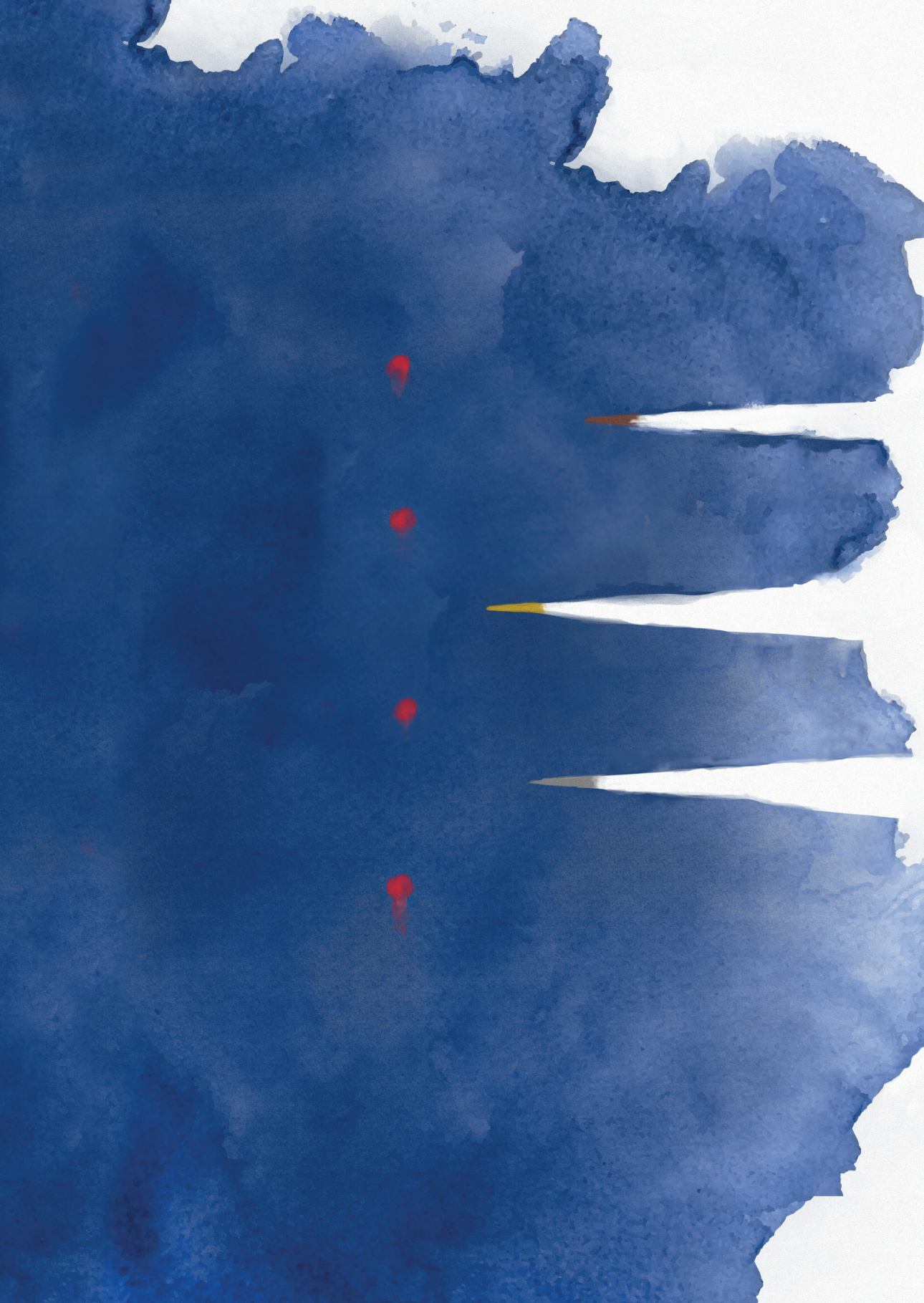
What makes the best performing hospital? the IQ Joint study

Schie, P. van



Chapter 2

International comparison of variation in performance between hospitals for THA and TKA: Is it even possible?

A systematic review including 33 studies and 8 arthroplasty register reports

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Abstract

Purpose

To improve care for total hip and knee arthroplasties (THA/TKA), hospitals may want to compare their performance with hospitals in other countries. Pooling data across countries also enables earlier detection of infrequently occurring safety issues. We therefore aimed to assess the between-hospital variation and definitions used for revision, readmission, and complications across countries.

Methods

PubMed, Embase, Web of Science, Cochrane library, Emcare, and Academic Search Premier were searched from January 2009 to August 2020 for studies reporting on: 1) Primary THA/TKA; 2) Revision, readmission, or complications; 3) Between-hospital variation. Most recent registry reports of Network of Orthopedic Registries of Europe (NORE) members were also reviewed. Two reviewers independently screened records, extracted data, and assessed the risk of bias (RoB) using the Integrated quality Criteria for the Review Of Multiple Study designs (ICROMS) tool for studies and relevant domains for registries. We assessed agreement for the following domains: 1) Outcome definition; 2) Follow-up and starting point; 3) Case-mix adjustment; 4) Type of patients and hospitals included.

Results

Between-hospital variation was reported in 33 (1 high-quality, 13 moderate-quality, and 19 low-quality) studies and 8 registry reports. The range of variation for revision was 0%-33% for THA and 0%-27% for TKA varying between assessment within hospital admission until 10 years of follow-up; for readmission 0%-40% and 0%-32%, respectively; and for complications 0%-75% and 0%-50%, respectively. Indicator definitions and methodological variables varied considerably across domains.

Conclusion

The large heterogeneity in definitions and methods used likely explains the considerable variation in between-hospital variation reported for revision, readmission, and complications , making it impossible to benchmark hospitals across countries or pool data for earlier detection of safety issues. It is necessary to collaborate internationally and strive for more uniformity in indicator definitions and methods in order to achieve reliable international benchmarking in the future.

