Enhanced recovery principles applied to revision hip and knee arthroplasty leads to better patient outcomes

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ABSTRACT

Aims: There is very little published literature on Enhanced Recovery Principles (ERP) used in primary joint replacements applied to revision hip and knee arthroplasty (rTHA, rTKA).

Methods: Retrospective series of 268 rTHA and rTKA surgeries from 2010–2018, treated with ERP, focusing on multimodal pain management, blood management and early functional recovery.

Results: No patients from the latest cohort required readmission within 6 weeks. Only 20 patients (7.5%) required a blood transfusion. Surgical site local anaesthetic infiltration was associated with lower PCA use in aseptic rTHA and rTKA ($p < 0.001$; $p < 0.001$). Revisions for infection had a longer length of stay (LOS) and increased PCA usage in both rTHA (6.5 vs. 5.2 days) and rTKA (10.1 vs. 5.3 days), similar to our previous study.¹ Use of an intra-articular catheter for analgesia in rTKA showed reduced PCA use. Tourniquets were not beneficial for blood loss in rTKA and had greater PCA use post-operatively ($p < 0.001$).

Conclusion: The application of ERP to revision THA and TKA surgery is safe and effective.

1. Introduction

Enhanced Recovery Principles (ERP) in primary hip and knee arthroplasty have been well established to show a positive benefit on patient outcomes peri-operatively.^{1–4} This follows on from their success in other surgical specialities, including general surgery, thoracic surgery and urology.^{5–8}

There still remains a gap in the literature relating to the application of ERP to revision arthroplasty cases, despite the ageing population and increased incidence of revision arthroplasty surgery.^{9,10} Current literature predicts that the frequency of revision arthroplasty in the United States of America will double in the next decade, with the burden of this posing an overwhelming strain on health care systems.^{9,10} By employing methods to reduce this strain, we can give patients the best chance for a successful return to their best quality of life post major surgery. ERP are multimodal, multidisciplinary interventions that help achieve better patient outcomes, and these revolve around pre-operative patient education and physiotherapy, effective peri-operative analgesia, optimisation of haemoglobin, patient education and management of

expectations, and ongoing mobility and physiotherapy post-operatively.^{11–13} We first described the outcomes of ERP in revision hip and knee arthroplasty at our institution in our original study, demonstrating that this practice is safe, with improved outcome measures and better re-admission rates at six weeks post discharge from hospital.¹ As part of this, we demonstrated that high volume infiltration of the surgical site with local anaesthetic (LA) was a crucial factor in reducing hospital length of stay and the rate of blood transfusion.¹

The aim of this single site, retrospective observational study was to further investigate outcomes of ERP applied to revision total hip and total knee arthroplasty (rTHA, rTKA) over the past 8 years from 2010 to 2018. Changes in the ERP protocol between this cohort and the previous cohort include the use of high volume, low concentration surgical site infiltration for all cases without pre-operative evidence of infection, more frequent infiltration of LA via an intra-articular catheter post-operatively amongst patients in the rTKA cohort and reduction in the use of tourniquets.¹⁴

It was hypothesised that this larger cohort would provide further evidence to the proposed better outcomes for rTHA and rTKA patients

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receiving ERP, in terms of incidence of blood transfusion, length of in-patient hospital stay, rate of PCA and prn oral opiate use and patient reported outcome measures.^{15,16}

2. Methods

All patients undergoing rTHA or rTKA between 2010 and 2018 with the senior author as the primary surgeon were included in this study. The indications for revision arthroplasty and operative procedure performed were recorded, with all patients undertaking education pre-operatively, as per the original study guidelines. Patients were mobilised by a physiotherapist either on the day of surgery, or day one post-operatively, with no patients requiring bed rest. All patients received prophylactic antibiotics, as well as oral tranexamic acid 1 h pre-operatively. Mechanical and chemical venous thromboprophylaxis was administered peri-operatively, depending on the patient's comorbidities. Spinal anaesthetic with fentanyl or morphine and heavy bupivacaine was used in all but 25 patients. Fentanyl patient-controlled analgesia (PCA) was available if needed post-operatively (20 µg/mL), but was entirely phased out later in the study. Regular paracetamol and slow release oral opiates were prescribed, with oral prn opiates available if needed. A majority of the rTKA surgeries were performed with the use of a tourniquet (95/142), but again this was entirely phased out in the last few years. All patients were allowed to fully weight bear post-operatively.

