Over the last 2 decades, there has been a rapid increase in the utilization of total knee arthroplasty (TKA), with a significant socioeconomic impact.§,¶ TKA has not only restored mobility in seniors, but its expanding indications have included young arthritic in whom it has restored a productive lifestyle. With its proven benefits and increasing demand, most health care systems are struggling to maintain access and quality of arthroplasty services for their society.||,‡ The growing financial burden of TKA has necessitated the introduction of clinical care pathways (CCPs) to maximize the number of TKAs while maintaining quality and reducing cost.** One such initiative is Bundled Payment for Care Initiative (BPCI) implemented by the American government.††,‡‡ Retrospective studies have identified various preoperative risk factors that are strongly correlated with the incidence of complications and readmissions after TKA.²⁻⁴ Being an elective procedure,

**Background:** With ever-increasing demand for total knee arthroplasty (TKA), most healthcare systems around the world are concerned about its socioeconomic burden. Most centers have universally adopted well-defined clinical care pathways to minimize adverse outcomes, maximize volume, and limit costs. However, there are no prospective comparative trials reporting benefits of these risk mitigation (RM) strategies.

**Methods:** This is a prospective cohort study comparing post-TKA 90-day complications between patients undergoing RM before surgery and those following a standard protocol (SP). In the RM group, we used a 20-point checklist to screen for modifiable risk factors and evaluate the need for optimizing non-modifiable comorbidities. Only when optimization goals were achieved, patients were offered TKA.

**Results:** TKA was performed in 811 patients in the SP group and in 829 in the RM group, 40% of which were simultaneous bilateral TKA. In both groups, hypertension was the most prevalent comorbidity (48%), followed by diabetes (20%). A total of 43 (5.3%) procedure-related complications were seen over the 90-day postoperative period in the SP group, which was significantly greater than 26 (3.1%) seen in the RM group (p = 0.039). The commonest complication was pulmonary thromboembolic, 6 in each group. Blood transfusion rate was higher in the SP group (6%) than in the RM group (< 1%).

**Conclusions:** Screening and RM can reduce 90-day complications in patients undergoing TKA.

**Keywords:** Total knee arthroplasty, Risk mitigation, Complications

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Over the last 2 decades, there has been a rapid increase in the utilization of total knee arthroplasty (TKA), with a significant socioeconomic impact.§,¶ TKA has not only restored mobility in seniors, but its expanding indications have included young arthritic in whom it has restored a productive lifestyle. With its proven benefits and increasing demand, most health care systems are struggling to maintain access and quality of arthroplasty services for their society.||,‡ The growing financial burden of TKA has necessitated the introduction of clinical care pathways (CCPs) to maximize the number of TKAs while maintaining quality and reducing cost.** One such initiative is Bundled Payment for Care Initiative (BPCI) implemented by the American government.††,‡‡ Retrospective studies have identified various preoperative risk factors that are strongly correlated with the incidence of complications and readmissions after TKA.²⁻⁴ Being an elective procedure,
TKA allows an opportunity to mitigate various modifiable risk factors and optimize non-modifiable comorbidities.\(^{11}\) A multispecialty integrated approach to screen patients to mitigate risks and optimize comorbidities have been used by high-volume joint replacement centers around the world to reduce morbidity.\(^{12,13}\) American Health Care Association has implemented Comprehensive Care for Joint Replacement in 2015, and coupled with BPCI, it is proposed to improve arthroplasty care.\(^{5,14}\) The efficacy of these strategies has not been studied. We devised a checklist-based CCP for preoperative risk mitigation (RM), optimization of comorbidities, and perioperative care of patients undergoing TKA. We compared our results with those of a cohort of patients undergoing standard preoperative work-up and perioperative care. We hypothesized that the preoperative RM approach would decrease the incidence of complications at 90 days of follow-up. Our secondary objective was to look at the proportion of patients who required extended time period for optimization and delay in surgery.

**METHODS**

Our study is a prospective comparative cohort study conducted at 2 high-volume joint replacement centers, which are part of a chain of tertiary care military referral hospitals. We enrolled patients concurrently in the 2 cohorts in a consecutive manner from November 2017 to November 2019 at one center practising RM and the other following a standard protocol (RM and SP groups).

