid-term follow up [69–71].

2.7.2 Sensor based soft tissue balancing

Ligamentous laxity and joint instability are some of the leading causes of revision surgeries post TKA. Instability is reported as the indication in

22% of revision TKAs [72]. Ligamentous laxity can lead to a painful joint, effusions and inability to negotiate inclined planes. It can also cause accelerated polyethylene wear leading to early implant loosening. Currently most surgeons depend on 'tactile feel' and subjective experience for soft tissue balancing, this leads to discrepancies and inaccuracies differing from surgeon to surgeon based on experience [73].

Currently surgeons assess balance in the coronal plane by applying a varus/valgus moment and observing joint opening, and spacers are used to assess joint gaps in flexion and extension. When using spacer blocks, defining coronal inter-compartmental balance in mid flexion and full flexion is often inconsistent, secondary to the open capsule, a subluxated patella, and hip rotation. Thus, to address this and make the assessment more quantitative and objective, load bearing and alignment sensor based electronic microarrays are being housed within standard tibial trial to create the so called 'smart trials' [74]. The smart trial provides the surgeon with 3-dimensional soft tissue status, and real time loads in various compartments throughout the range of motion with patella reduced. This allows the surgeon to accurately identify the required soft tissue releases to be performed and allows targeted ligament balancing.

The accuracy of manual assessment of knee balance was found to be correct less than 50% of the times as compared to a smart trial [75]. In a multi-centric study, it was observed that using sensor-based technology, the loading across the knee joint decreased, and on an average 2 to 3 releases were performed per case [76]. Thus, sensor-based technology allows surgeons to objectively achieve soft tissue balance during TKA. In addition to this, patients undergoing sensor based TKA reported higher satisfaction rates of up to 90% as compared to patients undergoing conventional TKA [77]. A learning curve of an average of 41 cases was observed to achieve operating times equivalent to manually balanced TKA (Table 3) [78]. The use of smart trials is a new trend in TKA, long term outcomes are yet to be ascertained, but early results are definitely encouraging, and the technology has potential to become a routine part of TKA in coming times.

2.7.3 Robotic assisted knee arthroplasty

Despite advances in surgical technique, implant design, computer assisted navigation, pain management and rehabilitation, up to 20% patients still report dissatisfaction with their TKA surgery [79]. Robotic assisted TKA has assisted many concerns associated with conventional manual jig based TKA. Conventional TKA relies on the skill and experience of the surgeon, and anatomical reference points for implant alignment, soft tissue balancing, the soft tissue envelope is protected by handheld instruments during sawing, which may damage ligamentous structures and lead to instability intra-medullary alignment guides increase the risk of thromboembolic events [80,81].

Currently semi active robotic systems are more popular than fully active robotic systems, due to increased rate of complications during learning the procedure, and higher cost of the fully active systems [82]. Semi active robotic systems give the surgeon complete control over implant alignment and bone cuts while providing real time intra-operative tactile feedback about any deviation from preoperative plan. Action of the saw blade is limited to the confines of preoperative plan, thus increasing the accuracy of tibial and femoral cuts [83].

Similar to navigation assisted TKA, robot assisted TKA have a greater accuracy of implant alignment and restoration of the mechanical axis. Robot assisted TKA reported lesser outliers of more than 3 degrees from preoperative plan [66]. Robotic TKAs apply optical motion capture technology to assess flexion/extension gaps, range of motion, implant alignment, the real time feedback can help surgeons modify their bone cuts accurately and thus, reduce the need for ligamentous release. The occurrence of injury to peri articular soft tissue is also lesser with Robotic TKA [84].