Introduction

Arthroplasty registries were originally established to monitor safety and compare the survival of different types of implants. In recent years, however, registries have also been used to show between-hospital variation for various quality indicators and provide hospitals and surgeons with feedback on their performance, usually compared with a reference standard (i.e., the benchmark) which is mostly the national average.(1-8) Most registries give feedback through annual reports intended to encourage quality improvement initiatives in low-performing hospitals and learn from high-performing hospitals by adopting best practices.(1-8) In addition, scientific articles are published for quality improvement purposes; for example, hospitals are benchmarked, ranked, or (statistical) methods are compared to monitor the quality of care delivered.(9-13) The most commonly used quality indicators in this context are implant revision, readmission, and complications, as these indicators are considered reliable, actionable, and fit for purpose.(14-19) However, the reliability of hospital rankings has been shown to be affected by e.g., minor registration incompleteness in the outcome and low event rates, with particularly low volume providers being less likely to become an outlier in funnel plots.(11,13)

The rationale for benchmarking is that if another hospital treating comparable patients achieves better outcomes, there is potential to improve the underlying quality of care processes and patient outcomes. However, there may be less incentive to improve further for hospitals that are among the best performing hospitals in their own country. These hospitals may have an interest to compare their outcomes with hospitals from other countries or healthcare systems to stimulate further improvement. In addition, pooling of data across countries would also enable to detect any safety issues that occur with low frequency much earlier. Both of these are only possible if there is consistency in the indicator definitions and methods used to collect data, as these will determine the frequency of occurrence. For example, a previous study showed that a change in definition within the same surgical context increased the occurrence of adverse outcomes from 7% to 27%.(20) Similarly, data from one study where the complication rate is defined as the case-mix adjusted proportion of complications within 14 days post-surgery cannot be pooled with another study where it is defined as non-case-mix adjusted proportion of complications within 30 days post-surgery. (9,21)

The present study, therefore, aims to systematically assess the between-hospital variation and definitions used for revision, readmission, and complications after total hip and knee arthroplasties (THA and TKA) across countries, including both

scientific papers published in the past decade and the most recent arthroplasty registry reports from the Network of Orthopedic Registries of Europe (NORE).

Materials and Methods

This systematic review was registered at inception with PROSPERO (CRD42019122779) and conducted according to the PRISMA 2020 statements. (22) The authors received a grant from the Van Rens Foundation (VRF2018-001) to perform this study.

Search strategy

PubMed, Embase, Web of Science, Cochrane library, Emcare, and Academic Search Premier were searched for publications from January 2009 to August 2020 using a systematic search created by a librarian (JS). The search consisted of three components: 1) Primary THA/TKA; 2) Revision, readmission, complication, length-of-stay (LOS), and mortality; 3) Between-hospital variation (Appendix I). LOS and mortality were included as secondary outcomes. LOS was included because it indicates the severity/complexity of patients treated or more time to identify complications during admission, both of which may influence the need for subsequent readmission. Prolonged LOS may also be a proxy for a complicated disease course, even without these complications being reported. Therefore between-hospital variation in LOS can act as a proxy for between-hospital variation in complications within a given healthcare system. Mortality was included because this is a highly undesirable outcome.

Study and report selection

Titles and abstracts were screened independently by two reviewers (PvS/SH), and discrepancies resolved through discussion. Senior researchers (PM/RN) were available if consensus could not be reached. Inclusion criteria were studies reporting on 1) Primary THA and/or TKA; 2) National or regional between-hospital variation for revision, readmission, complication, LOS, or mortality with at least 2 hospitals included. All studies using registry, administrative, claim, or audit data were directly included for full-text screening, as these are usually national or regional studies that are likely to report between-hospital variations even if not included in the title and abstract. Reviews and study protocols were excluded. Studies in English, Dutch, German, French, and Danish were eligible for inclusion and were translated by both reviewers (PvS/SH). Authors were contacted if the full text could not be found.

In parallel, all most recent registry reports of NORE members including registries in and outside Europe, were reviewed in full-text on reporting between-hospital variation for the same indicators.(23)

Data extraction

Data were extracted independently by two reviewers (PvS/SH) using a prespecified SPSS file (Version 26, IBM Corp). Data extracted were first author, title, year of publication, country of the first author, and type of implant (i.e., THA and/or TKA). For arthroplasty reports, the first author was replaced by the country or region of origin. In addition, data sources, data collection period, and data completeness were collected, and the number of patients and hospitals included. The between-hospital variations as reported for the outcomes were collected in the original unit, including mean, standard deviation (sd), standard error (se), 95%-confidence interval (95%-CI), median, interquartile range (IQR), and range. If between-hospital variation was not reported in the text, but hospital outcomes were reported individually, hospital variation was calculated using the individual hospital outcomes. If the variation was only reported in a graph, the values were derived from the chart. Outcome definitions and any adjustment for case-mix were also collected and the type of patients and/or hospitals included. In addition, we documented for what purpose the between-hospital variation was reported (e.g. pay for performance or quality improvement) and whether it was reported using one overall estimate (i.e., mean (sd), median (IQR) or range) or whether also individual hospitals outcomes were shown (e.g., in funnel plots or forest plots).

Definition of outcomes

All outcomes were reviewed on the following domains: 1) Outcome definition (i.e., what constitutes a revision, readmission, or complications); 2) Follow-up and starting point (e.g., post-discharge or post-surgery); 3) Case-mix adjustment (yes/no); 4) Type of patients (e.g., osteoarthritis or trauma) and hospitals (e.g., hospital type or size) included. For each outcome, it was assessed how often perfect agreement was reached across all these domains, which would be needed to allow for the pooling of data. In addition to documenting case-mix adjustment or not, it was assessed for which confounding factors the between-hospital variation was adjusted.

