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"Is every revision the same?" definition of complexity in knee revision surgery

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Abstract

Purpose The purpose of this paper is to define a subset of complex rTKA in terms of preoperative, intraoperative, and postoperative outcomes and complications. The secondary outcome of the authors is to propose a simple and easy-to-use guide for clinical network in rTKA management.

Methods Complex rTKAs were defined according to the presence of at least two of the following features: periprosthetic joint infection, re- revision, femoral and/or tibial massive bone defects, soft tissue impairment, stiffness, fracture requiring fixed component revision.

Results Twenty-six patients underwent a standard rTKA (group A) while 24 had a complex rTKA (group B). The mean follow-up was 50.2 ± 16.4 months in group A and 49.5 ± 16.8 in group B (p = 0.44). The operative time was longer in group B (200.4 ± 131.4 min vs 110.2 ± 59.8 min). A greater intraoperative total blood loss (3014.2 ± 740.0 vs 2328.5 ± 620.6 ml, p < 0.001), intra and postoperative blood infusion (3.6 ± 1.2 vs 2.1 ± 1.2 units, p < 0.001) was reported in group B. Significant difference was obtained for global complication rate (11.5% group A vs 37.5% group B, p = 0.04), reoperation (7.7% group A vs 33.3% group B, p = p = 0.03) and re-revision (3.8% group A vs 25% group B, p = p = 0.04).

Conclusion This study describes a specific entity of rTKA that require higher surgical effort and increased surgical challenge (measured as increased surgical time, need of transfusions and complications). The proposed classification could provide an easy-to-use tool for quick grading of complexity in rTKA.

Keywords Revision · Total Knee Arthroplasty · Complexity · Classification · Outcomes

Introduction

In the last decade, the number of total knee arthroplasty (TKA) has significantly increased and consequently the number of revision total knee arthroplasty (rTKA) is expected to grow [1].

RTKA represent one of the most challenging procedures in orthopaedic surgery. To achieve knee functional improvement and durable prosthesis survivorship, the goals are joint line restoration, bone loss management and stable implant fixation. At the same time, solid fixation is essential to allow early post-operative rehabilitation and good functional outcomes [2, 3]. In the United States, the average length of hospital stay for all revision TKA procedures was 5.1 days, and the average total charges were $49,360; considerably varying according to census region, hospital type, and procedure performed [4]. Consequently, it is crucial for healthcare professionals to recognize the complexity of rTKA and allocate resources accordingly. The complexity of a revision knee arthroplasty plays a significant role in determining the required resources and expertise. Studies have shown that specialized centers and experienced surgeons tend to have better outcomes in managing complex revision cases compared to less specialized centers [5]. Technical skills, such as bone reconstruction and soft tissue management, are critical for successful outcomes in complex revision procedures [6]. Moreover, identifying highly demanding rTKA will guide surgeons to avoid a hasty approach and will also prevent high volume centres to be overloaded by revision procedures supporting clinical networking. Although RTKA

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should be always considered a challenging surgery, there is a distinct group of procedures that could be considered particularly complex. The authors hypothesized that Complex rTKA are associated with higher surgical efforts and complications rate that standard rTKA. The primary aim of this study is to define Complex rTKA and to compare preoperative, intraoperative, and postoperative features, outcomes, and complications of two concurrent cohorts of standard rTKA and complex rTKA. The secondary outcome of the authors is to propose a simple and easy-to-use guide for clinical network in rTKA management.

Methods

All data had been prospectively collected by our Institutional Arthroplasty Registry from January 2018 to December 2020 and then analysed. The Institutional Review Board (IRB) approved this single centre study. Written and informed consent was obtained from all the included participants. All procedures were conducted according to Declaration of Helsinki.

All patients undergoing rTKA with age > 18 and a minimum follow-up of 24 months were enrolled in this study. The reason for exclusion was incomplete preoperative, intraoperative, or postoperative clinical and radiological data.

Criteria to stratify procedures were:

1) periprosthetic joint infection
2) re- revision
3) femoral and/or tibial massive bone defects (AORI type 2B/3)
4) soft tissue impairment (involving soft tissue envelope and/or extensor mechanism)
5) stiffness
6) fracture requiring fixed component revision.

