

The revision partial knee classification system: understanding the causative pathology and magnitude of further surgery following partial knee arthroplasty



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Aims

Joint registries classify all further arthroplasty procedures to a knee with an existing partial arthroplasty as revision surgery, regardless of the actual procedure performed. Relatively minor procedures, including bearing exchanges, are classified in the same way as major operations requiring augments and stems. A new classification system is proposed to acknowledge and describe the detail of these procedures, which has implications for risk, recovery, and health economics.

Methods

Classification categories were proposed by a surgical consensus group, then ranked by patients, according to perceived invasiveness and implications for recovery. In round one, 26 revision cases were classified by the consensus group. Results were tested for inter-rater reliability. In round two, four additional cases were added for clarity. Round three repeated the survey one month later, subject to inter- and intrarater reliability testing. In round four, five additional expert partial knee arthroplasty surgeons were asked to classify the 30 cases according to the proposed revision partial knee classification (RPKC) system.

Results

Four classes were proposed: PR1, where no bone-implant interfaces are affected; PR2, where surgery does not include conversion to total knee arthroplasty, for example, a second partial arthroplasty to a native compartment; PR3, when a standard primary total knee prosthesis is used; and PR4 when revision components are necessary. Round one resulted in 92% inter-rater agreement (Kendall's W 0.97; $p < 0.005$), rising to 93% in round two (Kendall's W 0.98; $p < 0.001$). Round three demonstrated 97% agreement (Kendall's W 0.98; $p < 0.001$), with high intra-rater reliability (interclass correlation coefficient (ICC) 0.99; 95% confidence interval 0.98 to 0.99). Round four resulted in 80% agreement (Kendall's W 0.92; $p < 0.001$).

Conclusion

The RPKC system accounts for all procedures which may be appropriate following partial knee arthroplasty. It has been shown to be reliable, repeatable and pragmatic. The implications for patient care and health economics are discussed.

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Introduction

Partial knee arthroplasty (PKA) is revised more frequently than total knee arthroplasty (TKA), as reflected by joint registries across the world.¹⁻³ The complexity of PKA revision can vary significantly: for example, a patient

undergoing exchange of polyethylene bearing will likely have very different perioperative risks and postoperative rehabilitation regimen compared to a PKA revised to a TKA with a revision implant, stems, and metaphyseal augments.⁴ Progression of arthritis in a

native compartment is one of the most common causes of revision of PKA, usually addressed by removal of the existing PKA components and conversion to TKA.⁵ An alternative is a stepwise ‘compartmental approach’ to further arthrosis through the addition of a PKA to the newly degenerate compartment.⁶ Currently, National Joint Registry (NJR) revision rates for PKA do not differentiate between these different types of revision procedure.

A number of studies have indicated that thresholds for revision may be lower for UKA than for TKA.^{5,7-9} The National Institute for Health and Clinical Excellence (NICE) recently highlighted the disparity in threshold for revision rate between PKA and TKA and the size of the interventions, and suggested that revisions should be separated into major and minor procedures.¹⁰ When judged in terms of safety and cost-effectiveness, PKA dominates, with better health outcomes and reduced lifetime costs compared to TKA.¹¹ PKA is also associated with fewer postoperative complications,¹² higher patient reported satisfaction,¹³ and shorter hospital stays.¹⁴ The cost burden for revision of knee arthroplasty is significant, and correlates with the complexity of the second procedure.^{15,16}

The varying complexity of revision following primary total arthroplasty was recognized in a recently published paper on revision knee complexity classification (RKCC).¹⁷ In this, revisions were subcategorized according to six variables: integrity of the soft-tissue envelope; presence of infection; patient factors; the requirement for augmented implants; metaphyseal reconstruction; and hinged or stemmed implants. The RKCC reduced these to three categories of revision:

- R1 (less complex): revision of primary unicompartmental or TKA, aseptic loosening, simple instability, revision of partial to TKA, or polyethylene exchange.
- R2 (complex): includes knees with significant instability, the need for metaphyseal fixation, and re-revisions or those requiring enhanced exposure techniques.
- R3 (most complex): multiple re-revisions, those requiring a hinge or where salvage, arthrodesis, or amputation may be required.

