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Revision knee complexity classification—RKCC: a common-sense guide for surgeons to support regional clinical networking in revision knee surgery

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Abstract

Purpose There is considerable variation in practice throughout Europe in both the services provided and in the outcomes of Revision Knee Surgery. In the UK, a recent report published called get it right first time (GIRFT) aims to improve patient outcomes through providing high quality, cost-effective care, and reducing complications. This has led to the development of a classification system that attempts to classify the complexity of revision knee surgery, aiming to encourage and support regional clinical networking.

Methods The revision knee classification system (RKCC) incorporates not only complexity, but also patient factors, the presence of infection, the integrity of the extensor mechanism, and the soft tissues. It then provides guidance for clinical network discussion. Reliability and reproducibility testing have been performed to establish the inter- and intra-observer variabilities using this classification.

Results Good correlation between first attempt non-expert and experts, good intra-observer variability of non-expert, and an excellent correlation between second attempt non-expert and experts has been achieved. This supports the use of RKCC by both inexperienced and experienced surgeons.

Conclusions The revision knee complexity classification has been proposed that offers a common-sense approach to recognize the increasing complexity in revision TKR cases. It provides a methodological assessment of revision knee cases and support regional clinical networking and triage of appropriate cases to revision units or specialist centres.

Level of Evidence Expert opinion, Level V.

Introduction

An increasing number of primary Total knee arthroplasty (TKA) will inevitably lead to increasing number of revisions [9, 10, 24]. The outcomes following revision TKA are worse than after primary TKA, with a greater incidence and greater complexity of complications [4, 6, 8]. The UK has traditionally set high standards for the regulation of joint replacements, through the use of the National Joint Registry, ODEP, and Beyond Compliance.

In the UK in 2012, the get it right first-time (GIRFT) report was published in the UK [3]. This report discussed the benefits of improving patient outcomes in orthopaedics through ensuring that patients have the correct procedure performed by the correct surgeon, thereby avoiding complications and minimizing costs [3].

It has been proposed that surgeons who perform high volumes of complex surgeries are more likely to be familiar with the techniques required with fewer complications [12]. Complications are not only expensive (an infected knee replacement costs on average over 23,000 Euros to treat) [4, 21], but also more importantly complications have a deleterious effect on the patient's outcome after what should be 'routine' surgery. The GIRFT report recommended that surgeons work within networks and concentrate the most complex work in specialist centres.

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Formal clinical networks currently exist in Europe for major trauma and bone cancer services and have been found to improve patient care [20, 17]. No such network exists for arthroplasty surgery, and as such there is considerable variation in practice in both the services provided and in outcomes around the UK and in Europe [4].

Outcomes after revision TKR can be very variable. Comparisons between cases can be difficult. For example, a failed unicompartmental arthroplasty becomes very much more complicated in the presence of significant bone loss or infection. No current classification systems distinguish between multiple levels of complexity from different variables.

Having reflected on their current practice, the authors believe that a strategy is needed for classifying the complexity of revision surgery, such that the best revision is performed at the earliest opportunity by the most appropriate surgical team. This will guide low-volume surgeons to seek advice in complex cases, avoiding the 'have a go' approach, but will also prevent revision centres being overwhelmed by the revision workload by encouraging clinical networking.

The aim of this manuscript is to propose a classification system to stratify the complexity of revision surgery, enabling surgeons in either referring or specialist units, to grade each case on its complexity and to act as a framework for appropriate and decision making. This subject is very topical at present; knee revision surgery can be complex and expensive [3]. Ensuring that the most appropriate surgeon performs, the surgery is likely to lead to better results and will be more cost effective. There are no other classification systems that address this issue in orthopaedics. This common-sense approach, enabled by the RKCC classification, should help both surgeons and improve care for patients.

The proposed RKCC classification has good inter- and intra-observer reproducibility between 'experts' and 'non-experts'.

Materials and methods

A collaborative consensus meeting was held on March 12–14th 2015 during the Cardiff-infected TKA meeting [18], where the outline of a revision TKR classification was agreed.

Table 1 outlines the proposed revision knee complexity classification.

The principles of the classification were agreed and were:

- A graded system of increasing complexity.
- Greater weight given to factors known to adversely affect outcome, e.g., infection.
- Incorporating existing classifications where appropriate, e.g., AORI for bone loss.
- To help guide the user towards multi-disciplinary team (MDT) and network discussion and to classify the level of expertise needed to manage each case.
- Good inter and intra-observer reproducibility.