**RM Protocol**

The primary components of RM were as follows: (1) Once the need for surgery was confirmed, the patient and caretaker of the patient (patient coach; frequently a home member) were counselled regarding the nature of the surgery, expected outcomes, the importance of prehabilitation, dietary interventions, the advantage of risk assessment and its mitigation, comorbidity optimization, and milestones of recovery. (2) Patients were assigned to clinical coordinators (PY and VL) who arranged for all preoperative investigations and preliminary anaesthetic assessment, following which the patient was risk screened as per a 20-point checklist (Fig. 1). Based on the checklist, RM steps were taken to optimize modifiable risk factors and nonmodifiable comorbidities, utilizing cross-referral services. (3) Surgery was deferred until the patient was cleared as per the 20-point checklist. A week before the planned TKA, final preanesthetic review was done and the perioperative care pathway was initiated. (4) Pre-discharge training and counselling of patient and coaching were done by the clinical coordinators, including the home rehabilitation protocol to be monitored digitally. The success of the screening and optimization was dependent upon interdepartmental coordination, hence the checklist-based protocol was reviewed, modified, and ratified by all other departments to make it purposeful. To ensure efficient patient risk screening and mitigation, an algorithmic approach was used (Fig. 2). All caretakers including surgeons, paramedics, and nurse coordinators were educated regarding the checklists, referral triggers, and risk orders to be carried out in the perioperative period.

In the SP group, the team followed the standard screening\(^{15}\) and preanesthetic checkup, and the patient underwent surgery within 1 to 3 weeks of waiting time.

**Patients**

All patients with advanced knee arthritis requiring TKA (assessed for the need for surgery and cleared for surgery by the anaesthetist) were screened for enrollment in the study. Included were patients who accepted to undergo RM as per the 20-point checklist (Fig. 1). Excluded were patients (1) who failed the 20-point checklist but due to severe disability or socioeconomic reasons had to be offered compassionate arthroplasty without optimization with appropriate shared decision making and (2) who were put on risk factor mitigation but opted out of surgery or were lost to follow-up (Fig. 3). Acting as a study nurse, the counselor (JN) obtained informed consent of the patients included in the study. The comparative cohort was enrolled after standard preanesthetic fitness for surgery. Patients selected for simultaneous bilateral TKA (SBTKA) were separately screened as per the predefined criteria (Table 1) and, if not found suitable, were only offered unilateral TKA. As a part of blood conservation protocol, a strict algorithmic approach was taken for managing anemia and intravenous iron therapy and EPO supplements were used when indicated (Fig. 4). Records were maintained of all the patients who required RM or cross-referral and optimization for any reason.