The causative pathology, variety, and complexity of surgery following PKA do not fit well into this system; many appear more minor than R1, while others are clearly R2. We surmised that a classification system specific to further surgery following PKA would have a use; preoperative decision-making might be improved by detailing the complexity of planned revision of PKA, as the RKCC recommends for revision of TKA.¹⁷ By paying particular attention to the mode of failure of the primary procedure, the underlying pathology and complexity of revision of PKA, our primary aim was to produce a robust and usable

system to classify these further surgical procedures. Our secondary aim was to help appreciate the impact of the different classes of procedure, something which is often not reflected in existing tariffs for revision of a PKA.¹⁸

Methods

This study did not require institutional review board approval. The proposed system was conceived, modified, and tested for reliability according to the stepwise process shown in Figure 1. First, a collaborative consensus group met, consisting of three orthopaedic consultant surgeons (JPC, ADL, GGJ) experienced in primary and revision knee arthroplasty surgery, and two orthopaedic higher speciality trainees (AJG, TCE) with at least five years of arthroplasty experience each. The group was asked to consider all possible modes of failure, including implant wear, loosening, native compartment degeneration, instability, stiffness, and pain, then list all potential revision procedures, categorizing them according to underlying causative pathology, technical complexity, invasiveness of the procedure, and anticipated recovery times. It was agreed that the principles of the classification should be:

- A reproducible, reliable grading system.
- That each grade reflects the magnitude of undertaking for the patient and the technical complexity of the procedure for the surgeon.
- Incorporation of other grading systems: e.g. Anderson Orthopaedic Research Institute (AORI) classification of bone loss¹⁹ and the RKCC system.¹⁷
- To facilitate a discussion regarding the level of expertise required to manage each case.

Accordingly, the consensus group resolved upon five revision categories, with the procedures in each category perceived to be of similar surgical complexity. Anonymized case reports of each of these categories were then presented, in a randomized unranked order, to a patient and public involvement (PPI) group. The PPI group consisted of 14 non-medical volunteers, some of whom had previously undergone hip and knee arthroplasty procedures. Medical terminology was explained in plain, non-technical English and picture form. Descriptions included: the size of the wound; extent of soft-tissue dissection; length of procedure; length of hospital stay; postoperative mobilization regimen; and rate of return to routine activities. The PPI group volunteers were then asked to individually rank the categories, according to three criteria:

1. The severity of the proposed surgical procedure, leading to the level of anxiety such a procedure would likely cause them prior to surgery (1= least anxiety, 5= most anxiety).

