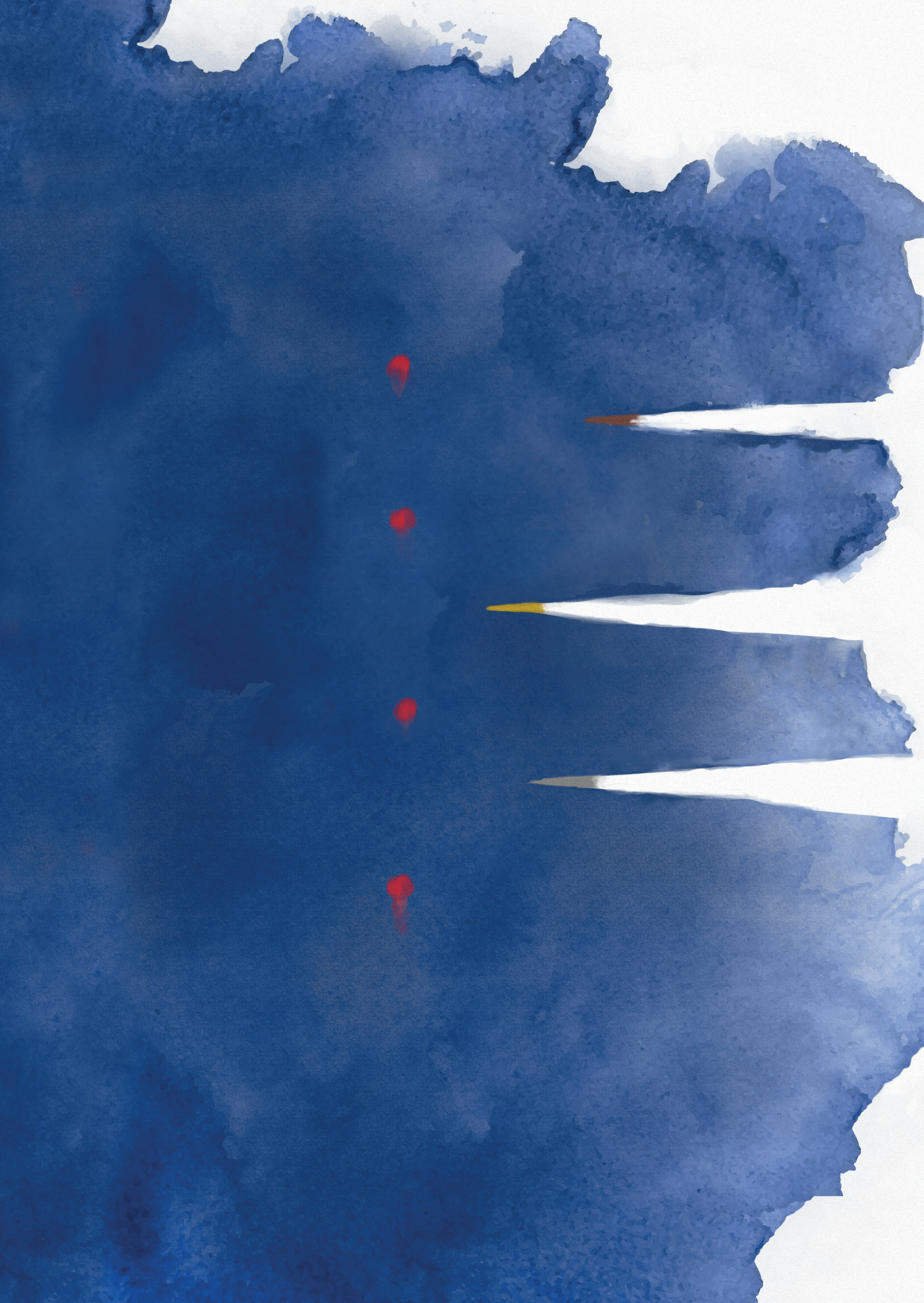
What makes the best performing hospital? the IQ Joint study

Schie, P. van



Chapter 8

Effectiveness of a multifaceted quality improvement intervention to improve patient outcomes after Total Hip and Knee Arthroplasty: A registry nested cluster randomised controlled trial

Peter van Schie, MD[1,2], Leti van Bodegom-Vos, PhD[2], Tristan M. Zijdeman[2], Rob G.H.H. Nelissen, MD, PhD[1], Perla J. Marang-van de Mheen, PhD[2], and the IQ Joint study group

1. Department of Orthopaedics, Leiden University Medical Centre, Leiden, The Netherlands;
2. Department of Biomedical Data Sciences, Medical Decision Making, Leiden University Medical Centre, Leiden, The Netherlands.

BMJ Qual Saf. 2023 Jan;32(1):34-46

Abstract

Objective

To assess the effectiveness of a prospective multifaceted quality improvement intervention on patient outcomes after total hip and knee arthroplasty (THA and TKA).

Design

Cluster randomised controlled trial nested in a national registry. From 1 January 2018 to 31 May 2020 routinely submitted registry data on revision and patient characteristics were used, supplemented with hospital data on readmission, complications, and length of stay (LOS) for all patients.

Setting

20 orthopaedic departments across hospitals performing THA and TKA in The Netherlands.

Participants

32,923 patients underwent THA and TKA, in 10 intervention and 10 control hospitals (usual care).

Intervention

The intervention period lasted 8 months and consisted of the following components: 1) Monthly updated feedback on 1-year revision, 30-day readmission, 30-day complications, long (upper quartile) LOS, and these 4 indicators combined in a composite outcome; 2) Interactive education; 3) An action toolbox including evidence-based quality improvement initiatives (QIIs) to facilitate improvement of above indicators; and 4) Bimonthly surveys to report on QII undertaken.

Main outcome measures

The primary outcome was Textbook Outcome (TO), an all-or-none composite representing the best outcome on all performance indicators (i.e., the absence of revision, readmissions, complications, and long LOS). The individual indicators were analysed as secondary outcomes. Changes in outcomes from pre-intervention to intervention period were compared between intervention versus control hospitals, adjusted for case-mix and clustering of patients within hospitals using random effect binary logistic regression models. The same analyses were conducted for intervention hospitals that did and did not introduce QII.

Results

16,314 patients were analysed in intervention hospitals (12,475 before and 3,839 during intervention) versus 16,609 in control hospitals (12,853 versus 3,756). After the intervention period, the absolute probability to achieve TO increased by 4.32% (95% confidence interval (CI) 4.30-4.34) more in intervention than control hospitals, corresponding to 21.6 (95%CI 21.5-21.8), i.e., 22 patients treated in intervention hospitals to achieve one additional patient with TO. Intervention hospitals had a larger increase in patients achieving TO (ratio of adjusted odds ratios 1.24, 95%CI 1.05-1.48) than control hospitals, a larger reduction in patients with long LOS (0.74, 95%CI 0.61-0.90) but also a larger increase in patients with reported 30-day complications (1.34, 95%CI 1.00-1.78). Intervention hospitals that introduced QII increased more in TO (1.32, 95%CI 1.10-1.57) than control hospitals, with no effect shown for hospitals not introducing QII (0.93, 95%CI 0.67-1.30).

Conclusion

The multifaceted QI intervention including monthly feedback, education, and a toolbox to facilitate QII effectively improved patients achieving TO. The effect size was associated with the introduction of (evidence-based) QII, considered as the causal link to achieve better patient outcomes.

Trial registration number

NCT04055103.

Summary boxes

What is already known on this topic

Given the increasing number of total hip and knee arthroplasties (THA and TKA) performed worldwide, the number of adverse events and revision surgeries are expected to increase as well as societal costs. High-quality care may reduce the risk of adverse events and improve efficiency by avoiding unnecessarily long length-of-stays (LOS).

What this study adds

A multifaceted quality improvement intervention including frequent feedback on performance, interactive education combined with an action implementation toolbox containing evidenced-based quality improvement initiatives (QIIs) was effective to improve patient outcomes after THA and TKA. The absolute probability of patients achieving Textbook outcome (TO)(i.e., absence of revision, readmission, complications, and length-of-stay (LOS)) increased by 4.32% (95% CI 4.30 to 4.34) more in intervention hospitals than control hospitals, with effect size depending on QII introduced. Intervention hospitals particularly improved more in reducing patients with long LOS.

How this study might affect research, practice and/or policy?

These findings support that frequent feedback to surgical teams should be supplemented by interactive education and facilitated by evidence-based improvement initiatives tailored to specific outcomes, to further improve the quality of delivered patient care in arthroplasty surgery.

Introduction

Total hip and knee arthroplasties (THA and TKA) are frequently used cost-effective treatments for symptomatic osteoarthritis and end-stage rheumatoid arthritis to reduce pain and improve patients' functionality.(1-3) Due to the increasing number of procedures, the absolute number of adverse events and costly revision surgeries are likely to increase if the risk remains the same.(4-7) Several studies and arthroplasty reports have shown considerable between-hospital variation in revision, readmission, complications, and length of stay (LOS) for both THA and TKA, indicating huge improvement potential.(7-17)

In recent years, arthroplasty registries have provided surgeons and hospitals with Audit and Feedback (A&F) on their performance, aiming to improve the quality of care delivered.(7,11-18). A Cochrane review showed A&F to be effective with a median absolute improvement of 4.3% (interquartile range (IQR): 0.5% to 16%).(19) Worldwide, arthroplasty registries include different performance indicators in their feedback, with revision most commonly used.(7,11-18). A recent study showed that Dutch orthopaedic surgeons would like to receive feedback not just on revisions but also on readmission, complications, and LOS.(20) For arthroplasty surgery, even a relatively small absolute improvement will have huge impact considering the large annual number of THA and TKA performed worldwide. Studies have shown that A&F maybe more effective when for example, an action implementation toolbox is added to facilitate actions undertaken instead of a "passive" single element (feedback or education alone).(19,21-23) However, a previous study including such an action implementation toolbox only showed improvement in process indicators whereas the ultimate goal is to improve patient outcomes.(23) In addition, A&F seems to be more effective when feedback is delivered by a senior colleague, at least monthly, in both verbal and written format and when explicit goals and specific actions are planned.(19)

We aimed to evaluate the effect of a prospective multifaceted A&F intervention on a composite of clinical outcomes (including 1-year revision, 30-day readmission, 30-day complications, and long LOS) for patients undergoing THA and TKA.

Methods

Study design and participants

A cluster randomised controlled trial (RCT) was nested in the nationwide Dutch Arthroplasty Register (LROI), including 20 hospitals performing THA and TKA across the Netherlands. During the 21 months pre-intervention period (from 1 January 2018 to 30 September 2019) all 20 hospitals established a data linkage between the registry and hospital data, and the research group developed the feedback and action implementation toolbox. Participating orthopaedic departments were then randomised into 10 intervention and 10 control hospitals. The intervention was applied over an 8 months period (1 October 2019 - 31 May 2020) (Figure 1). Control hospitals continued with usual care . We compared the change in patient outcomes from the pre-intervention to the end of the intervention period between intervention and control hospitals as the effect attributable to introduction of the intervention. The trial was pre-registered (ClinicalTrial.gov, NCT04055103) and the LUMC Medical Ethical Committee waived the need for ethical approval under Dutch law (CME, G18.140).(24) The study was announced on the website of the Dutch Orthopaedic Association and the first 20 orthopaedic departments agreeing to participate in the study were included. All THA and TKA procedures performed in the 20 departments were included. No exclusion criteria were used.

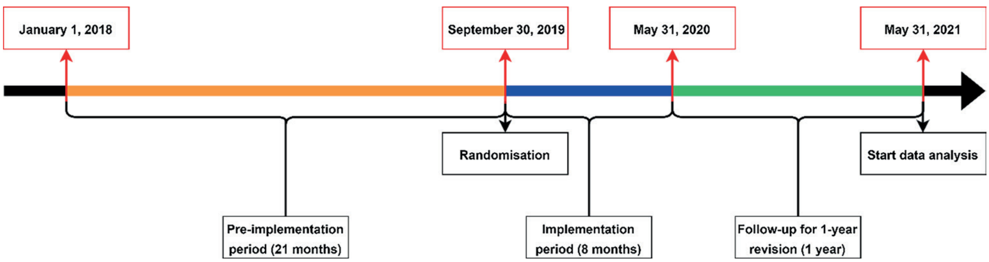


Figure 1 Study period

COVID-19

We originally planned to include a "sustainability phase" after 6 months, where intervention hospitals would no longer be actively supported and the control hospitals would receive the intervention (ClinicalTrial.gov, NCT04055103).(24) This planned sustainability phase was delayed by 2 months so that the intervention period ended May 2020 rather than the planned March 2020 to maintain sufficient statistical power, given the reduction in elective care caused by the COVID-19 outbreak in early March 2020. The number of procedures decreased to 625, 54, and 545 in March, April, and May 2020, respectively, compared with an average 1,215 THA and TKA per month in

2018-2019. In addition, we had planned to match hospitals as part of the intervention to exchange information on best practices and identify areas for improvement, which could not be implemented due to government-imposed COVID-19 restrictions.(24)

Randomisation and masking

Randomisation was stratified by hospital type to achieve an equal distribution of academic, teaching, non-teaching, and private hospitals, as these generally differ in size and are therefore likely to differ in available IT and quality improvement (QI) capacity. Participating hospitals were categorised within one of four groups and then allocated in a 1:1 ratio to the intervention or control group. Due to the nature of the intervention, orthopaedic surgeons of intervention hospitals could not be masked but patients were masked to study group allocation. By liaising with hospital IT specialists to extract hospital data on readmissions, complications, and LOS, we tried to minimize potential bias as they were masked to study group allocation. In all intervention hospitals, the head of the orthopaedic department was appointed as contact person and acted as ''clinical champion".

Intervention

The intervention was designed based on evidence regarding effective feedback(19,21-23) for orthopaedic surgeons(20) and included the following components:

1) Monthly updated feedback was (securely) emailed individually to all orthopaedic surgeons performing THA and TKA in the intervention hospitals. Feedback included case-mix-adjusted indicator outcomes graphically presented in funnel plots and CUSUM charts.(25) The following indicators were reported: 1-year revision (including reasons for revision to align with Quality Improvement Initiatives (QIIs), that is, infection, dislocation (only THA), prosthesis loosening, and technical failure (only TKA)(8)), 30-day readmission, 30-day complications, long (upper quartile) LOS and a composite outcome including all above mentioned indicators. A brief description to interpret the findings for each indicator was provided below each graph tailored to that specific hospital (Appendix I).

