Stratification of Standardized TKA Complications and Adverse Events: A Brief Communication

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Abstract

Background The Total Knee Arthroplasty (TKA) Complications Workgroup of the Knee Society developed a standardized list and definitions of complications associated with TKA. Twenty-two complications and adverse events believed important for reporting outcomes of TKA were identified. The Editorial Board of *Clinical Orthopaedics and Related Research*®, the Executive Board of the Knee Society, and the members of the Knee Society TKA Complications Workgroup came to the conclusion that reporting of a list of TKA adverse events and complications would be

more valuable if they were stratified using a validated classification system.

Questions/purposes The purpose of this article was to stratify the previously published standardized list of TKA adverse events and complications.

Methods A modified version of the Sink adaptation of the Clavien-Dindo Surgical Complication Classification was applied to the list of standardized TKA complications and adverse events.

Results The proposed stratified classifications of TKA complications were reviewed and endorsed by the Knee Society.

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Table 1. Standardized TKA complications and adverse events

Complication/adverse event	ICD-9 code	Definition
1. Bleeding	998.11	Postoperative bleeding requiring surgical treatment
2. Wound complication	998.32	Failure of wound healing requiring reoperation or a change in TKA protocol
3. Thromboembolic disease	453.40	Symptomatic thromboembolic event requiring more intensive, nonprophylactic anticoagulant or antithrombotic treatment during the first 3 months after index TKA
4. Neural deficit	997.09	Postoperative neural deficit (sensory or motor) related to the index TKA
5. Vascular injury	997.20	Intraoperative vascular injury requiring surgical repair, bypass grafting, or stenting (compartment syndrome or amputation should be reported)
6. Medial collateral ligament injury	844.10	Intraoperative or early postoperative medial collateral ligament injury requiring repair, reconstruction, a change in prosthetic constraint, revision surgery, or TKA protocol
7. Instability	996.42	Symptomatic instability reported by the patient and confirmed by laxity on physical examination as defined by The Knee Society Knee Score
8. Malalignment		Symptomatic malalignment reported by the patient and confirmed radiographically with angular deformity in the coronal plane greater than 10° from the mechanical axis
9. Stiffness	719.56	Limited ROM as reported by the patient and demonstrated in a physical examination with extension limited to 15° short of full extension or flexion less than 90° (not applicable if preoperative arc of motion less than 75°)
10. Deep periprosthetic joint infection	996.66	A deep periprosthetic joint infection can be diagnosed when there is a sinus tract communicating with the prosthesis; or a pathogen is isolated by culture from at least two separate tissue or fluid samples obtained from the affected prosthetic joint; or 4 of the following 6 criteria exist: elevated ESR and serum CRP concentration; elevated synovial WBC count; elevated synovial PMN; presence of purulence in the affected joint; isolation of a microorganism in one culture of periprosthetic tissue or fluid; or > 5 neutrophils/high-power field in 5 high-power fields observed from histologic analysis of periprosthetic tissue at × 400 magnification [17]
11. Periprosthetic fracture	996.44	Periprosthetic fracture of the distal femur, proximal tibia, or patella (operative or nonoperative treatment should be recorded)
12. Extensor mechanism disruption	729.65 727.66	Disruption of the extensor mechanism (surgical repair and/or extensor lag should be recorded)
13. Patellofemoral dislocation	996.42	Dislocation of the patella from the femoral trochlea (direction of instability should be recorded)
14. Tibiofemoral dislocation	996.42	Dislocation of the tibiofemoral joint (direction of instability should be recorded)
15. Bearing surface wear	996.46	Wear of the bearing surface which is symptomatic or requires reoperation
16. Osteolysis	996.45	Expansile lytic lesion adjacent to one of the implants $\geq$ 1 cm in any one dimension or increasing in size on serial radiographs/CTs
17. Implant loosening	996.41	Implant loosening confirmed intraoperatively or identified radiographically as a change in implant position or a progressive, radiolucent line at the bone-cement or bone-implant interface
18. Implant fracture or tibial insert dissociation	996.43	Implant fracture or dissociation of the tibial insert from the tibial implant
19. Reoperation		Return to the operating room related to the index TKA (reasons for reoperation should be recorded)
20. Revision		Revision of one or more of the TKA implants (femur, tibia, tibial insert, patella)
21. Readmission		Admission to the hospital for any reason during the first 90 days after TKA (reasons for admission and relation to index TKA should be recorded)
22. Death		Death occurring for any reason during the first 90 days after TKA not related to other listed complications (cause of death and relation to index TKA should be recorded)

* All of the proposed TKA complications and adverse events and their definitions were endorsed by the members of the Knee Society ($p < 0.001$); ICD-9 = International Classification of Diseases, 9th Revision; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; WBC = white blood cell; PMN = neutrophil percentage.