Reduced post-operative pain, lesser swelling, increased early ROM and reduced length of hospital stay was reported with robotic TKA as compared to conventional TKA [85]. In a meta-analysis conducted by Ren et al [86]. It was found that patients undergoing Robotic TKA had better Knee Society Score (KSS) and WOMAC scores at 6 months follow up [86]. However, this early improved outcome does not translate into long term results. Liow et al [8]. Prospectively compared 29 conventional zig based TKA to 31 robotic TKAs, and found that both groups had similar Oxford Knee Score (OKS) and KSS at 2 years follow up [87]. Cho et al [88]. Compared outcomes in 155 robotic TKA vs 196 conventional TKA at 10 years follow up, found that both the groups had similar OKS, KSS and

WOMAC score. Studies of longer duration are required to comment on implant survival [88].

The drawbacks of robotic TKA are high installation and maintenance costs, increased radiation exposure, increased operating time during learning phase and only limited number of implants are compatible with robotic TKA (Table 3) [89]. Further studies are required to assess implant survivorship, complications and long term follow up to completely ascertain the benefits of robotic TKA.

2.7.4 Patient-specific cutting blocks

3D printing is the new area of growing interest in Orthopaedics. Additive manufacturing technique is used in Orthopaedics, in which metal or polymer powder is deposited layer by layer based on a computer designed 3-D model [90]. Patients undergo CT scan and 3D reconstruction of the joint, which is then used to print patient specific jigs, this can help in surgical planning and surgeon education. They allow to make cuts according to patient specific femoral valgus angle [90].

Patient specific instrumentation has shown results similar to computer assisted navigation in terms of restoration of mechanical axis and accuracy of implant alignment, further added benefits are that it is cost effective, reduces operating time and avoids thromboembolic complications associated with intra-medullary guides [91,92]. A study by Watters et al [93]. Reported reduced operating times by up to 28 minutes as compared to conventional TKA [93]. However, the benefits need to be weighed against the cost and time increased for surgical planning. Further studies are required to assess the impact on long term patient outcomes and implant survival.

3. DISCUSSION

The prevalence of osteoarthritis of knee is on the rise, with changing patient characteristics. The comorbidity burden and average BMI of patients undergoing TKA has increased.

Trends in patient management are also changing, emphasis is being put on blood preservation. Emerging strategies are iron therapy or erythropoietin to treat anemia preoperatively, use of tranexamic acid intra operatively via multiple routes, especially a combination of intra articular and intravenous route and following a six-dose regimen has been found to be effective. Use of low-pressure tourniquet for short duration is also effective. Acute normovolemic hemodilution is a cheap alternative to allogenic blood transfusion. Post-operative use of suction drain for 1 day after clamping for 4 hours and positioning the limb in flexion have been effective in reducing blood loss and pain (Table 4).

Patients undergoing TKA must be given multimodal analgesia including pre-emptive analgesia, peri articular injections, peripheral nerve blocks along with conventional NSAIDS, Opiates.