2) Education to interpret the feedback was provided by PvS (medical doctor) in the first month of the intervention period, combined with clear targets for improvement of specific indicators. Orthopaedic surgeons learned how to interpret funnel plots and CUSUM charts, and how to use these charts for QI. This was based on a previous survey showing this represented a knowledge gap so that education should be part of the intervention .(20,21) As a reference, a video (Appendix II) and pocket card (Appendix III) were available to summarize the educational meeting.

3) An action implementation toolbox including evidence-based QII for each indicator reported in the feedback, to facilitate taking actions to improve care, based on scientific literature, expert opinion, and guidelines. The plan-do-study-act (PDSA) cycle was added to help surgeons design local QI projects (Appendix IV).

4) A short survey was emailed every 2 months together with the feedback to evaluate adherence to the intervention, encourage reviewing the feedback, verify which QII were introduced, and stimulate trial engagement. Participants could report best practices and experiences to be added to the toolbox and shared with others, also to stimulate trial engagement (Appendix V).

Control hospitals continued with usual care, meaning that no specific intervention was implemented. This means that orthopedic surgeons have access to the password-protected LROI-dashboard where overall between-hospital variation in revision could be viewed in real-time, as well as averages for patient characteristics and patient-reported outcome measures. However, it requires logging in to look up the information, rather than receiving it through email, and gives no comparative information on readmission, complications, and long LOS (or the composite). Since 2015, all surgeons in both control and intervention hospitals have had access to the LROI-dashboard, however, a recent study showed that 39% of the orthopaedic surgeons did not interpret funnel plot correctly, and 34% never logged in.(20)

Graphical displays of performance

Funnel plots are already used in the LROI dashboard as a graphical aid to show between-hospital variation in revisions, adjusted for case-mix. Hospitals plotted between the control limits (2 standard deviations (SD)) perform as expected given their case-mix, while hospitals plotted above or under the control limit perform significantly worse or better, respectively.

A CUSUM chart was added to the monthly feedback since it shows patient-level rather than aggregated performance data during a time period. For every consecutive patient, the observed minus expected probability for an event is plotted. When the score goes up, the observed performance is worse than expected, and vice versa when going down. A signal (alert) was generated when crossing the 5.0 control limit meaning that hospital performance was ''out-of-control" for the quality indicator, after which the chart was reset to zero. When no signal is generated a hospital is "in-control".(26) The level of the control limit determines the trade-off between the number of false-positive and false-negative signals. We showed previously that the CUSUM chart with a 5.0 control limit enabled earlier detection of worsening performance for 1-year revisions with good accuracy compared with the funnel plot, thereby allowing initiatives to start earlier.(25)

Outcome evaluation

The primary outcome was the Textbook Outcome (TO) composite, with the individual outcomes included in TO analysed as secondary outcomes. The TO composite is an all-or-none concept representing the best outcome on commonly used indicators for THA and TKA (i.e., the absence of 1-year revision, 30-day readmission, 30-day complications, and long LOS). The 1-year revision was calculated based on primary and revision surgery dates, with all patients having at least 1-year follow-up, as routinely collected in the LROI. By including revisions in the composite, a 1-year follow-up was needed after the implementation period to calculate TO (Figure 1). Other outcomes were calculated based on the index hospitalisation in which the primary THA or TKA was performed. Outcomes were defined as follows:

- Revision: Exchange, removal, or addition of any component within one year after the primary surgery.

- Readmission: Any admission within 30 days after discharge of the index hospitalisation to the same hospital.

- Complication: Any complication other than revision during the index hospitalisation or within 30 days after discharge, using the nationwide definition of a complication.(27)

- Long LOS: LOS of the index hospitalisation longer than the 75th percentile (upper quartile), based on all patients treated, to take into account possible between-hospital differences in sensitivity to report complications.(28)

Data collection

Routinely submitted LROI data regarding revisions and patient characteristics were used, supplemented with hospital data on readmission, complications, and LOS for all patients. LROI data were linked to hospital data by an IT specialist from each hospital to ensure anonymous data exchange. LROI data completeness is checked annually against Hospital Electronic Health Records and currently exceeds 99% for primary procedures, and 97% for revisions.(29,30) The LROI uses barcode scanning to enable tracing of prosthetic components so revisions performed in another hospital are included. The following patient-level LROI data were provided: whether a revision had taken place, reason for revision and the patient characteristics age at surgery, gender, body mass index (kg/m^2), current smoking status (yes/no), American Society of Anaesthesiologists (ASA) classification (I-IV) and diagnosis (osteoarthritis/non-osteoarthritis). Collected data were locked prior to the analyses.

Statistical analysis

At least 18 participating hospitals (9 per arm) were needed to detect a difference in TO of 70% versus 80% with 80% power, α of 0.05, a median of 100 procedures per hospital, and assuming an intra-hospital correlation of 0.02. We included 20 hospitals (10 per arm) in case hospitals would drop out. To assess whether participating hospitals were a representative selection, we compared the median number of procedures and median percentage of revisions for both THA and TKA during the study period in participating centers versus all other Dutch centers, using a Mann-Whitney U test.

Patient characteristics were missing in less than 2% of patients. These were considered missing at random and imputed using multiple imputations for 10 rounds with predictive mean matching as the underlying model. All patient characteristics and outcomes (i.e., TO, revision, readmission, complications, and long LOS) were used as predictors, but only patient characteristics were imputed.

Data were analyzed following an intention to treat approach, classifying hospitals in study groups as randomised. Random effects binary logistic regression models were used to estimate the impact of the intervention on TO as the primary outcome and each secondary outcome, while accounting for patient clustering within hospitals. All models were adjusted for all measured patient characteristics. Outcomes between pre-intervention and intervention period were first compared within intervention and control hospitals, expressed as adjusted odds ratios. The change in outcomes from pre-intervention period was then compared between intervention and control hospitals by including an interaction term between study group and period, and quantified as the ratio of adjusted odds ratios with corresponding 95% confidence intervals (CI). We calculated the number of patients needed to be treated during the intervention period to achieve one additional patient with TO in intervention hospitals as 1 divided by the absolute risk difference. The absolute difference in TO probability was derived from the estimated parameters obtained by the above logistic regression models using a marginal standardisation method.(31) Corresponding 95% CI were computed from non-parametric bootstrapping based on 2000 replications. The same analyses were performed to compare intervention hospitals introducing QII and intervention hospitals not introducing QII, versus control hospitals. These analyses were conducted from the rationale that these QII were the causal link to achieve improved patient outcomes, which would thereby support intervention efficacy. Information on QII introduced was taken from the process evaluation (see below). All analyses were conducted for all patients, and separately for THA and TKA patients, given the known difference in revisions and complication risks and that a difference in baseline risk may affect the absolute risk reduction achieved.(7-17,32)

All p values were two-sided and values below 0.05 were considered statistically significant in all analyses. Analyses were performed using STATA (version 14; StataCorp).

Process evaluation and intervention fidelity

Surveys were sent by email in November 2019, January 2020, and March 2020 and compiled using Qualtrics^{XM} (Appendix V). As surveys were sent together with the feedback, response also indicated the email was read and feedback received. Questions were asked to evaluate adherence to intervention components and therefore included whether orthopaedic surgeons could interpret the feedback and what other information or tools were needed for further improvement. In addition, we asked which QIIs were undertaken as ultimately the feedback was intended to initiate actions, including whether these QII were based on the toolbox or other evidence. Descriptive statistics were used to explore the number of QII per intervention hospital and the source of the initiatives.

Patient and public involvement

Patients or the public were not involved in the design of the study.

Results

Of the 33,205 patients who underwent THA or TKA in the 20 participating hospitals during the pre-intrevention and intervention period, 282 had missing data for TO, leaving 32,923 (99.2%) patients eligible for analysis. Of these, 16,314 patients were analysed in the intervention hospitals (12,475 before and 3,839 during the intervention period) versus 16,609 in control hospitals (12,853 versus 3,756). Participating hospitals were comparable to all other Dutch hospitals in distribution of type of hospital, median revision rate (1.7% versus 1.7% for THA, p=1.00 and 1.4% versus 0.9% for TKA, p=0.62) and median number of THA surgeries (930 versus 699; p=0.21) but had higher median number of TKA surgeries (700 versus 582; p<0.05) (Figure 2).

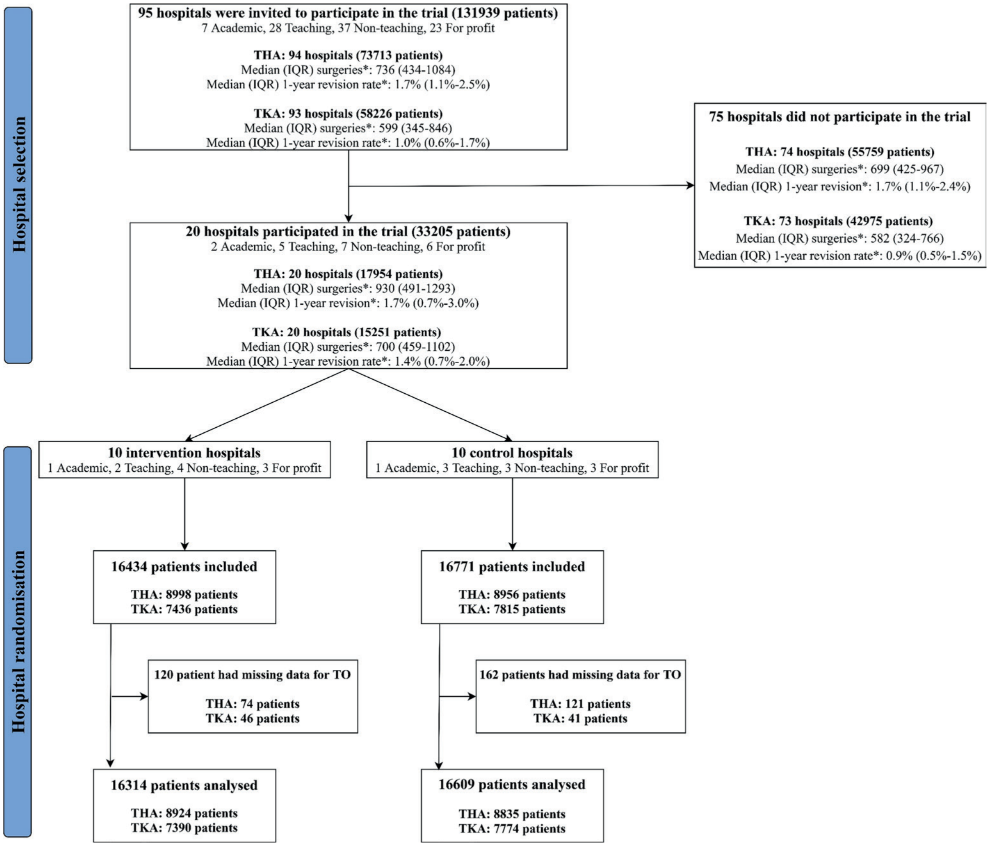


Figure 2 Trial profile

Table 1 shows that hospital and patient characteristics were comparable between intervention and control hospitals, except for slightly more smokers and fewer ASA III-IV patients in intervention hospitals. During the study period, 28,108 patients achieved TO (85.4%), 529 (1.6%) underwent a revision within one year, 1218 (3.7%) had a readmission within 30 days, 1,214 (3.7%) experienced a complication within 30 days, and 3,662 (11.1%) had a long LOS, with considerable between-hospital variation in all outcomes (shown by the interquartile range in table 1) in both intervention and control hospitals. LOS was not normally distributed, making it challenging to create equal quartiles so that the closest integer value was chosen. This resulted in above 4 days defined as long LOS for both THA and TKA, and explains that the median percentage of patients with long LOS is considerably smaller than 25%.

Table 1 Hospital and patient characteristics by hospital group during the study period (1 January 2018 to 31 May 2020)

Hospitals characteristics		**All hospitals (n=20)**			**Intervention hospitals (n=10)**			**Control hospitals (n=10)**	
Geographical region:									
Northwest		3 (15)			1 (10)			1 (10)	
Northeast		4 (20)			2 (20)			2 (20)	
Southwest		6 (30)			3 (30)			2 (20)	
Southeast		5 (25)			3 (30)			3 (30)	
Central area		2 (10)			1 (10)			2 (20)	
Status:									
Academic		2 (10)			1 (10)			1 (10)	
Teaching		5 (25)			2 (20)			3 (30)	
Non-teaching		7 (35)			4 (40)			3 (30)	
For-profit		6 (30)			3 (30)			3 (30)	
Median (IQR) number of surgeons*:		6 (5-7)			6 (5-7)			7 (5-9)	
	All surgeries	**THA**	**TKA**	**All surgeries**	**THA**	**TKA**	**All surgeries**	**THA**	**TKA**
Median (IQR) number of surgeries in study period*:	1472 (1059-2371)	920 (487-1292)	667 (454-1098)	1472 (1350-2152)	920 (723-1133)	612 (388-1041)	1452 (766-2525)	772 (257-1473)	728 (605-1177)
Indicator outcomes:									
Median (IQR) TO (%)*	85.1 (77.0-95.6)	84.4 (75.9-95.6)	84.5 (77.1-95.7)	87.0 (75.0-96.6)	86.9 (76.8-96.9)	84.5 (72.2-95.5)	85.0 (77.2-95.0)	83.6 (71.8-94.1)	85.0 (79.9-96.1)
Median (IQR) revision (%)*	1.4 (0.8-2.6)	1.7 (0.7-3.0)	1.3 (0.7-2.0)	1.6 (0.8-3.0)	1.7 (0.6-3.2)	1.7 (0.8-2.2)	1.3 (0.9-2.3)	1.8 (0.8-3.1)	0.9 (0.7-1.8)
Median (IQR) readmission (%)*	4.4 (1.6-5.0)	4.3 (1.8-5.1)	4.0 (1.6-5.2)	4.6 (1.2-4.9)	4.0 (1.1-5.4)	4.7 (2.5-5.4)	4.2 (1.8-5.1)	4.3 (2.2-5.1)	3.6 (1.4-5.2)
Median (IQR) complications (%)*	3.0 (1.9-4.5)	3.6 (2.1-5.9)	2.5 (1.3-3.7)	2.2 (1.5-3.9)	2.8 (1.6-4.7)	2.3 (1.2-3.9)	3.3 (2.9-6.1)	4.1 (3.2-7.6)	2.8 (1.0-4.6)
Median (IQR) Long LOS (%)*	10.9 (2.1-19.7)	10.3 (2.1-19.3)	9.9 (2.1-19.4)	8.6 (2.0-20.7)	9.3 (2.1-19.0)	9.5 (1.7-23.3)	11.4 (1.5-19.6)	10.9 (1.4-25.0)	11.8 (2.1-17.1)