Data analysis

The between-hospital variation for revision, readmission, complications, LOS, and mortality was reported separately for THA, TKA and THA&TKA combined and plotted in a forest plot. When available, the mean, median, and range were plotted, and when both 95%-CI and IQR were available, only the IQR was plotted. When mean and se were available, we calculated the 95%-CI. If only the sd was available,

the se was calculated by dividing the sd by the square root of the number of hospitals included.(24) If variation for an outcome was longitudinally reported multiple times, the most recent variation was reported and plotted. Data were not pooled as there was considerable heterogeneity, in which case it is recommended to refrain from pooling as the resulting estimate will be rather unreliable.(25)

Risk of bias assessment

The Integrated Quality Criteria for Review of Multiple Study Designs (ICROMS) was used to assess the risk of bias (RoB) independently by both reviewers (PvS/SH).(26) The ICROMS is a comprehensive tool to evaluate the quality of multiple study designs and includes a set of universally applicable and study-specific quality criteria for each study design. Every study design must meet a minimum score and mandatory criteria to be included in the review. The specific criteria for cohort studies and controlled before-after studies were addressed as these were the study designs included in this review (Table 1A). We included all studies independent of the ICROMS score and reported the RoB for every study, with the rationale that RoB could be taken into account when weighting study results, whereas excluding studies with medium or low RoB could result in the loss of potentially valuable information. Studies scoring at least 18 points out of the total of 26 points for cohort studies or at least 18 of the 28 points for controlled-before-after studies and meeting the mandatory criteria were classified as high-quality (HQ) studies.(26) Studies scoring at least 18 points for both study designs but failing to meet the mandatory criteria were classified as moderate-quality (MQ) studies. Studies scoring less than 18 points for both study designs were classified as low-quality (LQ) studies.

Since there is no tool available to assess the RoB for registry reports, we tailored the RoB assessment to our research question, that is those factors that could potentially bias the between-hospital variation as reported in registries (Table 1B). Consistent with the ICROMS tool, each item could get 0-2 points, resulting in a range of 0-14 points. No reports were excluded based on the RoB assessment, but the RoB could be considered when weighing the reports' results.

Results

Studies and reports

The search identified 1,643 records, including 1621 scientific papers and 22 registry reports. After removing duplicates, 943 remained (i.e., 921 studies and 22 reports). Title and abstract screening excluded 625 studies, as 157 did not involve primary THA or TKA, 373 did not report between-hospital variation, 38 did not report at least one

of the outcomes, 54 were reviews, and 3 were study protocols. All registry reports were directly selected for full-text screening, resulting in 22 reports and 296 papers to be further assessed. During the full-text review, 14 reports and 263 papers were excluded as 3 did not involve primary THA or TKA, 270 did not report between-hospital variation, and 4 did not report at least one indicator outcome, leaving 33 papers and 8 arthroplasty reports to be included (Figure 1).

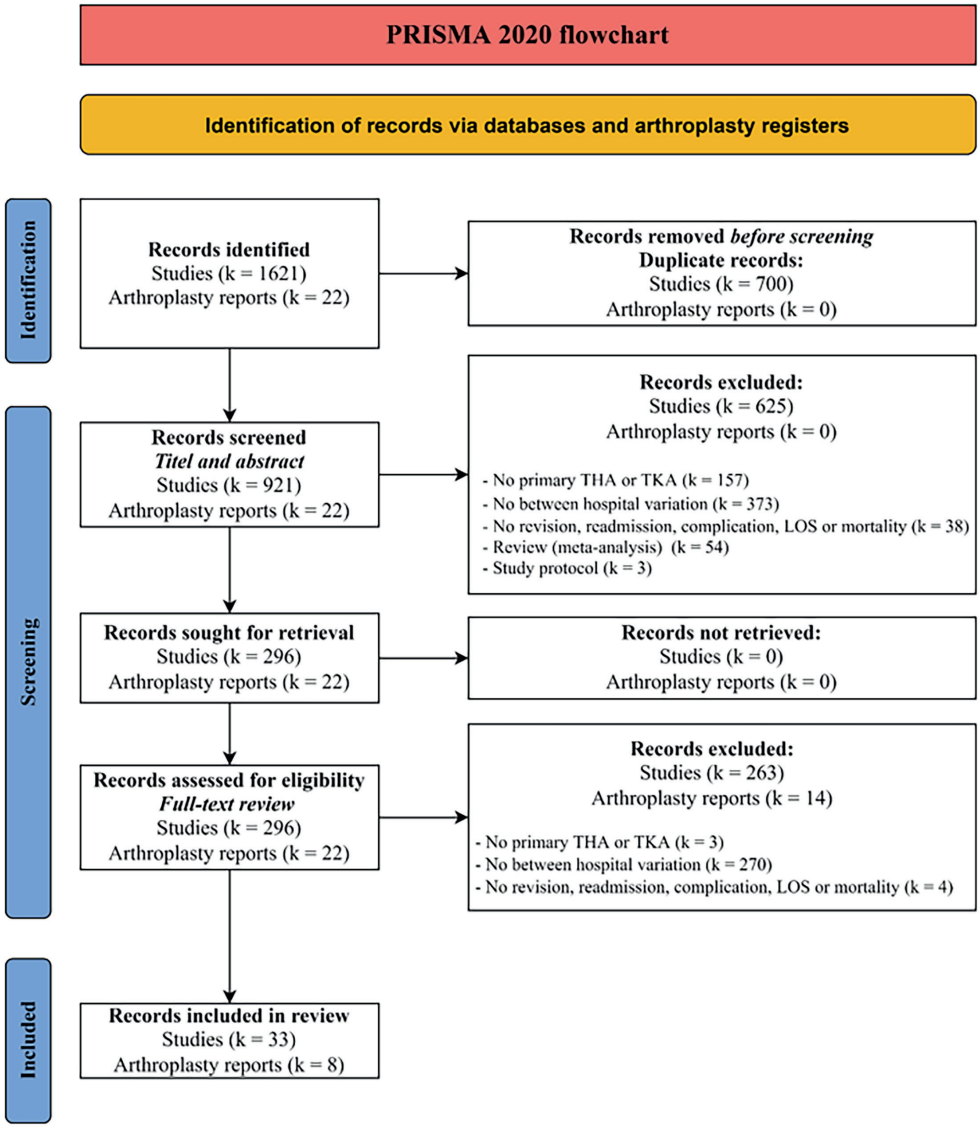

Figure 1 PRISMA 2020 flowchart
THA=total hip arthroplasty; TKA=total knee arthroplasty.