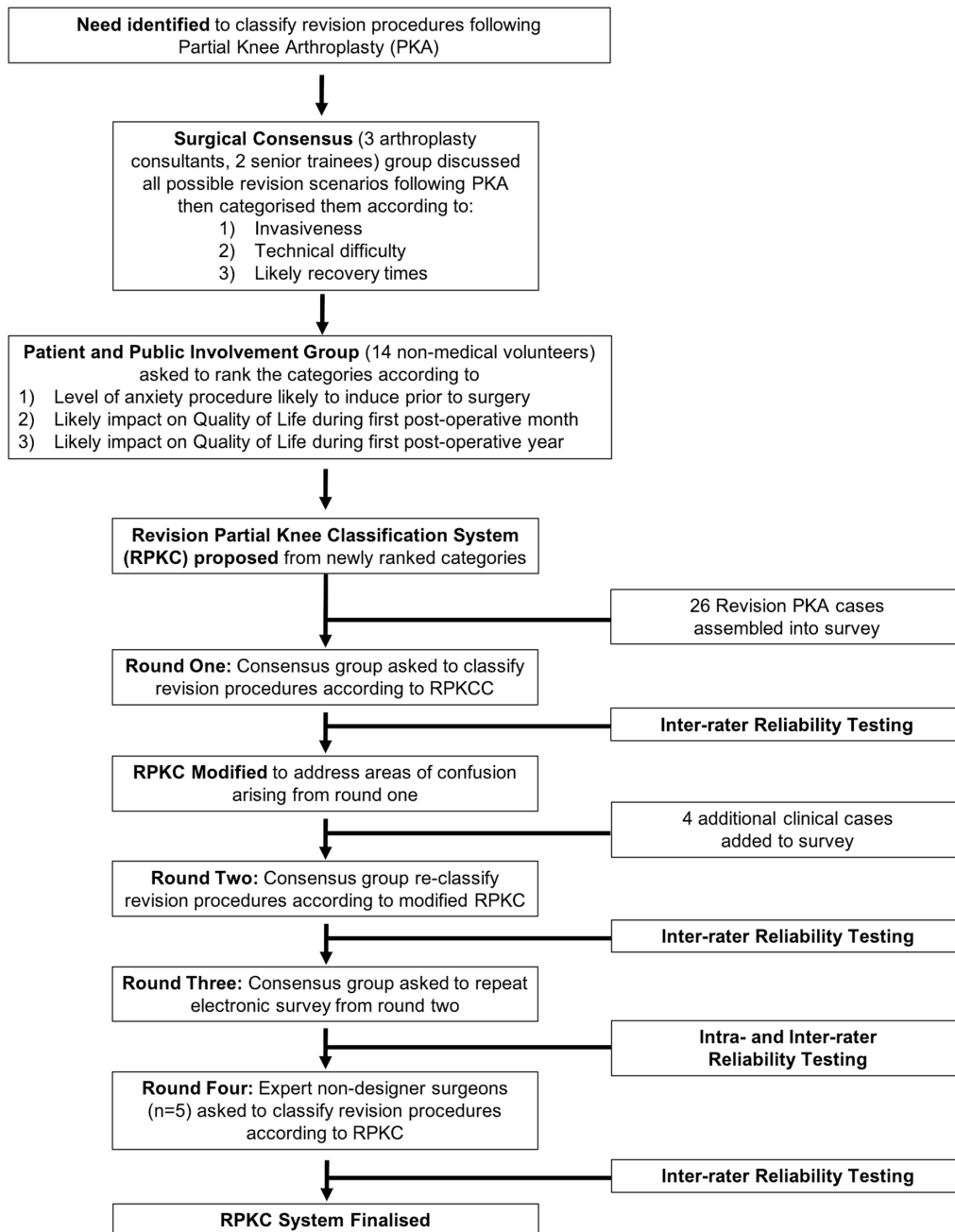


Fig. 1

Flow diagram for the process of creation and validation of the proposed revision partial knee classification (RPKC) system.

2. The impact of the procedure on quality of life in the first 30 days post-surgery (1= least impact, 5= most impact).
3. The impact of the procedure on quality of life two to 12 months post-surgery (1= least impact, 5= most impact).

Testing the proposed RPKC system. Results from the PPI rankings were used to inform the development of the RPKC classification system, which was then tested for inter-rater reliability. Hospital operating lists from the

past 12 months revealed that 26 cases had undergone revision of PKA. These were collated into an anonymized encrypted electronic survey, which included clinical and radiological information and the revision procedure performed.

Round one. The electronic survey of 26 cases was distributed among the five members of the surgeon consensus group. Blinded to the identity of the patient, respondents were asked to classify the revision procedure. The order of cases presented to each respondent was randomized. Where disagreement was found, the consensus group

Table 1. Scores ranked by patient and public involvement group volunteers (n = 14), with 1 = least impact on anxiety levels and quality of life, and 5 = greatest impact.