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Conclusions Stratification of TKA complications will allow more in-depth and detailed outcome reporting for surgeons, hospitals, third-party payers, government

agencies, joint replacement registries, and orthopaedic researchers. This improvement in reporting of TKA complications will also improve the quality of orthopaedic literature.

Introduction

Despite the importance of complications and adverse events in evaluating patient outcomes, definitions of complications have not been standardized in most surgical subspecialties. Recently, 22 complications and adverse events believed to be important for reporting outcomes of TKA were identified and defined (Table 1) [8]. Acceptance and use of these standardized TKA complications will improve collection and evaluation of TKA complications, which should improve investigations of patient outcome after TKA.

In the general surgery literature, complications from surgical procedures are classified and stratified with the Clavien-Dindo classification [2]. The original classification system proposed by Clavien et al. [3] in 1992 includes four stages of severity, which were developed through an evaluation of 650 cholecystectomy operations. In 2004, Dindo et al. [6] proposed a modification of the Clavien system that included a five-grade classification system with the possibility of combining grades. The so-called “Clavien-Dindo” classification has been adapted for use in general surgery, gastroenterology/hepatology [1, 5, 8, 11–14, 17], and urology/nephrology [4, 9, 10, 16]. In orthopaedic surgery, Sink et al. [15] applied an adapted five-grade Clavien-Dindo system to hip preservation surgery (Table 2).

The classification system proposed by Sink et al. shows high interobserver and intraobserver reliabilities for grading of surgical complications when applied to hip preservation surgery.

When a standardized list and definitions of complications and adverse events was published [8], the Editorial Board of *Clinical Orthopaedics and Related Research*® suggested that stratification of the TKA complications and adverse events would be more valuable if it was stratified for severity. The purpose of this article is to stratify the previously published TKA complications using a modification of the Sink classification adapted for TKA.

Materials and Methods

A modification was done of the Sink adaptation of the Clavien-Dindo Surgical Complication Classification System to the previously published Knee Society list of complications and adverse events (Table 1) [7, 15]. The Sink Classification System was modified to present a stratification of complications, which are consistent and applicable to TKA (Table 2). Grades 1, 2, and 5 of the Sink modification were adopted verbatim. Grade 3 was changed to read: “A complication that is treatable but requires surgical, arthroscopic, or radiographic interventions, closed manipulation of the knee under anesthesia, or an unplanned hospital admission or prolonged index admission.” Grade 4 was changed to read: “A complication that is life threatening, requires ICU admission, or is not treatable with potential for permanent disability; a complication that requires resection arthroplasty, arthrodesis, or amputation.”

Table 2. Modification of the Sink adaptation of the Clavien-Dindo surgical complication classification system for TKA complications

Grade	Original definition as per Sink et al. [15]	Modified definition for TKA complications
I	A complication that requires no treatment and has no clinical relevance; there is no deviation from routine followup during the postoperative period; allowed therapeutic regimens include: antiemetics, antipyretics, analgesics, diuretics, electrolytes, antibiotics, and physiotherapy	No change
II	A deviation from the normal postoperative course (including unplanned clinic visits) that requires outpatient treatment: either pharmacologic or close monitoring as an outpatient	No change
III	A complication that is treatable but requires surgical, endoscopic, or radiographic interventions or an unplanned hospital admission	A complication that is treatable but requires surgical, arthroscopic, or radiographic interventions, closed manipulation of the knee under anesthesia, or an unplanned hospital admission or prolonged index admission
IV	A complication that is life = threatening, requires ICU admission, or is not treatable with potential for permanent disability; a complication that requires organ resection (THA)	A complication that is life-threatening, requires ICU admission, or is not treatable with potential for permanent disability; a complication that requires resection arthroplasty, arthrodesis, or amputation
V	Death	No change

ICU = intensive care unit.