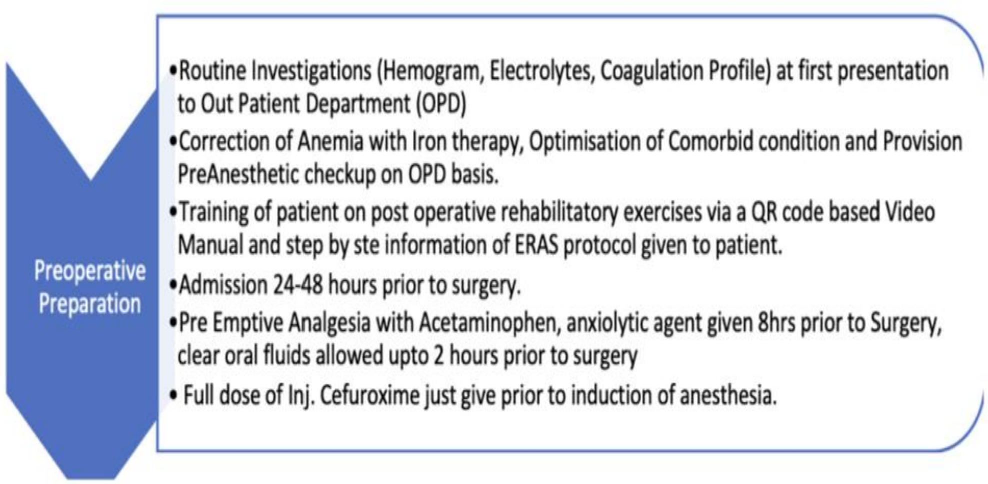

Fig.1

Fig. 1. Preoperative ERAS protocol followed at our institution

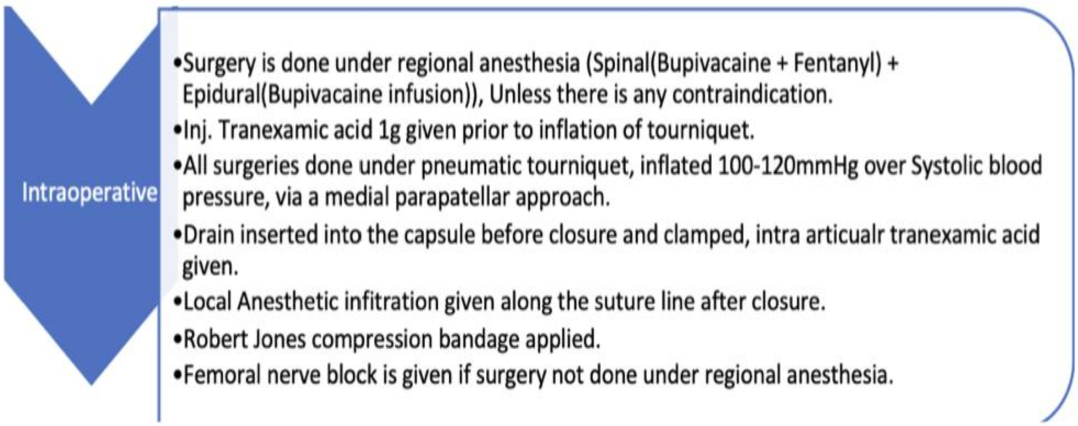

Fig.2

Fig. 2. Components of ERAS protocol applied Intra-operatively

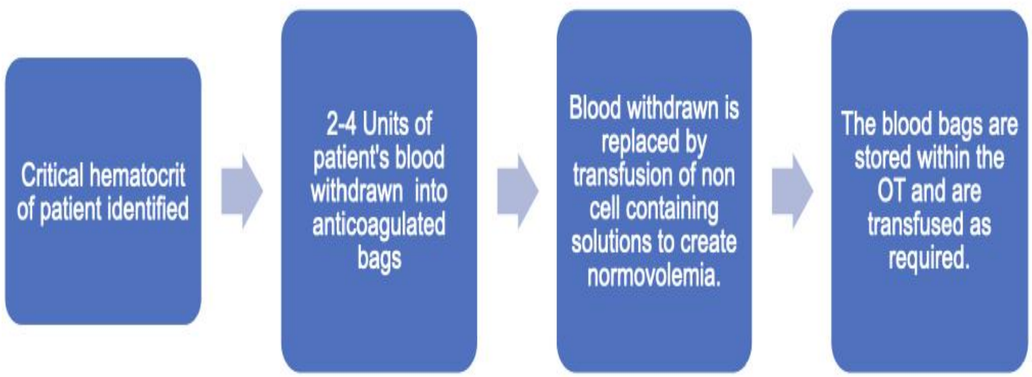

Fig.3

Fig. 3. Outline of acute normovolemic hemodilution

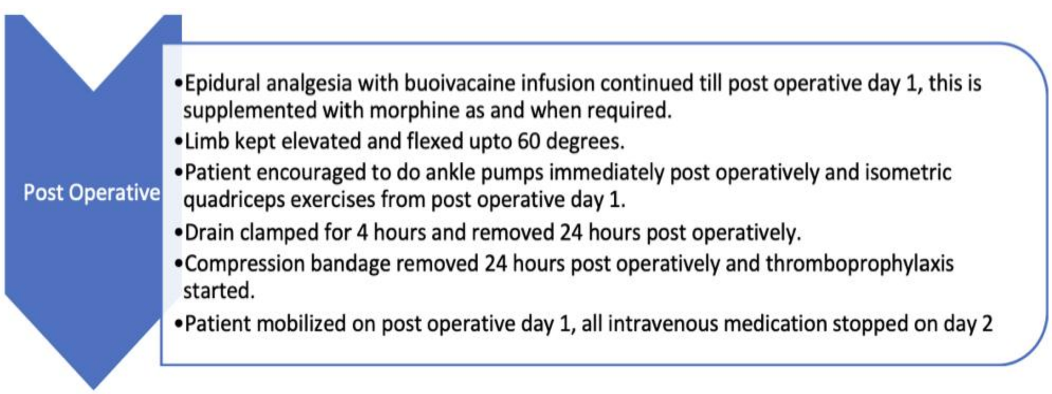

Fig.4

Fig. 4. Post operative care in ERAS protocol

Table 1. Multiple regimens of tranexamic acid and comparison of their efficacy

Sr. No.	Study Group	Journal	Year of Study/Publication	No. Of Patients	Mean Age of Patients (in Years)	Dosage Regimen	Conclusion
1	Sun et al. [18]	Journal of arthroplasty	2017	180	67.4 ± 8.4	Comparison of – • single dose 20 mg/kg IV TXA pre incision • 10mg/kg 15 minutes before tourniquet inflation, 10mg/kg 3 and 6 hours post operatively	• Lesser total blood loss in multiple dose regimen (P value <0.001)
2	Morrison et al. [19]	Bone and joint research	2017	2537	68.2	Comparison of pre operative – • single low dose (10mg/kg) • single high dose(30mg/kg)	• Mean fall of Haemoglobin significantly lower with high dose.(P value <0.001) • Mean length of hospital stay reduced from 4.6 to 3.6 in the high dose group.