Table 1 Continued

Hospitals characteristics	**All hospitals (n=20)**			**Intervention hospitals (n=10)**			**Control hospitals (n=10)**		
Patients characteristics	**All surgeries (n=32923)**	**THA (n=17759)**	**TKA (n=15164)**	**All surgeries (n=16314)**	**THA (n=8924)**	**TKA (n=7390)**	**All surgeries (n=16609)**	**THA (n=8835)**	**TKA (n=7774)**
Mean (SD) age (years)	68.5 (9.6)	68.5 (10.3)	68.4 (8.7)	68.1 (9.6)	67.9 (10.3)	68.3 (8.6)	68.9 (9.5)	69.1 (10.2)	68.6 (8.7)
Gender, female	20656 (62.7)	11323 (63.8)	9333 (61.5)	10233 (62.7)	5670 (63.5)	4563 (61.7)	10423 (62.8)	5653 (64.0)	4770 (61.4)
Mean (SD) BMI (kg/m^2)	28.1 (4.8)	27.0 (4.5)	29.4 (4.8)	28.0 (4.8)	26.9 (4.4)	29.3 (4.8)	28.3 (4.8)	27.2 (4.5)	29.5 (4.9)
Smoking	3068 (9.3)	1830 (10.3)	1238 (8.2)	1595 (9.8)	964 (10.8)	631 (8.5)	1473 (8.9)	866 (9.8)	607 (7.8)
ASA classification								1392 (15.8)	959 (12.3)
• ASA I	5158 (15.7)	3204 (18.0)	1954 (12.9)	2807 (17.2)	1812 (20.3)	995 (13.5)	2351 (14.2)	5501 (62.3)	5138 (66.1)
• ASA II	21083 (64.1)	11029 (62.1)	10054 (66.3)	10444 (64.0)	5528 (62.0)	4916 (66.5)	10639 (64.1)	1940 (22.0)	1676 (21.6)
• ASA III-IV	6673 (20.3)	3521 (19.8)	3152 (20.8)	3057 (18.7)	1581 (17.7)	1476 (20.0)	3616 (21.8)		
Diagnosis								7744 (89.4)	7502 (98.4)
• Osteoarthritis	30258 (93.7)	15643 (89.8)	14615 (98.2)	15012 (93.7)	7899 (90.2)	7113 (97.9)	15246 (93.6)	921 (10.6)	119 (1.6)
• Non-osteoarthritis	2051 (6.3)	1780 (10.2)	271 (1.8)	1011 (6.3)	859 (9.8)	152 (2.1)	1040 (6.4)		

Values are numbers (percentages) unless stated otherwise. Data relative to the pre-implementation and implementation period were pooled in intervention and control hospitals. Percentages for ASA classifications might not sum to 100 because of roundings. ASA=American Society of Anaesthesiologists; BMI=body mass index; IQR=Interquartile range; LOS=length-of-stay; SD=standard deviation; THA=total hip arthroplasty; TKA=total knee arthroplasty; TO=Textbook Outcome.

*The value under "Median (IQR)" indicates percentage of the median hospital.

Table 2 Comparison of primary and secondary outcomes by study group (i.e., intervention or control hospitals) between pre-implementation and implementation period

Surgical outcomes	Intervention hospitals			Control hospitals			Intervention versus control hospitals		
	Pre-implementation	Implementation	Implementation versus pre-implementation adjusted odds ratio (95% CI)	Pre-implementation	Implementation	Implementation versus pre-implementation adjusted odds ratio (95% CI)	Ratio of adjusted odds ratios (95% CI)	*p*-value	ICC
All surgeries (*n*=32923)									
Textbook Outcome*	10930 (87.6)	3421 (89.1)	1.39 (1.23 to 1.58)	10615 (82.6)	3142 (83.7)	1.14 (1.02 to 1.27)	1.24 (1.05 to 1.48)	0.011	0.299
1-year revision	199 (1.6)	61 (1.6)	0.93 (0.69 to 1.24)	202 (1.6)	67 (1.8)	1.12 (0.85 to 1.48)	0.82 (0.55 to 1.23)	0.341	0.074
30-days readmission	399 (3.2)	118 (3.1)	0.89 (0.72 to 1.10)	547 (4.3)	154 (4.1)	0.95 (0.79 to 1.14)	0.95 (0.71 to 1.25)	0.697	0.108
30-days complications	303 (2.4)	112 (2.9)	1.12 (0.90 to 1.40)	638 (5.0)	161 (4.3)	0.85 (0.71 to 1.01)	1.34 (1.00 to 1.78)	0.046	0.208
Long LOS	1154 (9.3)	302 (7.9)	0.67 (0.57 to 0.77)	1731 (13.5)	475 (12.6)	0.85 (0.71 to 1.01)	0.74 (0.61 to 0.90)	0.002	0.533
Total hip arthroplasty (*n*=17759)									
Textbook Outcome*	6015 (88.0)	1863 (89.3)	1.39 (1.17 to 1.67)	5533 (80.9)	1611 (80.8)	1.06 (0.92 to 1.23)	1.34 (1.06 to 1.69)	0.013	0.303
1-year revision	112 (1.6)	36 (1.7)	0.98 (0.69 to 1.43)	130 (1.9)	44 (2.2)	1.13 (0.80 to 1.60)	0.86 (0.51 to 1.30)	0.572	0.104
30-days readmission	224 (3.3)	61 (2.9)	0.82 (0.61 to 1.10)	295 (4.3)	104 (5.2)	1.20 (0.95 to 1.51)	0.69 (0.48 to 1.00)	0.051	0.105
30-days complications	194 (2.8)	72 (3.4)	1.12 (0.85 to 1.49)	390 (5.7)	106 (5.3)	0.90 (0.72 to 1.13)	1.25 (0.87 to 1.80)	0.218	0.219
Long LOS	616 (9.0)	164 (7.9)	0.66 (0.54 to 0.82)	1025 (15.0)	296 (14.8)	0.91 (0.77 to 1.07)	0.70 (0.54 to 0.92)	0.010	0.531
Total knee arthroplasty (*n*=15164)									
Textbook Outcome*	4915 (87.2)	1558 (88.9)	1.39 (1.16 to 1.67)	5082 (84.5)	1531 (86.9)	1.25 (1.05 to 1.48)	1.12 (0.87 to 1.44)	0.371	0.333
1-year revision	87 (1.5)	25 (1.4)	0.89 (0.57 to 1.40)	72 (1.2)	23 (1.3)	1.11 (0.69 to 1.79)	0.80 (0.41 to 1.53)	0.492	0.053
30-days readmission	175 (3.1)	57 (3.3)	0.98 (0.72 to 1.33)	252 (4.2)	50 (2.8)	0.65 (0.48 to 0.89)	1.50 (0,97 to 2.32)	0.071	0.095
30-days complications	109 (1.9)	40 (2.3)	1.13 (0.78 to 1.65)	248 (4.1)	55 (3.1)	0.75 (0.57 to 1.01)	1.52 (0.94 to 2.46)	0.085	0.204
Long LOS	538 (9.5)	138 (7.9)	0.66 (0.53 to 0.82)	706 (11.7)	179 (10.2)	0.83 (0.68 to 1.00)	0.79 (0.59 to 1.06)	0.115	0.515

Values are numbers (percentages) unless stated otherwise. Odds ratios were estimated using random effect binary logistic regression models to compare surgical outcomes between pre-implementation and implementation periods in intervention and control hospitals. The ratio of adjusted odds ratios captured the effect of the intervention by comparing the change in outcomes from the pre-implementation to implementation periods between the intervention and control hospitals based on the interaction term. A ratio of adjusted odds ratios value above 1 for the Textbook outcome indicates improvement in the intervention versus control hospitals and a value below 1 deterioration. In contrast, a ratio of adjusted odds ratios value below 1 for 1-year revision, 30-days readmission, 30-days complications, and long LOS indicates improvement and a value below 1 deterioration. Estimates and 95% CI considered clustering of patients at the hospital level. All outcomes were adjusted for gender, age, body mass index, smoking, American Society of Anesthesiologists score, and diagnosis (osteoarthritis versus non-osteoarthritis)

*Composite of an all-or-none concept with the best outcome on all performance indicators (i.e., 1-year revision, 30-day readmission, 30-day complications, and long LOS).
CI=confidence interval; ICC=intraclass correlation; LOS=length-of-stay; PROMs=patient-reported outcome measures.

Outcome evaluation

Table 2 shows changes in clinical outcomes from the pre-intervention to intervention period for both intervention and control hospitals. Intervention hospitals significantly improved in achieving more patients with TO over time for THA/TKA combined (adjusted odds ratio 1.39, 95 % CI 1.23-1.58), as did control hospitals (adjusted odds ratio 1.14, 95% CI 1.02-1.48). Even though intervention hospitals had better pre-intervention TO performance, that is, potentially less room for improvement, they improved significantly more than control hospitals (ratio of adjusted odds ratios 1.24, 95% CI 1.05-1.48). The effect was also significant for THA alone (1.34, 95% CI 1.06-1.69), but not for TKA (1.12, 95% CI 0.87-1.44) although it went in the same direction. For the secondary outcomes, intervention hospitals also showed a significantly higher reduction in the percentage of patients with long LOS than control hospitals for THA/TKA combined and THA. The same trend was observed for 30-day readmission for THA, albeit non-significant. The percentage of patients with reported 30-day complications increased more in intervention than control hospitals for THA/TKA combined but not for THA or TKA separately. No significant effects were found for revisions.

The absolute probability of TO increased by 4.32% (95% CI 4.30-4.34) more in intervention hospitals than control hospitals, corresponding to 21.6 (21.5-21.8), that is, 22 patients treated in intervention hospitals to achieve one additional patient with TO.

Process evaluation and intervention fidelity

The education meetings were scheduled such that all orthopedic surgeons could attend (unless still in surgery). Each meeting ended by discussing which performance indicators would be the focus of improvement initiatives and which specific actions would be taken. Two orthopaedic surgeons were absent during this interactive education session in 3 intervention hospitals and 1 surgeon in 3 hospitals, meaning that 52 of the total of 61 orthopaedic surgeons (85%) attended. From all surgeons, 45 (74%) completed the first survey, 39 (64%) the second survey, and 35 (57%) the third survey. Fifty-five surgeons (90%) completed the survey at least once, meaning that the feedback was reviewed by at least 90% of the surgeons since it was sent together with the survey. Twenty-three (38%) orthopedic surgeons completed the survey at all time points, and at least 1 surgeon for each hospital. In addition, 91% of respondents reported the feedback was clear after receiving the education. In terms of trial engagement, 4 hospitals reported they needed additional educational explanations on funnel plots and CUSUM charts, and 2 hospitals would appreciate more QIIs included in the toolbox. In addition, 7 hospitals requested being linked to a hospital that scored better on a performance indicator to improve further (“learning from the best”).

Table 3 Quality improvement initiatives per hospital and the source of the initiatives

Intervention hospital	Quality improvement initiatives	Toolbox	Literature	Expert opinion
1	*LOS:*			
	- Discharge 1 day postoperative if possible.	No	Yes	No
2	*Revision:*			
	- Reduce the number of dislocations for THA by no longer placing a 28mm cup and placing an "Avantage" cup earlier in older patients.	Yes	Yes	Yes
	- Pairing surgeons with more dislocations with surgeons with few dislocations to learn from best practices.	No	Yes	Yes
	LOS:			
	- Start mobilizing earlier after surgery.	No	No	No
	- Improve patient expectation management.	No	Yes	No
	- Earlier consultation of transfer agency.	No	Yes	No
3	*Readmission and complications:*			
	- Reduce wound leakage and surgical site infections by adjusting the wound closure technique, tissue protector for THA, and tranexamic acid during wound closure for TKA.	No	Yes	Yes
4	*LOS:*			
	- Earlier consultation of transfer agency.	No	No	Yes
5	*Revision, readmission, and complications:*			
	- Reduce surgical site infections and prosthetic joint infections by adjusting the wound closure technique (Roerdink et al, 2019).	No	Yes	Yes
	- Covering the sterile surgical field differently.	No	No	Yes
	- Short-term use of the tourniquet for TKA.	No	No	Yes
	- Use of prophylactic antibiotic as suggested in de guidelines of the Netherlands Orthopaedic association.	No	Yes	No
6	*Revision:*			
	- Reduce the number of infections by adopting pre-operative, intra-operative and post-operative interventions from the toolbox and the literature (not defined).	Yes	Yes	No
	LOS:			
	- Earlier consultation of transfer agency.	Yes	Yes	No
7	*LOS:*			
	- Mobilizing on the day of surgery.	Yes	No	No
	- Inform the patient before surgery about the expected LOS.	Yes	No	No
8	*Revision:*			
	- Introduction of a new type of prosthesis.	No	Yes	Yes
	- Introduction of an infection discussion in which improvement initiatives are evaluated.	No	Yes	No
	LOS:			
	- Prevent wound leakage by keeping the compression bandage in place longer in patients who have had surgery late in the day.	No	No	Yes
	- Closing the fascia with polydioxanone suture.	No	No	Yes
	- Close the subcutis in 2 layers.	No	No	Yes
	- Improve patient flow to the care hotel.	No	No	Yes

These are the quality improvement initiatives as reported in the bi-monthly surveys by the orthopaedic surgeons in the intervention hospitals. The initiatives are described under the indicator that the hospital aimed to improve with the initiative. However, the quality initiatives mentioned could affect other indicators, both positively and negatively. Two hospitals did not introduce any initiatives and are not included in the table.