Table 3. Definitions and stratification of TKA complications

Number	Complication	Definition	Stratification
1	Bleeding	Postoperative bleeding requiring surgical treatment	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3, 4, 5 depending on severity of symptoms and treatment
2	Wound Complication	Failure of wound healing requiring reoperation or a change in TKA protocol	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment or admission Grade 4, 5 if complications arise from treatment
3	Thromboembolic disease	Symptomatic thromboembolic event requiring more intensive nonpharmacologic anticoagulant or antithrombotic treatment during the first 3 months after TKA	Grade 1 not applicable* Grade 2 prolonged anticoagulation Grade 3 operative treatment or procedural intervention Grade 4, 5 if complications arise from treatment
4	Neural deficit	Postoperative neural deficit (sensory or motor) related to the index TKA	Grade 1, not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4 if permanent deficit [†] Grade 5 if complications arise from treatment [†]
5	Vascular injury	Intraoperative vascular injury requiring surgical repair, bypass grafting or stenting (compartment syndrome or amputation should be reported)	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment or procedural intervention Grade 4, 5 if complications arise from treatment
6	Medial collateral ligament injury	Intraoperative or early postoperative medial collateral ligament injury requiring repair, reconstruction, a change in prosthetic constraint, revision surgery, or TKA protocol	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
7	Instability	Symptomatic instability reported by the patient and confirmed by laxity on physical examination as defined by The Knee Society Knee Score	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
8	Malalignment	Symptomatic malalignment reported by the patient and confirmed radiographically with angular deformity in the coronal plane greater than 10° from the mechanical axis	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
9	Stiffness	Limited ROM as reported by the patient and demonstrated in a physical examination with extension limited to 15° short of full extension or flexion less than 90° (not applicable if preoperative arc of motion less than 75°)	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]

Table 3. continued

Number	Complication	Definition	Stratification
10	Deep periprosthetic joint infection	A deep periprosthetic joint infection can be diagnosed when there is a sinus tract communicating with the prosthesis; or a pathogen is isolated by culture from at least two separate tissue or fluid samples obtained from the affected prosthetic joint; or 4 of the following 6 criteria exist: elevated ESR and serum CRP concentration; elevated synovial WBC count; elevated synovial PMN; presence of purulence in the affected joint; isolation of a microorganism in one culture of periprosthetic tissue or fluid; or > 5 neutrophils/high-power field in 5 high-power fields observed from histologic analysis of periprosthetic tissue at $\times 400$ magnification	Grade 1, 2 not applicable Grade 3 if treated successfully Grade 4 if resection arthroplasty or disability occurs Grade 5 if complications arise from treatment [†]
11	Periprosthetic fracture	Periprosthetic fracture of the distal femur, proximal tibia, or patella (operative or nonoperative treatment should be recorded)	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†] Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
12	Extensor mechanism disruption	Disruption of the extensor mechanism (surgical repair and/or extensor lag should be recorded)	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†] Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
13	Patellofemoral dislocation	Dislocation of the patella from the femoral trochlea (direction of instability should be recorded)	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†] Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
14	Tibiofemoral dislocation	Dislocation of the tibiofemoral joint (direction of instability should be recorded)	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†] Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
15	Bearing surface wear	Wear of the bearing surface which is symptomatic or requires reoperation	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†] Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
16	Osteolysis	Expansile lytic lesion adjacent to one of the implants ≥ 1 cm in any one dimension or increasing in size on serial radiographs/CTs	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†] Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]

Table 3. continued

Number	Complication	Definition	Stratification
17	Implant loosening	Implant loosening confirmed intraoperatively or identified radiographically as a change in implant position or a progressive, radiolucent line at the bone-cement or bone-implant interface	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
18	Implant fracture or tibial insert dissociation	Implant fracture or dissociation of tibial plastic from the tibial implant	Grade 1 not applicable* Grade 2 nonoperative treatment Grade 3 operative treatment Grade 4, 5 if complications arise from treatment [†]
19	Reoperation	Return to the operating room related to the index TKA (reasons for reoperation should be recorded)	Grade 1, 2 not applicable Grade 3 operative treatment Grade 4, 5 if complications arise from treatment
20	Revision	Revision of one or more of the TKA implants (femur, tibia, tibial insert, patella)	Grade 1, 2 not applicable Grade 3 operative treatment Grade 4, 5 if complications arise from treatment
21	Readmission	Admission to the hospital for any reason during the first 90 days after TKA (reasons for admission and relation to index TKA should be recorded)	Grade 1, 2 not applicable Grade 3 operative treatment Grade 4, 5 if complications arise from treatment
22	Death	Death occurring for any reason during the first 90 days after TKA not related to other listed complications (cause of death and relation to index TKA should be recorded)	Grade 4, 5 if complications arise from treatment Grade 1, 2, 3, 4 not applicable Grade 5 death