**Arthroplasty Protocol**

The arthroplasty protocols followed at both centers were similar. Enrolled patients were admitted in the evening prior to surgery. Overnight chlorhexidine wipes were used for preoperative limb preparation. Risk orders as per comorbidities were followed to optimize perioperative care (Fig. 1). On the day of surgery, preemptive pain control was started using acetaminophen, cyclooxygenase-2 selective inhibitor, and pregabalin. Broad-spectrum antibiotic
| Patient care pathway: 20-point checklist & risk orders | Preoperative measures | Risk orders |
|-----------------------------------------------------|-----------------------|-------------|
| **Referral triggers / 20-point checklist**           | Prehabilitation       | Check drug modifications |
| Confirm need for surgery                            | Surgery deferred / transferrable | Avoid/ defer all high-risk medications/ corticosteroids |
| - Severity of disease affecting activities of daily living | Start weight reduction program / plan surgery | No NSAID or ACE inhibitors /ARB / diuretic adjustment |
| - Radiologically advanced disease                   | Plan control / counselling about surgery and recovery | Reduce dose of LMWH, avoid sedatives, muscle relaxants |
| - Fast food intolerance                             | fianlethion control    | Specific renal risk interventions |
| - Radiotherapy to 3 months                          |                         | - Renal diet |
| - Risk of other pathology, spine / hip / ankle      | If UTEI follow blood conservation program | - Reinsert nephrology consult if urine output less than 120 mL in any 4-6 hour period |
| - Screen for SBTKA if planned                       |                         | - Check serum urea nitrogen and creatinine preoperatively and calculate GFR / BUN / creatinine / electrolytes daily |
| **1. Obesity**                                       |                         | Specific perioperative complications |
| - BMI > 35                                          |                         | - Monitor patient carefully for fluid overload, hypertension, excessive bleeding |
| - BMI > 30                                          |                         | - Daily review by nephrologist for patients on dialysis |
| **2. Anemia**                                       |                         | **Pulmonary risk orders** |
| - Hb level                                          |                         | Preoperative |
| - Hb > 12 g/dl (for SBTKA)                          |                         | Bronchodilator nebulization albuterol 2.5 mg |
| - Hb > 11 g/dl (for UTE)                            |                         | Preoperative morning |
| - Hb > 10 g/dl for rheumatoid disease               |                         | CVS/GA confirm and presence of mask |
| **3. Nutritional status**                           | Specific referral to dietician to improve protein supplementation / postprn until they improve | - Check renal status of all inpatients as used by patient, optimize use |
| - Serum albumin > 3.5 g/dl                          | Refer to endocrinologist to alter drug therapy and review at 6-12 weeks till levels come to normal | **Postoperative** |
| - Absolute leucocyte count < 1,500                   | Refer to dermatologist to rule out / treat infection and review after recovery | - HOB 20 white resting, |
| - BMI > 35                                          | Refer to dermatologist to initiate treatment review at 6 weeks to plan surgery if recovered | - Aspiration precautions |
| **4. Diabetic control**                             |                         | - Oxygen by humidified nasal cannula to keep saturation > 92% |
| - HbA1c > 7.5                                       |                         | - Incentive spirometer every hour while awake |
| - Fasting/postprandial sugar > 200 mg%              |                         | - A continuous pulse oximetry throughout admission |
| **5. Dental risk**                                  |                         | - Elevate HOB N45° while eating |
| - History of recent dental procedure                 |                         | - If OSA use CPAP per home setting |
| - History of caries, gum disease                     |                         | - Pulmonologist consult on arrival |
| - History of dental surgery                          |                         | - Avoid narcotics & sedatives, aggressive chest physio and early setting and ambulation |
| - Radiologically advanced disease                    |                         | **Renal risk orders** |
| - Radiography to 3 months                           |                         | Preoperative |
| **6. Skin & foot health**                            |                         | Bronchodilator nebulization albuterol 2.5 mg |
| - Look for wound problems                           |                         | Preoperative morning |
| - History suggestive area                            |                         | CVS/GA confirm and presence of mask |
| - Fungal infections                                  |                         | - Check renal status of all inpatients as used by patient, optimize use |
| **7. Smoking / tobacco use / abuse**                 |                         | **Postoperative** |
| - To be stopped at least 6 weeks prior              |                         | Bronchodilator nebulization albuterol 2.5 mg |
| **8. Intraarticular injection**                      |                         | Preoperative morning |
| - Osteoarthritis, synovitis                         |                         | CVS/GA confirm and presence of mask |
| - Biomechanical hyperpthyicosis                     |                         | - Check renal status of all inpatients as used by patient, optimize use |
| - Obstructive symptoms                              |                         | **Cardiac risk orders** |
| - Intraarticular injection                          |                         | Preoperative |
| - Synovitis, chronic synovitis                       |                         | - Check baseline ECG availability |
| - Intraarticular injection                          |                         | - Check all drop to be continued all morning of surgery |
| - Intraarticular injection                          |                         | - Check if on dual anti-platelet therapy when to restart check |
| - Use of blood thinners (dilated PT/INR)             |                         | **Postoperative** |
| - Dual antiplatelet / OAC                            |                         | - Close monitoring of vitals / restent medication after physician consult |
| **9. Urological symptoms**                          |                         | - ECG daily + Trop T (first and second Postoperative day) |
| - Dysuria, incontinence                              |                         | - Cardiologist consult if any symptom / ECG / hemodynamic instability |
| - Bladder neck obstruction                           |                         | - DVT prophylaxis as per risk screening chart |
| - Bladder symptoms                                  |                         | **DVT risk orders** |
| - History of prostate disease                       |                         | Preoperative |
| - History of prostate cancer                        |                         | No hemoderivational factor in epidual gabepentin or tramadol / narcotics |
| - History of diabetes                               |                         | Postoperative |
| - History of diabetes                               |                         | - Lucid patient close to nursing station. Continuous pulse oximetry & keep oxygen saturation at 95% |
| - History of diabetes                               |                         | - Check vital every 4 hours. Daily laboratory tests |
| - History of diabetes                               |                         | - Avoid physical/chemical restraints. Daily caloric counts |
| - History of diabetes                               |                         | **HELP protocol** |
| - History of diabetes                               |                         | - Orientation (right / left) |
| - History of diabetes                               |                         | - Ensure frequent communication with patient |
| - History of diabetes                               |                         | - Involve family in daily care. 1:1 supervision to be considered to help with eating/walking/leithumking |
| - History of diabetes                               |                         | - Alternative methods to help with sleep |
| - History of diabetes                               |                         | - Mobilize patient quickly out of bed with physical therapy |
| - History of diabetes                               |                         | **Treat suspected diltium** |
| - History of diabetes                               |                         | - Movement status examination (include rectification figure drawing) |
| - History of diabetes                               |                         | - Assess focus, attention, speech (diagnosulvesteins), sulria changes |
| - History of diabetes                               |                         | - Evaluate care based on signs/symptoms of ialturium, up taketime causes of ialturium (ejection, drugs, alcohol) |
| - History of diabetes                               |                         | **Carotid risk orders** |
| - History of diabetes                               |                         | Preoperative |
| - History of diabetes                               |                         | - Check baseline ECG availability |
| - History of diabetes                               |                         | - Check all drop to be continued all morning of surgery |
| - History of diabetes                               |                         | - Check if on dual anti-platelet therapy when to restart check |
| - History of diabetes                               |                         | **Postoperative** |
| - History of diabetes                               |                         | - Close monitoring of vitals / restent medication after physician consult |
| - History of diabetes                               |                         | - ECG daily + Trop T (first and second Postoperative day) |
| - History of diabetes                               |                         | - Cardiologist consult if any symptom / ECG / hemodynamic instability |
| - History of diabetes                               |                         | - DVT prophylaxis as per risk screening chart |
| - History of diabetes                               |                         | **Pulmonary risk orders** |
| - History of diabetes                               |                         | Preoperative |
| - History of diabetes                               |                         | Bronchodilator nebulization albuterol 2.5 mg |
| - History of diabetes                               |                         | Preoperative morning |
| - History of diabetes                               |                         | CVS/GA confirm and presence of mask |
| - History of diabetes                               |                         | - Check renal status of all inpatients as used by patient, optimize use |
| - History of diabetes                               |                         | **Postoperative** |
| - History of diabetes                               |                         | Bronchodilator nebulization albuterol 2.5 mg |
| - History of diabetes                               |                         | Preoperative morning |
| - History of diabetes                               |                         | CVS/GA confirm and presence of mask |
| - History of diabetes                               |                         | - Check renal status of all inpatients as used by patient, optimize use |
| - History of diabetes                               |                         | **Cardiac risk orders** |
| - History of diabetes                               |                         | Preoperative |
| - History of diabetes                               |                         | - Check baseline ECG availability |
| - History of diabetes                               |                         | - Check all drop to be continued all morning of surgery |
| - History of diabetes                               |                         | - Check if on dual anti-platelet therapy when to restart check |
| - History of diabetes                               |                         | **Postoperative** |
| - History of diabetes                               |                         | - Close monitoring of vitals / restent medication after physician consult |
| - History of diabetes                               |                         | - ECG daily + Trop T (first and second Postoperative day) |
| - History of diabetes                               |                         | - Cardiologist consult if any symptom / ECG / hemodynamic instability |
| - History of diabetes                               |                         | - DVT prophylaxis as per risk screening chart |