LOS=length-of-stay; THA=total hip arthroplasty; TKA=total knee arthroplasty.

Table 3 shows descriptions of QIIs introduced in each hospital, intended to improve patient outcomes, including whether these were taken from the toolbox or based on other evidence. The median number of performance indicators for which QII were undertaken per hospital was 2 (IQR 1-2). Two hospitals did not introduce any QII, and of the remaining 8 hospitals most introduced QII to improve LOS.

Intervention hospitals that introduced QIIs improved significantly more in TO than control hospitals (1.32, 95% CI 1.10-1.57), whereas intervention hospitals not introducing any QII showed similar changes as control hospitals (0.93, 95% CI 0.67-1.30) (Figure 3). Of note, pre-intervention TO on average was lower for intervention hospitals that introduced QII compared with hospitals not introducing QII (85.2% versus 94.5%, $p<0.01$) with control hospitals at 82.6%. For the secondary outcomes, intervention hospitals that introduced QII to reduce long LOS improved significantly more than control hospitals. For complications, no difference was found for intervention hospitals that introduced QII targeting complications but hospitals not introducing these QII increased more in complications than control hospitals. No significant differences were found for hospitals introducing QII to reduce revisions or readmissions.

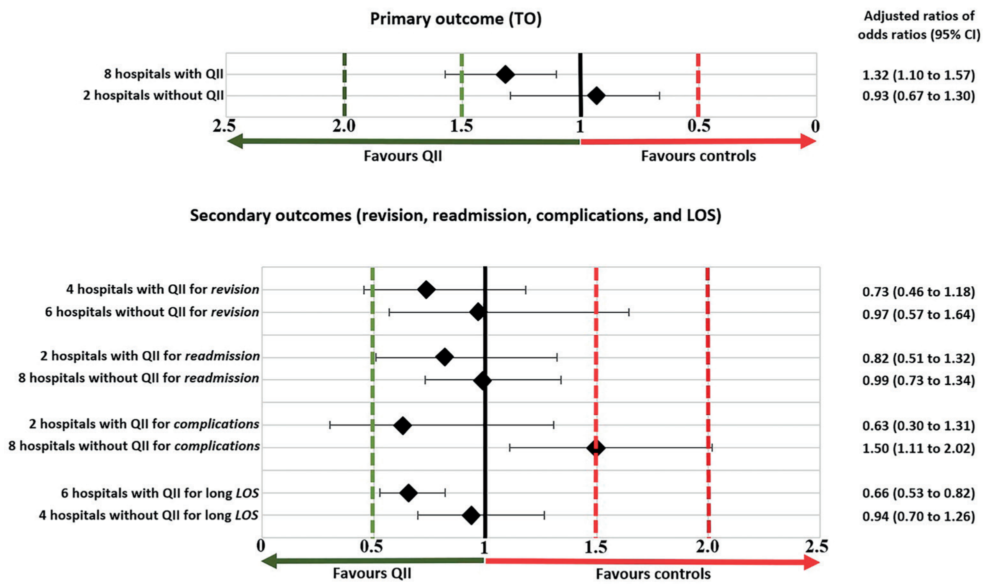


Figure 3 Primary and secondary outcomes by implementation of quality improvement initiatives
LOS=length of stay; TO=textbook outcome.

Discussion

The present study has shown that the multifaceted QI intervention was effective to increase the percentage of patients achieving TO more in intervention than control hospitals. Intervention hospitals that introduced QII improved significantly more in performance on TO than control hospitals, whereas intervention hospitals not introducing any QII showed comparable changes as control hospitals (but had higher pre-implementation TO). For the secondary outcomes, a higher reduction in patients with long LOS was found for intervention than control hospitals, and hospitals introducing QII to reduce LOS improved significantly more than control hospitals whereas hospitals not introducing these QIIs showed similar changes. Effects for readmission and revision seemed to go in the same direction, but were non-significant. However, intervention hospitals also showed a higher increase in the percentage of patients with reported complications than control hospitals. This seemed to be due to hospitals not introducing QII targeting complications, as those hospitals showed a higher increase in reported complications than control hospitals whereas hospitals introducing QIIs targeting complications showed similar changes. In addition, it may reflect increased sensitivity in reporting complications associated with the intervention. Taken together, these findings suggest that our multifaceted QI intervention was effective to improve TO for THA/TKA patients, most likely through the introduction of targeted QII particularly reducing long LOS.

Although a significant effect was only found for THA, the direction of the effect and some secondary outcomes (e.g., long LOS) were similar for TKA. This may be due to the smaller volume, as the median number of TKA surgeries was considerably smaller than for THA in intervention hospitals (Table 1), which may explain why the effect went in the same direction but was not significant. In addition, the baseline risks for revisions and complications were lower for TKA, mostly associated with smaller absolute risk reductions.

Comparison to the literature

The present study showed an absolute larger improvement of 4.32% in intervention versus control hospitals, similar to the median improvement shown for A&F interventions in a Cochrane review including 140 studies.(19) This suggests that about 50% of included studies in that review had smaller effects than the present study. A comparable cluster RCT using control charts and regular feedback resulted in an absolute reduction of major adverse events of 0.9%, or 114 patients needed to treat in intervention hospitals to prevent 1 adverse event.(33) However, such comparisons need to be done cautiously as included studies involve different populations being targeted and different control groups. For interventions like statins and aspirin it is known that both the absolute reduction and the number needed to treat (NNT) depend on the baseline risk.(32) This is equally relevant in our study, as the baseline risk for particularly revision and complications are already low, meaning that absolute risk reductions tend to be lower. This likely explains why the overall effect is driven by LOS and readmissions, with higher baseline risk.

Other QI initiatives have been described within orthopedics, such as the Continuous Quality Improvement Program for hip and knee replacement surgical care Canada.(34) A standardised care pathway was developed guided by the Triple Aim framework and six quality dimensions derived from the Institute of Medicine, using key performance indicators and benchmarked to give feedback twice a year to individual physicians, hospital administrators, and quality review teams on how they compare against a set threshold of good quality. Currently, 83% of orthopaedic surgeons participate in the program, representing 95% of the total volume of THA and TKA. In another QI project performed in the UK, a reduction in LOS was achieved from 3.6 to 2.4 days in one hospital for THA and TKA and 3.6 to 2.0 days in another, both by the introduction of PDSA cycles to improve on postoperative analgesia, physiotherapy and local policy.(35)

A previous study targeting quality of pain management in intensive care units showed an improvement in pain management when an action implementation toolbox was added to feedback compared with feedback alone, but only in process indicators and not in clinical outcomes.(23) The present study therefore adds that a comparable intervention where the toolbox included evidence-based measures targeting outcomes rather than merely process measures such as having a protocol in place, was effective in improving patient outcomes.

Strengths and limitations of this study

The strengths of this study include the robust randomised trial design, limited selection bias given that LROI data include more than 99% of all primary THA and TKA performed, and the required sample size of the power calculation achieved. [(29,30)] In addition, the intervention was developed guided by evidence and following the latest theory and recommendations.(22,23,36) The risk of contamination among control hospitals seems unlikely because control hospitals were not aware of the start of the implementation period and received the intervention at a later point in time, and feedback was tailored to a specific hospital. If contamination did occur, this would have diluted the intervention effect so that the true effect would potentially be larger. In addition, given the lower pre-implementation TO in control hospitals than in intervention hospitals, one would expect a larger change in control hospitals due to more potential for improvement and regression to the mean, making the opposite effect all the more notable. (19,37)

However, some limitations remain. First, the potential influence of a Hawthorne effect on study findings was largely compensated by control hospitals, as performance improved in both hospital groups. Second, information bias may occur if coding accuracy changed within hospitals between periods and differently for intervention than control hospitals. This seems unlikely, including that it would occur to such an extent that it would explain our results. Third, since outcome frequencies vary considerably between performance indicators, TO is dominated by long LOS, a well-known disadvantage of binary all-or-none composite outcomes.(38,39) However, estimates for the individual outcomes largely went in the same direction, albeit non-significant. Fourth, implementing the intervention in a specific country and for a specific type of surgery limits the generalisability of the results. Thus, the feasibility and impact of the intervention in a different context requires further study. Finally, patients were not involved in the design of this study which could have resulted in different outcomes being targeted by QI initiatives.

Implications and future research

Even though the multifaced QI intervention in the present study was shown to improve the quality of delivered care, the question is what is needed for hospitals to sustain these effects and potentially continue improving further. Only few studies describe how QI interventions became adopted in everyday practice.(40-43) Implementing a bundle of common QI interventions (e.g., staff education, A&F, alerts) to "quick fix" poor hospital performance may provide a temporary solution, but is not sustainable.(40,41) It appears from the emerging literature that sustainable interventions must provide solutions for the underlying problem. Only through understanding the problem, both an effective and sustainable intervention can be created that becomes part of everyday practice in the long term.(44) This may require that first an effective intervention needs to be found, to then solve how it can be adapted for everyday practice to be sustainable, using resources that remain available after the QI intervention ends.(45) In the present study's design, it was taken into account that intervention components would remain available for the LROI to apply them in other hospitals if the intervention proved to be effective. The CUSUM charts developed for the intervention are currently being implemented by the LROI.(25) In addition, the educational video and pocket card remain available, as well as the toolbox which can be kept up-to-date and further expanded with new effective QII appearing in the literature. Also, an annual educational session or workshop may keep hospitals both engaged to continue improving their care and act as further education, where participants in the current study may act as champions to share what worked and what not. Further engagement can also be supported by the toolbox being continuously updated as participants share and use each other's best practices and experiences, rather than a static list that may become outdated when new evidence appears.

Conclusions

The effect of QI interventions is known to vary, but an optimal design will reasonably improve patient care. The multifaceted intervention in the present study has shown that monthly updated feedback, education, an evidence-based implementation toolbox with suggested QII, and bimonthly surveys achieve a statistically significant larger improvement in outcomes for patients undergoing THA and TKA. The intervention effect was most likely achieved by introducing targeted QII particularly reducing long LOS.

Collaborators

We gratefully acknowledge the Dutch Arthroplasty Register (L.N. van Steenbergen, PhD) and the 20 hospitals who provided their data to complete this study, as part of the IQ Joint study group (in alphabetic order): Antonius Hospital, Sneek (S.T. Hokwerda, MD); Bergman Clinics (P.M. van Kampen, PhD); Bergman Clinics, Arnhem (I. Buchholz, MD); Bergman Clinics, Breda (J. Schrier, MD); Bergman Clinics, Delft (F. de Graaff, MD); Bergman Clinics, Naarden (H. Bouma, MD); Bergman Clinics, Rijswijk (T. Hogervorst, MD, PhD and J. Wolkenfelt, MD); Bergman Clinics, Rotterdam (M. Vischjager, MD, PhD); Catharina Hospital, Eindhoven (R.W.T.M. van Kempen, MD); Dijklander Hospital, Hoorn (G.C. Huitema, MD); Dijklander Hospital, Hoorn (L. de Vries, PhD); Elisabeth-TweeSteden Hospital (T. Gosens, MD, PhD); Gelderse Vallei Hospital, Ede (W. Beijneveld, MD); Maxima Medical Centre, Eindhoven (M. van den Besselaar, MD); Medical Spectrum Twente, Enschede (W. Verra, MD, PhD); OLVG, Amsterdam (R.W. Poolman, MD, PhD); OLVG, Amsterdam (V.A. Scholtes, PhD); Sint Anna Hospital, Geldrop (W. van der Weegen, PhD); Sint Franciscus Hospital, Schiedam (A. Polak, MD); Tjongerschans Hospital, Heerenveen (M. Mulder, PhD); University of Groningen, University Medical Center Groningen, Groningen (M. Stevens, PhD); Zuyderland Hospital, Sittard (B. Boonen, MD, PhD).