* Does not meet the definition of a complication or adverse event; [†] if complication occurs as a result of the complication or adverse event, then Grades 4 or 5 apply, if complication or adverse event occurs as a result of reoperation, then 19 (reoperation) is applied as the causative complication; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; WBC = white blood cell count; PMN = neutrophil percentage.

Table 4. Stratification of the Knee Society TKA complications and adverse events

1.	Bleeding: Postoperative bleeding requiring surgical treatment
	Bleeding Grade 1: bleeding that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication)
	Bleeding Grade 2: bleeding that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol
	Bleeding Grade 3: anemia or active bleeding that requires surgical or interventional radiology invasive intervention or unplanned admission or prolonged index admission
	Bleeding Grade 4: blood loss resulting in anemia, which leads to ICU admission or permanent disability
	Bleeding Grade 5: blood loss resulting in death
2.	Wound Complication: failure of wound healing requiring reoperation or a change in TKA protocol
	Wound Complication Grade 1: wound complication that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Wound Complication Grade 2: wound complication that requires outpatient followup or minor débridement in an outpatient setting, antibiotic treatment is included
	Wound Complication Grade 3: wound complication that requires surgical or interventional radiology invasive intervention or unplanned admission or prolonged index admission
	Wound Complication Grade 4: wound complication that results in ICU admission or permanent disability
	Wound Complication Grade 5: wound complication or intervention for wound complication that results in death
3.	Thromboembolic Disease: symptomatic thromboembolic event requiring more intensive nonprophylactic anticoagulant or antithrombotic treatment during the first 3 months after TKA
	Thromboembolic Disease Grade 1: thromboembolic disease that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Thromboembolic Disease Grade 2: deep venous thrombosis or pulmonary embolism that requires additional aggressive anticoagulation and a deviation from the postoperative prophylactic protocol
	Thromboembolic Disease Grade 3: deep venous thrombosis or pulmonary embolism that requires surgical or interventional radiology invasive intervention or unplanned admission or prolonged index admission
	Thromboembolic Disease Grade 4: deep venous thrombosis or pulmonary embolism that requires ICU admission or results in permanent disability
	Thromboembolic Disease Grade 5: deep venous thrombosis or pulmonary embolism or intervention for deep venous thrombosis or pulmonary embolism that results in death
4.	Neural Deficit: postoperative neural deficit (sensory or motor) related to the index TKA
	Neural Deficit Grade 1: Neural deficit that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Neural Deficit Grade 2: neural deficit that requires additional nonoperative treatment (orthosis or bracing), which is a deviation from the postoperative protocol
	Neural Deficit Grade 3: neural deficit that requires surgical or interventional radiology intervention or unplanned admission or prolonged index admission
	Neural Deficit Grade 4: neural deficit that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
	Neural Deficit Grade 5: neural deficit or intervention for neural deficit, which results in death
5.	Vascular Injury: intraoperative vascular injury requiring surgical repair, bypass grafting, or stenting (compartment syndrome or amputation should be reported)
	Vascular Injury Grade 1: vascular injury which does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Vascular Injury Grade 2: vascular injury that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol
	Vascular Injury Grade 3: Vascular injury that requires surgical or interventional radiology intervention or unplanned admission or prolonged index admission
	Vascular Injury Grade 4: vascular injury that requires ICU admission or results in permanent disability
	Vascular Injury Grade 5: vascular injury or intervention for vascular injury that results in death

Table 4. continued

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6. Medial Collateral Ligament Injury: intraoperative or early postoperative medial collateral ligament injury requiring repair, reconstruction, a change in prosthetic constraint, revision surgery, or TKA protocol

Medial Collateral Ligament Injury Grade 1: medial collateral ligament injury that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)