A graded classification of increasing complexity

The proposed classification has three categories (R1, R2, and R3; Table 1). The simplest, R1, is a revision of a primary TKR requiring standard revision implants for minimal bone loss, uncomplicated fixation with no confounding factors. Increasing complexity, with greater bone loss, poorer fixation, difficult joint line restoration and balance, and moving from revision to re-revision are seen in R2. The final category, R3, covers salvage for limb-threatening scenarios such as multiple revisions, recurrent infection, or massive bone loss.

Greater weight given to factors known to adversely affect outcome

It was agreed that among many factors that may influence outcomes, the following were the factors that significantly impacted on the complexity during revision TKR:

- Patient co-morbidities.
- Infection.
- Extensor mechanism compromise.
- Soft-tissue coverage.

Each of these independently immediately increases the level of complexity of the surgery and equally have a cumulative effect on potential technical difficulties and complication rates.

Host factors such as co-morbidities have a significant impact on the patient's outcome or ability to undergo major surgery and are often overlooked [26]. These include local issues such as peripheral vascular disease, or systemic issues such as immunosuppression or cardiovascular disease. The McPherson classification is an established method to identify the level of compromise within the host [15]. Highly compromised patients with significant co-morbidities may benefit from high-level experienced medical care. These patients are at the highest risk of mortality and complications [15].

The management of Prosthetic Joint Infection (PJI) can be extremely challenging and it is a continually evolving field. High-level microbiology, plastic surgery, and medical input are frequently required and early MDT discussion is vital [25].

The outcome following extensor compromise is poor, and frequently requires significant surgical expertise [2]. Skills in fracture surgery, revision techniques, augmentation, or

Table 1 Revision knee classification system (RKCC)

R1 (Revision 1)—less complex revision surgery
Examples:
Primary/unicompartmental TKA—aseptic loosening, simple instability, revision of partial to total knee replacement, or polyethylene exchange
AORI 1 or 2A bone loss (no requirement for supplemental metaphyseal fixation)
Debridement with implant retention (DAIR) for acute infection
No significant confounding factors or PIES (co-morbidities, infection, extensor or soft-tissue compromise)
R2 (Revision 2)—complex revision surgery
Examples:
AORI 2B—bone loss requiring supplemental metaphyseal fixation e.g. cones or sleeves
Re-revision operations
Stiff knees for revision that may require enhanced exposure techniques such as tubercle osteotomy
Revision for first-time infection
Revision for femoral periprosthetic fracture around primary implant
Complex instability—where correction of the joint line to achieve stability may require the use of cones or sleeves with or without large augments
Includes R1 cases with significant confounding factors or PIES (patient co-morbidities, infection, extensor or soft-tissue compromise)
R3 (Revision 3)—most complex and salvage cases
Examples:
Multiple previous revisions
AORI 3—balance of massive prosthesis ± metaphyseal reconstruction
Requires Hinge for massive bone loss ± ligament instability
Revision for periprosthetic fracture around stemmed implant or non-union
Recurrent Infection after previous revision surgery
Consideration for salvage: arthrodesis, amputation or suppression therapy

even extensor mechanism transplant may be required in the most severe cases [1, 13].

As bone loss becomes more severe, the importance of the soft-tissue envelope is also, therefore, increasingly important. The need for soft-tissue coverage is associated with poorer outcomes [30]. The careful handling of the soft tissue is crucial to minimize wound healing problems, wound break down, and subsequent infection. Anticipation of inadequacy of soft-tissue closure, especially in the presence of infection, should prompt the surgeon to think about the soft-tissue reconstructive ladder and involve plastic surgical colleagues early [5].

Incorporating existing classifications

The following existing classifications have been incorporated into the RKCC:

The AORI classification of bone loss [7] (Table 2) is widely used for classifying intra-operative bone loss. This classification system is useful to determine the type of implant construct required to reconstruct in revision surgery, helping to delineate between R1 cases with minimal bone loss, and R3 cases, where there may be extensive bone loss. However, this classification was originally designed to be an intra-operative classification not just an X-ray or even CT classification, but it starts the discussion and gives most surgeons a familiar framework to start with.