References

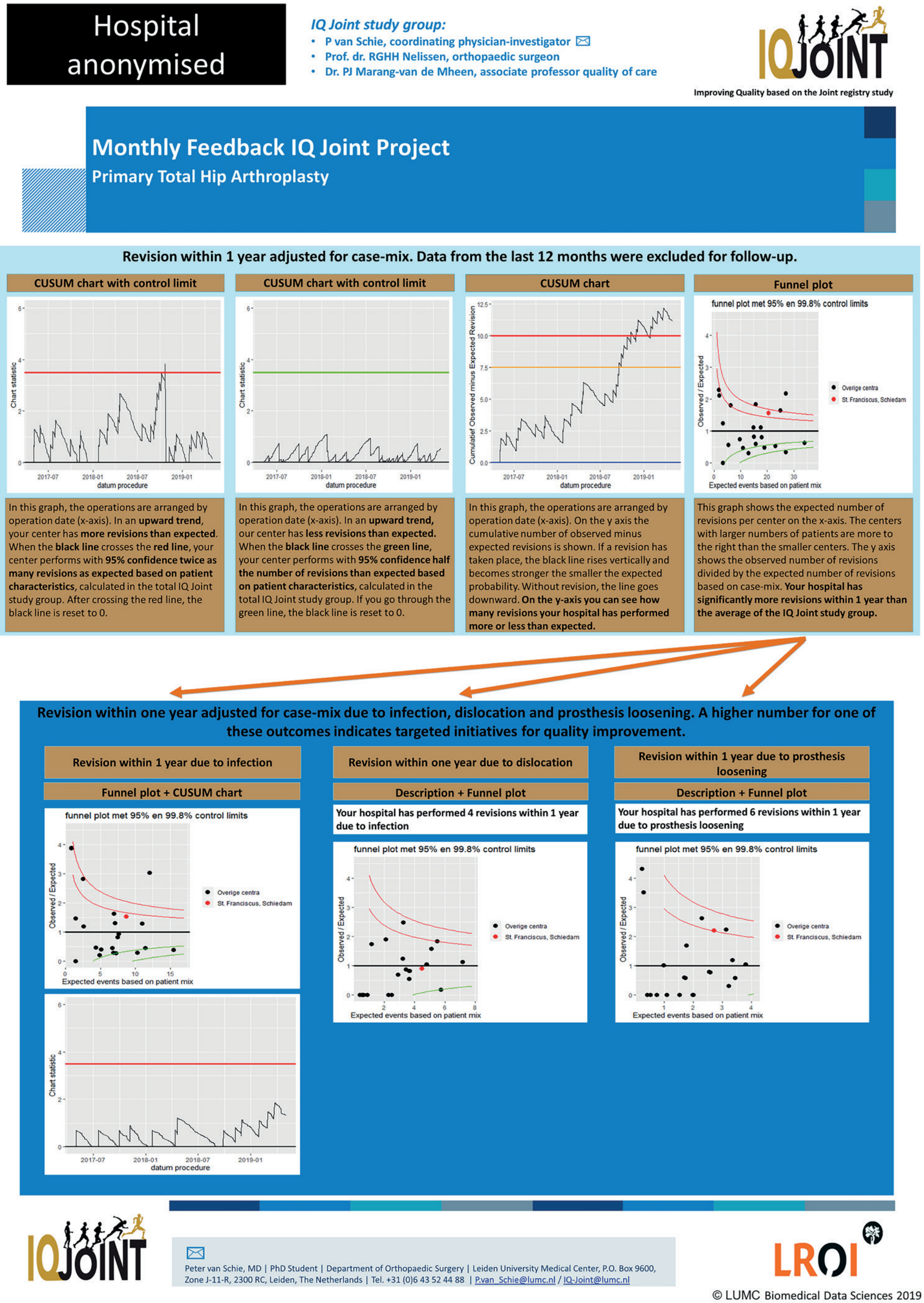
1. Nelson AE, Allen KD, Golightly YM, Goode AP, Jordan JM. A systematic review of recommendations and guidelines for the management of osteoarthritis: The chronic osteoarthritis management initiative of the U.S. bone and joint initiative. Semin Arthritis Rheum. 2014;43(6):701-12.
2. Bachmeier CJ, March LM, Cross MJ, Lapsley HM, Tribe KL, Courtenay BG, et al. A comparison of outcomes in osteoarthritis patients undergoing total hip and knee replacement surgery. Osteoarthritis Cartilage. 2001;9(2):137-46.
3. Wilson RA, Gwynne-Jones DP, Sullivan TA, Abbott JH. Total Hip and Knee Arthroplasties Are Highly Cost-Effective Procedures: The Importance of Duration of Follow-Up. J Arthroplasty. 2021.
4. Kurtz SM, Ong KL, Lau E, Bozic KJ. Impact of the economic downturn on total joint replacement demand in the United States: updated projections to 2021. J Bone Joint Surg Am. 2014;96(8):624-30.
5. Khan M, Osman K, Green G, Haddad FS. The epidemiology of failure in total knee arthroplasty: avoiding your next revision. Bone Joint J. 2016;98-b(1 Suppl A):105-12.
6. Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic burden of periprosthetic joint infection in the United States. J Arthroplasty. 2012;27(8 Suppl):61-5.e1.
7. Dutch Arthroplasty Register (LROI). Online Annual Report. https://www.lroi-report.nl/.
8. van Schie P, van Steenbergen LN, van Bodegom-Vos L, Nelissen R, Marang-van de Mheen PJ. Between-Hospital Variation in Revision Rates After Total Hip and Knee Arthroplasty in the Netherlands: Directing Quality-Improvement Initiatives. J Bone Joint Surg Am. 2019.
9. Bozic KJ, Grosso LM, Lin Z, Parzynski CS, Suter LG, Krumholz HM, et al. Variation in hospital-level risk-standardized complication rates following elective primary total hip and knee arthroplasty. J Bone Joint Surg Am. 2014;96(8):640-7.
10. Fry DE, Pine M, Nedza SM, Locke DG, Reband AM, Pine G. Risk-Adjusted Hospital Outcomes in Medicare Total Joint Replacement Surgical Procedures. J Bone Joint Surg Am. 2017;99(1):10-8.
11. Norwegian Arthroplasty Register (NAR). Annual Report 2020. http://nrlweb.ihelse.net/eng/Rapporter/Report2020_english.pdf.
12. Swedish Knee Arthroplasty Register (SKAR). Annual Report 2020. http://myknee.se/pdf/SVK_2020_Eng_1.0.pdf.
13. Danish Hip Arthroplasty Register (DHAR). Annual report 2020. http://danskhoftealloplastikregister.dk/wp-content/uploads/2020/11/dhr-aarsrapport-2020_til_offentliggoerelse-1.pdf.
14. Swedish Hip Arthroplasty Register (SHAR). Annual Report 2018. https://registercentrum.blob.core.windows.net/shpr/r/Arsrapport_2018_Hoftprotes_ENG_26mars_Final-rJepCXNsLI.pdf.
15. Danish Knee Arthroplasty Register (DKAR). Annual Report 2020. https://www.sundhed.dk/content/cms/99/4699_dkr-arsrapport-2020_offentliggorelse.pdf.
16. Finnish Arthroplasty Register (FAR). Online Annual Report. https://www.thl.fi/far/#index.
17. Swiss Arthroplasty Register (SAR). Annual Report 2020. https://www.siris-implant.ch/de/Downloads&category=16.
18. National Joint Registry (NJR). Annual report 2021. https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2018th%20Annual%20Report%202021.pdf.
19. Ivers N, Jamtvedt G, Flottorp S, Young JM, Odgaard-Jensen J, French SD, et al. Audit and feedback: effects on professional practice and healthcare outcomes. Cochrane Database Syst Rev. 2012(6):Cd000259.

20. Van Schie P, Van Bodegom-Vos L, Zijdeman TM, Nelissen R, Marang-Van De Mheen PJ. Awareness of performance on outcomes after total hip and knee arthroplasty among Dutch orthopedic surgeons: how to improve feedback from arthroplasty registries. Acta Orthop. 2020:1-8.
21. Soong C, Shojania KG. Education as a low-value improvement intervention: often necessary but rarely sufficient. BMJ quality & safety. 2020;29(5):353-7.
22. Gude WT, Roos-Blom MJ, van der Veer SN, de Jonge E, Peek N, Dongelmans DA, et al. Electronic audit and feedback intervention with action implementation toolbox to improve pain management in intensive care: protocol for a laboratory experiment and cluster randomised trial. Implement Sci. 2017;12(1):68.
23. Roos-Blom MJ, Gude WT, de Jonge E, Spijkstra JJ, van der Veer SN, Peek N, et al. Impact of audit and feedback with action implementation toolbox on improving ICU pain management: cluster-randomised controlled trial. BMJ quality & safety. 2019;28(12):1007-15.
24. ClinicalTrial.gov. https://clinicaltrials.gov/ct2/show/NCT04055103?term=Arthroplasty&cntry=NL&city=Leiden&draw=2&rank=2.
25. van Schie P, van Bodegom-Vos L, van Steenbergen LN, Nelissen R, Marang-van de Mheen PJ. Monitoring Hospital Performance with Statistical Process Control After Total Hip and Knee Arthroplasty: A Study to Determine How Much Earlier Worsening Performance Can Be Detected. J Bone Joint Surg Am. 2020;102(23):2087-94.
26. Woodall WH, Fogel, S.L., Steiner, S.H.. The monitoring and improvement of surgical-outcome quality. J Qual Technology. 2015(47):383-99.
27. Marang-van de Mheen PJ, van Hanegem N, Kievit J. Effectiveness of routine reporting to identify minor and serious adverse outcomes in surgical patients. Qual Saf Health Care. 2005;14(5):378-82.
28. El Bitar YF, Illingworth KD, Scaife SL, Horberg JV, Saleh KJ. Hospital Length of Stay following Primary Total Knee Arthroplasty: Data from the Nationwide Inpatient Sample Database. J Arthroplasty. 2015;30(10):1710-5.
29. van Steenbergen LN, Denissen GA, Spooren A, van Rooden SM, van Oosterhout FJ, Morrenhof JW, et al. More than 95% completeness of reported procedures in the population-based Dutch Arthroplasty Register. Acta Orthop. 2015;86(4):498-505.
30. Dutch Arthroplasty Register (LROI). Data completeness. https://www.lroi-report.nl/data-quality/completeness/.
31. Austin PC. Absolute risk reductions, relative risks, relative risk reductions, and numbers needed to treat can be obtained from a logistic regression model. J Clin Epidemiol. 2010;63(1):2-6.
32. McAlister FA. The "number needed to treat" turns 20--and continues to be used and misused. CMAJ. 2008;179(6):549-53.
33. Duclos A, Chollet F, Pascal L, Ormando H, Carty MJ, Polazzi S, et al. Effect of monitoring surgical outcomes using control charts to reduce major adverse events in patients: cluster randomised trial. BMJ. 2020;371:m3840.
34. Marshall DA, Christiansen T, Smith C, Squire Howden J, Werle J, Faris P, et al. Continuous quality improvement program for hip and knee replacement. Am J Med Qual. 2015;30(5):425-31.
35. Parkes RJ, Ayeko O, Brunton L, Griffiths-Jones W, Ungvari Z, Goss H. Revolutionising rapid recovery: a quality improvement project in hip and knee replacement. BMJ Open Qual. 2021;10(2).
36. Brehaut JC, Colquhoun HL, Eva KW, Carroll K, Sales A, Michie S, et al. Practice Feedback Interventions: 15 Suggestions for Optimizing Effectiveness. Ann Intern Med. 2016;164(6):435-41.
37. Marang-van de Mheen PJ, Abel, G. A., Shojania, K. G.. Mortality alerts, actions taken and declining mortality: true effect or regression to the mean? BMJ quality & safety. 2018.

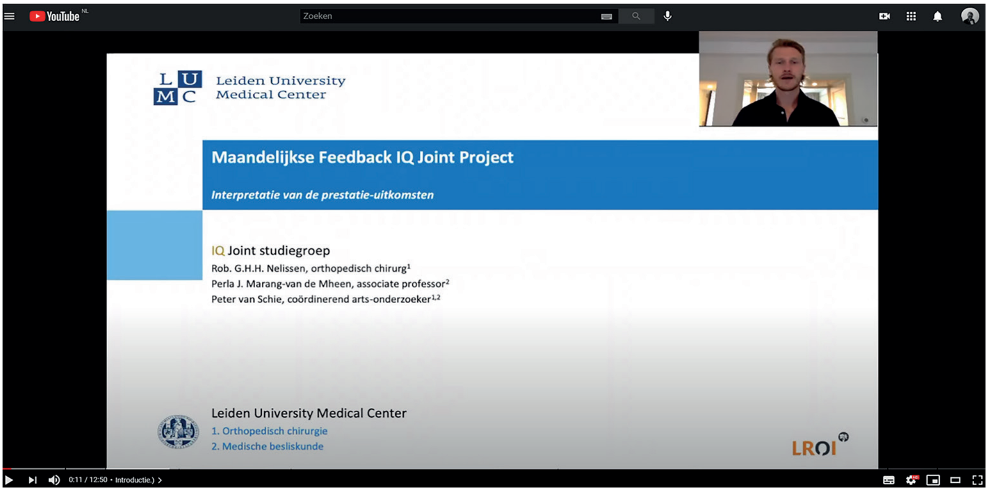
38. Montori VM, Permanyer-Miralda G, Ferreira-González I, Busse JW, Pacheco-Huergo V, Bryant D, et al. Validity of composite end points in clinical trials. BMJ. 2005;330(7491):594-6.
39. Barclay M, Dixon-Woods M, Lyratzopoulos G. The problem with composite indicators. BMJ quality & safety. 2019;28(4):338-44.
40. Glasgow JM, Davies ML, Kaboli PJ. Findings from a national improvement collaborative: are improvements sustained? BMJ quality & safety. 2012;21(8):663-9.
41. Bridges J, May C, Fuller A, Griffiths P, Wigley W, Gould L, et al. Optimising impact and sustainability: a qualitative process evaluation of a complex intervention targeted at compassionate care. BMJ quality & safety. 2017;26(12):970-7.
42. Lipitz-Snyderman A, Needham DM, Colantuoni E, Goeschel CA, Marsteller JA, Thompson DA, et al. The ability of intensive care units to maintain zero central line-associated bloodstream infections. Arch Intern Med. 2011;171(9):856-8.
43. Pronovost PJ, Watson SR, Goeschel CA, Hyzy RC, Berenholtz SM. Sustaining Reductions in Central Line-Associated Bloodstream Infections in Michigan Intensive Care Units: A 10-Year Analysis. Am J Med Qual. 2016;31(3):197-202.
44. Trbovich P, Shojania KG. Root-cause analysis: swatting at mosquitoes versus draining the swamp. BMJ quality & safety. 2017;26(5):350-3.
45. Burke RE, Marang-van de Mheen PJ. Sustaining quality improvement efforts: emerging principles and practice. BMJ quality & safety. 2021.

Supplemental data

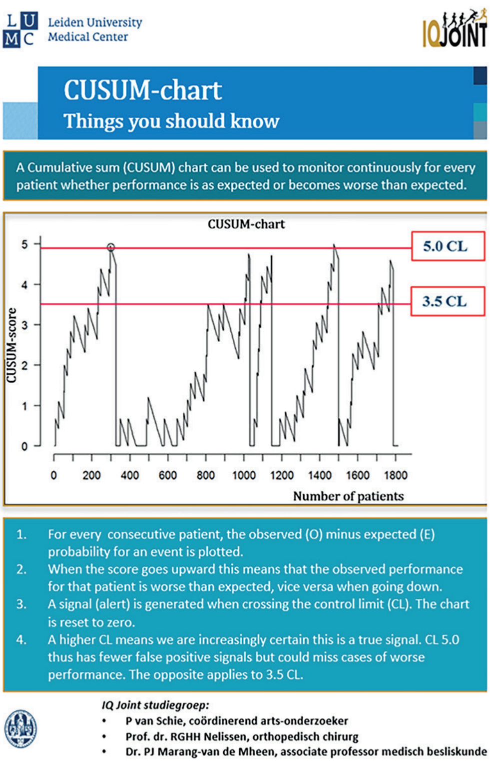
Appendix I

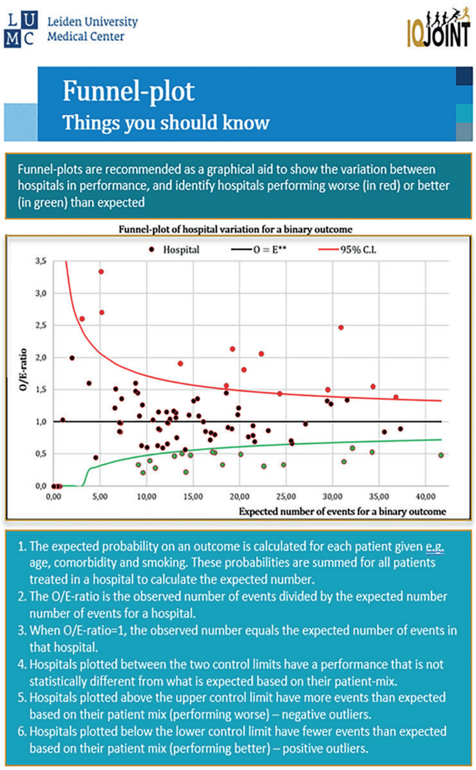


Appendix II



Appendix III





Appendix IV

Leiden University
Medical Center

IQ Joint study
Toolbox

Content of Toolbox

In this toolbox we offer starting points for quality improvement initiatives based on the currently available literature. The chapters are ordered according to the performance outcomes as offered in the monthly feedback. It is noted that this is not an exhaustive list.