3	Lee et al. [20]	Clinical orthopaedics and related research	2017	376	72.6 ± 6.3	Comparison of - • Intravenous(IV) only (10mg/kg prior to incision and 3 hours post operatively) • Intraarticular(IA) only (1g) • Low dose combined (1g IV +1g IA) • High dose combined (2g IV+ 2g IA)	• High- and low-dose combined groups and the IA-only group had lower total blood loss (564 ± 242 mL, 642 ± 242 mL, and 633 ± 205 mL, respectively) than the IV-only group (764 ± 217 mL • P value (<0.001)

4	Wang et al. [21]	The bone and joint journal	2018	200	64.1 ± 11.3	Comparison of – • single dose oral TXA 2g pre operatively • multiple dose regimen 1g oral TXA pre operatively, repeated 3 and 9 hours post operatively.	• Mean blood loss in multiple dose group (661.1+/-262.4mL) was significantly lower than single dose group (p value<0.001).
5	Zhang et al. [16]	International journal of surgery	2019	704	53.6 to 68.3	Comparison of • Placebo • Single preoperative dose (20mg/kg) • 6 dose regimen beginning from start of procedure to 24 hours post operatively (total>6g)	• Mean Haemoglobin Drop in 6 dose group= 2.06 ± 0.73g/dL • Mean haemoglobin drop with single dose = 2.77 ± 0.78 g/dL (P value <0.001)
6	Chen et al. [14]	Medicine	2019	1250	55.7 to 67.4	Meta Analysis on- • Oral Tranexamic acid • Intravenous Tranexamic Acid	• Mean haemoglobin drop was similar in both groups (2.85 (oral) vs 2.81 (IV)). • Transfusion rates and blood loss were also found to be similar. • Oral TXA has the benefit of lesser cost.