Table 2 Anderson Orthopaedic Research Institute (AORI) classification of bone defects [7]

Type 1: minor femoral or tibial defects with intact metaphyseal bone, not compromising the stability of a revision component
Type 2: damaged metaphyseal bone. Loss of cancellous metaphyseal femoral bone requiring reconstruction to provide stability of the revision component
A: defect in one femoral or one tibial condyle
B: defects in both femoral or both tibial condyles
Type 3: deficient metaphyseal segment compromising a major portion of either femoral condyles or tibial plateau, occasionally associated with collateral or patellar ligament detachment

The classification of the host proposed by McPherson (Table 3) makes the relationship between pre-existing co-morbidities and poorer outcome clear [15, 16]. It also may predict the level of additional medical support that may be required over the perioperative period.

To help guide the user towards MDT and network discussion and to classify the level of expertise needed to manage each case

It is the belief of the authors that complex surgery is best managed within an experienced team. A surgeon cannot operate in isolation, and revision knee surgery requires the support and experience from medical, anaesthetic, theatre, microbiological, and rehabilitation teams. In units where sufficient experience is present, revision surgery is appropriate.

For example, revision surgery of a failed unicompartmental knee replacement is not the same as revision surgery for an infected stemmed implant. In addition, the presence of multiple co-morbidities, extensor disruption, infection, or soft-tissue problems further add to the challenge of revision surgery.

The RKCC system supports the surgeon to classify their surgery pre-operatively and prompts them to think about whether their unit is the most appropriate place to perform the revision surgery. Revision knee multidisciplinary team (MDT) meetings are appropriate forums for such discussions to take place. The use of MDTs has been well proven to improve outcomes in many surgical specialties, and it is now routine for the treatment of cancer, as they ensure that all the senior decision makers make decisions together [11, 19, 27, 28].

While most R1 surgeries can be appropriate to be undertaken within an arthroplasty unit, it is the belief of the authors that R2 or R3 surgeries should be discussed within a regional network, and the most appropriate place for this surgery to be performed is likely be at a specialist revision centre or regional referral unit.

It must be noted that all revision surgery may be unpredictable, even in 'straight forward' cases. Intra-operative events may occur such as fractures that immediately increase the complexity of surgery. The revision surgeon must ensure that strategies and protocols are available to encounter such difficulties intra-operatively.

The authors believe that the RKCC system provides a forum for discussions between surgeons and promotes the development of regional networks for revision knee surgery.

Table 3 McPherson Systemic Host Grade [15]

A: uncompromised
B: compromised (1–2 compromising factors)
C: significant compromise (> 2 compromising factors) or one of
Absolute neutrophil count < 1000
CD4 T cell count < 100
Intravenous drug abuse
Chronic active infection at another site
Dysplasia or neoplasm of the immune system
Compromising factors:
Age > 80
Immunosuppressive drugs
Alcoholism
Malignancy
Chronic active dermatitis or cellulites
Pulmonary insufficiency
Chronic indwelling catheter
Renal failure requiring dialysis
Chronic malnutrition
Systemic inflammatory disease
Current nicotine use
Systemic immune compromise
Diabetes
Hepatic insufficiency

Good inter- and intra-observer reproducibility

Approval was obtained from North Bristol NHS Trust and the University of West of England to analyse the data collected.

To establish the reliability and reproducibility of the classification system, all revision TKR cases during the year 2012 were reviewed using an electronic record of the clinic note and pre-operative imaging (radiographs and CT scans). All the cases were classified by the LA (Fourth year orthopaedic trainee—a 'non-expert') and secondly by JM and AP (experienced revision knee surgeons—'experts'). The classification process was repeated after 1 month. Cohen's Kappa Index was measured to estimate the inter-observer agreement. The study was powered at 90%, with confidence interval of Kappa between 0.3 and 0.8. The Gamma correlation coefficient was also measured, which is a correlation coefficient to indicate the strength of correlation, whereas kappa measures agreement. The percentage change for the intra-observer testing was measured. The authors were blinded to the identity of the patients and only given the numbers to identify the radiographs.

Results

Reliability and reproducibility testing

Round 1 non-expert versus experts

There was agreement in 68 cases (out of 85). The simple agreement percentage is, therefore, 80% with a 95% confidence interval of 69.9–87.8%. A strong correlation between non-expert and expert data was found (Table 4).

Round 2 non-expert versus experts

There was disagreement in 6 cases (i.e., 7.1% disagreement with a 95% confidence interval of 2.6–14.7%). A high degree of correlation between non-expert and expert opinions was identified (Table 5).

Round 1 versus Round 2 non-expert:

80% of the classifications remained unchanged (95% Confidence Interval 69.9–87.9%; Table 6).

Therefore, there was a good correlation between first attempt non-expert and experts, good intra-observer variability of non-expert and an excellent correlation between second attempt non-expert and experts.