We advise to implement quality improvement initiatives according to the Plan-Do-Check-Act cycle.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

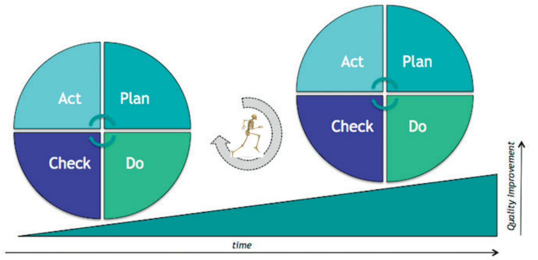
Leiden University Medical Center

IQ Joint study
Toolbox

Plan - Do - Check – Act cycle[1]

A iterative four-step management method used for the control and continuous improvement of processes, service and care delivery.

Plan	1. For which outcome an improvement is possible (outlier). • *Example: Infection.* 2. Identify possible reasons for the problem (define the process). • *Example: Check the electronic patient files to see if the last 100 patient have all received antibiotic prophylaxis. No, 4 patient did not.* 3. Plan Improvement/change. • *Example: Ask the anaesthetist for each patient during the ''Time Out Procedure'' whether the patient had received antibiotic prophylaxis and do this for 6 months.*
Do	1. Pilot → Carry out the improvement/change. • *Example: As described under Plan → 3.*
Check	1. What is the effect and is it as desired. • *Example: Check the electronic patient files to see if the last 100 patients have all received antibiotic prophylaxis. No, 1 patient did not.*
Act	1. Adopt the improvement/change or abandon it. • *Example: Adopt the change because it has led to a substantial improvement.* 2. Run through the cycle again.



Plan-Do-Check-Act cycle - Tague, Nancy R 2005

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Chapter 8

Leiden University Medical Center

IQ Joint study
Toolbox

Outcome: Infection (THA & TKA)

Topics are described where quality improvement initiatives could be considered.

Pre-operative	**Patient-specific factor optimization** • Poor nutritional status: Aim for Albumine blood levels >34g/L (healthy range: 34-54 g/L).[1,2,25] • Overweight: Aim for a BMI <30 kg/m^2. Every BMI-point decrease in obese patients reduces the chance on postoperative infection.[3-6] • Smoking: Convince patients to participate in smoking cessation programs. Smoking cessation for at least 4 weeks before surgery reduced infections.[7-9] • Immunocompromising diseases / Immunosuppressive drugs: Choose the most suitable moment to perform the operation. Consult other physicians if needed. • Glycaemic blood level control. Different glucose target levels were specified.[24] **MRSA screening & decolonisation** • Screening & decolonisation with mupirocin ointment and chlorhexidine show minimal reduction for infections.[10-15,24] Not recommended in NOV-guidelines (NOV guidelines - preoperative decolonisation) **Skin disinfection** • Consider to apply chlorhexidine around the operating area the night before and the morning of surgery.[16,17]
Intra-operative	**Antibiotic prophylaxis** • As recommended in NOV-guidelines (NOV guideline - systemic antibiotic prophylaxis). • Consider vancomycin for MRSA-colonized patients and institutions with high prevalence of MRSA-infections.[18] **Lavage** • Consider 3 minutes lavage with dilute anitsepticum (betadine/chlorhexidine).[19] Avoid lavage with surfactants or antibiotics.[23] Use a low-pressure delivery system for a <2L volume of solution.[23] **Prevent transfusions** • Check pre-operative hemoglobin level and correct if necessary preoperatively. • Tranexamic acid might help minimize blood loss and wound infection.[20,21] **Cement loaded with antibiotics** • As recommended in NOV-guidelines (NOV guidelines - Antibiotica-laden cement). **Surgical approach** • Lateral surgical approach results in more infections compared to posterior approach.[6] However, aach of the approaches has their own set of complications and benefits. **Bearing surface** • Ceramic-on-ceramic and ceramic-on-polyethylene surfaces are associated with lower risk of revisions for infection after 12 and 24 months respectively compared to metal-on-polyethylene.[6]
Post-operative	**Antibiotic prophylaxis** • As recommended in NOV-guidelines (NOV guideline - systemic antibiotic prophylaxis). **Wound leakage** • Is a wound leakage protocol available and is it followed sufficient? **Patient-specific factor optimization** • Blood glucose levels: Fasting blood glucose value <200mg/dl is suggested.[22]

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University
Medical Center

IQ Joint study

References

1. Mainous, M.R. and E.A. Deitch, Nutrition and infection. Surg Clin North Am, 1994. 74(3): p. 659-76.
2. Devoto, G., et al., Prealbumin serum concentrations as a useful tool in the assessment of malnutrition in hospitalized patients. Clin Chem, 2006. 52(12): p. 2281-5.
3. Dowsey, M.M. and P.F. Choong, Obese diabetic patients are at substantial risk for deep infection after primary TKA. Clin Orthop Relat Res, 2009. 467(6): p. 1577-81.
4. Dowsey, M.M. and P.F. Choong, Early outcomes and complications following joint arthroplasty in obese patients: a review of the published reports. ANZ J Surg, 2008. 78(6): p. 439-44.
5. D'Apuzzo, M.R., W.M. Novicoff, and J.A. Browne, The John Insall Award: Morbid obesity independently impacts complications, mortality, and resource use after TKA. Clin Orthop Relat Res, 2015. 473(1): p. 57-63.
6. Lenguerrand, E., et al., Risk factors associated with revision for prosthetic joint infection after hip replacement: a prospective observational cohort study. Lancet Infect Dis, 2018. 18(9): p. 1004-1014.
7. Kapadia, B.H., et al., Tobacco use may be associated with increased revision and complication rates following total hip arthroplasty. J Arthroplasty, 2014. 29(4): p. 777-80.
8. Kapadia, B.H., et al., Increased revision rates after total knee arthroplasty in patients who smoke. J Arthroplasty, 2012. 27(9): p. 1690-1695.e1.
9. Sorensen, L.T., Wound healing and infection in surgery. The clinical impact of smoking and smoking cessation: a systematic review and meta-analysis. Arch Surg, 2012. 147(4): p. 373-83.
10. Kapadia, B.H., et al., Pre-admission cutaneous chlorhexidine preparation reduces surgical site infections in total hip arthroplasty. J Arthroplasty, 2013. 28(3): p. 490-3.
11. Baratz, M.D., et al., Twenty Percent of Patients May Remain Colonized With Methicillin-resistant Staphylococcus aureus Despite a Decolonization Protocol in Patients Undergoing Elective Total Joint Arthroplasty. Clin Orthop Relat Res, 2015. 473(7): p. 2283-2290.
12. Rao, N., et al., Preoperative screening/decolonization for Staphylococcus aureus to prevent orthopedic surgical site infection: prospective cohort study with 2-year follow-up. J Arthroplasty, 2011. 26(8): p. 1501-7.
13. Sporer, S.M., T. Rogers, and L. Abella, Methicillin-Resistant and Methicillin-Sensitive Staphylococcus aureus Screening and Decolonization to Reduce Surgical Site Infection in Elective Total Joint Arthroplasty. J Arthroplasty, 2016. 31(9 Suppl): p. 144-7.
14. Schweizer, M.L., et al., Association of a bundled intervention with surgical site infections among patients undergoing cardiac, hip, or knee surgery. Jama, 2015. 313(21): p. 2162-71.
15. Stambough, J.B., et al., Corrigendum to "Decreased Hospital Costs and Surgical Site Infection Incidence With a Universal Decolonization Protocol in Primary Total Joint Arthroplasty" [Journal of Arthroplasty 32 (2017) 728-734]. J Arthroplasty, 2017. 32(8): p. 2625.
16. Kapadia, B.H., et al., Pre-admission cutaneous chlorhexidine preparation reduces surgical site infections in total hip arthroplasty. J Arthroplasty, 2013. 28(3): p. 490-3.
17. Johnson, A.J., et al., Chlorhexidine reduces infections in knee arthroplasty. J Knee Surg, 2013. 26(3): p. 213-8.
18. Bratzler, D.W., et al., Clinical practice guidelines for antimicrobial prophylaxis in surgery. Surg Infect (Larchmt), 2013. 14(1): p. 73-156.
19. Brown, N.M., et al., Dilute betadine lavage before closure for the prevention of acute postoperative deep periprosthetic joint infection. J Arthroplasty, 2012. 27(1): p. 27-30.
20. Sukeik, M., et al., Systematic review and meta-analysis of the use of tranexamic acid in total hip replacement. J Bone Joint Surg Br, 2011. 93(1): p. 39-46.
21. Sukeik, M., et al., The effect of tranexamic acid on wound complications in primary total Hip Arthroplasty: A meta-analysis. Surgeon, 2019.
22. Mraovic, B., et al., Perioperative hyperglycemia and postoperative infection after lower limb arthroplasty. J Diabetes Sci Technol, 2011. 5(2): p. 412-8.
23. Kavolus, J., et al., Irrigation fluids used for the prevention and treatment of orthopaedic infections. J Bone Joint Surg Am, 2020;102:76-84.
24. Fields, A.C., J.C. Pradarelli, and K.M.F. Itani, Preventing Surgical Site Infections: Looking Beyond the Current Guidelines. Jama, 2020.
25. Gu A, et al., Preoperative malnutrition negatively correlates with postoperative wound complications and infection after total join arthroplasty: a systematic review and meta-analysis. J Arthroplasty. 2019 May;34(5):1013-24.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University
Medical Center

IQ Joint study
Toolbox

Outcome: Prosthesis loosening (THA & TKA)

Topics are described where quality improvement initiatives could be considered.

Aseptic loosening	Patient risk factors	Patient-specific factor optimization • Smoking: Convince patients to participate in smoking cessation programs. Smoking significantly increases risk of aseptic loosening.[1] • Age: Postpone the operation if possible. Lower age has a higher chance on aseptic loosening in the future.[2]
Aseptic loosening	Prosthesis factors	THA • Advise low-impact activities such as walking, swimming and cycling. Patient undertaking intermediate to intense activity are four times more likely than less active people to develop acetabular prosthesis loosening due to more wear.[3-6] • Use cross-linked polyethylene liners instead of conventional liners to reduce wear and revisions.[7-9] TKA • Roentgen stereophotogrammetric analyses (RSA)-studies showed favorable outcomes on prosthesis loosening in the first two year for cemented implants, but unfavorable outcomes after two years when compared to uncemented implants.[10] THA &TKA • Has a new prothesis been implemented recently? Has sufficient training taken place? Schedule a meeting where experiences can be shared.
Aseptic loosening	Surgical factors	Cementation techniques • Distal and proximal prosthesis centralization • Adequate canal preparation with pulsatile lavage to increase cement penetration and interdigitation. • Is there profit to be gained within one of the phases: mixing, waiting, working or setting? • Check the most recent manual for use of the cement.
Septic loosening	Take a look at the toolbox for infection	

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University Medical Center

IQ Joint study

References

1. Teng, S., et al., Smoking and risk of prosthesis-related complications after total hip arthroplasty: a meta-analysis of cohort studies. PLoS One, 2015. 10(4): p. e0125294.
2. Bordini, B., et al., Factors affecting aseptic loosening of 4750 total hip arthroplasties: multivariate survival analysis. BMC Musculoskelet Disord, 2007. 8: p. 69.
3. Flugsrud, G.B., et al., The effect of middle-age body weight and physical activity on the risk of early revision hip arthroplasty: a cohort study of 1,535 individuals. Acta Orthop, 2007. 78(1): p. 99-107.
4. Lubbeke, A., et al., Influence of patient activity on femoral osteolysis at five and ten years following hybrid total hip replacement. J Bone Joint Surg Br, 2011. 93(4): p. 456-63.
5. Schmalzried, T.P., et al., The John Charnley Award. Wear is a function of use, not time. Clin Orthop Relat Res, 2000(381): p. 36-46.
6. Emms, N.W., et al., Long-term outcome of a cementless, hemispherical, press-fit acetabular component: survivorship analysis and dose-response relationship to linear polyethylene wear. J Bone Joint Surg Br, 2010. 92(6): p. 856-61.
7. Australian Orthopaedic Association National Joint Registry, Annual report. 2017
8. Paxton, E.W., et al., Metal-on-conventional polyethylene total hip arthroplasty bearing surfaces have a higher risk of revision than metal-on-highly crosslinked polyethylene: results from a US registry. Clin Orthop Relat Res, 2015. 473(3): p. 1011-21.
9. Hanna, S.A., et al., Highly cross-linked polyethylene decreases the rate of revision of total hip arthroplasty compared with conventional polyethylene at 13 years' follow-up. Bone Joint J, 2016. 98-b(1): p. 28-32.
10. Nakama, G.Y., et al., Cemented, cementless or hybrid fixation options in total knee arthroplasty for osteoarthritis and other non-traumatic diseases. Cochrane Database Syst Rev, 2012. 10: p. CD006193.

IQ Joint studiegroep:

•P van Schie, coördinerend arts-onderzoeker

•Prof. dr. RGHH Nelissen, orthopedisch chirurg

•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University Medical Center

IQ Joint study
Toolbox

Outcome: Dislocation (THA)

Topics are described where quality improvement initiatives could be considered.

