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Does Risk Mitigation Reduce 90-Day Complications in Patients Undergoing Total Knee Arthroplasty?: A Cohort Study

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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*

Over the last 2 decades, there has been a rapid increase in the utilization of total knee arthroplasty (TKA), with a significant socioeconomic impact.[1-3] 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.[4,5] 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.[6] One such initiative is Bundled Payment for Care Initiative (BPCI) implemented by the American government.[7,8] Retrospective studies have identified various preoperative risk factors that are strongly correlated with the incidence of complications and readmissions after TKA.[9-11] Being an elective procedure,

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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 counsellor (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

Referral triggers / 20-point checklist	Preoperative measures	Risk orders
		Renal risk orders
Confirm need for surgery ・Severity of disease effecting activities of daily living ・Radiologically advanced disease ・Failed trial of conservative (> 3 months) ・Rule out other pathology, spine / hip / ankle ・Screen for SBTKA if planned	**Prehabilitation** ・Exercise program: quadriceps & hamstring strengthening, general conditioning, isometric back exercise ・Dietary supplements : Iron, Vit D, Vit C, and protein ・Pain control / counselling about surgery and recovery milestones. Improve and maintain skin hygiene	**Check drug modifications** ・Avoid / altered dose of nephrotoxic drugs Aminoglycoside ・No NSAID/ no ACE inhibitors / ARB / diuretic adjustment ・Reduce dose of LMWH; avoid sedatives, muscle relaxants **Specific renal risk interventions** ・Renal diet ・Request nephrology consult if urine output less than 120 mL in any 4-hr period ・Check serum urea nitrogen and creatinine preoperatively and calculate GFR / BUN / creatinine / electrolytes daily ・Strict intake output monitoring and fluid orders as per physician **Specific perioperative complications** ・Monitor patient carefully for: fluid overload, hyperkalemia (high potassium), excessive bleeding ・Daily review by nephrologist for patients on dialysis
1. **Obesity**: BMI > 40 BMI 35−40 BMI < 35	Surgery deferred / bariatric referral Start weight reduction program & plan surgery Counsel for need to watch weight & plan surgery	
2. **Anemia**: Hb level Hb > 12 gm% (for SBTKA) Hb > 11 gm% (for UTKA) Hb > 10 gm% for rheumatoid disease	If less follow blood conservation program	
3. **Nutritional status** Serum albumin < 3.5 g/dL Absolute leucocyte count < 1,500	Specific referral to dietician to improve protein supplementation (postpone until they improve)	
		Pulmonary risk orders
4. **Diabetic control** Hb A1C < 7.5 Fasting/postprandial sugar < 200 mg%	Refer to endocrinologist to alter drug therapy and review at 6−12 weeks till levels come to normal	**Preoperative** ・Bronchodilator nebulization albuterol 2.5 mg on preoperative morning ・If OSA confirm setting and presence of mask ・Check availability of all inhalers as used by patient, optimize use
5. **Dental risk** History of recent dental procedure Bleeding/painful gums	Refer to dental surgeon to rule out / treat infection and review after recovery	
6. **Skin & foot health** Look for wet psoriasis Eczema/infected lesions Fungal infections	Refer to dermatologist to initiate treatment review at 6 weeks to plan surgery if recovered	**Postoperative** ・HOB 20° while resting. ・Aspiration precautions ・Oxygen by humidified nasal cannula to keep saturation > 92% ・Incentive spirometer every hour while awake & continuous pulse oximetry throughout admission ・Elevate HOB N45° while eating ・If OSA use CPAP per home setting ・Pulmonologist consult on arrival ・Avoid narcotics & sedatives; aggressive chest physio and early sitting and ambulation
7. **Smoking / tobacco use / abuse** To be stopped at least 6 weeks prior	Advise abstinence and take psychologist help	
8. **Intraarticular injection**	If there is history of intraarticular injection defer surgery by 6 months	
9. **Urinary symptoms** Dysuria, incontinence Benign prostatic hypertrophy Obstructive symptoms	Urine culture / treat and repeat culture ensure asymptomatic and colony count less than 100,000 / Cu mm. obtain urology consult / start medication	**Notify physician immediately for any of the following** ・Any difficulty breathing or significant change in breathing ・Significant and sustained drop in O_2 saturation or CO_2 level ・Any suspicion of aspiration. Increasing coughing or exudates. ・Any negative change in breath sounds. Keep patient vertical more, out of bed more, and ambulate more ・Watch all feedings. Low threshold for pulmonary consult shift to ICU if patient requires continuous oxygen / NIV