**Fig. 1.** Patient care pathway. SBTKA: simultaneous bilateral total knee arthroplasty, BMI: body mass index, Hb: hemoglobin, UTKA: unilateral total knee arthroplasty, HbA1C: hemoglobin A1C, PT: prothrombin time test, INR: international normalized ratio, OAC: oral anticoagulants, COPD: chronic obstructive pulmonary disease, IHd: ischemic heart disease, CVA: cerebrovascular accident, Vit: vitamin, PVD: peripheral vascular disease, CKD: chronic kidney disease, CPAP: continuous positive airway pressure, PFT: pulmonary function test, ECG: electrocardiogram, ITP: idopathic thrombocytopenic purpura, NSAID: non-steroidal anti-inflammatory drug, ARB: angiotensin receptor blockers, LMWH: low-molecular-weight, GFR: glomerular filtration rates, BUN: blood urea nitrogen, HOB: head of bed, OSA: obstructive sleep apnea, ICU: intensive care unit, NIV: noninvasive ventilation, DVT: deep vein thrombosis.
Patients were enrolled in the risk mitigation strategy. An intravenous injection of tranexamic acid 1 gm and dexamethasone 8 mg was given intravenously 20 minutes to 1 hour before surgery. All operations were done under low-dose single-shot spinal anesthesia. We performed the standard medial parapatellar arthrotomy in all cases. A tourniquet was used throughout surgery in all unilateral cases. All SBTKAs were done by two surgical teams operating simultaneously; in these cases, a tourniquet was used only on one side. Depending on deformity, bone quality, and soft-tissue balance achieved, we decided the implant to be used. In most cases, we used ultracongruent cruciate-sacrificing cemented knee or a dual pivot knee design. In a few cases, we had to use a cemented posterior-stabilized knee with a cam and post design and rarely used a stemmed tibial implant when the tibial bone stock was poor or deficient. We used barbed bidirectional suture to close the arthrotomy without a drain. The skin was closed with staples and an occlusive dressing was applied. Immediately after the surgery, all patients received adductor canal block for pain control. Postoperatively, all patients received an additional intravenous injection of tranexamic acid 2 hours after completion of surgery. On the evening of surgery, they received an additional dose of antibiotic and deep vein thrombosis (DVT) prophylaxis as per the risk screening score. All the patients received an intravenous injection of dexamethasone 8 mg once a day for 48 hours. Patients who underwent bi-
lateral TKA received injectable iron supplement iron carboxymaltose 500 mg stat and three doses of erythropoietin (EPO; 10,000 IU daily). All patients ambulated the next morning, and most were discharged to either step-down care (in-hospital rehabilitation facility) or home within 2 to 3 days of surgery. We ensured the patients could carry out activities of daily living with support before discharge.