When two or more of the presented features are contemporary present, the procedure was classified as complex rTKA. PJI diagnosis was made according to the proposed 2018 International Consensus Meeting (ICM) criteria for PJI [7]. Femoral and tibial bone defects were classified radiographically in the preoperative and confirmed during surgery according to the Anderson Orthopaedic Research Institute (AORI) classification [8]. Although there is no consensus in defining a stiff TKA, stiffness has been defined with a flexion limit < 90°, flexion contracture greater than 10°, or a combination of the two [9].

Patients were divided into two groups: Group A that included standard rTKA and group B that included Complex rTKA.

Main demographic (age, sex, diagnosis, affected side, body mass index (BMI), comorbidities, smoke status, previous surgical procedures) surgical data (surgical time, surgical approach, intraoperative blood loss, intra and postoperative blood infusion units, final prosthetic constrain) were recorded. If the proposed strategy required a two-step revision, the duration of each was collected and the sum was considered as the total surgical time. In case of chronic infections, a two stage procedure was adopted. Revision or reoperations after the indexed procedure was not considered in the surgical time evaluation but was recorded as a complication. Patients were classified according to systemic host grade McPherson staging system [10]. Both intraoperative and postoperative blood transfusions were considered for estimate the total number of blood transfusion units.

Clinical and radiographic evaluation

Clinical and radiographic evaluation were performed before and after surgery at 45 days, three, six and 12 months, and annually thereafter. Clinical assessment included physical examination, the Visual Analogue Scale (VAS), the Knee Society Score (KSS), the Oxford Knee Score (OKS), the Knee Injury and Osteoarthritis Outcome score (KOOS) for pain, symptoms, activity of daily life (ADL), sport/recreational activities and quality of life (QoL), the passive and active Range of Movement (ROM) along with flexion contracture of extension lag. The ROM was determined with the use of a standard clinical goniometer. Standing AP, lateral, long-leg and Merchant radiographs were performed in the preoperative and at 45 days follow up. Standing AP, lateral, and Merchant plain x-ray analysis was performed during the other follow-up time points.

Radiological evaluation was carried out according to the Knee Society total knee arthroplasty radiographic evaluation for long- stemmed revision prostheses [11]. This approach ensures proper radiographic documentation of coronal and sagittal implant alignment, fixation interface integrity with respect to radiolucent lines and osteolysis according to a zonal classification system even for stemmed implants. Radiographs were assessed by two well-trained orthopaedic fellows. Doubtful cases were solved with by consensus. Osseointegration, migration, loosening, osteolysis, cortical hypertrophy or malalignment were evaluated. Cortical hypertrophy was considered as any abnormal thickening of the cortical bone around the stem. Implant axial alignment was evaluated with neutral defined as between 3° and 9° of valgus [12].

Every possible minor (wound dehiscence, superficial wound troubles) or major complication (deep infection, aseptic loosening, intra-operative or post-operative fractures, revision, reoperation) related to the operated knee was recorded.

The authors considered as revision any kind of surgical procedure after the indexed operation that required fixed component

removal. Reoperation was defined as any kind of surgery that involved the specific knee joint after the indexed procedure with or without implant components removal. We defined septic recurrence as each new infection or positive culture at reimplantation with isolation of the original infecting organism.

Postoperative course

Partial weight-bearing with crouches started on the second postoperative day after removal of the surgical drain. Full weight-bearing were allowed after eight weeks from surgery, whenever possible. Passive and progressive knee mobilization started on the first day after surgery and continued for the first six weeks. This postoperative course was adopted for standard and complex rTKA. In case of extensor mechanism reconstruction, three weeks of full extension with partial weight bearing were performed after surgery. Standard venous thromboembolism prophylaxis with enoxaparin and compression stockings was prescribed at least for 35 days. This postoperative course was adopted independently for standard and complex rTKA, when feasible. In case of septic revision, a specific intravenous antibiotic course of at least 14 days was administered in agreement with the infectious disease team and continued thereafter if necessary.

Statistical analysis

Continuous variables were reported as mean ± standard deviation (SD) and compared between preoperative and final follow-up using the paired Student t-test. Categorical variables were expressed as the number of cases or percentage. All the comparison between continuous variables were performed with the unpaired Student t-test. For all the radiological parameters, inter-observer reliability was evaluated with the Cohen's kappa coefficient. For all the analysed data, a two-tailed, p-value < 0.05 was considered statistically significant.