Table 2. Summary of different regimens of peri articular analgesia

Sr. No.	Study Group	Journal	Year of Study/Publication	No. Of Patients	Mean Age of Patients (in years)	Drug Composition	Conclusion
1	Tsukada et al. [51]	The Bone & Joint Journal	2016	77	74 (47 to 88)	Comparison of peri articular injection (7.5mg/ml ropivacaine+1:1000 epinephrine+50mg Ketoprofen+10mg Morphine) • With 40mg Methylprednisolone • Without methylprednisolone	The corticosteroid group had • lower VAS scores • greater mean ROM.

Sr. No.	Study Group	Journal	Year of Study/Publication	No. Of Patients	Mean Age of Patients (in years)	Drug Composition	Conclusion
2	Iwakiri et al. [53]	Journal of Arthroplasty	2017	102	73.9 ± 8.3	Comparison of Periarticular injection (7.5mg/mL ropivacaine + 1:1000 epinephrine+ 50 mg Ketoprofen + 40 mg Methylprednisolone) • with morphine • without morphine	No statistically significant difference in: • VAS scores • Thigh girth • ROM • WOMAC scores Incidence of Nausea and vomiting higher in the morphine group. (P Value <0.001)
3	Tammachote et al. [55]	European Journal of Orthopaedic Surgery & Traumatology	2017	64	67 ± 8	Comparison of • Multimodal injection(Levobupivacaine 150mg + Ketorolac 30mg+ 5mg morphine) • Single anaesthetic injection (Levobupivacaine 150mg)	Multimodal injection group • Less VAS at rest (30 vs 46, p=0.020) • Less VAS at motion (45 vs 66, p=0.030) • Lesser consumption of morphine (5 vs 12mg, p<0.0001)
4	Danoff et al. [54]	Journal of Arthroplasty	2018	26 bilateral TKA (52knees) and 3 bilateral UKA (6 Knees)	62.9 (41.4 to 77.0)	Comparison between- • 20mL Liposomal Bupivacaine+ 30 ml 0.25% Bupivacaine • 5mg/ml ropivacaine + 1mg/ml epinephrine+ 30mg/ml Ketorolac + 0.1mg/ml Clonidine.	No statistical difference seen in • VAS (41.9mm (Liposomal Bupivacaine)vs 43.4mm(Ropivacaine cocktail))
5	Kong et al. [56]	Journal of Arthroplasty	2020	134	70.76 ± 7.15	Comparison of periarticular injection 20ml of 0.5% Ropivacaine+ 1ml Triamcinolone acetonide • With 0.3ml 1:1000 epinephrine. • Without epinephrine	No significant difference in • Numeric Rating Scale for pain. • Active ROM • Cumulative Fentanyl consumption

Table 3. Learning curves linked with new emerging techniques in TKA

Sr. No.	Technique	Mean Learning Curve*
1	Unicompartmental Knee Arthroplasty[63]	25 cases
2	Computer Navigated TKA[64]	20 cases
3	Accelerometer based navigation assisted TKA[65]	3 cases
4	Sensor Based Soft Tissue balancing[66]	41 cases
5	Robotic arm assisted TKA[67]	7 cases

**Learning curve is the number of cases taken by a novice surgeon to achieve mean operative times equivalent to manual conventional TKA*

Table 4. Summary of emerging trends in knee arthroplasty

Sr. No.	Concern	Recommendations
1	Management of Blood Loss	Pre-Operative anemia correction with iron therapy Intraoperative tourniquet use and Tranexamic acid prior to and post-operatively, if possible through 2 different routes (IV + IA) Drain for only 24 hours post operatively with early clamping.
2	Pain Management	Multimodal analgesia incorporating pre-emptive analgesia and periarticular injections.
3	Rehabilitation	Pre operative counselling and post operative follow up with telerehabilitation.
4	Single compartment Osteoarthritis/ young patients	Use of UKA wherever possible.
5	Implant alignment and soft tissue balance	Computer assisted, accelerometer based and robotic arm guided navigation systems allow better implant alignment and sensor based technology has improved accuracy of soft tissue balancing.
6	Patient Specific Instrumentation	Emerging as an alternative to navigation systems, reduce operative times, but technology is not easily accessible.