Follow-up and Adverse Event Reporting
All local and systemic complications were classified and listed in the adverse event reporting form (Table 2). On occurrence of any complication, the team filled the incident reporting form, which described in detail the complication, its classification as per list, actions taken, and the outcome. The study nurse in the ward maintained adverse event reporting register and forms. Following discharge, active phone follow-up was done for all patients by the study coordinators (PY and VL). Outpatient visits were planned at 2 weeks after discharge for removal of skin staples and at 6 weeks and 3 months for clinical follow-up and documentation of any adverse events. During the visit, the follow-up records were updated in the complica-
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Sample Size Calculation and Data Analysis
We used Stata ver. 12 (StataCorp., College Station, TX, USA). Recent literature (Table 3) shows that with risk screening, expeditious surgery, and rapid rehabilitation, the rate of complications after primary TKA varies from 2.5% to 5.1% and all-cause readmission has been seen to be varying from 6% to 15%.[16–20] Complication rate being our primary objective, to look at 50% reduction in complication rates, we would need 792 patients in each cohort for the study to have at least 80% power (allowing on-sided alpha error of 0.05). As our study involved a minimum of 90 days of follow-up, we did not expect many losses to follow-up and planned to enroll 800 patients in each group to ensure an adequate sample size. We looked at the demographics, disease profile including comorbidities in both groups of patients to ensure comparability of the cohorts. The mean, standard deviation, and range were presented for continuous parameters. Most of the outcome data were discrete, hence frequency and percentage were calculated. We calculated the incidence of complications along with the relative risk and number needed to treat (NNT).

RESULTS
A total of 811 patients underwent TKA in the SP group, of whom 325 were bilateral TKA patients; 829 patients underwent TKA in the RM group, of whom 325 were bilateral TKA patients. In both groups, age and sex distribution were similar (average age was 63 years and 60% were female). Hypertension was the commonest comorbidity present in more than 48% of the patients, followed by diabetes, which was present in more than 20% of the patients in both groups. Most of the patients (70%) exhibited American Society of Anesthesiologists (ASA) grade II in the preoperative anesthesia evaluation (Table 4). In the RM group, the average hemoglobin was 13% as against 12% in the SP group. After being accepted for surgery by the anesthesia team, all patients were screened as per the 20-point checklist. Out of 829 patients in the RM group, 128 patients required optimization of anemia as per the blood conservation protocol, dietary intervention for hypoalbuminemia was required for 68 patients, 42 patients had hemoglobin A1C > 7.5 and required review of antidiabetic drugs to optimize glycaemia control, 22 male patients had urinary symptoms attributable to prostatic hypertrophy and required review and management by a urologist, in 16 male smoker patients surgery was deferred to ensure 6 weeks of abstinence, in 14 patients the surgery was deferred as they had been given an intra-articular injection within 6 months of planned date of surgery, 12 patients with hypothyroidism required optimization of thyroid profile with adjustment of thyroxine dosage, 11 patients with rheumatoid disease showed signs of flare of the inflammatory disease and required optimization by a rheumatologist with disease modifying anti-rheumatoid drugs and biologics to control the disease before surgery, 9 patients had suspicious skin lesions in the lower limbs requiring review and management by a dermatologist to minimize risk of infection, 8 patients with alcohol dependence syndrome needed preoperative counselling and drug therapy was started by the counsellor and psychiatrist to minimize risk of withdrawal, 5 patients required optimization of obstructive sleep apnea by starting home use of continuous airway pressure machine, 4 patients with parkinsonism needed optimization of drug therapy by a neurologist to improve gait and balance, and in 4 patients with mood disorder surgery was deferred to optimize drug therapy in consultation with a psychiatrist. Of all 295 (36%) patients who required optimization after screening
by the 20-point checklist, 44 had more than 1 risk predictor needing optimization. In most cases, optimization required 6 to 12 weeks.

In both SP and RM groups, 40% of patients underwent SBTKA performed by 2 teams under the same anesthesia. DVT chemoprophylaxis was used as per risk assessment and aspirin was used in the majority (74.9%) of patients. The mean length of stay was 4.7 days (range, 3–11 days). All patients were followed up at 90 days after surgery. All the complications were classified as per the adverse event reporting format. A total of 43 adverse events (5.3%) were seen over the 90-day postoperative period in the SP group as compared to 26 (3.1%) in the RM group. RM resulted in significant (p = 0.039) risk reduction of complications (relative risk [RR], 0.60; 95% confidence interval, 0.38–0.97; NNT 50).

In the RM group, the incidence of complications was 3.1% as against 5.3% in the SP group. In both groups, pulmonary thromboembolic complications were the commonest complications (6 in each group and 2 of them were fatal in both groups). Cardiac complications were more common in the SP group (n = 6) as compared to the RM group (n = 2). Most of the complications were less than 1% (Table 3). Four deaths (0.43%) were seen in the SP group and 3 in the RM group, 2 were due to pulmonary embolism in both groups, 1 due to myocardial infarction in both groups and 1 due to urosepsis in the SP group. Blood transfusion rate was significantly higher in the SP group.