Category	Description of revision procedure by category	Rank preoperative anxiety, mean (SD)	Rank QoL, first month, mean (SD)	Rank QoL, two to 12 months, mean (SD)	Proposed class
A	<ul style="list-style-type: none"> ■ No removal of metal components, polyethylene exchange. ■ Ligament repair/reconstruction (e.g. ACL, MPFL). ■ Debridement with implant retention for acute infection. 	1.14 (0.36)	1.21 (0.43)	1.0 (0.00)	PR1
B	<ul style="list-style-type: none"> ■ Addition of partial knee to one native compartment (primary procedure unchanged). ■ Revision of one metal component for pain, instability, or loosening (e.g conversion from mobile to fixed bearing tibial component). 	2.0 (0.55)	1.79 (0.43)	2.21 (0.43)	PR2a
C	<ul style="list-style-type: none"> ■ Addition of partial knees to two native compartments (primary procedure unchanged). ■ Addition of partial knee to the remaining native compartment of a knee previously subject to a PR2a (addition of partial knee to one native compartment) procedure. ■ Revision of two or more metal components to another PKA for pain, instability, loosening or malalignment. 	2.86 (0.36)	3.07 (0.27)	2.93 (0.62)	PR2b
D	<ul style="list-style-type: none"> ■ PKA to TKA with AORI 1 or 2A (no requirement for supplemental metaphyseal fixation). 	4.0 (0.00)	3.93 (0.27)	3.93 (0.47)	PR3
E	<ul style="list-style-type: none"> ■ PKA to TKA with AORI 2B/3 (requirement for supplemental metaphyseal fixation). ■ Requirement for augments, stemmed or hinged prosthesis. ■ Requirement for enhanced exposure techniques such as tubercle osteotomy. 	5.0 (0.00)	5.0 (0.00)	4.93 (0.27)	PR4

ACL, anterior cruciate ligament; AORI, Anderson Orthopaedic Research Institute; MPFL, medial patellofemoral ligament; PKA, partial knee arthroplasty; QoL, quality of life; SD, standard deviation; TKA, total knee arthroplasty.

was asked to clarify the wording of the classification category, and where disagreement occurred, additional similar cases were added to clarify the criteria and validate the category.

Round two. The original 26 cases, plus four additional cases added for clarification, were included in round two, which was conducted one month after round one. The order of cases was re-randomized and respondents were once again asked to classify the proposed revision surgery according to the RPKC system.

Round three. Since there had been significant changes to the wording of the classification system and additional cases added between rounds one and two, a third round was conducted one month after round two.

Round four. In the final round of testing, the survey of 30 cases was disseminated to a group of five world-leading experts in partial knee arthroplasty. The electronic survey was identical to the version used in rounds two and three. The experts had not been part of the design or creation of the proposed classification system, but were asked to comment on it and suggest modifications where they felt appropriate. The expert surgeons were asked to classify each case according to the management plan proposed by the multidisciplinary team.

Statistical analysis. Estimation of inter-rater reliability was conducted, after each round of testing, using Kendall's coefficient of concordance, W (Kendall's W).^{20,21} Intrarater reliability, using the interclass correlation coefficient

(ICC), was used to compare responses between rounds two and three. For round four, the inter-rater reliability was calculated using Kendall's W, first among the expert non-designer surgeons themselves, and then for the consensus group plus the expert surgeon group.

Results

The surgeon consensus group agreed on four partial revision categories (Table 1).

1. When no revision of any bone-implant interface is performed, such as a bearing change or anterior cruciate ligament (ACL) reconstruction, or fracture fixation with implant retention.
2. When bone surgery is involved but the ACL is preserved, avoiding a TKA.
3. When a TKA is required using a primary TKA device.
4. When stems, augments or supplemental metaphyseal fixation are required.

After discussion, 2 was subdivided into 2a, when a single component of a PKA was revised, or an additional PKA was added,²²⁻²³ or 2b for anything more complex than this, when the ACL is preserved, and monolithic femoral or tibial components are avoided (Figure 2).