Results

Demographic data

Seventy-six (76) patients underwent a rTKA at a single tertiary care centre between January 2018 and December 2020. Fifty (50) patients satisfied the eligibility criteria. No bilateral cases were included. Twenty-four of the included procedures were classified as complex rTKA (group B), the remainders were included in the standard rTKA group (group A). Figure 1 describe the study population, the included and excluded patients, the reason for exclusion and the criteria for stratification in both groups.

Main demographic data are summarized in Table 1. No relevant differences were observed between groups in terms of sex, age, BMI, affected side, indication for revision surgery, comorbidities, smoke status and Mc Pherson systemic host grade. Group B reported a significantly high number of previous surgeries on the affected knee. The mean follow-up was 50.2 ± 16.4 months in group A and 49.5 ± 16.8 in group B ($p = 0.44$).

Surgical data

Medial parapatellar approach was used in all the included patients, two cases require a tibial tuberosity osteotomy in group B. Group B reported a statistically significant high number of massive tibial or femoral massive bone defects,

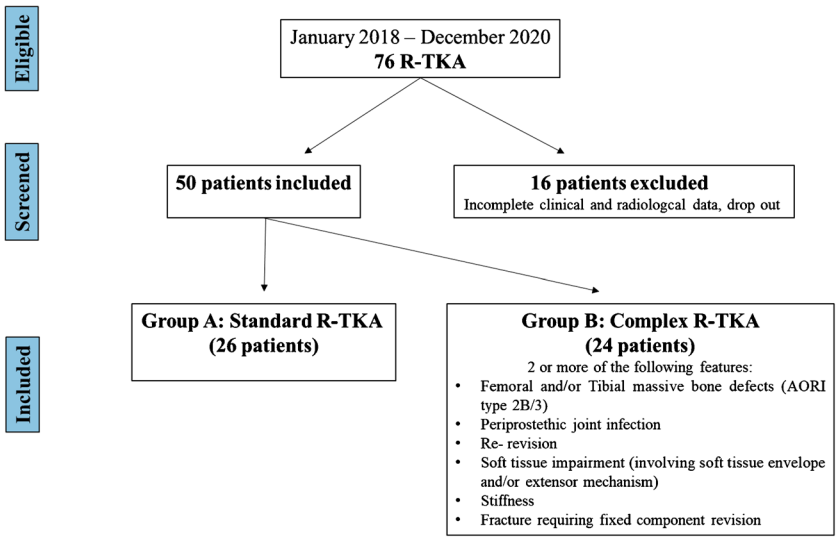

Fig. 1 Flowchart describing the inclusion and exclusion criteria, the reason for exclusion and the criteria for distribution in the study groups

Table 1 Preoperative main demographic data

	Standard, group A (26 pts)	Complex, group B (24 pts)	*P* value
Sex	11 M (42.3%) 15 F (57.7%)	10 M (41.7%) 14 F (58.3%)	0.90
Age at surgery*	69.5 y ± 8.6	72.0 y ± 6.9	0.13
BMI*	28.5 ± 3.8	28.3 ± 4.7	0.43
Side	14 R (53.8%) 2 L (46.2%)	10 R (41.7%) 14 L (58.3%)	0.41
Indication for revision surgery	AL: 16 (61.5%) PJI: 5 (19.3%) Instability: 4 (15.4%) Stiffness: 1 (3.8%)	AL (2 cases with PPF): 16 (54.2%) PJI: 7 (29.2%) Instability: 4 (8.3%) Stiffness: 1 (8.3%)	AL: 0.77 PJI: 0.51 Instability: 0.67 Stiffness: 0.60
Relevant Comorbidities	Diabetes: 5 (19.2%) Heart disease: 2 (7.7%) Hepatopathy: 1 (3.8%) Parkinson disease:1 (3.8%) Autoimmune disease: 0 Renal disease: 1 (3.8%) Neoplasm: 1 (3.8%) Drug abuse: 0 Global n° of comorbidities: 11 (42.3%)	Diabetes: 5 (20.8%) Heart disease: 2 (8.3%) Hepatopathy: 2 (8.3%) Parkinson disease:1 (4.2%) Autoimmune disease: 1 (4.2%) Renal disease: 1 (4.2%) Neoplasm: 1 (4.2%) Drug abuse: 1 (4.2%) Global n° of comorbidities: 14 (58.3%)	0.77 (global)
Smoke status	Smokers: 7 (26.9%), Non smokers: 19 (73.1%)	Smokers: 8 (33.3%) Non smokers: 16 (66.7%)	0.76
Mc Pherson Systemic Host grade	A: 13 (50.0%) B: 11 (42,3%) C: 2 (7.7%)	A: 10 (41.7%) B: 11 (45.8%) C: 3 (12.5%)	A: 0.59 B: 1.0 C: 0.66
Number of previous surgeries	1.4 ± 0.9	3.0 ± 2.1	**0.001**
Follow-up (months)*	50.2 ± 16.4	49.5 ± 16.8	0.44

* *mean ± Standard deviation*

M: male, F: Female, R: right, L: left, AL: aseptic loosening, PJI: periprosthetic joint infection, PPF: periprosthetic fracture

number of re-revision procedures and soft tissue or extensor mechanism disruptions.