**Blood conservation program/hematology referral trigger**

**Risk of blood transfusion**

High risk (> 50%) if Hb < 11.5 gm% (male) & < 10.5 gm% (female)
Moderate risk (< 40%) if Hb 11.5–13 gm% (male) & 10.5–12 gm% (female)
Low risk (< 10%) if Hb > 13 gm% (male) & > 12 gm% (female)

**Intervention for moderate risk (male, Hb 11.5–13 gm & female, 10.5–12 gm%)**

Review drug therapy like antiplatelet drugs and anticoagulants
Prefer SA over GA/discuss hypotensive anesthesia with anesthetist

**Intervention for high risk patients (male, Hb < 11.5 gm% & < female, 10.5 gm%)**

| On admission/OPD | MCV & creatinine | Serum ferritin & retics |
|-----------------|------------------|------------------------|
| Hb < 11.5 gm% (males) | MCV < 80 FL Creatinine < 1.3 | Serum ferritin < 100 ng/L |
| Hb < 10.5 gm% (females) | MCV < 80–100 FL Creatinine > 1.3 | Serum ferritin > 100 ng/L |
| MCV > 100 FL | Retic < 2% | Retic > 2% |

Reassess after 4 weeks ➔ low & moderate risk

Proceed with surgery, 1 g IV Tranexamic acid for all patients, unless contraindicated

* Avoid EPO in patients with uncontrolled HTN and IHD with stent/SKD
EPO dosing: preoperative 40,000 IU weekly (on 21, 14, 7, 0 days before surgery) or 10,000 IU alternate day starting 2 days before surgery
postoperative 10,000 IU daily for 4 days
Special precaution: all patients on EPO should receive DVT prophylaxis as high risk.

**Fig. 4.** Blood conservation program. Hb: hemoglobin, SA: spinal anaesthesia, GA: general anaesthesia, OPD: outpatient department, MCV: mean corpuscular volume, EPO: erythropoietin, FS: ferrous sulphate, FA: folic acid, IV: intravenous, HTN: hypertension, IHD: ischemic heart disease, SKD: severe kidney disease.
DISCUSSION

With the rapid increase in the global demand for TKA, every healthcare system is striving to establish safe and efficient care pathways to maximize the number of TKAs, while minimizing untoward events, which increase the cost of care.\(^1,2\) Efficiency coupled with safety would ensure meeting population need. In the evolution of TKA, the early emphasis had been on designing implants that reproduce natural knee kinematics and minimize wear to improve longevity.\(^2,3,4\) Subsequently, the focus shifted to optimizing surgical techniques to ensure precise alignment, accurate soft-tissue balance, and good implant fixation. This required improvement in instrumentation and surgeon training. Over the last decade, the emphasis has been on safe and efficient anesthesia, expeditious surgery, effective pain control, and rapid rehabilitation to ensure early return to home with minimum adverse events and readmissions.\(^5,6\) To achieve this goal, most centers are practicing meticulous preoperative screening and prehabilitation of patients planned to undergo TKA.\(^7,8,9\) High-volume joint replacement centers have been designing their own screening and perioperative care strategies (CCP), to bring down adverse events.\(^5,10-13\) Most of these pathways have adopted screening and optimization strategies based on risk predictors brought out by registry data analysis and retrospective studies.\(^14,15,16\) Many studies have reported acceptable complication rates using CCPs, but there are limited studies in which CCPs have been scientifically implemented on a large cohort with RM endpoints comparing their outcomes with the standard of care cohort (Table 5). There is no prospective comparative concurrent cohort trial till date. This is one such study that implemented a scientifically designed CCP on a large cohort of patients and ensured RM endpoints were met before surgery, which led to a significant reduction in the risk of procedure-related complications (RR, 0.60; \(p = 0.039\)). In 36% of patients, additional optimization and RM measures were required and some of them had to delay their surgery. Despite implementing stringent optimization and RM protocol, most of the patients could...
be offered surgery by 3 months of their initial presentation. Anemia, hypoalbuminemia, and poor diabetic control were reasons for optimization in most patients (more than 200 patients). In the present study, both groups were comparable in respect of demographics and comorbidities. However, as the RM group was optimized prior to surgery, the hemoglobin level was higher in this group. Also, there were fewer patients who were in ASA grade III in the RM group as compared to the SP group.