Medial Collateral Ligament Injury Grade 2: medial collateral ligament injury that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, a change in weightbearing status, an intraoperative change in implant constraint or design)

Medial Collateral Ligament Injury Grade 3: medial collateral ligament injury that requires surgical intervention or unplanned admission or prolonged index admission

Medial Collateral Ligament Injury Grade 4: medial collateral ligament injury that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])

Medial Collateral Ligament Injury Grade 5: medial collateral ligament injury or intervention for medial collateral ligament injury, which results in death (if this is the result of a reoperation, see 19 [reoperation])
 7. Instability: symptomatic instability reported by the patient and confirmed by laxity on physical examination as defined by The Knee Society Knee Score

Instability Grade 1: instability that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)

Instability Grade 2: instability that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol

Instability Grade 3: instability that requires surgical intervention or unplanned admission or prolonged index admission

Instability Grade 4: instability which requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])

Instability Grade 5: instability or intervention for instability that results in death (if this is the result of a reoperation, see 19 [reoperation])
 8. Malalignment: symptomatic malalignment reported by the patient and confirmed radiographically with angular deformity in the coronal plane greater than 10° from the mechanical axis

Malalignment Grade 1: malalignment that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)

Malalignment Grade 2: malalignment that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol

Malalignment Grade 3: malalignment that requires surgical intervention or unplanned admission or prolonged index admission

Malalignment Grade 4: malalignment that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])

Malalignment Grade 5: malalignment or intervention for malalignment, which results in death (if this is the result of a reoperation, see 19 [reoperation])
 9. Stiffness: limited ROM as reported by the patient and demonstrated in a physical examination with extension limited to 15° short of full extension or flexion less than 90° (not applicable if preoperative arc of motion less than 75°)

Stiffness Grade 1: stiffness that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)

Stiffness Grade 2: stiffness that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, a change in weightbearing status, an intraoperative change in implant constraint or design)

Stiffness Grade 3: stiffness that requires surgical intervention or unplanned admission or prolonged index admission

Stiffness Grade 4: stiffness that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])

Stiffness Grade 5: stiffness or an intervention for stiffness that results in death (if this is the result of a reoperation, see 19 [reoperation])
 10. Deep Periprosthetic Joint Infection: a deep periprosthetic joint infection can be diagnosed when there is a sinus tract communicating with the prosthesis; or a pathogen is isolated by culture from at least two separate tissue or fluid samples obtained from the affected prosthetic joint; or 4 of the following 6 criteria exist: elevated ESR and serum CRP concentration; elevated synovial WBC count; elevated synovial PMN; presence of purulence in the affected joint; isolation of a microorganism in one culture of periprosthetic tissue or fluid; or > 5 neutrophils/high-power field in 5 high-power fields observed from histologic analysis of periprosthetic tissue at × 400 magnification [17]

Deep Periprosthetic Joint Infection Grade 1: not applicable

Deep Periprosthetic Joint Infection Grade 2: deep periprosthetic joint infection, which requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol

Deep Periprosthetic Joint Infection Grade 3: deep periprosthetic joint infection, which requires surgical intervention or unplanned admission or prolonged index admission
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Table 4. continued