Table 1A Risk of Bias (RoB) studies

Study number	Author	Year	Design	1A*	2D*	2E*	3B*	3C*	3E	3F	3G*	4C*	5A	5B	F3	7A	7B	7C	7D	7E	ICROMS score
1	Bozic(14)	2014	CS	2		2			0	2	2	2		1	2	2	2	2	1	2	22
2	Thirukumaran(15)	2020	CBA	2	2		2	1	0	2		0	2		2	2	2	2	2	0	21
3	Courtney(39)	2018	CS	2		1			0	2	2	2		1	2	1	2	2	1	2	20
4	van Schie(30)	2020	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
5	Graham(21)	2019	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
6	Sheetz(9)	2019	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
7	Bottle(36)	2018	CS	1		1			0	1	2	2		1	2	2	2	2	1	2	19
8	Padegimas(34)	2018	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
9	Marang-vd Mheen(50)	2017	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
10	Hollis(40)	2017	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
11	Qian(42)	2013	CS	2		1			0	2	2	0		1	2	2	2	2	1	2	19
12	Voorn(10)	2017	CS	2		1			0	1	2	0		1	2	2	2	2	1	2	18
13	Cram(43)	2012	CS	2		1			0	2	2	0		1	1	2	2	2	1	2	18
14	Cai(49)	2012	CS	2		1			0	1	2	0		1	2	2	2	2	1	2	18
15	Padegimas(31)	2017	CS	2		1			0	2	2	0		1	2	2	2	2	1	0	17
16	Chen(52)	2017	CS	2		1			0	2	2	0		1	2	2	2	2	1	0	17
17	Courtney(16)	2017	CS	2		0			0	1	2	1		1	1	2	2	2	1	2	17
18	Husni(54)	2010	CS	2		0			0	2	1	2		1	1	2	2	1	1	2	17
19	Hofstede(41)	2018	CS	2		1			0	1	2	0		1	2	2	2	2	1	0	16
20	Pross(27)	2017	CS	2		1			0	1	2	0		1	2	2	2	2	1	0	16
21	Calderwood(44)	2013	CS	2		1			0	2	2	2		1	1	2	0	2	1	0	16
22	Kurtz(38)	2016	CS	2		1			0	1	1	0		1	2	2	2	2	1	0	15
23	Kurtz(37)	2016	CS	2		1			0	1	1	0		1	2	2	2	2	1	0	15
24	Jergesen(48)	2016	CS	2		1			0	1	1	0		1	1	2	2	1	1	2	15
25	Makela(32)	2011	CS	2		1			0	1	2	2		1	2	2	0	1	1	0	15
26	Mittal(28)	2018	CS	2		1			0	1	1	0		1	1	2	2	2	1	0	14
27	Skufca(45)	2017	CS	2		1			0	1	2	0		1	0	2	2	2	1	0	14
28	Asaid(51)	2013	CS	2		0			0	2	1	0		1	1	2	2	2	1	0	14

Table 1A Continued

Study number	Author	Year	Design	1A*	2D*	2E*	3B*	3C*	3E	3F	3G*	4C*	5A	5B	F3	7A	7B	7C	7D	7E	ICROMS score
29	**Dailey(46)**	2009	CS	**2**		**1**			0	2	**2**	**0**		1	1	2	0	2	1	0	**14**
30	**Martino(53)**	2018	CS	**2**		**1**			0	1	**2**	**0**		1	1	2	0	1	0	2	**13**
31	**Singh(33)**	2017	CS	**2**		**1**			0	1	**1**	**0**		1	0	2	2	1	1	0	**12**
32	**Husted(29)**	2010	CS	**2**		**0**			0	2	**1**	**0**		1	1	2	0	2	1	0	**12**
33	**Lopez-Contreras(47)**	2012	CS	**1**		**1**			0	1	**2**	**0**		1	1	2	0	1	1	0	**11**

32 cohort studies (CS) and 1 controlled before-and-after study were included. Following domains were assessed: 1A*) Clear statement of the aims of the research; 2D*) Intervention and control group selection designed to protect against systematic difference/selection bias; 2E*) Comparability of groups; 3B*) Baseline measurement-protection against selection bias; 3C*) Protection against contamination; 3E) Protection against detection bias: blinded assessment of primary outcome; 3F) Reliable primary outcome measure; 3G*) Comparability of outcomes; 4C*) Incomplete outcome data addressed; 5A) Protection against detection bias: Intervention unlikely to affect data collection; 5B) Protection against information bias; 6C) Analysis sufficiently rigorous/free from bias; 7A) Free of selective outcome reporting; 7B) Limitations addressed; 7C) Conclusions clear and justified; 7D) Free of other bias; 7E) Ethics issues addressed.

Scores for each domain were assigned as follows: 0=Did not fulfil the criteria; 1=Unclear if criteria are fulfilled; 2=Did meet the criteria.

*Indicates the mandatory criteria, and these criteria are darker coloured and in bold.

The green highlighted study has an ICROMS score ≥18, and fulfils the mandatory criteria, and was therefore classified as low RoB/high quality. The grey highlighted studies have an ICROMS ≥18 points, but do not fulfil the mandatory criteria and were therefore classified as moderate RoB/moderate quality. The red highlighted studies have an ICROMS <18 points, and do not fulfil the mandatory criteria, and were therefore classified as high RoB/low quality.

CBA=controlled before-after study; CS=cohort study; ICROMS=integrated quality criteria for review of multiple study designs.