TKA being a quality-of-life surgery, it is now understood that it needs stringent screening and all necessary steps to ensure an optimum outcome. As the volume of TKAs has gone up, most of the centers have a waiting period varying from 3 to 6 months before the patient can be offered the surgery. This gives the surgeon adequate time to prehabilitate the patient, actively look for poor risk factors, and optimize every health condition, which can affect the outcome. Although preanesthetic evaluation screens the patient to avoid anesthetic perioperative complications, the aim of it is not to improve or maintain the good health of the patient, ensuring optimum musculoskeletal rehabilitation. We aggressively managed anemia and optimized preoperative hemoglobin, even using pharmacological intervention as guided by the hematologist (HK). We did not use any postoperative transfusion trigger. Out of 829 patients in the RM group, we transfused blood in only 2 cases, which is significantly better when compared to any other recently published studies (3% to 26%)\(^{18,19,30}\) and this is when 40% of patients underwent SBTKA. Transfusion itself increases the risk of procedure-related complications as prosthetic joint infection in the postoperative period.\(^{11,31}\)

Evidence-based preoperative optimization as a risk reduction tool has been recommended by several authors, who have acknowledged its benefits in reducing the incidence of complications, length of stay, and 90-day readmission rates, akin to our study.\(^{5,7,20,22,33}\) In contrast to our findings, Bernstein et al.,\(^7\) Ryan et al.,\(^20\) and Dlott et al.\(^33\) in their studies using an RM strategy did not appreciate significant difference in 90-day readmission rates and emergency room visits although they too found reduction in length of stay and discharge to the skilled nursing facili-

### Table 3. Preoperative Demographics and Comorbidities

| Variable                                    | SP group n Mean ± SD | RM group n Mean ± SD |
|---------------------------------------------|----------------------|----------------------|
| Age (yr)                                    | 811 62.91 ± 8.60     | 829 63.54 ± 9.10     |
| Sex                                         | 811                   | 829                   |
| Male                                        | 319                   | 355                   |
| Female                                      | 492                   | 474                   |
| Body mass index (kg/m\(^2\))                | 811 27.83 ± 4.40      | 829 28.13 ± 4.40      |
| Functional comorbidity index                | 811 0.97 ± 0.98       | 829 0.84 ± 0.87       |
| Hypertension                                | 404                   | 405                   |
| Diabetes                                    | 175                   | 146                   |
| Coronary artery disease                     | 34                    | 31                    |
| Chronic obstructive pulmonary disease       | 35                    | 22                    |
| Chronic kidney disease                      | 15                    | 11                    |
| American Society of Anesthesiologists      | 811                   | 829                   |
| Grade I                                     | 93                    | 94                    |
| Grade II                                    | 591                   | 656                   |
| Grade III                                   | 127                   | 78                    |
| Hemoglobin (%)                              | 811 12.08 ± 1.50      | 829 13.01 ± 1.61      |

SP: standard protocol, RM: risk mitigation, SD: standard deviation.
This may be attributed to the lack of uniform protocols, as the study was conducted at 3 different centers and they themselves pointed out that although there was some attempt at RM by deferring the surgery by few weeks, unlike our study, they could not establish whether endpoints of optimization of comorbidities or RM were achieved before surgery. A few of these studies had a small sample size and were retrospective in design.\(^7,33\) Our 90-day complication rate after RM (3.1%) was lower than the rates reported by Bozic et al.\(^4\) (3.40%), Ryan et al.\(^28\) (3.46%), and Zmistowski et al.\(^34\) (6.02%). However, complication rates (1.72) found in the work by Clair et al.\(^35\) were significantly lower as compared to our study.

In conclusion, our study demonstrated a reduction in procedure-related complications in patients undergoing TKA when a CCP was followed and RM goals were achieved. In light of TKA being an elective surgical procedure chosen to improve the quality of life of the patient, it may be prudent to define optimization goals and ensure RM before offering surgery to patients.

### Table 4. Complications in Total Knee Replacement (TKA/SBTKA)

| Complication                        | Group | No. (% ) |
|-------------------------------------|-------|----------|
| Wound complication                  | RM    | 5 (0.6)  |
|                                     | SP    | 2 (0.2)  |
| Pulmonary                           | RM    | 6 (0.7)  |
|                                     | SP    | 6 (0.7)  |
| Stiff knee                          | RM    | 6 (0.7)  |
|                                     | SP    | 6 (0.7)  |
| Periprosthetic fracture             | RM    | 2 (0.2)  |
|                                     | SP    | 1 (0.1)  |
| Cardiac                             | RM    | 2 (0.2)  |
|                                     | SP    | 6 (0.7)  |
| Prosthetic joint infection           | RM    | 3 (0.4)  |
|                                     | SP    | 7 (0.9)  |
| Neurological                        | RM    | 2 (0.2)  |
|                                     | SP    | 2 (0.3)  |
| Urological                          | RM    | 1 (0.1)  |
|                                     | SP    | 5 (0.6)  |
| Miscellaneous                       | RM    | 2 (0.2)  |
|                                     | SP    | 5 (0.6)  |
| Total complications                 | RM    | 26 (3.1) |
|                                     | SP    | 43 (5.3) |