When presented with these different classes in random order, the PPI group scored the classes using the three metrics: severity of surgical procedure; short-term impact

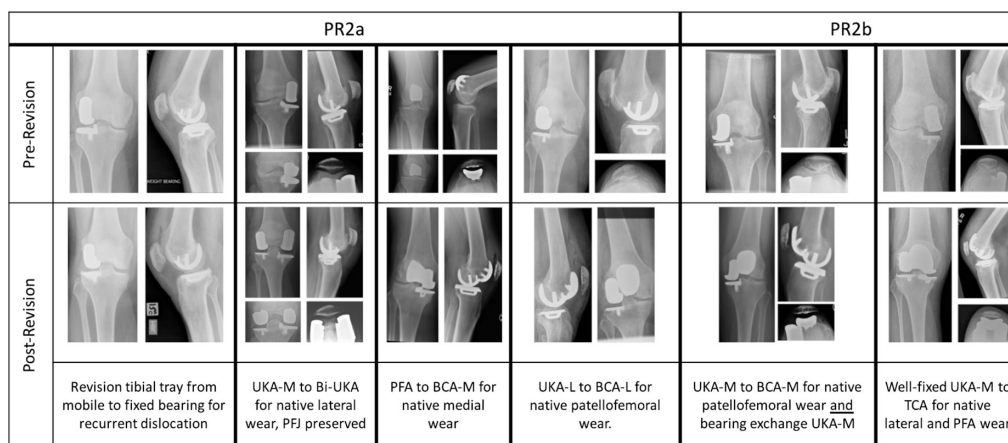


Fig. 2

Radiographic examples of partial revision two (PR2) procedures. BCA-L, lateral bicompartamental arthroplasty; BCA-M, medial bicompartamental arthroplasty; Bi-UKA, bi-unicondylar arthroplasty; PFA, patellofemoral arthroplasty; PTCA, tricompartmental arthroplasty; UKA-L, lateral unicondylar arthroplasty; UKA-M, medial unicondylar arthroplasty.

Revision Partial Knee Classification System (RPKC)
PR1 – Revision Partial 1
<i>Joint Registry Procedures:</i>
- UKA Polyethylene exchange
- No removal of metal components
<i>Non Joint Registry Procedures:</i>
- Ligament Repair / Reconstruction (E.g. ACL, MPFL)
- Debridement with implant retention (DAIR)
- Fracture Fixation – all components left in situ
PR2a – Revision Partial 2a
- Addition of partial knee to one native compartment (primary procedure unchanged)
- Revision of one metal component e.g. conversion from mobile to fixed bearing tibial component
- Revision of patella button)
PR2b – Revision Partial 2b
- Addition of partial knees to two native compartments (primary procedure unchanged)
- Addition of partial knee to the remaining native compartment of a knee previously subject to PR2a
- Revision of two or more components (e.g. femoral and tibial components)
- Cases simultaneously undergoing an ipsilateral PR1 and a PR2a procedure
PR3 – Revision Partial 3
- PKA to standard TKA implant, with AORI 1 or 2A: no augments, stemmed implants or supplemental metaphyseal fixation
PR4 – Revision Partial 4
- PKA to TKA with AORI 2B/3 (requirement for supplemental metaphyseal fixation)
- Requirement for augments, stemmed or hinged prosthesis
- Requirement for enhanced exposure techniques such as tubercle osteotomy

Fig. 3

Newly-defined revision partial knee classification (RPKC) system. ACL, anterior cruciate ligament; AORI, Anderson Orthopaedic Research Institute; MPFL, medial patellofemoral ligament; PKA, partial knee arthroplasty; TKA, total knee arthroplasty.

of surgery on the patient; and longer-term impact on quality of life. Their scores on all counts increased with the grade of procedure. PR1 procedures ranked lowest, scoring 1.14 (standard deviation (SD) 0.36) for operative severity, 1.21 (SD 0.43) for short-term impact, and 1.0 for long-term impact, while PR4 scored 5 for severity and short-term impact, and 4.9 for longer-term impact (Table I). Although the PPI group scored PR2b as a more

major procedure than PR2a on all three scales, the group felt that implant procedures which did not result in TKA should be grouped together in a single group, PR2 for ease of understanding. The name 'revision partial knee classification' (RPKC) system was proposed, to follow the precedent set by the RKCC system.