10. **Use of blood thinners** (deranged PT/INR) Dual antiplatelet / OAC	Review by treating physician/ switch to single antiplatelet preferably aspirin and stop oral anticoagulant if mandatory switch to low molecular weight heparin ensure INR < 1.5 and normal PT	
11. **Need for decolonization** History of recent hospitalization, health care worker	Use nasal mupirocin and chlorhexidine wipes for 5 days	**Delirium risk orders**
12. **Renal risks** Serum creatinine > 1.3 gm% Glomerular filtration rate < 60 Patient on dialysis/transplant recipient History of diabetes type I > 5 yr / type II > 10 yr	Nephrologist review / avoid nephrotoxic drugs	**Preoperative** ・No benzodiazepines/ fentanyl in epidural gabapentin or tramadol / narcotics **Postoperative** ・Locate patient close to nursing station. Continuous pulse oximetry & keep oxygen saturation at 95% ・Check vitals every 4 hours. Daily laboratory tests ・Avoid physical/chemical restraints. Daily calorie counts
13. **Pulmonary risks** Known case of asthma / COPD History of interstitial lung disease Morbid obesity history of obstructive sleep apnea	Refer to pulmonologist / start aggressive bronchodilator therapy with aerosolized steroids. If CPAP required train in home use. PFT screening before surgery	**HELP protocol:** ・Orientation (reality / time) ・Ensure frequent communication with patient ・Involve family in daily care. 1:1 supervision to be considered to help with eating/toileting/turning ・Alternative methods to help with sleep ・Mobilize patient quickly out of bed with physical therapy
14. **Cardiac risks** Known case of IHD / on drugs / stent / surgery Known case of CVA / PVD / CKD Diabetic on insulin History of cardiac arrhythmia / on pacemaker History of valvular heart disease History suggestive of cardiac failure in past	Cardiologist consult; ECG / echocardiography/ stress test advise regarding dual antiplatelet therapy, risk of stent re-occlusion/ need to defer surgery; anticoagulant/ antibiotic cover for valvular lesion Optimization of antiarrhythmic therapy / pacemaker setting	**Treat suspected delirium** ・Mini-mental status examination (include replication/figure drawing) ・Assess focus, attention, speech (illogical/disoriented), subtle changes ・Educate care team regarding signs/symptoms of delirium, up treatable causes of delirium (infection, drugs, alcohol)
15. **Delirium & fall risk** Age > 75 with forgetfulness History of memory loss and falls Cognitive impairment History of agitation / hallucinations Parkinsonism Old CVA Neuromuscular disorder	Neurologist consult / optimize drug therapy like in parkinsonism / neuromuscular training and gait prehabilitation	**Cardiac risk orders** **Preoperative** ・Check baseline ECG availability ・Check all drugs to be continued till morning of surgery ・Check if on double anti-platelet therapy when to restart check
16. **Addiction risks / anxiety & depression** Alcohol dependence (liver function including gama glutaryl transferase) Narcotic overuse	Psychologist and psychiatrist consult to avoid risk of withdrawal in postoperative period and prevent adverse effects of narcotics and alcohol dependence	**Postoperative** ・Close monitoring of vitals / restart medication after physician consult ・ECG daily + trop T (first and second Postoperative day) ・Cardiology consult If any symptom / ECG / hemodynamic instability ・DVT prophylaxis as per risk screening chart
17. **Endocrinology risks** Chronic steroid intake Hypo or hyperthyroid	Endocrinologist review/ if on long term steroid will need to continue / based on thyroid profile will need adjustment of drug dose	
18. **Rheumatoid disease control** Disease modifying drugs Rule out acute flare Nutritional status & anemia	To stop biologics 3 weeks prior to surgery, acute flare may need to drug therapy to control inflammation. Improve nutrition and anemia as per protocol	
19. **Platelet counts** < 100,000 or > 600,000 /cu mm	Hematology consults to rule out ITP / thrombocytosis	
20. **Vascular risks** Deep vein thrombosis Peripheral pulses Venous stasis	Get venous and arterial doppler done and obtain vascular consult / in PVD endorse no tourniquet for surgery	
21. **Dyselectolytemia risk** (Na < 128 / K < 3.5 / > 5.5) Patient on diuretics / antihypertensives Impaired renal function	Obtain physician consult to change drug therapy and improve electrolyte balance	