Due to the evidence from the previous study of similar design and application in primary arthroplasty,^{1–4} all patients were planned to receive infiltration of the surgical field with local anaesthetic intra-operatively. The only indication for not using local infiltration in more recent years was in revision arthroplasty for established infection. These patients did not receive any infiltration of the surgical field. For those cases that did receive infiltrate, it was distributed into the deep and superficial tissues for rTHA, and into the posterior capsule, collateral ligaments, synovium and superficial tissues for rTKA, with dosage dependant on patient weight and dose of local anaesthetic used elsewhere during surgery.

Pre-operative and post-operative staged follow up of patients was conducted, with functional outcomes measured using the Oxford Hip/Knee score questionnaire.^{15,16} Patients were asked to fill out the questionnaire at their initial pre-operative consultation, then at 3, 6 and 12 months (where applicable) follow up consultations.

Outcomes measured for the 2 cohorts were patient demographics, type of anaesthetic administered, if a nerve block was used, infiltration of the surgical field with local anaesthetic, further post-operative intra-articular analgesia using a catheter, PCA usage (mL/kg/h), prn opiate requirement, tourniquet time, time to mobilise post-operatively, length of stay (LOS) including transfer to rehabilitation facility, drop in haemoglobin level (g/dL), incidence of blood transfusion, complications and functional Oxford scores.

Statistical analysis was performed using STATA 15 (Survey Design and Analysis Services, Australia). Student t-tests were used to compare mean values for normally distributed continuous data. A Mann-Whitney U Test was used to compare median values for non-normally distributed continuous data. Nominal variables were analysed by a Chi-Square test. Statistical significance was set at $p < 0.05$.

3. Results

Two hundred and sixty-eight revision arthroplasty surgeries were identified in 232 patients (126 rTHA and 142 rTKA) over the study period. The mean patient age for the rTHA cohort was 65.3 years (60.3% female) and rTKA cohort was 66.3 years (55.6% female). The mean LOS was 5.7 days (median 5 days) with 1 patient recording a 32 day inpatient LOS and 2 patients recording a 20 day inpatient LOS. 243 procedures were carried out under a spinal anaesthetic. 69 rTHA and 105 rTKA patients received surgical field infiltration, and 74 patients from the

rTKA cohort received 2 further doses of LA over 48 h from an intra-articular catheter. 80 patients from the rTKA cohort received either an adductor canal (or rarely a femoral nerve block) pre-operatively. Nine patients from the rTHA group received a pre-operative block, but none of this cohort received LA via indwelling intra-articular catheter post-operatively.

Table 1 shows that the most common indication for rTHA was loosening/lysis (43%) and the majority of these revisions involved exchanging all components (43%). Table 1 also shows that the most common indication for rTKA was malrotation (27.5%), with the majority of these surgeries requiring an all component revision (70%). Ten patients underwent a two-stage procedure for infection, requiring 20 separate hospital admissions. Only 19 patients required transfer to another facility for ongoing rehabilitation prior to discharge home. There was 1 death in hospital from a pulmonary embolus (not from recent cohort).¹

3.1. Infiltration in the absence of infection

Absolute contraindications for receiving surgical site infiltration in recent years was for established infection pre-operatively, as per change to the ERP protocol. Infiltration of the surgical field was undertaken in 63 rTHA and 90 rTKAs aseptic cases over the study period. This practice extends from the success of this technique, as established in our previous study. Due to the benefits of high volume, low concentration LA from this study, this strategy was employed in all patients who received surgical site infiltrate from 2012 onwards.

Table 2 shows that both infiltrated aseptic rTHA and rTKA had a decreased PCA usage rate (rTHA $p < 0.001$; rTKA $p < 0.001$), which is a new finding compared to our previous study.¹ Although both groups also showed a decreased LOS (rTHA 5.0 days vs. 5.4 days; rTKA 5.0 days vs. 5.8 days) and drop in haemoglobin level (rTHA 25.3 g/L vs 27.1 g/L; rTKA 25.1 g/L vs 26.4 g/L) with infiltration of the surgical field, these results were not significant. These were similar to our previous reported findings.¹

3.2. Infection

Table 3 shows that there was a more appreciable difference between infected and non-infected rTKA cases with a statistically significantly lower length of in-patient hospital stay (10.1 days vs. 5.3 days, $p < 0.001$), absolute number of patients requiring a transfusion post-operatively (8 vs. 2, $p < 0.001$) and lower rate of PCA usage (0.016 mL/kg/h vs. 0.007 mL/kg/h, $p = 0.01$) in those cases undergoing revision surgery for reasons other than infection. In the rTHA cohort, a shorter hospital length of stay was also seen in the non-infected cases (6.5 days vs. 5.2 days), however this result was not significant.