Reliability testing. The newly-defined RPKC system (Figure 3) consists of four classes: PR1 to PR4, with class

Table II. Results of intra- and interobserver reliability testing of proposed revision partial knee classification (RPKC) system.

Round	Cases, n	Agreement, %	Inter-rater reliability			Intrarater reliability	
			Kendall's W	p-value*	Reliability	ICC	95% CI
One	26	92.3	0.97	< 0.0005	Very good		
Two	30	93.3	0.98	< 0.001	Very good	0.99	0.98 to 0.99
Three	30	96.7	0.98	< 0.001	Very good		
Four	30	80	0.92	< 0.001	Very good		

*Chi-squared test.

CI, confidence interval; ICC, interclass correlation coefficient; Kendall's W, Kendall's Coefficient of Concordance W, where 1 is perfect agreement.

PR2a and PR2b being within the same class PR2 on the advice of our PPI group. Round one of reliability testing consisted of an electronic survey of 26 cases. Kendall's W was used to determine if there was agreement between the five surgeons' judgement of revision class. The surgeons agreed on 24/26 cases, Kendall's W 0.97; $p \leq 0.0005$, chi-squared test (Table II). Consequently, agreement between surgeons can explain 96.5% of all possible variability, concluding that agreement between raters is 'very good.'²⁴ Disagreement was observed in two of the 26 questions. The first of these related to exchange of a patella button, with two participants regarding this as a 'PR1' revision, with the understanding that this was exchange of polyethylene, whilst the remaining three participants regarded this as a component revision, although the original wording related to a 'metal component'. A further consensus meeting concluded that removal of the patella button was a more technical procedure than exchange of a meniscal bearing, and may require augmentation of the remaining patella, hence it should be included in PR2a. The word 'metal' was subsequently removed from the description of PR2a and 'revision of patella button' included in parenthesis. The second case which divided opinion regarded the choice of prosthesis for revision of a UKA to TKA. In this particular case, the surgeon opted for a standard primary TKA femoral component but used a short stem extension on the tibial component, without the need for augmentation, bone grafting, metaphyseal sleeves, or cones. Two participants ranked this as a PR3, while the remaining three participants ranked this as a PR4. During the second consensus meeting, it was agreed that the additional wording of PR3 be amended to 'PKA to standard TKA, with AORI 1 or 2A (no requirement for augments, stemmed implants or supplemental metaphyseal fixation) be inserted into the description of a PR3 revision to resolve this ambiguity.

The issues raised during round one were clarified and round two was conducted one month later. For round two, raters were in agreement on 28/30 cases (93%; Kendall's W 0.98, $p < 0.001$, chi-squared test). In round three, raters agreed on 29/30 cases (97%; Kendall's W 0.98; $p < 0.001$, chi-squared test; Table II), Intrarater reliability between rounds two and three demonstrated excellent agreement with narrow confidence intervals (ICC 0.99; 95% confidence interval 0.98 to 0.99 (Table II).

In round four, all five members of the expert non-designer surgeon group completed the electronic survey. The expert surgeons were in agreement for 24/30 cases (80%; Kendall's W 0.87; $p < 0.0001$, chi-squared test) Of the remaining six questions, four of the five surgeons were in agreement in all cases, though the one in disagreement were not always the same surgeon. When all responses were analyzed for the consensus designer-surgeon group together with the expert non-designer surgeon group, respondents were in agreement for 24/30 cases (80%; Kendall's W 0.92; $p < 0.0001$, chi-squared test).