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: idiopathic 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.

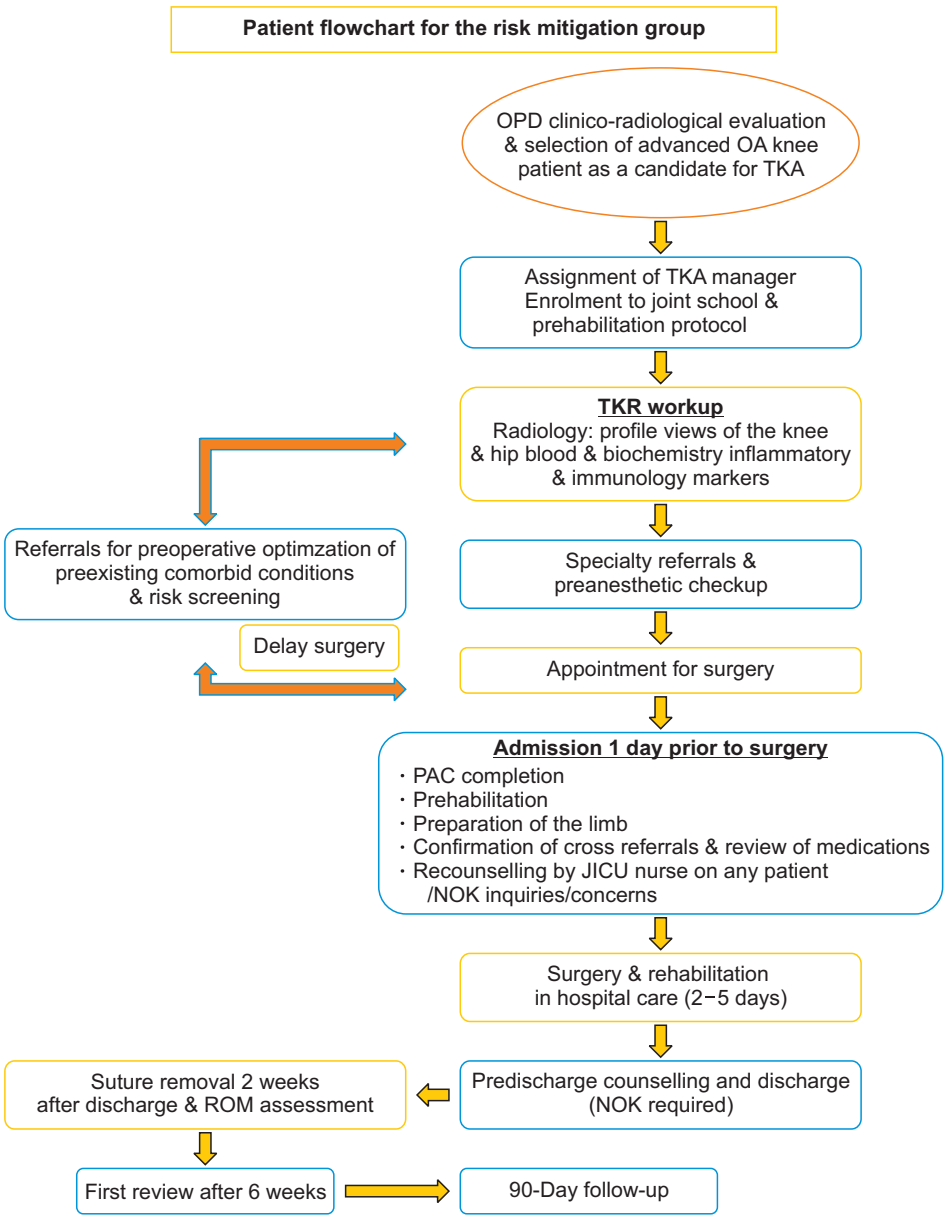

Fig. 2. Patient flowchart risk mitigation pathway. OPD: outpatient department, OA: osteoarthritis, TKA: total knee arthroplasty, TKR: total knee replacement, PAC: preanaesthesia checkup, JICU: joint intensive care unit, NOK: next of kin, ROM: range of motion.

cover (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[16] All the patients received an intravenous injection of dexamethasone 8 mg once a day for 48 hours. Patients who underwent bi-