Table 1
Indications for revision and procedure performed.

	Hip		Knee
Infection	21	Malrotation	39
Periprosthetic Fracture	6	Infection	34
Loosening/Lysis	54	PFJ Problem	10
Instability	17	Instability	22
Metal on Metal	15	Loosening/Lysis	19
Other	13	Stiffness	11
		Uni – Total	4
		Other	3
All Components	54	All Components	95
Acetabular Component	43	Patella	10
Femoral Component	15	Femoral Component	1
Fracture Fixation ^a	3	DAIR/Liner Exchange	14
DAIR/Head Liner Exchange	9	1st Stage Insertion of Spacer	8
1st Stage Insertion of Spacer	4	2nd Stage All Components	14

^a 1 patient also included in the Femoral Component group and 1 patient also included in the DAIR/Head Liner Exchange group.

Table 2Comparison of outcomes with and without surgical field infiltration for aseptic cases. 2010–2014 data taken from Kent et al.¹

	Aseptic rTHA		p-value ^a	Aseptic rTKA		p-value ^a
	Infiltration	No Infiltration		Infiltration	No Infiltration	
Number of patients	63	41		90	18	
Age (mean)	69	65		67	67	
Gender						
Male	22	14		42	10	
Female	41	27		48	8	
Haemoglobin difference (g/L)	25.3	27.1	0.944	25.1	26.4	0.726
Number of patients receiving transfusion	4	4	0.831 ^a	1	0	0.000
Length of stay (days)	5.0	5.4	0.191	5.0	5.8	0.126
PCA use (mL/kg/h)	0.005	0.019	0.001	0.005	0.018	0.001
Number of patients requiring prn opiate use	42	33	0.646 ^a	81	16	0.974 ^a

⁺p-value calculated with the Chi-Square test.^a p-value calculated with the Mann-Whitney *U* test unless stated.**Table 3**Comparison of outcomes in the presence and absence of infection. 2010–2014 data taken from Kent et al.¹

	rTHA		p-value ^a	rTKA		p-value ^a
	Infection	No Infection		Infection	No Infection	
Number of patients	21	105		34	108	
Age (mean)	61	66		67	66	
Gender						
Male	15	36		10	52	
Female	6	69		24	56	
Haemoglobin difference (g/L)	25.1	25.7	0.522	26.7	25.3	0.803
Number of patients receiving transfusion	3	8	0.375 ^a	8	2	0.001 ^a
Length of stay (days)	6.5	5.2	0.757	10.1	5.3	0.001
PCA use (mL/kg/h)	0.008	0.01	0.001	0.016	0.007	0.010
Number of patients requiring prn opiate use	20	75	0.406 ^a	32	97	0.869 ^a

⁺p-value calculated with the Chi-Square test.^a p-value calculated with the Mann-Whitney *U* test unless stated.

Compared to our previous study, we show a statistically significant reduction in PCA usage amongst aseptic rTKA cases, with further evidence to reinforce previous conclusions of reduced blood transfusions and LOS in this aseptic rTKA group.¹

3.3. Catheter in knees

Table 4 shows that PCA usage (0.006 mL/kg/h vs. 0.011 mL/kg/h, *p* = 0.035) was lower in the group of rTKA who received LA post-operatively via an intra-articular catheter. Although the LOS (5.4 days vs. 6.1 days, *p* = 0.421) and difference in haemoglobin levels (24.8 g/L vs. 24.9 g/L) were lower in the catheter group, these results were not significant. Compared to our previous study, we have shown that intra-articular catheters delivering post-operative analgesia have a benefit in reducing PCA usage.¹

Table 4Comparison of outcomes with rTKA treated with indwelling intra-articular catheter and infiltration alone. 2010–2014 data taken from Kent et al.¹

	rTKA		p-value ^a
	Catheter	No catheter	
Number of patients	74	31	
Age (mean)	67	66	
Gender			
Male	33	15	
Female	41	16	
Haemoglobin difference (g/L)	24.8	24.9	0.522
Number of patients receiving transfusion	2	2	0.382 ^a
Length of stay (days)	5.4	6.1	0.412
PCA use (mL/kg/h)	0.006	0.011	0.035
Number of patients requiring prn opiate use	67	23	0.537 ^a

⁺p-value calculated with the Chi-Square test.^a p-value calculated with the Mann-Whitney *U* test unless stated.