Pre-operative

Patient-specific factor optimization
- Overweight: Aim for a BMI<30 kg/m². Dislocation after THA occurs more often in obese patients.[1-4]

Intra-operative

Femoral head size
- In most patients a femoral head size of 32 mm is recommended following the NOV-guidelines (NOV guideline - femoral head diameter).
- Larger femoral head size decreases dislocation rates due to greater jumping distance and a greater range of motion.[1,5-7] However, heads above 32-mm lead to more friction and more wear with prosthesis loosening as a possible consequence.[8,9]
- If a head larger than 32 mm is indicated, it seems best to use a ceramic-on-ceramic prosthesis because this combination shows lowest wear (NOV guideline - femoral head diameter).[8]
- For the posterolateral approach 36-mm head can safely further reduce the risk of revision for dislocation (without an increased number of revisions for all other reasons within 6 years).[10]

Surgical approach
- Each of the approaches has their own set of complications and benefits. Both the posterior, lateral and anterior approach can be used (NOV guideline - surgical approach).
- Some registries report increased dislocation rates for posterior approach when compared to anterior and direct lateral at 6-year follow-up.[10,11] However, the revision rate for all other revisions was higher with anterior approach and lowest with posterior approach.[10]
- If the posterior approach is chosen, surgeons should reconstruct the posterior capsule and the external rotators to prevent dislocations (NOV guideline - surgical approach).

Dual mobility cup
- Dual mobility articulations are a viable alternative in cases with increased risk of instability or dislocation, however, evidence is limited (NOV guideline - dual mobility cup). Following patient groups have an increased risk of dislocations and may benefit from a dual mobility cup: spinal injury, poliomyelitis, cerebral palsy, femoral neck fracture, acetabular dysplasia, muscular dystrophy and intellectual impairment.[12-16]
- The 5-year cup revision rates are comparable to that of traditional unipolar cups.[17]

Stability Assessment
- Minimize impingement by removing osteophytes, thickened capsule or increase offset.
- A lipped liner can offer stability in extremes of movement.[18]

New prosthesis
- Has sufficient training taken place?
- Schedule a meeting where experiences can be shared.

Post-operative

Hip dislocation precaution
- Early dislocation rates do not decrease with hip dislocation precaution.[16,19] Evidence is limited and included only studies with anterolateral and posterolateral approaches. Further, abandoning mobilization restrictions increases patient satisfaction through earlier return of daily activities to preoperative levels.[20,21]

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University Medical Center

IQ Joint study
References

1. Howie, D.W., O.T. Holubowycz, and R. Middleton, Large femoral heads decrease the incidence of dislocation after total hip arthroplasty: a randomized controlled trial. J Bone Joint Surg Am, 2012. 94(12): p. 1095-102.
2. Haverkamp, D., et al., Obesity in total hip arthroplasty--does it really matter? A meta-analysis. Acta Orthop, 2011. 82(4): p. 417-22.
3. Wagner, E.R., et al., Effect of Body Mass Index on Complications and Reoperations After Total Hip Arthroplasty. J Bone Joint Surg Am, 2016. 98(3): p. 169-79.
4. Li, W., et al., Functional Gain and Pain Relief After Total Joint Replacement According to Obesity Status. J Bone Joint Surg Am, 2017. 99(14): p. 1183-1189.
5. Stroh, D.A., et al., Reduced dislocation rates and excellent functional outcomes with large-diameter femoral heads. J Arthroplasty, 2013. 28(8): p. 1415-20.
6. Sariali, E., et al., Mathematical evaluation of jumping distance in total hip arthroplasty: influence of abduction angle, femoral head offset, and head diameter. Acta Orthop, 2009. 80(3): p. 277-82.
7. Kostensalo, I., et al., Effect of femoral head size on risk of revision for dislocation after total hip arthroplasty: a population-based analysis of 42,379 primary procedures from the Finnish Arthroplasty Register. Acta Orthop, 2013. 84(4): p. 342-7.
8. Tsikandylakis, G., et al., Head size in primary total hip arthroplasty. EFORT Open Rev, 2018. 3(5): p. 225-231.
9. Charnley, J., A. Kamangar, and M.D. Longfield, The optimum size of prosthetic heads in relation to the wear of plastic sockets in total replacement of the hip. Med Biol Eng, 1969. 7(1): p. 31-9.
10. Zijlstra, W.P., et al., Effect of femoral head size and surgical approach on risk of revision for dislocation after total hip arthroplasty. Acta Orthop, 2017. 88(4): p. 395-401.
11. Sheth, D., et al., Anterior and Anterolateral Approaches for THA Are Associated With Lower Dislocation Risk Without Higher Revision Risk. Clin Orthop Relat Res, 2015. 473(11): p. 3401-3408.
12. Hernigou, P., et al., Dual-mobility or Constrained Liners Are More Effective Than Preoperative Bariatric Surgery in Prevention of THA Dislocation. Clin Orthop Relat Res, 2016. 474(10): p. 2202-10.
13. Queally, J.M., A. Abdulkarim, and K.J. Mulhall, Total hip replacement in patients with neurological conditions. J Bone Joint Surg Br, 2009. 91(10): p. 1267-73.
14. Houdek, M.T., et al., Total Hip Arthroplasty in Patients with Cerebral Palsy: A Cohort Study Matched to Patients with Osteoarthritis. J Bone Joint Surg Am, 2017. 99(6): p. 488-493.
15. Sanders, R.J., B.A. Swierstra, and J.H. Goosen, The use of a dual-mobility concept in total hip arthroplasty patients with spastic disorders: no dislocations in a series of ten cases at midterm follow-up. Arch Orthop Trauma Surg, 2013. 133(7): p. 1011-6.
16. Barnsley, L., L. Barnsley, and R. Page, Are Hip Precautions Necessary Post Total Hip Arthroplasty? A Systematic Review. Geriatr Orthop Surg Rehabil, 2015. 6(3): p. 230-5.
17. Bloemheuvel, E.M., L.N. van Steenbergen, and B.A. Swierstra, Dual mobility cups in primary total hip arthroplasties: trend over time in use, patient characteristics, and mid-term revision in 3,038 cases in the Dutch Arthroplasty Register (2007-2016). Acta Orthop, 2019. 90(1): p. 11-14.
18. Sculco, P.K., et al., Avoiding Hip Instability and Limb Length Discrepancy After Total Hip Arthroplasty. Orthop Clin North Am, 2016. 47(2): p. 327-34.
19. Gromov, K., et al., Removal of restrictions following primary THA with posterolateral approach does not increase the risk of early dislocation. Acta Orthop, 2015. 86(4): p. 463-8.
20. Ververeli, P.A., et al., Evaluation of reducing postoperative hip precautions in total hip replacement: a randomized prospective study. Orthopedics, 2009. 32(12): p. 889.
21. Peak, E.L., et al., The role of patient restrictions in reducing the prevalence of early dislocation following total hip arthroplasty. A randomized, prospective study. J Bone Joint Surg Am, 2005. 87(2): p. 247-53.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University Medical Center

IQ JOINT

IQ Joint study
Toolbox

Outcome: Technical failure (TKA)

Topics are described where quality improvement initiatives could be considered.

Malalignment

Coronal plane (varus/valgus)
- Former studies suggest that mechanical malalignment with an angle >3° results in higher revision rates.[1,2] However, more recent studies suggest anatomical alignment is more important and showed no association between mechanical malalignment (>3°) and revision rates.[3-7] Optimal alignment seems an anatomical tibiofemoral angle of 7 to 9° valgus with the mechanical axis through the medial third of the knee.[8-10]

Sagittal and axial plane
- Sagittal and axial malalignment is associated with increases revision rates.[9]

Rotational alignment
- A positive correlation was found between external rotation of the tibial and the femoral component and the Knee Society Score.[19]

New prosthesis
- Has sufficient training taken place?
- Schedule a meeting where experiences can be shared.

Instability

Etiology
- Early (within one year) postoperative instability may be required for various reasons, including malalignment of components, implant loosening, improper balance of the flexion-extension space, rupture or laxity of the posterior cruciate ligament or medial collateral ligament and patellar tendon rupture or patella fracture.[11-16]
- Some patient are prone to instability. Those who have rheumatoid arthritis, connective tissue disease, severe osteoporosis, neuromuscular pathology, gross deformities who need severe correction with ligament release, foot deformities and quadriceps/medial thrust hip abductor weakness.[15,17]

Patient-specific factor optimization
- Overweight: Aim for a BMI<30 kg/m^2. Obesity is a risk factor because it complicates surgical exposure, jeopardizes the collateral ligament.[15]

Pre-operative / intra-operative
- Evaluation the state of the lateral and medial collateral ligament and posterior cruciate ligament (PCL) with physical examination in order to select the right implant for each patient.[16] Instability can be prevented in most cases with appropriate prosthesis selection and good surgical technique (e.g. prevent soft tissue damage, correct implantation of components in every plane).[12,14] Posterior stabilized implants should be utilized in those patients with PCL insufficiency and in those with increase risk of posterior instability (e.g. rheumatoid arthritis, need to resect the PCL, flexion contracture or previous tibial osteotomy). If the choice is made to preserve the PCL, it is important to take special care in maintaining its integrity when the tibial cut is made. In case of doubt, it is preferable to convert the arthroplasty to a posterior stabilized design. In some patients with marked instability (medial or lateral collateral loss, massive bone loss including the femoral condyles, complete or insufficiency of the PCL, poliomyelitis , or Charcot arthropathy), a primary constrained or linked hinge implant may me indicated.[16]

Patellar dislocation

Intra-operative
- Patella maltracking or dislocation is closely related to malalignment. In most patients, functional patellar tracking is achieved by a good prosthesis positioning by checking the femoral implant rotation, femoral implant flexion, femoral implans varus/valgus positioning, femoral implant mediolateral or medialization, tibial implant rotation. Excessive internal rotation of the tibial component or femur component promotes external rotation during walking, thereby increasing the risk of patellar dislocation. The more externally rotated the implant, the less risk there is for lateral patellar maltracking. However, , this must not be at the expense of tibiofemoral alignment and stability.[11] Postoperative patella alta and non-medialized implantation of a patellar prosthesis are also risk factor.[18]

Leiden University Medical Center

IQ JOINT

IQ Joint study

References

1. Jeffery, R.S., R.W. Morris, and R.A. Denham, Coronal alignment after total knee replacement. J Bone Joint Surg Br, 1991. 73(5): p. 709-14.
2. Kim, Y.H., et al., Computer-assisted surgical navigation does not improve the alignment and orientation of the components in total knee arthroplasty. J Bone Joint Surg Am, 2009. 91(1): p. 14-9.
3. Hadi, M., et al., Does malalignment affect revision rate in total knee replacements: a systematic review of the literature. Springerplus, 2015. 4: p. 835.
4. Parratte, S., et al., Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. J Bone Joint Surg Am, 2010. 92(12): p. 2143-9.
5. Bonner, T.J., et al., The effect of post-operative mechanical axis alignment on the survival of primary total knee replacements after a follow-up of 15 years. J Bone Joint Surg Br, 2011. 93(9): p. 1217-22.
6. Magnussen, R.A., et al., Residual varus alignment does not compromise results of TKAs in patients with preoperative varus. Clin Orthop Relat Res, 2011. 469(12): p. 3443-50.
7. Matziolis, G., J. Adam, and C. Perka, Varus malalignment has no influence on clinical outcome in midterm follow-up after total knee replacement. Arch Orthop Trauma Surg, 2010. 130(12): p. 1487-91.
8. Ritter, M.A., et al., The effect of alignment and BMI on failure of total knee replacement. J Bone Joint Surg Am, 2011. 93(17): p. 1588-96.
9. Kim, Y.H., et al., The relationship between the survival of total knee arthroplasty and postoperative coronal, sagittal and rotational alignment of knee prosthesis. Int Orthop, 2014. 38(2): p. 379-85.
10. Fang, D.M., M.A. Ritter, and K.E. Davis, Coronal alignment in total knee arthroplasty: just how important is it? J Arthroplasty, 2009. 24(6 Suppl): p. 39-43.
11. Bozic, K.J., et al., The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res, 2010. 468(1): p. 45-51.
12. Sharkey, P.F., et al., Insall Award paper. Why are total knee arthroplasties failing today? Clin Orthop Relat Res, 2002(404): p. 7-13.
13. Gioe, T.J., et al., Why are total knee replacements revised?: analysis of early revision in a community knee implant registry. Clin Orthop Relat Res, 2004(428): p. 100-6.
14. Chang, M.J., et al., Diagnosis, causes and treatments of instability following total knee arthroplasty. Knee Surg Relat Res, 2014. 26(2): p. 61-7.
15. Vince, K.G., A. Abdeen, and T. Sugimori, The unstable total knee arthroplasty: causes and cures. J Arthroplasty, 2006. 21(4 Suppl 1): p. 44-9.
16. Rodriguez-Merchan, E.C., Instability following total knee arthroplasty. Hss j, 2011. 7(3): p. 273-8.
17. Meding, J.B., et al., Genu recurvatum in total knee replacement. Clin Orthop Relat Res, 2003(416): p. 64-7.
18. Berger, Crossett, Jacobs, Rubash. 1998.
19. Valkering K.P., et al. Effect of rotational alignment on outcome of total knee arthroplasty; A systematic review of the literature and correlation analysis. Acta Orthopaedica, 86:4, 432-439.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University Medical Center

IQ Joint study
Toolbox

Length of hospital stay

Below, topics are described where quality improvement initiatives can be considered.

Pre-operative

Fast-track program

- Implement a fast track surgery program in THA surgery is associated with a reduction in post-operative length of stay (LOS), shorter convalescence and rapid functional recovery, without increased morbidity and mortality.[1,2] (NOV guidelines - fast-track program)
- Mention the expected date of discharge prior to operation so that patients know what is to be expected.