Discussion

This study set out to classify revision procedures following PKA. The RPKC appears to be simple, robust, and reliable, allowing patients, surgeons, and commissioners of healthcare to appreciate the complexity and costs of the different procedures. The validation process returned Kendall's W scores above 0.92 in all four rounds, suggesting "very good" inter-rater reliability for both the designer surgeon consensus group and a group of expert PKA surgeons whom had not been involved in the design or creation of the RPKC system.

By describing the different procedures, with a rising level of complexity and cost, NICE's recommendations can be easily realized. The insight of our PPI group seems reasonable: procedures where the original PKA and ACL are left undisturbed should be considered relatively minor, while conversion to TKA or beyond should be considered major. This framework may contribute to the recommendation from NICE, allowing revision surgery to be reported accurately, and enabling the surgeon to make decisions based upon clinical need and patient safety. Detail regarding the nature of further surgery is imperative to understand and interpret big data sets, such as the NJR.

Across the whole of medicine, classification systems are properly based upon pathology, given that this is usually the determinant of prognosis. Systems that focus on the magnitude and complexity of surgery, or the impact on patient anxiety levels and postoperative quality of life, have also been shown to be useful tools in patient-surgical decision-making, clinical prioritization in resource-limited healthcare systems, and appropriate remuneration.^{6,17,25,26} The proposed RPKC system follows

this philosophy. It has been designed by surgeons, patients, and public volunteers, and validated by expert surgeons in the field of PKA, to reflect the causative pathology, complexity, magnitude, and likely impact on patient anxiety levels and postoperative quality of life following revision of a PKA. Patient perceptions of surgery have been shown to have a significant impact on recovery and willingness to undergo future procedures. By asking the PPI group to 'rank' their perceptions on the magnitude of surgery, in the short and medium term, we were able to classify the invasiveness of each class. Well informed patients tend to make better decisions regarding their care, and recover faster as they know what to expect from the process would likely be quite different.^{27–29} The difference between PR3 and PR4 may be vulnerable to surgeon choice and preference. While significant bone loss may require additional constraint, stems, or metaphyseal augments, it is possible that surgeons may prefer them or choose to use them routinely when revising PKA, even if a standard TKA implant may suffice.⁵ Finally, further surgery as a result of periprosthetic joint infection does not immediately fit into any one particular category and, therefore, must be assessed on a case by case basis depending on the management of that case. Infection of PKA is, itself, quite rare; however, debridement, antibiotics and implant retention (DAIR) and implant retention, for example, would likely be PR1, while a two-stage revision would likely be PR4. Although it is entirely possible to revise an infected UKA to a standard primary TKA prosthesis, the outcomes may well be worse than revision of a PKA to a highly constrained hinge, for example, for instability secondary to medial collateral ligament failure.⁵

This study has certain limitations. First, the consensus group was small, and a wider group of opinions may be required to formally adapt and mould the classification system into its final iteration, although the five independent world experts did not suggest any further modifications. Second, all classification systems are subject to interpretation and surgeon choice. There is a significant difference in 'severity' between a simple liner exchange and an ACL reconstruction or tibial plateau fracture fixation, yet all sit best as PR1, since none require the removal or arthroplasty of metallic arthroplasty components. However, the short- and medium-term impact on quality of life and implications for recovery.

In conclusion, this classification of further surgery following PKA is reliable, reproducible, and pragmatic. The system compliments other, more established, systems, including AORI and RKCC. It may help patients understand the different modes of failure of primary PKA and the options available for second surgery, in line with the principles of 'getting it right first time'. This system may prove useful for more detailed audit of joint registry data to better understand the relatively higher rates of PKA revision compared to TKA. For health economists and

healthcare providers, the proposed classification system might assist with more accurate coding and appropriate remuneration of further surgery.



Take home message

- The reasons for second surgery following primary partial knee arthroplasty are not well understood or differentiated by joint registries.
- A classification system for revision of partial knee arthroplasty is proposed to categorize second surgery, based on technical difficulty, invasiveness, and implications for recovery and future function.
- The proposed system is reliable and reproducible.

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- A. D. Liddle: Interpreted the data, Reviewed the manuscript.
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