Table 1B Risk of Bias (RoB) arthroplasty reports

Report code	Arthroplasty report	Year	1	2*	3	4	5**	6***	7****	Total RoB score for reports
A	**Norwegian Arthroplasty Register(1)**	2020	2	2	2	2	1	2	0	**11**
B	**Dutch Arthroplasty Register(2)**	2020	2	2	0	2	2	0	2	**10**
C	**Swedish Knee Arthroplasty Register(3)**	2020	2	2	2	2	2	2	0	**12**
D	**Danish Hip Arthroplasty Register(4)**	2020	2	2	2	1	0	2	0	**9**
E	**Swedish Hip Arthroplasty Register(5)**	2018	2	2	2	2	2	0	0	**10**
F	**Danish Knee Arthroplasty Register(6)**	2020	2	2	2	1	0	0	0	**7**
G	**Finnish Arthroplasty Register(7)**	2020	2	2	2	0	0	1	0	**7**
H	**Swiss Arthroplasty Register(8)**	2020	1	2	2	0	0	2	0	**7**

Since there is no tool available to assess RoB for registry reports, we tailored the ICROMs to our research question, i.e. those factors that could potentially bias the between-hospital variation as reported in registries. Following domains were assessed: 1) Patients could be traced when treated in another hospital; 2) Data completeness was reported for THA and TKA separately; 3) Data completeness was reported for single hospitals; 4) Indicator outcomes were validated for at least a part of the data; 5) Indicator outcomes were adjusted for covariates; 6) Missing data for covariates were reported; 7) Missing values for covariates were imputed.

Scores for each criterium were assigned as follows: 0 (red-color)=Did not fulfil the criteria; 1 (yellow-color)=Unclear if criteria are fulfilled; 2 (green-color)=Did fulfil the criteria.

*For this domain. 0=No; 1=Yes, for THA and TKA combined; 2=Yes, for THA and TKA separately. **For this domain. 0=No; 1=Yes, for age and gender; 2=Yes, for age, gender and comorbidities. ***For this domain. 0=Did not fulfil the criteria; 1=for at least one covariate; 2=Did fulfil the criteria. ****For this domain. 0=Data were not imputed; 1=Unclear if criteria are fulfilled; 2=Data were imputed.

Risk of bias

Thirty-two cohort studies and 1 controlled before-and-after study were included. One study was classified as a HQ study, 13 as MQ, and 19 as LQ. The median ICROMS score was 17 points (IQR:15-19). Most studies did not meet the mandatory criteria, often involving the comparability of groups (Table 1A, domain 2E) and incomplete outcome data addressed (Table 1A, domain 4C).

The RoB for registry reports ranged from 7 for the Swiss Arthroplasty Register to 11 for the Norwegian Arthroplasty Register (out of the maximum of 14). The median score was 9 points (IQR:7-10). Most variation was in the covariates used to adjust outcomes (Table 1B, domain 5) and whether missing values for covariates were imputed (Table 1B, domain 7).

Characteristics

Seven of the 33 studies included THA, 4 TKA, 12 both THA and TKA, and 10 studies combined THA&TKA as one group (Appendix IIA). Six studies reported the between-hospital variation for revision (18%), 13 for readmission (39%), and 20 for complications (61%). The studies included numbers of patients ranging from 122 to 524,892 for THA, from 84 to 952,593 for TKA, and from 1596 to 878,098 for THA&TKA combined. Four studies did not report the number of patients included. (15,27-29) A wide range was found for the number of hospitals included for THA, TKA, and THA&TKA combined (i.e., 2 to 3479). Data completeness on THA/TKA included was reported in 8 of the 33 studies and was at least 75% for 7 studies. Twenty studies used administrative data and 13 clinical data. Data were routinely collected for 23 studies and clinician-reported for 10 studies (Appendix IIA).

Two of the 8 registry reports included THA, 2 TKA, and 4 both THA and TKA. All reports included between-hospital variation for revision, 2 for readmission, and 3 for complications. Reports showed smaller variation in the number of patients (i.e., 7161 to 33248) and hospitals included (i.e., 47 to 152) compared with studies. All reports stated their overall data completeness in THA/TKA included to be at least 94.9%, but was only reported for individual hospitals by 7 reports (Appendix IIB).

Between-hospitals variation and indicator definitions

Revision

From the 6 studies reporting revision rates, the between-hospital variation was reported in 5 studies (1 MQ, 4 LQ) for THA(27,30-33) and 4 studies (2 MQ, 2 LQ) for TKA(30,32-34). Notable differences were seen with regard to the extent of between-hospital variation across studies, as shown in Figure 2. This is likely due to the large variety in definitions used, both to indicate what constituted a revision, the follow-up, patient selections, and whether hospital differences were adjusted for case-mix (Table 2). Revision within 1 year was mainly reported (33% of studies reporting revision), but even then, the variation remained large (Figure 2).

Revisions were reported in all 8 registry reports, but the between-hospital variation was reported in 6 reports for both THA(2,4,5,7,8,35) and TKA(2,3,6-8,35). Again, there were notable differences in the between-hospital variation across registries (Figure 2). As for the included studies, we found a large variety in definitions used, both in what constituted a revision, the follow-up, type of patients and hospitals selected, and adjustment for case-mix (Table 2). The only aspect where all reports were consistent was that follow-up started post-surgery. Revision within 5 years was most reported regarding follow-up (50% of reports reporting revision), followed by 1 year (38%) and 2 year (38%) revision.