	Deep Periprosthetic Joint Infection Grade 4: deep periprosthetic joint infection, which requires ICU admission or results in permanent disability
	Deep Periprosthetic Joint Infection Grade 5: deep periprosthetic joint infection or an intervention for deep periprosthetic joint infection, which results in death
11.	Periprosthetic Fracture: periprosthetic fracture of the distal femur, proximal tibia, or patella (operative or nonoperative treatment should be recorded)
	Periprosthetic Fracture Grade 1: periprosthetic fracture that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Periprosthetic Fracture Grade 2: periprosthetic fracture that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status, an intraoperative change in implant constraint or design)
	Periprosthetic Fracture Grade 3: periprosthetic fracture that requires surgical intervention or unplanned admission or prolonged index admission
	Periprosthetic Fracture Grade 4: periprosthetic fracture which requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
	Periprosthetic Fracture Grade 5: periprosthetic fracture or an intervention for periprosthetic fracture, which results in death (if this is the result of a reoperation, see 19 [reoperation])
12.	Extensor Mechanism Disruption: disruption of the extensor mechanism (surgical repair and/or extensor lag should be recorded)
	Extensor Mechanism Disruption Grade 1: extensor mechanism disruption that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Extensor Mechanism Disruption Grade 2: extensor mechanism disruption that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status, an intraoperative change in implant constraint or design)
	Extensor Mechanism Disruption Grade 3: extensor mechanism disruption that requires surgical intervention or unplanned admission or prolonged index admission.
	Extensor Mechanism Disruption Grade 4: extensor mechanism disruption that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
	Extensor Mechanism Disruption Grade 5: extensor mechanism disruption or an intervention for extensor mechanism interruption, which results in death (if this is the result of a reoperation, see 19 [reoperation])
13.	Patellofemoral Dislocation: dislocation of the patella from the femoral trochlea (direction of instability should be recorded)
	Patellofemoral Dislocation Grade 1: patellofemoral dislocation that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Patellofemoral Dislocation Grade 2: patellofemoral dislocation that requires additional non-operative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status, an intraoperative change in implant constraint or design)
	Patellofemoral Dislocation Grade 3: patellofemoral dislocation that requires surgical intervention or unplanned admission or prolonged index admission.
	Patellofemoral Dislocation Grade 4: patellofemoral dislocation that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
	Patellofemoral Dislocation Grade 5: patellofemoral dislocation or an intervention for patellofemoral dislocation, which results in death (if this is the result of a reoperation, see 19 [reoperation])
14.	Tibiofemoral Dislocation: Dislocation of the tibiofemoral joint (direction of instability should be recorded)
	Tibiofemoral Dislocation Grade 1: tibiofemoral dislocation that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
	Tibiofemoral Dislocation Grade 2: tibiofemoral dislocation that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status, an intraoperative change in implant constraint or design)
	Tibiofemoral Dislocation Grade 3: tibiofemoral dislocation that requires surgical intervention or unplanned admission or prolonged index admission
	Tibiofemoral Dislocation Grade 4: tibiofemoral dislocation that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
	Tibiofemoral Dislocation Grade 5: tibiofemoral dislocation or an intervention for tibiofemoral dislocation, which results in death (if this is the result of a reoperation, see 19 [reoperation])

Table 4. continued

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15. **Bearing Surface Wear:** wear of the bearing surface, which is symptomatic or requires reoperation
 - Bearing Surface Wear Grade 1: bearing surface wear that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
 - Bearing Surface Wear Grade 2: bearing surface wear that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status or activity level)
 - Bearing Surface Wear Grade 3: bearing surface wear that requires surgical intervention or unplanned admission or prolonged index admission.
 - Bearing Surface Wear Grade 4: bearing surface wear which requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
 - Bearing Surface Wear Stage 5: bearing surface wear or an intervention for bearing surface wear, which results in death (if this is the result of a reoperation, see 19 [reoperation])
 16. **Osteolysis:** expansile lytic lesion adjacent to one of the implants ≥ 1 cm in any one dimension or increasing in size on serial radiographs/CTs
 - Osteolysis Grade 1: osteolysis that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
 - Osteolysis Grade 2: osteolysis that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status or activity level)
 - Osteolysis Grade 3: osteolysis that requires surgical intervention or unplanned admission or prolonged index admission
 - Osteolysis Grade 4: osteolysis that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
 - Osteolysis Grade 5: osteolysis or an intervention for osteolysis that results in death (if this is the result of a reoperation, see 19 [reoperation])
 17. **Implant Loosening:** implant loosening confirmed intraoperatively or identified radiographically as a change in implant position or a progressive, radiolucent line at the bone-cement or bone-implant interface
 - Implant Loosening Grade 1: implant loosening that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
 - Implant Loosening Grade 2: implant loosening that requires additional nonoperative treatment, which is a deviation from the operative or postoperative protocol (ie, bracing, casting, a change in weightbearing status or activity level)
 - Implant Loosening Grade 3: implant loosening that requires surgical intervention or unplanned admission or prolonged index admission
 - Implant Loosening Grade 4: implant loosening that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
 - Implant Loosening Grade 5: implant loosening or an intervention for implant loosening that results in death (if this is the result of a reoperation, see 19 [reoperation])
 18. **Implant Fracture or Tibial Insert Dissociation:** implant fracture or dissociation of tibial plastic from the tibial implant
 - Implant Fracture or Tibial Insert Dissociation Grade 1: implant fracture or tibial insert dissociation that does not require additional intervention or a deviation from the operative or postoperative protocol (does not rise to the level of a complication or adverse event)
 - Implant Fracture or Tibial Insert Dissociation Grade 2: implant fracture or tibial insert dissociation that requires additional nonoperative treatment (orthosis or bracing), which is a deviation from the postoperative protocol
 - Implant Fracture or Tibial Insert Dissociation Grade 3: implant fracture or tibial insert dissociation that requires surgical intervention or unplanned admission or prolonged index admission
 - Implant Fracture or Tibial Insert Dissociation Grade 4: implant fracture or tibial insert dissociation that requires ICU admission or results in permanent disability (if this is the result of a reoperation, see 19 [reoperation])
 - Implant Fracture or Tibial Insert Dissociation Grade 5: implant fracture or tibial insert dissociation or an intervention for implant fracture or tibial insert dissociation, which results in death (if this is the result of a reoperation, see 19 [reoperation])
 19. **Reoperation:** return to the operating room related to the index TKA (reasons for reoperation should be recorded)
 - Reoperation Grade 1: not applicable
 - Reoperation Grade 2: not applicable
 - Reoperation Grade 3: reoperation that requires surgical intervention or unplanned admission or prolonged index admission
 - Reoperation Grade 4: reoperation that requires ICU admission or results in permanent disability
 - Reoperation Grade 5: reoperation that results in death
 20. **Revision:** revision of one or more of the TKA implants (femur, tibia, tibial insert, patella)
 - Revision Grade 1: not applicable
 - Revision Grade 2: not applicable
 - Revision Grade 3: revision that requires surgical intervention or unplanned admission or prolonged index admission
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Table 4. continued