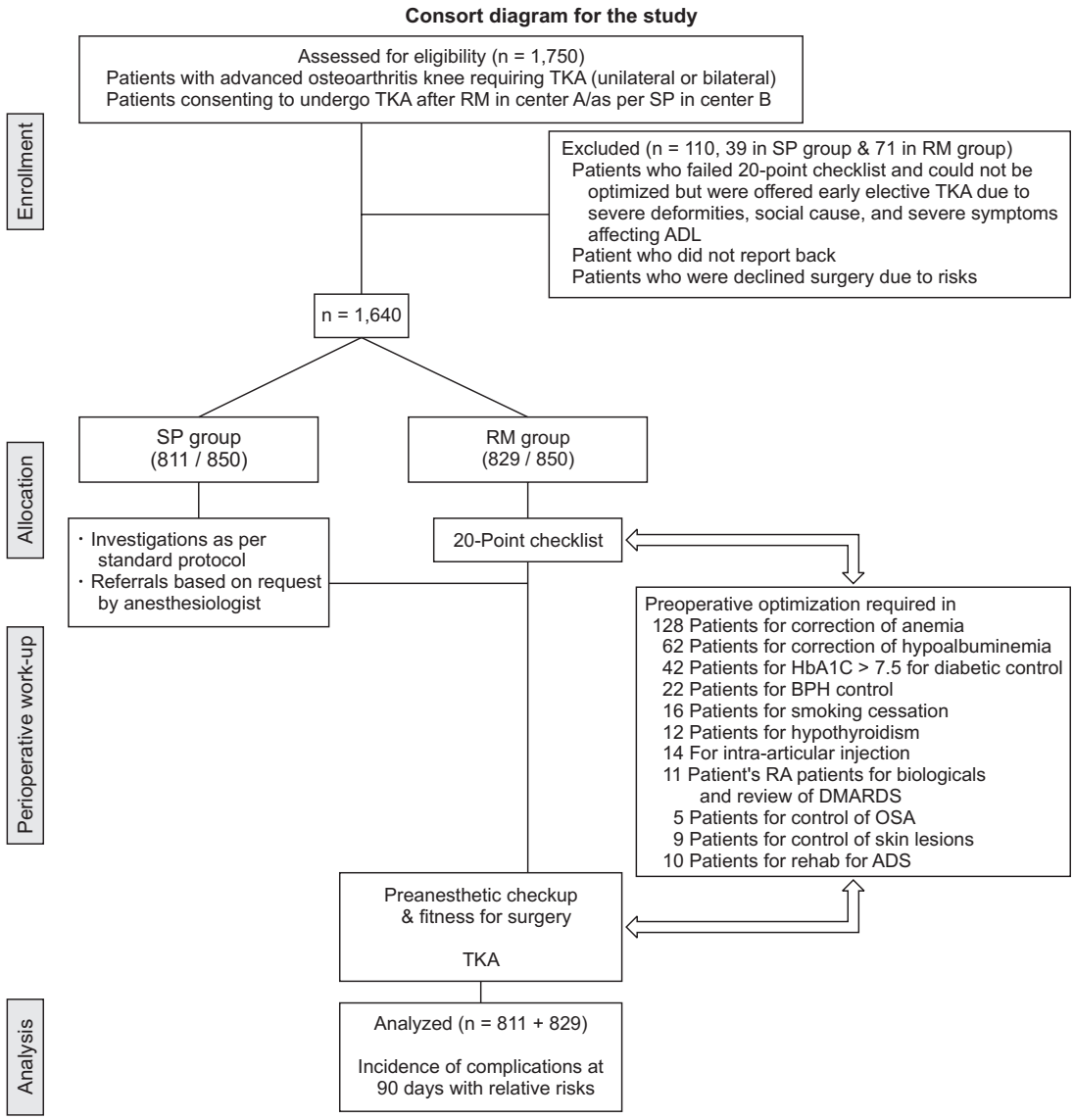

Fig. 3. Consort diagram. TKA: total knee arthroplasty, RM: risk mitigation, SP: standard protocol, ADL: activities of daily living, HbA1C: hemoglobin A1C, BPH: benign prostatic hyperplasia, RA: rheumatoid arthritis, DMARDS: disease modifying antirheumatic drugs, OSA: obstructive sleep apnea, ADS: alcohol dependent syndrome.

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-

Table 1. Risk Orders

Contraindication for simultaneous bilateral total knee arthroplasty
1. Age > 75 yr
2. American Society of Anesthesiologists grade 3 or 4
3. Ischemic heart disease
4. On aggressive anticoagulation or clopidogrel
5. Left ventricular ejection fracture < 50%
6. Oxygen dependent pulmonary disease
7. End-stage renal disease: creatinine > 1.6 mg/dL
8. Steroid dependent asthma/chronic obstructive pulmonary disease
9. Pulmonary arterial hypertension (pulmonary artery pressure > 45 mmHg)
10. Body mass index > 40 kg/m^2
11. Chronic liver disease
12. Cerebral vascular disease
13. Obstructive sleep apnea without treatment
14. Diabetes mellitus with hemoglobin A1C > 7.5%
15. History of deep vein thrombosis or pulmonary embolism
16. History of chronic cardiac failure
17. Hemoglobin < 12 g/dL

tion register maintained by the study nurse (JN).

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%[16-20] and all-cause readmission has been seen to be varying from 6% to 15%.[1,19-21] 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