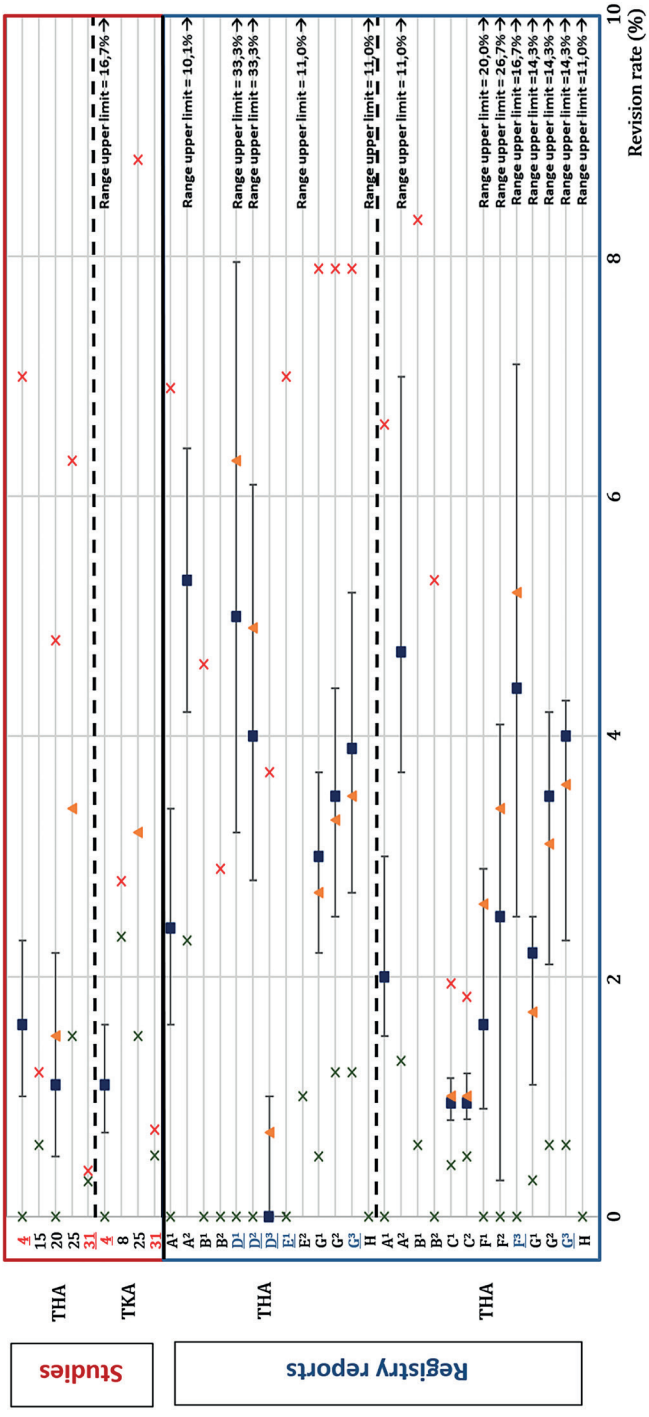

Figure 2 Between-hospital variation for revision

The numbers on the y-axis correspond with the study numbers from Table 1A and the letters on the y-axis with the report codes from Table 1B. A letter in superscript was added to a study number or a number in superscript to a report code when the revision rate was reported more than once with different definitions. Study numbers were underlined and red coloured when revision within 1 year was reported and registry reports were underlined and blue coloured when revision within 5 years was reported. The green and red cross represent the lower and upper range, respectively. The blue square represents the median and the yellow triangle the mean. The interquartile range is shown in a solid line through the median. Results of outlier procedures are shown below.

THA studies: 4=No:13, Po:18, Others:66. **TKA studies:** 4=No:7, Po:14, Others:77. **THA registry reports:** A^2=No:2, Po:8, Others:28; B^1=No:19, Po:31, Others:45; 2^B=No:18, Po:19, Others:58; D^1=No:4, Po:3, Others:36; D^2=No:3, Po:3, Others:36); D3=No:3, Po:3, Others:36; E^1=No:7, Po:12, Others:56); E^2=No:8, Po:14, Others:58; H=No:9, Po:5, Others:138.

TKA registry reports: A^2=No:6, Po:6, Others:21; B^1=No:20, Po:24, Others:53; B^2=No:22, Po:19, Others:56; H=No:12, Po:13, Others:128.

No=negative outlier; Po=positive outlier; THA=total hip arthroplasty; TKA=total knee arthroplasty.

Readmission

From the 13 studies reporting readmission rates, the between-hospital variation was reported in 5 studies (3 MQ, 2 LQ) for THA(9,21,31,36,37), 4 studies (3 MQ, 1 LQ) for TKA(21,34,36,38) and 6 studies (3 MQ, 3 LQ) for THA&TKA combined(15,16,28,39-41). Ten studies reported the variation for readmission more than once with different indicator definitions in all domains except for the type of patients selected (Table 3). Figure 3 shows large differences in the between-hospital variation across studies and the reported means and medians, likely due (at least in part) to variety in how readmissions were defined and which patients were included (Table 3). Studies combining THA&TKA in a single group were mostly case-mix adjusted, whereas studies reporting only THA and/or TKA separately were often unadjusted. Readmission within 30 days was the most often used definition (85% of studies reporting readmission).

Overall readmissions were reported in 2 registry reports (25% of reports), but the between-hospital variation was only given in 1 report with 3 different patient selections (i.e., all patients, only with osteoarthritis or with a fracture) for THA(4) and in 1 report for TKA(6) (Figure 3 and Table 3). All-cause readmission within 30 days post-surgery was reported for THA and readmission of at least 2 days within 30 days after discharge for TKA. No adjustments for case-mix were performed for these data.

Complications

From the 20 studies reporting complication rates, the between-hospital variation was reported in 11 studies (5 MQ, 6 LQ) for THA(9,10,21,27,42-48), 8 studies (4 MQ, 4 LQ) for TKA(10,21,34,45-49) and 8 studies (1 HQ, 3 MQ, 4 LQ) for THA&TKA combined(14-16,33,39,48,50,51). Eight studies reported the variation more than once with different outcome definition, follow-up, and type of hospitals selected (Table 4). Again, large differences were found in the between-hospital variation, which is (at least) partly explained by the different definitions used (Figure 4 and Table 4). Two studies used the same dataset and reported comparable between-hospital variations.(16,39) Studies varied particularly in the type of complications included, such as reoperations, surgical site infections, blood transfusions, and deep venous thrombosis. There were also large differences in follow-up, type of patients and hospitals selected, and whether between-hospital variation was adjusted for case-mix. Complications were mostly defined as occurring within 30 days (15% of studies reporting complications).