	Revision Grade 4: revision that requires ICU admission or results in permanent disability
	Revision Grade 5: revision that results in death
21.	Readmission: admission to the hospital for any reason during the first 90 days after TKA (reasons for admission and relation to index TKA should be recorded)
	Readmission Grade 1: not applicable
	Readmission Grade 2: not applicable
	Readmission Grade 3: readmission that requires surgical intervention or additional nonoperative treatment, which is a deviation from the postoperative protocol
	Readmission Grade 4: readmission that requires ICU admission or results in permanent disability
	Readmission Grade 5: readmission or an intervention during readmission, which results in death
22.	Death: death occurring for any reason during the first 90 days after TKA not related to other listed complications (cause of death and relation to index TKA should be recorded)
	Death Grade 1: not applicable
	Death Grade 2: not applicable
	Death Grade 3: not applicable
	Death Grade 4: not applicable
	Death Grade 5: death resulting from a cause unrelated to complications/adverse events 1–21

ICU = intensive care unit; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; WBC = white blood cell; PMN = neutrophil percentage.

Results

The modified classification system was applied to each of the 22 complications and adverse events (Table 2). Based on the definition of TKA complications, all grades of the modified classification system were not relevant to each TKA complication. If a stage did not rise to the level of the definition of the TKA complication, that stage was not included (Tables 3, 4). If a grade was not applicable, that grade was not included (Tables 3, 4; Grades 1 and 2 of 19 [reoperations], 20 [revision], 21 [readmission], and Grades 1–4 of 22 [death]). Death for reasons other than those that can be placed within complication or adverse events 1 to 21 would be categorized as 22 (death). For example, a death resulting from myocardial infarction without subsequent reoperation would be 22 (death, Stage 5). A death resulting from pulmonary embolism would be 3 (thromboembolic disease, Stage 5). Deaths and complications which are the result of reoperations are categorized under 19 (reoperation). Tables 3 and 4, which apply the five grade stratification schemes for TKA complications and adverse events, are presented in an abbreviated form (Table 3) for the published paper version and in a more detailed, lengthier version (Table 4) for the online, digital version of publication. The proposed stratified classifications of TKA complications was reviewed and endorsed by the Knee Society.

Discussion

To enhance the use and significance of the standardized TKA complications and adverse events published by the

Knee Society [7], we have adapted a classification scheme presented by Sink et al. [15] to stratify TKA complications and adverse events. The stratification of complications will allow more detailed outcome reporting of patient outcomes for knee surgeons, hospitals, third-party payers, government agencies, joint replacement registries, and orthopaedic researchers.

This improvement in reporting TKA complications will also improve the quality of orthopaedic literature.

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