RM group: n = 829, SP group: n = 811. TKA: total knee arthroplasty, SBTKA: simultaneous bilateral total knee arthroplasty, RM: risk mitigation, SP: standard protocol.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Table 5. Recent Literature Review on Early Complications Following Total Knee Arthroplasty

| Study                        | Study period | Number    | Day | Death (%) | Cardiovascular (%) | Pulmonary (%) | VTE (%) | CNS (%) | Wound (%) | PJI (%) | Genitourinary (%) | Stiff knee (%) | PPF (%) | Total (%) | Blood transfusion (%) |
|------------------------------|--------------|-----------|-----|-----------|--------------------|--------------|---------|---------|-----------|---------|---------------------|----------------|---------|-----------|-----------------------|
| Retrospective study          |              |           |     |           |                    |              |         |         |           |         |                     |                |         |           |                       |
| Kurtz et al.                 | 2010–2013    | 952,593   | 90  | NA        | 5.80               | 1.50         | 1.80    | 0.90    | 4.50      | 3.90    | NA                  | NA             | 18.40   | 12.60    |                       |
| Braud et al.                 | 2005–2011    | 419,805   | 90  | NA        | 13.35              | 5.00         | 0.70    | 1.24    | 6.35      | 11.40   | NA                  | NA             | 38.04   | 26.20    |                       |
| Ross et al.                  | 2003–2016    | 205,152   | 30  | NA        | 10.11              | 3.58         | 1.01    | 1.34    | 21.97     | 1.56    | NA                  | 1.03           | 40.60   | NA        |                       |
| Clair et al.                 | 2005–2011    | NA        | 90  | NA        | NA                 | NA           | 0.87    | NA      | 1.33      | NA      | 0.18                | 0.12           | 1.72    | NA        |                       |
| Nichols et al.               | 2009–2013    | 159,390   | 90  | NA        | 0.50               | 1.40         | 2.64    | 0.60    | NA        | 0.30    | NA                  | NA             | 6.04    | NA        |                       |
| Middleton et al.             | 2012–2014    | 355,155   | 90  | 0.37      | 0.19               | 0.55         | NA      | NA      | 0.48      | NA      | NA                  | NA             | 2.22    | NA        |                       |
| Zmistowski et al.            | 2004–2008    | 5,207     | 90  | NA        | 0.50               | NA           | 0.13    | 0.40    | 1.82      | NA      | 2.70                | NA             | 6.01    | NA        |                       |
| Bozic et al.                 | 2008–2010    | 626,781   | 90  | 0.30      | 0.40               | 0.90         | 1.29    | NA      | 0.60      | NA      | 0.30                | NA             | 3.40    | NA        |                       |
| Cram et al.                  | 2007–2010    | 915,562   | 30  | 0.30      | 0.30               | NA           | NA      | NA      | 0.40      | NA      | NA                  | 1.30           | NA      | NA        |                       |
| Keeney et al.                | 2006–2009    | 1,443     | 30  | NA        | 0.97               | 0.27         | 9.30    | 0.00    | 0.55      | 1.25    | 0.20                | 0.06           | 3.59    | 16.80    |                       |
| Keeney et al.                | 2010–2013    | 1,929     | 30  | NA        | 0.62               | 0.10         | 0.7     | 0.00    | 0.36      | 0.26    | 0.15                | 0.15           | 1.69    | 3.70     |                       |
| Ryan et al.                  | 2014–2018    | 1,564     | 90  | NA        | 0.19               | 1.02         | NA      | 0.45    | 0.51      | 1.08    | 0.44                | 0.13           | 4.41    | 0.19     |                       |
| Ryan et al.                  | 2014–2018    | 744       | 90  | NA        | 0.40               | 0.26         | 1.21    | 0.40    | 0.13      | 1.34    | 0.40                | 0.13           | 3.46    | 0.27     |                       |
| Van Horne et al.             | 2015–2017    | 337       | 30  | NA        | 0.30               | 0.30         | 1.20    | 0.00    | NA        | NA      | 0.30                | 1.20           | NA      | NA        |                       |
| Prospective study            |              |           |     |           |                    |              |         |         |           |         |                     |                |         |           |                       |
| This study (comparative)     | 2017–2019    | 829 / 811 | 90  | 0.36 / 0.49 | 0.20 / 0.70       | 0.70 / 0.70 | 0.20 / 0.25 | 0.20 / 0.60 | 0.36 / 0.90 | 0.13 / 0.62 | 0.70 / 0.10 | 3.10 / 5.30 | 0.20 / 6.00 |
| Yu et al.                    | 2012–2014    | NA        | 30  | 0.50      | NA                 | 0.71         | 0.88    | 1.17    | 0.38      | 0.46    | 1.63                | NA             | 5.06    | NA        |                       |
| Kulhrestha et al.            | 2012–2016    | 2,400     | 90  | 0.50      | 0.65               | 0.75         | 0.90    | NA      | 0.37      | NA      | 0.67                | 0.14           | 3.48    | NA        |                       |

VTE: venous thromboembolism, CNS: central nervous system, Wound: wound complication, PJI: prosthetic joint infection, PPF: periprosthetic fracture, NA: not applicable.
*Risk mitigation/standard protocol.
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