Table 2 Definitions to report between-hospital variation for revision

Revision	Studies (*n*=6)		Registry reports (n=8)	
	THA (*n*=5) [4,15,20,25,31]	**TKA (*n*=4)** [4,8,25,31]	**THA (*n*=13)** [A[1],A[2],B[1],B[2],D[1],D[2],D[3], E[1],E[2],G[1],G[2],G[3],H]	**TKA (*n*=13)** [A[1],A[2],B[1],B[2],C[1],C[2],F[1], F[2],F[3],G[1],G[2],G[3],H]
1) Outcome definition				
• Exchange, removal, or addition of any component	[4,25]	[4,25]	[A[1],A[2],B[1]]	[A[1],A[2]]
• Revision of at least acetabulum or femur component	---	---	[B[2]]	---
• Revision of at least femur or tibia component	---	---	---	[B[1]]
• Parts or the whole prosthesis is changed or extracted	---	---	[E[1], E[2]]	[B[2]]
• Parts or complete of the primary implant are replaced	---	---	[H]	[H]
• One or more of the components were exchanged, removed, or added, including soft tissue procedures	---	---	[G[1]-G[3]] ---	[G[1]-G[3]] [C[1],C[2]]
• One or more of the components are exchanged, removed, or added, including arthrodesis or amputation	---	---	---	---
• Due to infection	[31]	[31]		---
• Due to aseptic loosening	---	---	[D[3]]	
• Not specified	[15,20]	[8]	[D[1],D[2]]	[F[1]-F[3]]
2a) Follow-up				
• Within hospital admission	[20]	---	---	---
• Within 90 days	[15]	[8]	---	---
• Within 1 year	[4,31]	[4,31]	[B[1],B[2],G[1]]	[F[1], G[1]]
• Within 2 years	---	---	[A[1],H]	[A[1],F[2],H]
• Within 3 years	---	---	[G[2]]	[B[1],B[2],G[2]]
• Within 5 years	---	---	[D[1]-E[1],G[3]]	[F[3],G[3]]
• Within 10 years	---	---	[A[2],E[2]]	[A[2]]
• Any revision within a period of time	[25]	[25]	---	[C[1],C[2]]
2b) Follow-up starting point				
• Post-surgery	[4,31]	[4,31]	[A[1]-H]	[A[1]-H]
• Not specified	[15,25]	[8,25]	---	---
• Not applicable	[20]	---	---	---
3) Case-mix adjusted				
• Yes	[4,25]	[4,7]	[B[1],B[2],H]	[B[1]-C[2],H]
• No	[15,20,25]	[8,31]	[A[1],A[2],D[1]-G[3]]	[A[1],A[2],F[1]-G[3]]

Table 2 Continued

Revision	Studies (*n*=6)		Registry reports (n=8)	
	THA (*n*=5) [4,15,20,25,31]	**TKA (*n*=4)** [4,8,25,31]	**THA (*n*=13)** [A^1,A^2,B^1,B^2,D^1,D^2,D^3, E^1,E^2,G^1,G^2,G^3,H]	**TKA (*n*=13)** [A^1,A^2,B^1,B^2,C^1,C^2,F^1, F^2,F^3,G^1,G^2,G^3,H]
4a) Type of patient selected				
• Age selection(s)	---	---	[A^1,A^2]	[A^1,A^2]
• Osteoarthritis	[25]	[25]	[A^1,A^2,D^2]	[A^1,A^2,C^1,C^2]
• No trauma patients	[15]	[8]	---	---
• Comorbidity score selection	[15]	[8]	[A^1,A^2]	[A^1,A^2]
• Matching of patient groups	[15]	[8]	---	---
• No selections, all patients included	[4,20,31]	[4,31]	[B^1-D^1,D^3-H]	[B^1,B^2,F^1-H]
4b) Type of hospitals selected				
• Number of procedures limit	---	---	[A^1,A^2,E^1,E^2]	[A^1,A^2,C^1,C^2]
• Completeness of data limit	---	---	[A^1,A^2]	[A^1,A^2]
• No selections, all hospitals included	[4-31]	[4-31]	[B^1-D^3,G^1-H]	[B^1,B^2,F^1-H]

The definitions for revision were defined for 6 domains. The numbers in brackets correspond to the study number from Table 1A and the letters in brackets to the report codes from Table 1B.

No=negative outlier; Po=positive outlier; THA=total hip arthroplasty; TKA=total knee arthroplasty.

Complications were reported in 3 reports (38% of reports), with between-hospital variation reported in 2 reports for THA(4,5) and 1 report for TKA(3). All reports reported the variation more than once with different outcome definition, follow-up, and type of patients selected (Table 4). As with data reported from studies, a large between-hospital variation was found, although less variation in the type of complications was present, but more variation in the type of patients selected (Figure 4 & Table 4).

Length-of-stay and mortality

Nine studies (27% of studies)(10,29,31,34,41,50,52-54) reported the between-hospital variation for LOS and only 1 study (3% of studies)(9) represented mortality. Between-hospital variation for LOS was given by 1 report (13% of reports)(6), and for mortality by 2 reports (25% of reports).(3,5) (appendixes III-VI).

Perfect agreement

Given the heterogeneity in definitions used across studies and registry reports, none of the outcomes had perfect agreement across all 6 domains (i.e., what constituted a revision, readmission or complications, follow-up, and starting point, case-mix adjustment, and patient- and hospital selections) for both THA, TKA, and THA&TKA combined (Tables 2-4).

Variables used for case-mix adjustment

Both studies and reports varied whether rates were case-mix adjusted and which variables were used for case-mix adjustment (Tables 2-4). Revision rates, when adjusted, were always adjusted for age and gender. Considerable variation was observed with regard to additional case-mix adjustments: American Society of Anaesthesiology (ASA) score (2,8,30), diagnosis (osteoarthritis versus other)(2,30), body mass index (BMI) (8,30), Charnley score(8,30), smoking status(30), use of patellar button(3), previous contralateral arthroplasty(32), bilaterally of the operation(32), heart disease(32), hypertension(32), cancer(32), alcoholism(32), dementia(32), depression(32), Parkinson's disease(32), mental disorders(32), degenerative brain diseases(32) and atherosclerosis(32).

For readmissions, also wide variation in case-mix adjustments: for age(9,15,21,39), gender(9,15,21), ethnicity(21), functional status(21), ASA score(21), history of acute myocardial infarction(21), history of peripheral vascular disease(21), depression(21), diabetes mellitus(21), surgical time(21), work relative value unit(21), emergency surgery(21), patient comorbidities (16,28,39), Elixhauser comorbidities(9) procedure (THA/TKA)(16), demographics(40), healthcare use(40), comorbidities selected by veteran affair surgical quality improvement programme (VASQIP) nurses(40) and clinical comorbidity(15).