No significant differences were observed for PJI and stiffness between groups. Two patients required a fixed component revision for distal femoral fracture in group B. Focusing on infected cases, two patients underwent a debridement, antibiotics, and implant retention (DAIR) procedure for acute infections while three patients had a staged revision for chronic PJI in group A. Group B included seven cases of chronic PJI managed with staged procedures. A statistically significant difference was observed in final prosthetic constrain. In all the included patients, a NexGen Legacy System® (Zimmer-Biomet, Warsaw, IN) was used. Nineteen (79.2%) patients ended up with a hinged constrain in group B while only eight (30.8%) patients received a hinged prosthesis in group A. In all cases, hybrid fixation and uncemented stems were used. Metaphyseal fixation with tantalum cones was extensively used when needed.

The operative time was longer in group B (200.4 ± 131.4 min) compared to group A (110.2 ± 59.8 min). A greater intraoperative total blood loss (3014.2 ± 740.0 vs 2328.5 ± 620.6 ml, $p < 0.001$) as well as greater intra and postoperative blood infusion (3.6 ± 1.2 vs 2.1 ± 1.2 units, $p < 0.001$) was reported in group B. Table 2 summarizes the main surgical data.

Clinical data

Preoperative clinical features of both groups are presented in Table 3.

All subjective and objective scores improved significantly from preoperative to the final follow-up in both groups ($p < 0.01$). No extension lag was noted at final follow-up.

KSS showed a statistically significant higher score for group A at final follow-up (84.2 ± 5.7 vs 75.3 ± 6.8, $P < 0.001$). Patient reported outcomes at the last available follow-up did not show significant differences between groups except for KOOS ADL and KOOS QoL. Table 4 illustrates the postoperative clinical data of both groups. At final follow up, one patient walked with crutches in group A while three patients used canes or walker in group B.

Table 2 Surgical data

	Standard, group A (26 pts)		Complex, group B (24 pts)		*P* value
Surgical Time (min)*	110.2 ± 59.8		200.4 ± 131.4		**0.001**
Intraoperative total blood loss (ml)*	2328.5 ± 620.6		3014.2 ± 740.0		**0.001**
Intra and postoperative blood infusion (N° of units)	2.1 ± 1.2		3.6 ± 1.2		**0.001**
Surgical approach (N° of patients)	Medial parapatellar: 26 (100%)		Medial parapatellar: 22 (91.7%) Medial parapatellar + TTO: 2 (8.3%)		/
Final prosthetic constrain	CCK: 18 (69.2%)		CCK: 5 (20.8%)		**0.001**
	RHK: 8 (30.8%)		RHK: 19 (79.2%)		
Massive bone defects (N° of patients)	Yes: 5 (19.2%) No: 21 (80.8%)		Yes: 16 (66.7%) No: 8 (33.3%)		**0.001**
AORI distribution	Femur	Tibia	Femur	Tibia	/
	1: 13 (50.0%)	1: 12 (46.2%)	1: 5 (20.8%)	1: 8 (33.3%)	
	2A: 11 (42.3%)	2A: 10 (38.4%)	2A: 7 (29.2%)	2A: 6 (25.0%)	
	2B: 2 (7.7%)	2B: 2 (7.7%)	2B: 9 (37.5%)	2B: 7 (29.2%)	
	3: 0	3: 2 (7.7%)	3: 3 (12.5%)	3: 3 (12.5%)	
Re-revision (N° of patients)	Yes: 6 (26.1%) No: 20 (76.9%)		Yes: 15 (62.5%) No: 9 (37.5%)		**0.009**
Infection (N° of patients)	Yes: 5 (19.2%) No: 21 (80.8%)		Yes: 7 (29.2%) No: 17 (70.8%)		0.51
Soft tissue impairment (N° of patients)	Yes: 0 No: 26 (100%)		Yes: 4 (16.7%) No: 20 (83.3%)		**0.04**
Stiffness (N° of patients)	Yes: 2 (7.7%) No: 24 (92.3%)		Yes: 5 (20.8%) No: 19 (79.2%)		0.24
Fracture requiring fixed components revision (N° of patients)	Yes: 0 No: 26 (100%)		Yes: 2 (8.3%) No: 22 (91.7%)		0.23