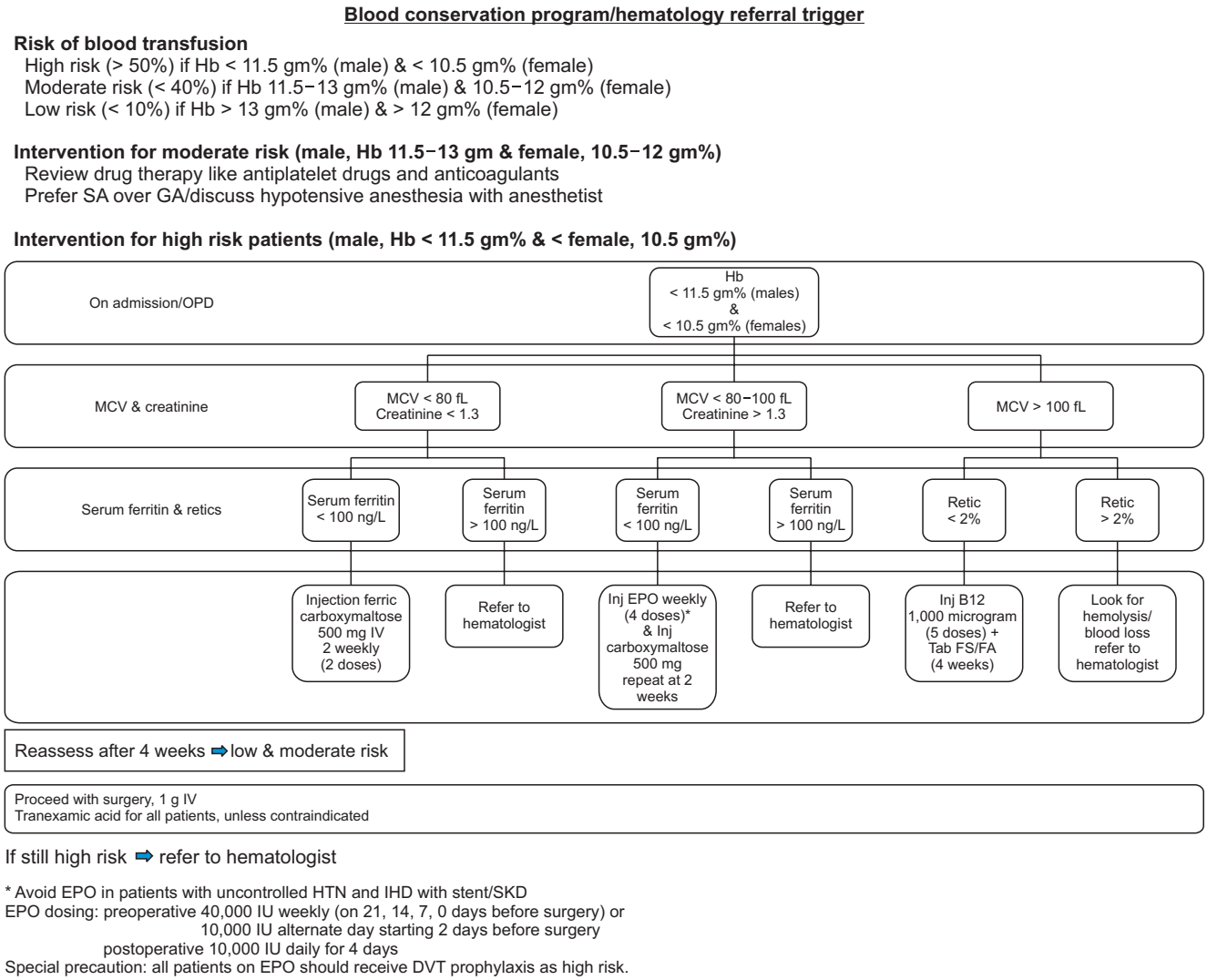

Fig. 4. Blood conservation program. Hb: hemoglobin, SA: spinal anaesthesia, GA: general anaesthesia, OPD: outpatient department, MCV: mean corpuscular volume, EPO: erythropoietin, FS: ferrous sulphate, FA: folic acid, IV: intravenous, HTN: hypertension, IHD: ischemic heart disease, SKD: severe kidney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

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

Table 2. Complications (Classification)

A. Wound complications
1. Wound disruption
2. Wound discharge/soakage (> 7 days)
3. Superficial incisional infection (superficial surgical site infection)
4. Deep incisional infection
5. Dermatitis
B. Cardiac events
1. Sustained hypotension requiring intervention
2. Myocardial infarction
3. Cardiac arrest requiring cardiopulmonary resuscitation
4. Fresh arrythmia
C. Pulmonary events
1. Pneumonia
2. Hypoxia requiring unplanned ventilation
3. Pulmonary embolism
D. Neurological events
1. Post spinal headache
2. Preoperative confusion/delirium
3. Seizures
4. Cerebrovascular accidents
5. Peripheral nerve injury
E. Urological events
1. Urinary tract infection
2. Progressive renal failure
3. Acute renal failure
F. Metabolic events
1. Hyponatremia
2. Diabetic keto acidosis
G. Miscellaneous
1. Blood transfusion
2. Deep vein thrombosis
3. Dislocation
4. Sepsis/septic shock
5. Haematemesis
6. Periprosthetic fracture
7. Stiff knee requiring manipulation
H. Prosthetic joint infection
I. All cause readmission

(6%) as compared to that in the RM group (< 1%).