3.4. Tourniquets in knees

Table 5 shows that the use of a tourniquet above the knee in rTKA surgery does not have a statistically significant advantage in terms of drop in haemoglobin levels post-operatively (*p* = 0.787). The use of a tourniquet was also associated with a higher incidence of blood transfusion post-operatively (7 patients vs. 2 patients), but this was not statistically significant. Patients who did not have a tourniquet intra-operatively had lower PCA use post-operatively (0.013 mL/kg/h vs. 0.002 mL/kg/h, *p* < 0.001). This data was not analysed in our previous study as these changes were new introductions to the ERP protocol over

Table 5Comparison of outcomes with rTKA treated with and without a tourniquet intra-operatively. 2010–2014 data taken from Kent et al.¹

	rTKA		p-value ^a
	Tourniquet	No tourniquet	
Number of patients	95	47	
Age (mean)	67	66	
Gender			
Male	43	20	
Female	52	27	
Haemoglobin difference (g/L)	25.8	25.4	0.787
Number of patients receiving transfusion	7	2	0.499 ^a
Length of stay (days)	6.9	5.4	0.177
PCA use (mL/kg/h)	0.013	0.002	0.001
Number of patients requiring prn opiate use	86	43	0.967 ^a

⁺p-value calculated with the Chi-Square test.^a p-value calculated with the Mann-Whitney *U* test unless stated.

recent years.¹

3.5. Transfusions

Twenty patients (7.5%) across both rTHA and rTKA cohorts received a post-operative blood transfusion due to symptomatic anaemia with a haemoglobin concentration of less than 80 g/L. Of the 11 rTHA patients requiring post-operative transfusions, 5 were for lysis, 2 were for instability, 3 were for infection and 1 was for a per-prosthetic fracture. Of the 9 rTKA patients requiring post-operative transfusions, 8 were for infection and 1 was for malrotation.

3.6. Complications

Here we report complications from 2014 to 2018 only, as our previous study has reported complications on the original cohort.¹ 16 patients had post-operative wound ooze, leading to an increased hospital in-patient length of stay (Table 6). One patient had an intra-operative peri-prosthetic fracture which was treated with cables in the same procedure. Another 2 patients from the rTHA group underwent planned revision surgery for management of a peri-prosthetic fracture and none were re-admitted for further failure. There were no other surgical complications or deaths during this study period.

3.7. Functional outcomes

There was an average 14 point increase in Oxford Hip Scores amongst the rTHA patients, from their pre-operative score to their most recent follow up score, and a 12 point average increase in the Oxford Knee Scores amongst rTKA patients.

4. Discussion

The main findings of this study, update and reinforce those presented in our previous study.¹ These being that in-hospital outcomes for patients undergoing rTHA and rTKA are improved by the implementation of ERP. After the positive outcomes with surgical field infiltration of local anaesthetic during that previous study,¹ senior author (PY) has further employed these techniques in practice for all patients undergoing rTHA and rTKA for reasons other than infection, with further success on patient outcomes, as identified in this study. Outcomes measured in this study are multifactorial, but they do demonstrate statistically significant benefits on in-hospital length of stay, the number of patients requiring post-operative transfusions and PCA usage.

Since 2014, further studies in ERP amongst the literature shows that it still remains an important intervention in improving patient outcomes and health related quality of life as opposed to conventional rehabilitation methods for primary hip and knee arthroplasty.^{2–4,17–19} There still remains a gap in the literature surrounding its application to rTHA and rTKA. Given the complexity and challenges of revision arthroplasty to primary arthroplasty, it is not appropriate to apply these conclusions to

revision patients and more studies need to be done, dedicated to exploring the outcomes of ERP in revision arthroplasty.

4.1. Pain management

A major finding in this study is the statistically significant reduction in PCA use for patients in both rTHA and rTKA since 2015. A fewer number of patients required the use of PCA fentanyl post-operatively, with those few that did using a lower dosage of fentanyl compared to patients from 2010 to 2014. This can be directly related to an increased volume of low concentration LA with surgical field infiltration by senior author (PY) intra-operatively for aseptic revisions. A systematic review by Andersen et al. showed that intra-operative local anaesthetic surgical field infiltration may have an analgesic effect in the early post-op period. They do report however that there is a lack of trials with systemic controls for the use of Ketorolac with the control group, as used by senior author (PY) in his surgical field infiltration regime.²⁰