* *mean ± Standard deviation*

Massive bone defects: AORI 2B or 3, TTO: tibial tubercle osteotomy, CCK: condylar constrained knee, RHK: rotating hinge knee

Table 3 Preoperative clinical data

	Standard (26 pts)	Complex (24 pts)	*P* value
KSS*	39.1 ± 7.7	36.7 ± 7.6	0.26
VAS*	7.3 ± 1.2	7.8 ± 1.1	0.11
OKS*	20.4 ± 4.5	20.0 ± 2.5	0.68
KOOS PAIN*	34.8 ± 7.6	31.7 ± 9.6	0.21
KOOS SYMPTOMS*	21.5 ± 4.6	18.9 ± 6.8	0.13
KOOS ADL*	35.7 ± 6.4	34.5 ± 8.3	0.57
KOOS SPORT/RECREATIONAL ACTIVITIES*	13.5 ± 5.0	11.1 ± 5.2	0.08
KOOS QOL*	34.2 ± 7.6	29.3 ± 8.6	**0.04**

* *mean ± standard deviation*

KSS: Knee Society Score, VAS: Visual Analogue Scale, KOOS: Knee injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Life, QOL: Quality of Life

Table 4 Postoperative clinical data

	Standard, group A (26 pts)	Complex, group B (24 pts)	*P* value
KSS*	84.2 ± 5.7	75.3 ± 6.8	**0.001**
VAS*	1.9 ± 1.3	2.2 ± 1.6	0.55
OKS*	39.6 ± 4.6	38.1 ± 2.9	0.16
KOOS PAIN*	70.1 ± 7.7	67.6 ± 8.6	0.31
KOOS SYMPTOMS*	66.1 ± 11.7	64.3 ± 7.2	0.52
KOOS ADL*	68.4 ± 9.5	63.1 ± 7.8	**0.04**
KOOS SPORT/RECREATIONAL ACTIVITIES*	29.5 ± 11.1	27.5 ± 7.9	0.46
KOOS QOL*	54.4 ± 12.9	46.9 ± 8.6	**0.02**

* *mean ± standard deviation*

KSS: Knee Society Score, VAS: Visual Analogue Scale, KOOS: Knee injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Life, QOL: Quality of Life

Radiographic evaluation

No cases of aseptic loosening (AL) were detected in group A while two AL (8.3%), one on the femoral side and one on the tibial side, were observed in group B (p = 0.23). Radiographs analysis showed 24 implants in neutral position (92.3%) and two slight valgus alignment (7.7%) for group A without functional limitation. Group B reported 21 neutral (87.5%),

three slight valgus alignments (12.5%) with no significant differences between groups (p = 0.66).

Until now, the authors reported three patients with non-progressive (11.5%) radiolucent lines of less than 1 mm, on the tibial side (1 in zone 1 on the LL view, 2 in zone 1 on AP view). Five non progressive radiolucencies (20.8%) were noted in group B (3 in zone 1 on AP view, 1 in zone 4 on AP view on the tibial side and 1 in zone 1 on LL view on the femoral side) with no relevant differences between groups (p = 0.46). One case of femoral cortical hypertrophy (4.2%) was registered in group B (p = 0.48). For all the included radiological parameters, very good (≥ 90%) Cohen's kappa inter-rater agreement was found.

Complications

No intraoperative complications were reported in both groups. For staged revisions, no relevant complications were noted during inter-stage interval.

In the standard rTKA group, three patients (11.5%) had postoperative complications: one positive culture from spacer sonication, one postoperative quadriceps tendon rupture at three months form the indexed operation and one septic recurrence.

Nine (37.5%) patients reported complications after the indexed operation in group B including septic recurrence (n = 3), positive culture from intraoperative samples (n = 1), persistent wound drainage (n = 1), AL (1 on the femoral and one on the tibial side, n = 2), fracture below the tibial stem (n = 1) and stiffness (n = 1). Globally, eight patients (33.3%) underwent reoperation in group B and six (25.0%) was re-revised. Statistically significant difference was obtained for global complication rate (11.5% vs 37.5%, p = 0.04), reoperation (7.7% vs 33.3%, p = p = 0.03) and re-revision rate (3.8% vs 25%, p = p = 0.04) between groups. Table 5 summarizes complications reoperations a re-revision and their reasons.