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.[1,22] 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.[23,24] 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.[25,26] To achieve this goal, most centers are practicing meticulous preoperative screening and prehabilitation of patients planned to undergo TKA.[7,10,11,27] High-volume joint replacement centers have been designing their own screening and perioperative care strategies (CCP), to bring down adverse events.[5,10-13,28] Most of these pathways have adopted screening and optimization strategies based on risk predictors brought out by registry data analysis and retrospective studies.[17,19,20,29] 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

Table 3. Preoperative Demographics and Comorbidities

Variable	SP group		RM group	
	n	Mean ± SD	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.

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 anaesthetic 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.[5,7,30,32,33] In contrast to our findings, Bernstein et al.,[7] Ryan et al.,[28] 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 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.

ty. 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. (6.02%).[34] However, complication rates (1.72) found in the work by Clair et al.[35] were significantly lower as compared to our study.

Our study has many strengths. It is the only prospective, concurrent, large comparative cohort study with apriori sample size calculation, which looked at the clinically important reduction in the procedure-specific complication of TKA while implementing a risk screening and mitigation pathway. Most of the published studies on the same type of subjects are noncomparative and although have followed a CCP, they did not ensure RM. Being a prospective trial, all the complication reporting was accurately done on a preformatted adverse event reporting form. The comparative cohort was from another institute, which might have hampered some comparability, but doing the study in a randomized manner in one institute had its own ethical challenges. Most studies have either looked at unilateral TKA (UTKA) or compared UTKA to SBTKA, which is not a true picture of the practice pattern in community; in most eastern world countries, 20%–30% are SBTKA. Our study mimics the same and has better external validity. Being a study conducted in a public-funded military healthcare facility, there are some limitations. Although most of such studies have included the cost of care and length of stay as additional outcome measures, we could not include these two parameters as our facilities offered free-of-cost care to the patients, our centers, being a military facility, had rehabilitation beds housed in hospital premises, and with patients coming from far away locations, frequently their discharge disposition depended on many other factors, which could not be controlled in our study, and hence we could not compare the length of stay as one of the outcome parameters, which was done in many other studies as it is important for its socioeconomic impact.

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.

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.[1]	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.[36]	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.[29]	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.[35]	2005–2011	NA	90	NA	NA	NA	0.87	NA	1.33		NA	0.18	0.12	1.72	NA
Nichols et al.[20]	2009–2013	159,390	90	NA	0.50	1.40	2.64	0.60	NA	0.6	0.30	NA	NA	6.04	NA
Middleton et al.[19]	2012–2014	355,155	90	0.37	0.19	0.55	NA	NA	NA	0.48	NA	NA	NA	2.22	NA
Zmistowski et al.[34]	2004–2008	5,207	90	NA	0.50	NA	NA	0.13	0.40	1.82	NA	2.70	NA	6.01	NA
Bozic et al.[4]	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.[18]	2007–2010	915,562	30	0.30	0.30	NA	NA	NA	0.40		NA	NA	NA	1.30	NA
Keeney et al.[30]	2006–2009	1,443	30	NA	0.97	0.27	9.30	0.00	0.55	1.25	0.20	NA	0.06	3.59	16.80
Keeney et al.[30]	2010–2013	1,929	30	NA	0.62	0.10	0.7	0.00	0.36	0.26	0.15	NA	0.15	1.69	3.70
Ryan et al.[28]	2014–2018	1,564	90	NA	0.19	1.02	NA	0.45	0.51	1.08	0.44	0.13	NA	4.41	0.19
Ryan et al.[28]	2014–2018	744	90	NA	0.40	0.26	1.21	0.40	0.13	1.34	0.40	0.13	NA	3.46	0.27
Van Horne et al.[37]	2015–2017	337	30	NA	0.30	0.30	1.20	0.00	NA	NA	NA	NA	0.30	1.20	NA
Prospective study															
This study (comparative)	2017–2019	829 / 811*	90 / 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 / 0.70	0.20 / 0.10	3.10 / 5.30	0.20 / 6.00
Yu et al.[38]	2012–2014	NA	30	0.50	NA	0.71		0.88	1.17	0.38	0.46	1.63	NA	5.06	NA
Kulshrestha et al.[15]	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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