Other Anaesthetic related interventions in this latest cohort include the increased use of low-volume single shot spinal anaesthetic of morphine and heavy bupivacaine and sedation peri-operatively, with only 6 patients needing a general anaesthetic since 2015, compared to 19 patients from 2010 to 2014.¹ A meta-analysis by Liu et al. found spinal anaesthetic the best form of analgesia post-operatively for patients undergoing total hip arthroplasty; the most effective time period for this being 6–12 h post-operatively.²¹

Another significant finding in this study involves the use of intra-articular catheters for analgesia administration post-operatively in rTKA. In our original study, we could not show any reduction in PCA use in this patient cohort.¹ In this study however, the implementation of more intra-articular catheters for LA infiltration post-operatively has shown a statistically significant reduction in PCA use compared to those patients who did not receive further post-operative doses of LA. Despite patients not being randomised, the positive results from this could be the catalyst for a prospective study investigating the benefit of an indwelling catheter for post-operative LA administration on patient outcomes.

4.2. Blood management

Twenty patients received a transfusion over both rTHA and rTKA cohorts (7.5%), due to symptomatic anaemia post-operatively. Surgical infiltration seemed to result in fewer transfusions for both rTHA and rTKA in 2015–2018 as compared to those without infiltration in 2010–2014 but neither of these results were significant. Similarly, a smaller but statistically insignificant drop in haemoglobin levels was seen between the 2 groups.

The reduction in use of tourniquets intra-operatively was a more recent change in the ERP protocol in our practice. Analysis of these 2 groups show no benefit with tourniquet usage for blood loss post-operatively or for reducing the incidence of blood transfusion. However, not using a tourniquet did reduce PCA usage post-operatively. There is a lack of literature regarding the use of tourniquets in revision knee arthroplasty, but several meta-analysis on primary and revision knee arthroplasty suggest that early tourniquet release reduces the incidence of wound complications, DVT, nerve injuries, compartment syndrome and cuff pressure injuries.^{22–24} They also suggested that an absolute tourniquet time of less than 100 min reduces this absolute risk.²² It does remain patient specific however, and further blood loss in an anaemic patient may have worse complications than those posed by an above knee tourniquet.²³

4.3. Hospital in-patient length of stay

Both rTHA and rTKA patients with surgical infiltration recorded shorter in-patient hospital LOS, while aseptic rTKA patients had a statistically significant reduction in this duration. There was an increase in the LOS for patients in the presence of infection for both hips and knees.

Table 6

Intra/post-operative complications (2014–2018 cohort only).

Complications	Number of patients
Wound ooze	16
Post-op anaemia	9
Periprosthetic fracture	1
Medical	
Cellulitis	3
Hypotension (ICU vasopressor)	2
Atrial fibrillation	3
Atelectasis	2
Rash (drug reaction)	1
Hyponatraemia	1
Acute kidney injury	1

This may be due to surgical technique and demand on the body, with revision surgery for infection often being more complex and extensive than that for other diagnoses. Interestingly, the LOS in rTKA was also reduced in patients who had received LA post-operatively via an intra-articular catheter, but this was not significant.

We do acknowledge certain limitations with the data presented in this study. We have presented a retrospective observational cohort study with a small patient number and compared outcomes to previously collected data from our previous study. Due to the nature of revision arthroplasty, there are 3 patients that had extended inpatient hospital length of stay, as such results may be skewed. Again however, no formal pain score was used to assess individual patient's response to any of these measures, similar to boundaries experienced in the original study.

5. Conclusion

This study assesses the ongoing practice of ERP in revision THA and TKA in our institution and further reinforces conclusions made in our original work.¹ ERP principles can be safely and effectively applied to revision surgery. We have shown that there is a significant reduction in hospital length of stay and now PCA use, in patients undergoing ERP with surgical field infiltration and in particular, those with LA administration via intra-articular catheters post-operatively in rTKA. The use of a tourniquet intra-operatively did not add an advantage for blood loss and these patients had increased PCA use post-operatively. Functional outcomes in post-operative follow up periods showed an increase in patient's Oxford hip and knee scores.

Conflicts of interest

All authors are in agreement with the content of the manuscript and have contributed significantly to its development. This manuscript has not been published previously, nor under consideration for publication elsewhere. The Authors do not have any potential conflicts of interests in relation to this body of work.

Ethics approval

Ethics approval for this study has been granted by St John of God Health Care Human Research Ethics Committee (ref: 1485).

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