Discussion

Although RTKA is generally considered a complex procedure, the specific subgroup of procedure described in this article as complex rTKA has been hypothesized to require greater surgical effort and to encompass greater intraoperative and postoperative risks.

The comparison of two small groups of patients (standard vs complex cases) demonstrates that rTKA should be divided in two categories with different surgical requirements (expressed as greater intraoperative blood loss, intra and postoperative blood transfusion units and surgical time), different objective clinical outcomes and postoperative complication (in terms of overall complication rate, reoperation, and re-revisions).

From the technical point of view, the complexity during the exposure time, the management of soft tissues and wide bone loss when required and the complexity in finding the proper biomechanical stability are key factors that increase the difficulty of the specific case (Fig. 2).

The authors found a statistically significant difference in postoperative KSS between groups (higher in standard revision patients). Interestingly, no relevant differences in postoperative PROMs (except for minimal differences in KOOS ADL and QOL) were detected between groups. We hypothesize that, despite the objective worse outcomes obtained in complex revision cases, such patients outcome fits the preoperative expectations, rating their results as satisfactory compared to preoperative clinical status.

Complication, reoperation, and revision rates were significantly higher in complex revision group. This data agrees with the most recent evidence.

In subgrouping the included patients, greater weight was given to features known to adversely affect outcomes. The literature underline poor outcomes and higher complication rate in particular knee revision situations (infection, stiffness, wide

Table 5 Complications, reoperation, and re-revision with details of complications

	Standard, group A (26 pts)	Complex, group B (24 pts)	*P* value
Complications *	3 (11.5%)	9 (37.5%)	**0.04**
Reoperation *	2 (7.7%)	8 (33.3%)	**0.03**
Re-revision *	1 (3.8%)	6 (25.0%)	**0.04**
Detail of complication **	Infection recurrence (1)	Infection recurrence (3)	/
	Postoperative quadriceps tendon rupture (1)	Positive culture at reimplantation (1)	
	Positive culture at reimplantation (1)	Aseptic loosening (femoral component) (1)	
		Aseptic loosening (tibial component) (1)	
		Persistent wound discharge (1)	
		Stiffness (1)	
		Postoperative tibial fracture (1)	

* *Number of patients + percentage*

** *Type + number of patients*

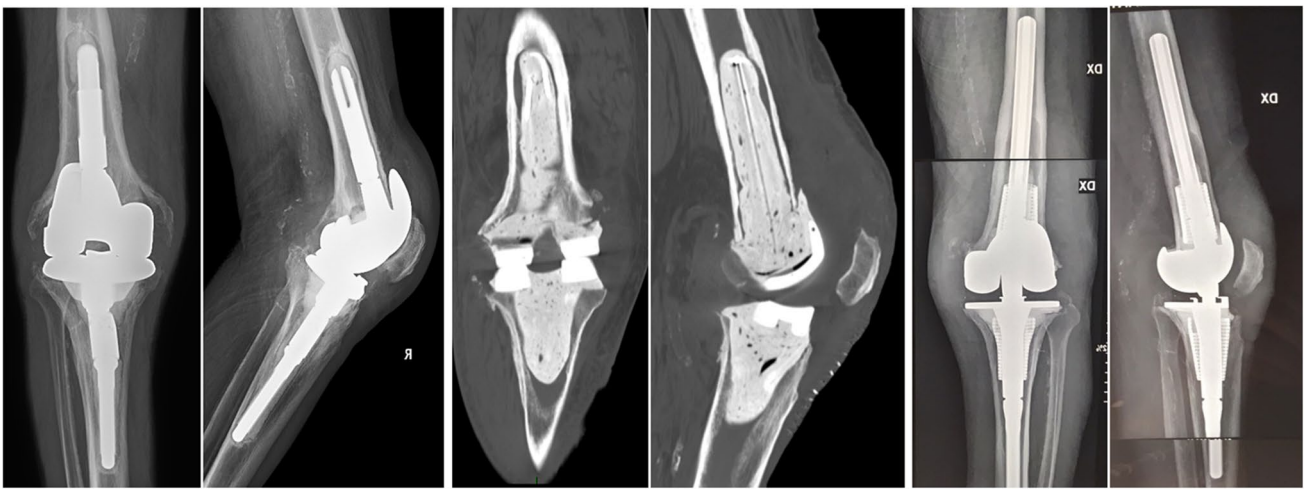

Fig. 2 Complex knee revision case (multiple rTKA, periprosthetic joint infection, massive bone defects)