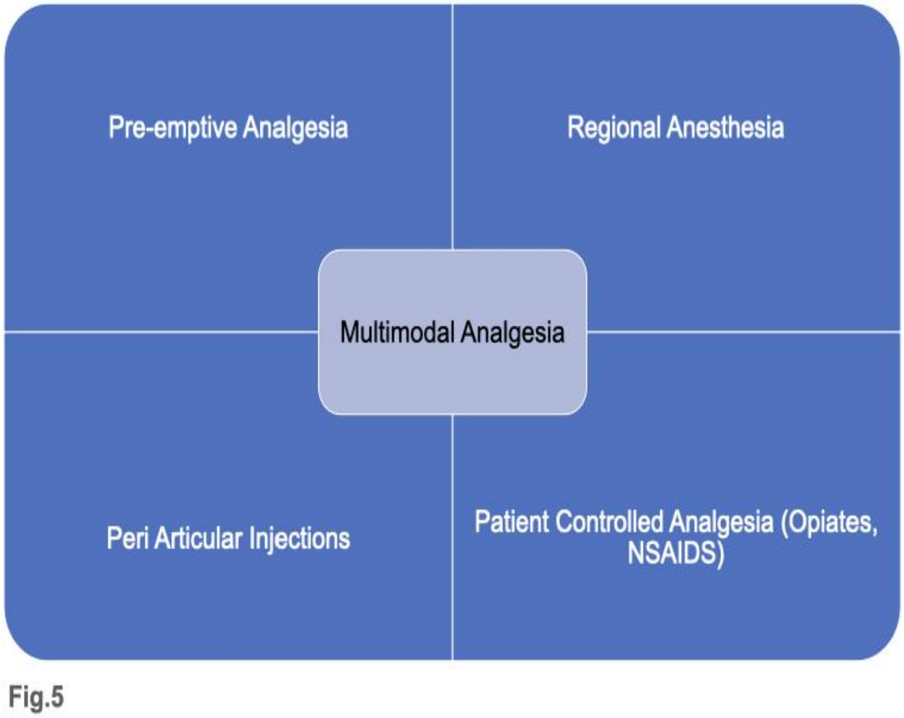

Fig. 5. Multimodal analgesia for total knee arthroplasty

Emerging surgical trends include the use of UKA, which offers advantages of better patient outcomes, lesser cost but increased rate of revision. Newer areas of research include the use of Artificial Intelligence, Robotics, 3D printing and microchip sensors. Computer assisted navigation, accelerometer-based navigation and 3D printed patient-specific cutting blocks have improved implant alignment and radiological outcome but have shown no long-term benefits in terms of patient outcomes.

Sensor based smart tibial trials have objectively improved soft tissue balancing and have improved short term outcomes. Robotic TKA has also improved patient outcomes but is expensive and has a steep learning curve.

With increasing prevalence and burden of osteoarthritis of knee joint, it is imperative to be abreast with emerging changes in practice as well as to identify lacunae and come up with more effective strategies to improve patient satisfaction and lower rates of revision (Table 4).

4. CONCLUSION

The prevalence of osteoarthritis of knee is greatly increasing, as are the comorbidities like obesity, diabetes, hypertension amongst the population undergoing TKA. Hence, ERAS protocols are being adopted globally for TKA, to ensure short hospital stay, early patient recovery and reduced hospital costs. Advances have been made in peri-operative management in order to reduce patient morbidity due to pain and blood loss and improve overall patient outcomes.

Newer trends emerging in surgical practice favor greater use of technology such as artificial intelligence, robotics, 3-D printing (Table 4). Use of these modern modalities has improved ROM, WOMAC scores post operatively. Further research is required to study the long-term benefits of these newer technologies.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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