Discussion

It is the author's belief that the use of the RKCC classification system, based on the complexity of the surgery and patient factors will act as a guide for the optimal management of revision TKA patients. The RKCC Classification will encourage surgeons to stop to think and evaluate each individual patient and to discuss their cases with colleagues at regular multidisciplinary meetings. This classification also supports the principles of the UK GIRFT report [4], and sets standards of care for the delivery of revision knee replacement surgery.

Revision knee surgery can be complex [29]. Intraoperatively, a simple situation may quickly evolve into an extremely complex situation, such as the identification of more bone loss than expected or compromise of the extensor mechanism [1, 23]. While there are elements of the classification system that may be applied to any type of surgery, it is our belief that this type of complexity classification system is very appropriate for revision knee surgery. The high costs, the increasing workload, and the complex equipment required make the RKCC extremely relevant to current practice.

The reliability and reproducibility testing demonstrate that the RKCC classification is reliable and reproducible for both expert and non-expert surgeons. This supports the widespread use of this classification, as it may be used not only surgeons in training, but by senior experienced surgeons.

Healthcare systems and funding structures are different in every country. A system that may work for the UK may not necessarily work in other healthcare systems. However, the underlying key message of this classification system is that patients are likely to suffer fewer complications if their surgery is performed to the highest possible standard at their first surgery, thereby avoiding predictable expensive complications and further surgery.

One of the principle aims of the UK Get It right first-time report was to improve patient care, such that patients with significant complexity are treated in centres that are used to managing patients with that degree of complexity, and not just a reflection of the surgeons' ability to do the individual case [4]. It includes the logistics of delivering complex care in a multi-disciplinary team who have expertise and skills to deliver that care, as well as the necessary implants and instrumentation on site rather than having to order in expensive loan kit. The presumption is that familiarity of the team with the equipment, medical conditions, instrumentation, and techniques in specialist centres will produce lower complication rates, and achieve better patient outcome and more

Table 4 Non-expert versus expert results

$N=85$	Measured outcome	Value	Asymp. std. error[a]	P value
Ordinal by ordinal	Gamma	0.971	0.29	0.0001
Measure of agreement	Kappa	0.661	0.70	0.001

Table 5 Non-expert versus expert round 2

$N=85$	Measured outcome	Value	Asymp. std. error[a]	P value
Ordinal by ordinal	Gamma	0.996	0.04	0.0001
Measure of agreement	Kappa	0.884	0.45	0.001

Table 6 Round 1 × round 2 cross tabulation

	Round 2				
Round 1		R1	R2	R3	Total
	R1	37	11	1	49
	R2	1	25	4	30
	R3	0	0	6	6

economically efficient care. The key question is: if you have to order kit in you need to ask whether you are the correct centre and surgical team to do that case? High-volume centres have been demonstrated to have fewer adverse outcomes in both primary (Odds Ratio 0.64), and revision arthroplasty (OR 0.49), supporting the argument for centralisation of complex revision cases in specialist centres [14, 22].

There are many potential limitations to this classification system. The design of the classification system is based on the expert opinion and potential biases of the authors, based on their experiences and the current increasing clinical workload in complex revision knee cases.

There may be cases that do not fit well within the RKCC classification, or cases where the best surgical experience in providing management is not at the specialist centre. However, through the development of a regional clinical network, the RKCC promotes discussion within geographical regions to ensure the appropriate team with the appropriate skills performs the surgery.

This classification cannot take into account every potential complication or confounding factor. However, by broadly grouping revision surgery into three groups: uncomplex, complex, and salvage cases, it aims to make surgeons think about challenges that may be encountered before surgery starts. The classification does not take into account unexpected complications intra-operatively; however, surgical experience and familiarity may reduce the number of unexpected problems encountered.

It is important to stress that the underlying message of this classification is that not every revision knee operation could or should be performed at a regional specialist centre. Often, patients prefer to be treated locally and there are many skilled revision surgeons with huge experience working in smaller regional units. This classification system provides the structure to support units to continue to perform revision knee surgery within a framework, where appropriate advice can be sought if indicated. This encourages surgeons to work within regional networks to raise and maintain high standards.

Conclusion

The Revision Knee Complexity Classification offers a common-sense and pragmatic approach to recognize the increasing complexity of revision TKA cases. The authors believe that using the RKCC will improve the methodological assessment of revision knee cases and support regional clinical networking and triage of cases to appropriate revision units or specialist centres.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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