bone loss and soft tissue damage) [13–15]. In their arthroplasty register-based study, Belt et al. [16] showed that poorest outcomes were found for rTKA for infection: over one out of four infection rTKAs required another surgical intervention, mostly due to infection relapse. Baek et al. [14] compared 36 septic loosening and 42 aseptic loosening TKA demonstrating that rTKA in patients with septic loosening had worse functional outcomes and higher mortality over a minimum ten year follow-up period compared to patients with aseptic loosening.

A stiff knee is commonly considered a difficult scenario in rTKA [17]. The timing of treatment and the identification of the underlying problem is a key factor for a correct management [9]. Although better postoperative results may be obtained in stiff TKAs, stiffness is globally considered to adversely affect final rTKA results [18].

Wide bone defects management is a key point to obtain a stable and sound prosthetic fixation. Massive bone loss as well as multiple revisions are commonly linked with failure in rTKA. Russo et al. [15] retrospectively observed 108 two-stage rTKA and concluded that difficult-to-treat pathogens, the number of previous surgeries, and the level of tibial bone defect were independent risk factors of two-stage knee revision failure.

Recently, a revision knee complexity classification (RKCC) has been proposed by Philips et al. [19]. This classification is based on the get it right first-time (GIRFT) report [20] and grades rTKA in three levels of increasing complexity focusing on factors that significantly adversely affect outcomes in rTKA: patient comorbidities, infection, extensor mechanism or soft-tissue compromise. RKCC divides rTKA in R1 (less complex revision surgery), R2 (complex revision surgery) and R3 (most complex and salvage cases). The purpose is to classify the level of expertise needed to manage each case and to provides a methodological assessment of revision knee cases and support regional clinical networking for rTKA. In particular, the authors propose to manage R1 surgeries in common arthroplasty units while R2 or R3 surgeries should be performed at a specialist revision centre or regional tertiary care units. There is some evidence to suggest that higher-volume units may achieve better outcomes following surgery [21, 22]. We completely agree with authors that complex rTKA cases should be managed in high-volume centres. To achieve this goal, a clear and friendly classification is necessary to grade the surgery pre-operatively and to set an adequate network for proper management of rTKA patients.

Despite RKCC is well-structured and validated for expert and non-expert surgeons, it is the authors belief that a simpler and easier to-use classification could provide a quicker tool for rTKA screening even for non-arthroplasty surgeons. The proposed classification is mainly based on the cumulative risk of complexity according to factors that significantly adversely affect outcomes in rTKA and could be considered as a guideline. Despite this consideration, every rTKA should be carefully prepared and planned as no classification could predict sudden intra or post-operative complications.

The main strength of this study is to have described a specific entity of rTKA, a distinct type of clinical scenarios that require higher surgical effort than standard rTKA and to have (despite the small numbers available) provided a proof of the increased surgical challenge (measured as increased surgical time, need of transfusions and complications).

Undoubtedly, this study has several limitations. Sixteen of the 70 eligible patients were excluded from the study group for missing clinical or radiological data or for follow-up drop-out. This could have caused selection bias. The criteria to classify cases as standard or complex rTKA were chosen by discussion and agreement among the research team, mainly based on literature data and on the experience of the authors.

Moreover, the observational structure of the study, the short follow-up period, a relatively low number of patients and the missing of host-related factors are strong limitations but considering low prevalence of such surgical setting, the reported data can provide a new perspective in complex rTKA.

Conclusions

This study describes a specific entity of rTKA, a distinct type of clinical scenarios that require higher surgical effort than standard rTKA and provides a proof of the increased surgical challenge (measured as increased surgical time, need of transfusions and complications). The proposed classification could provide an easy-to-use tool for quick grading of complexity in rTKA patients even for non-arthroplasty surgeons.

Data Availability The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations The authors did not receive support from any organization for the submitted work.

Informed consent Informed consent was obtained from all individual participants included in the study. The authors affirm that human research participants provided informed consent for publication of the images in Figs. 2.

All procedures were conducted according to Declaration of Helsinki.

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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