Patient-specific factor optimization

- Optimize glucose levels in patient with type I diabetes, since it gives an elevated risk of complications after THA / TKA surgery, thus a prolonged LOS.[3]
- Pre-operative iron-deficiency anaemia is associated with increased risk of LOS>5 days after adjustment for pre-operative patient-related risk factors. It should be detected in pre-operative evaluation and treated before surgery to ensure maximum rehabilitation.[4]
- Malnutrition; levels of albumin, total lymphocytes and transferrin should be monitored and be restored if not within the normal ranges (34-54 g/L, 3900-10000 cells/μL and 170-370 mg/dl respectively), because malnourished patients are at higher risk for surgical complications and thus a higher probability of prolonged LOS.[5]
- Pre-operative opioid use is a risk factor for post-operative pain at rest and during walking which impairs fast-track recovery among TKA patients and leads to increased opioid consumption post-operative. It should be detected in pre-operative evaluation and the patient need to be persuaded to keep opioid use to a minimum.[6,7]
- Social support; inadequate social support e.g. living alone, is associated with a longer LOS. Optimizing the organizational part of patient pathway and optimizing social support before admission for surgery avoids delayed discharge.[8,9]

Intra-operative

Medication

- A protocol of scheduled oral narcotics, cyclooxygenase-2 inhibitors, a local anesthetic for wound infiltration and no intrathecal narcotics (TKA: add femoral nerve catheter) shows significant improvements regarding LOS and post-operative pain-scores.[10] However, another study showed only a significant improvement in pain-scores and opioid requirements, but showed an effect on LOS although not significant.[11]
- A single dose of 125 mg methylprednisolone given pre-operatively, reduces pain in THA patient in the first post-operative 24 hours, thus enlarging the chance of satisfactory day-of-surgery mobilization and early discharge.[12,13]

Surgical technique

- Direct anterior approach (DAA) shows an advantage regarding mean hospital stay compared with posterolateral (PL) approach in THA surgery.[14]

Post-operative

Delay of discharge

- Medical interventions; delay of discharge due to e.g. waiting for blood transfusion, start of physiotherapy or post-operative radiographic examination, should be avoided through multidisciplinary organization and planning.[15]
- Repeating / mentioning of the expected date and time of delay when there are no complications.

Oral pain treatment

- Oral treatment should be a combination of a NSAID, paracetamol and short acting-opioid.

Mobilization on day of surgery

- Mobilization on the day of surgery significantly increases the probability of early discharge.[16]

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University
Medical Center

IQ Joint studie

Referenties

1. Ansari, D., et al. (2013). "Fast-track surgery: procedure-specific aspects and future direction." Langenbecks Arch Surg 398(1): 29-37.
2. Hansen, TB. Fast track in hip arthroplasty. 2017
3. Viens, N. A., et al. (2012). "Role of diabetes type in perioperative outcomes after hip and knee arthroplasty in the United States." J Surg Orthop Adv 21(4): 253-260.
4. Jans, O., et al. (2014). "Role of preoperative anemia for risk of transfusion and postoperative morbidity in fast-track hip and knee arthroplasty." Transfusion 54(3): 717-726.
5. Nicholson, J. A., et al. (2012). "Nutritional status and short-term outcome of hip arthroplasty." J Orthop Surg (Hong Kong) 20(3): 331-335.
6. Aasvang, E. K., et al. (2016). "Chronic pre-operative opioid use and acute pain after fast-track total knee arthroplasty." Acta Anaesthesiol Scand 60(4): 529-536.
7. Goesling, J., et al. (2016). "Trends and predictors of opioid use after total knee and total hip arthroplasty." Pain 157(6): 1259-1265.
8. Napier, R. J., et al. (2013). "Modifiable factors delaying early discharge following primary joint arthroplasty." Eur J Orthop Surg Traumatol 23(6): 665-669.
9. den Hartog, Y. M., et al. (2015). "Which patient characteristics influence length of hospital stay after primary total hip arthroplasty in a 'fast-track' setting?" Bone Joint J 97-B(1): 19-23.
10. Peters, C. L., et al. (2006). "The effect of a new multimodal perioperative anesthetic regimen on postoperative pain, side effects, rehabilitation, and length of hospital stay after total joint arthroplasty." J Arthroplasty 21(6 Suppl 2): 132-138.
11. Andersen, L. O. and H. Kehlet (2014). "Analgesic efficacy of local infiltration analgesia in hip and knee arthroplasty: a systematic review." Br J Anaesth 113(3): 360-374.
12. Husted, H., et al. (2010). "Care principles at four fast-track arthroplasty departments in Denmark." Dan Med Bull 57(7): A4166.
13. Lunn, T. H., et al. (2013). "Effect of high-dose preoperative methylprednisolone on recovery after total hip arthroplasty: a randomized, double-blind, placebo-controlled trial." Br J Anaesth 110(1): 66-73.
14. Godoy-Monzon, D., et al. (2019). "Comparative study of radiological and functional outcomes following a direct anterior approach versus to a posterolateral approach to the hip." Rev Esp Cir Ortop Traumatol 63(5): 370-375.
15. Husted, H., et al. (2011). "Why still in hospital after fast-track hip and knee arthroplasty?" Acta Orthop 82(6): 679-684.
16. Okamoto, T., et al. (2016). "Day-of-Surgery Mobilization Reduces the Length of Stay After Elective Hip Arthroplasty." J Arthroplasty 31(10): 2227-2230.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Chapter 8

Leiden University Medical Center

IQ Joint study
Toolbox

Outcome: Number of hospital readmission within 30 days

Topics are described where quality improvement initiatives could be considered.

General information	
General information	Readmissions • Primary diagnoses at readmission that were identified to be directly attributable to surgery comprised 38% readmissions at 0-30 days, 24% at 31-60 days and 16% at 60-90 days. Proportion attributable to surgery decreases significantly over the 90-day period after index surgery.[1] • The most frequent readmission diagnosis after TKA is surgical site infection.[2] • An increased length of stay, discharge disposition, blood transfusion and general anaesthesia are associated with readmission.[3] Length of hospital stay (LOS) and readmissions • Decreasing the LOS does not increase the risk of readmissions.[4-7] No difference in 90-day-readmission odds between patients with a 1-midnight LOS and those with a 2-midnight LOS for primary TKA was identified.[8,9] Patient-specific factor optimization • Smoking: Convince patients to participate in smoking cessation programs. Smoking increases the risk of 90-days readmission.[8,10]
What kind of readmissions are involved	An example of a plan of approach for file investigation: 1. Take a closer look at 50 file. Exclude patients with relatively high mortality risk. These are the patients with probably a high disease burden and therefore relatively little chance of finding points for improvement. 2. How soon after discharge did the readmission take place (within a week or later)? Selection for early readmissions gives maximum chance to find improvement regarding potential too early discharge or incorrect information transfer. Selection for late readmissions often indicates complications after discharge. 3. Make a distinction between re-admissions in the same diagnosis group as the index admission versus in another diagnosis group. If the re-admission diagnosis group is the same as the index admission, this may be an indication that the patient was discharged too soon. If the re-admission concerns a different diagnosis group than the index admission, then there may be a re-admission with a complication. Of course it is possible that there is no relationship with the surgical procedure earlier.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University
Medical Center

IQ Joint study
Referenties

1. Braud, J., Ramanathan, D., Klika, A., Navale, S., Higuera, C., Molloy, R. Temporal Relations of Unplanned Readmissions Following Total Knee Arthroplasty: A Study of Large State Inpatient Databases. J Arthroplasty. 2017; 32(9S): p. S119-S123.
2. WHO Regional Office for Europe. Do current discharge arrangements from inpatient hospital care for the elderly reduce readmission rates, the length of inpatient stay or mortality, or improve health status?. Copenhagen, Denmar: WHO Regional Office for Europe; 2005.
3. Mesko, N.W., Bachmann, K.R., Kovacevic, D., LoGrasso, M.E., O'Rourke, C., Froimson, M.I. Thirty-day readmission following total hip and knee arthroplasty - a preliminary single institution predictive model. J Arthroplasty. 2014; 29(8): p. 1532-8.
4. Sutton, J.C., 3rd, Antoniou, J., Epure, L.M., Huk, O.L., Zukor, D.J., Bergeron, S.G. Hospital Discharge within 2 Days Following Total Hip or Knee Arthroplasty Does Not Increase Major-Complication and Readmission Rates. J Bone Joint Surg Am. 2016; 98(17): p. 1419-28.
5. Bini, S.A., Inacio, M.C., Cafri, G. Two-Day Length of Stay is Not Inferior to 3 Days in Total Knee Arthroplasty with Regards to 30-Day Readmissions. J Arthroplasty. 2015; 30(5): p. 733-8.
6. Berg, U., BuLow, E., Sundberg, M., Rolfson, O. No increase in readmissions or adverse events after implementation of fast-track program in total hip and knee replacement at 8 Swedish hospitals: An observational before-and-after study of 14,148 total joint replacements 2011-2015. Acta Orthopaedica. 2018; 89(5): p. 522-527.
7. Zhu, S., Qian, W., Jiang, C., Ye, C., Chen, X. Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J. 2017; 93(1106): p. 736-742.
8. Charpentier, P.M., Srivastava, A.K., Zheng, H., Ostrander, J.D., Hughes, R.E. Readmission Rates for One Versus Two-Midnight Length of Stay for Primary Total Knee Arthroplasty: Analysis of the Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI) Database. J Bone Joint Surg Am. 2018; 100(20): p. 1757-1764.
9. Sibia, U.S., Waite, K.A., Callanan, M.A., Park, A.E., King, P.J., MacDonald, J.H. Do shorter lengths of stay increase readmissions after total joint replacements? Arthroplast Today. 2017; 3(1): p. 51-55.
10. Sahota, S., Lovecchio, F., Harold, R.E., Beal, M.D., Manning, D.W. The Effect of Smoking on Thirty-Day Postoperative Complications After Total Joint Arthroplasty: A Propensity Score-Matched Analysis. J Arthroplasty. 2018; 33(1): p. 30-35.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Leiden University Medical Center

IQ Joint study
Toolbox

Outcome: Textbook Outcome & Ordinal Composite Outcome Measure

Topics are described where quality improvement initiatives could be considered.

Separately looking at the 3 indicators revision within 1 year, readmission within 30 days and prolonged length-of-stay (a length of stay in the upper tertile) have disadvantages. When conducting file investigations, there is a chance that the same file will be requested 3 times and that many must be investigated to find opportunities for quality improvement. Furthermore, single outcomes do not provide insight for professionals and patients into which part of the patients everything went well. For the above 3 indicators, a TO would mean that a patient did not undergo a revision within 1 year, had no readmission within 30 days and had a normal length-of-stay.

However, hospitals with a TO that differs significantly form the average gives little information about which outcome was specifically worse/good. Therefore the Ordinal Composite Outcome measure (Textbook Outcome Plus; TOP) has been developed. This is an extension of the TO with the additional element that the different combinations of the results are arranged (instead of all in 1 non-TO group), so that it could be seen in which group the hospital deviates from the average. The order is from the best to the worst outcome as follows:

- No revision within one year, no readmission within 30 days, no prolonged length-of-stay (**Textbook Outcome**)
- No revision within one year, no readmission within 30 days, prolonged length-of-stay
- No revision within one year, readmission within 30 days, no prolonged length-of-stay
- No revision within one year, readmission within 30 days, prolonged length-of-stay
- Revision within one year, no readmission within 30 days, no prolonged length-of-stay
- Revision within one year, no readmission within 30 days, prolonged length-of-stay
- Revision within one year, readmission within 30 days, no prolonged length-of-stay
- Revision within one year, readmission within 30 days, prolonged length-of-stay

This ordered outcome measure can also be corrected for patient-mix by using different funnel-plots where group 1 is compared with the rest, group 2 versus the rest, etc.. With this method, it can be indicated in which group your hospital differs significantly. These funnel- plots can be supplied on request.

If a hospital deviates from one of these groups, specific file investigation on these patients could be performed. For possible quality improvement initiatives, I refer to the Toolboxes for revision, readmission and prolonged length of hospital stay.

IQ Joint studiegroep:
•P van Schie, coördinerend arts-onderzoeker
•Prof. dr. RGHH Nelissen, orthopedisch chirurg
•Dr. PJ Marang-van de Mheen, assistent professor medisch besliskunde

Appendix V Surveys

The survey was emailed every two months together with the feedback to evaluate adherence to the intervention, encourage reviewing the feedback, introduce QII if necessary, and stimulate trial engagement. Participants could report best practices and experiences to be added to the toolbox and shared with others, also to stimulate trial engagement. The questionnaire has been translated from Dutch.

1. Have you read and interpreted the monthly feedback containing the performance outcomes of primary total hip and/or knee arthroplasties (THP/TKP)?
   a. Yes, the feedback was clear
   b. Yes, but the feedback was not clear because ……
   c. No, I did not get around to this

2. Has the feedback been discussed within your department?
   a. Yes, we saw potential to improve at least one of the performance outcomes
   b. Yes, but we did not see any potential to improve one of the performance outcomes
   c. No, we did not get around to this

3. Are there any performance outcomes for which, according to the feedback, your center underperforms or has performed worse than the average for the IQ Joint study group? You may select multiple outcomes.
   a. Revision within one year
   b. Readmission within 30 days
   c. Complications within 30 days
   d. Long length of stay
   e. None

4. For which performance outcome(s) have improvement initiatives been undertaken since the start of the study (October 2019)? Enter what you/your healthcare institution have done in the free text field below the relevant performance outcome. You may select multiple outcomes.
   a. Revision within one year
      i. ……………………..
   b. Readmission within 30 days
      i. ……………………..
   c. Complications within 30 days
      i. ……………………..

Chapter 8

   d. Long length of stay
      i. ……………………..
   e. None

5. If applicable, indicate for each improvement initiative undertaken to improve a performance outcome, how your center chose this improvement initiative.

	Toolbox	Literature	Expert advice	Other (free text field)	No improvement initiative undertaken for this outcome
Revision	Yes/No	Yes/No	Yes/No	…..	Yes/No
Readmission	Yes/No	Yes/No	Yes/No	…..	Yes/No
Complications	Yes/No	Yes/No	Yes/No	…..	Yes/No
Long length of stay	Yes/No	Yes/No	Yes/No	…..	Yes/No

6. What would you or your center need to improve further? You may select multiple answers.
   a. Further explanation of the interpretation of performance outcomes in the feedback
   b. Link to another center that scores better for an outcome for which we score worse
   c. More items in the toolbox, namely ……

7. This is the last question. You can still click back to make adjustments. After this question, the questionnaire is sent immediately. There is still room for questions and/or suggestions in the free text field.

……………………………………………………………………………..……………

Thank you for participating in this survey. In order to be able to learn from each other and to give each other new ideas, the improvement initiatives of all participating centers will be included in the Toolbox.