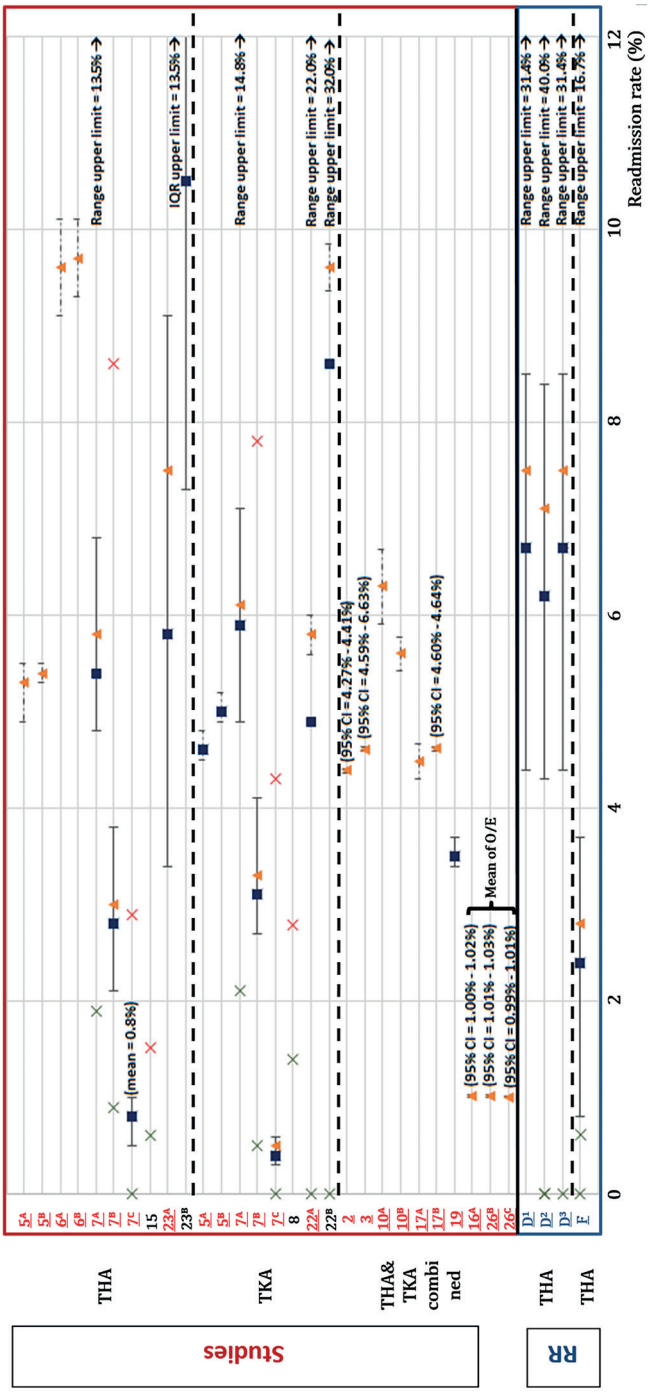

Figure 2 Between-hospital variation for readmission

The numbers on the y-axis correspond with the study numbers from Table 1A and the letters on the y-axis with the report codes from Table 1B. A letter in superscript was added to a study number or a number in superscript to a report code when the readmission rate was reported more than once with different definitions. Study numbers and report codes were underlined and red/blue coloured when readmission within 30 days was reported. The green and red cross represent the upper and lower range, respectively. The blue square represents the median and the yellow triangle the mean. The interquartile range is shown in a solid line through the median. The 95% confidence interval is shown with a dashed line through the mean. Results of outlier procedures are shown below. **THA registry reports:** D1=No:2, Po:8, Others:30; D2=No:0, Po:9, Others:31; D3=No:3, Po:2, Others:35. No=negative outlier; O/E=observed divided by expected; Po=positive outlier; RR=Registry reports; THA=total hip arthroplasty; TKA=total knee arthroplasty; 95% CI=95% confidence interval.

Table 3 Definitions to report between-hospital variation for readmission

Readmission	Studies (*n*=13)			Registry reports (*n*=2)	
	THA (*n*=10) [5[A],5[B],6[A],6[B],7[A],7[B],7[C],15,23[A],23[B]]	**TKA (*n*=8)** [5[A],5[B],7[A],7[B],7[C],8,22[A],22[B]]	**THA&TKA (*n*=10)** [2,3,10[A],10[B],17[A],17[B],19,26[A],26[B],26[C]]	**THA (*n*=3)** [D[1],D[2],D[3]]	**TKA (*n*=1)** [F]
1) Outcome definition					
• All-cause	[5[B],6[A],6[B],7[A],15]	[5[B],7[A],8]	[2-10[B],26[A]-26[C]]	[D[1]-D[3]]	---
• Emergency only	---	---	[19]	---	---
• Related to surgery	[5[A],7[B]]	[5[A],7[B]]	---	---	---
• Return to theatre	[7[C]]	[7[C]]	---	---	---
• Specific composition	[23[A],23[B]]	[22[A],22[B]]	[17[A],17[B]]	---	[F]
2a) Follow-up					
• Within 30-days	[5[A]-7[C],23[A]]	[5[A]-7[C],22[A]]	[2-26[C]]	[D[1]-D[3]]	[F]
• Within 90-days	[15,23[B]]	[8,22[B]]	---	---	---
2b) Fu time starting point					
• Post-surgery	---	---	---	[D[1]-D[3]]	---
• Post-discharge	[5[A],5[B],6[A],6[B],7[A],7[B],7[C],23[A],23[B]]	[5[A]-7[C],22[A],22[B]]	[2-26[C]]	---	[F]
• Not specified	[15]	[8]	---	---	---
3) Case-mix adjusted					
• Yes	[5[A]-6[B]]	[5[A]-5[B]]	[2,3,10[B]-17[B],26[A]-26[C]]	---	---
• No	[7[A]-23[B]]	[7[A]-22[B]]	[10[A],19]	[D[1]-D[3]]	[F]
4a) Type of patient selected					
• Age selection(s)	[6[A],6[B],23[A],23[B]]	[22[A],22[B]]	[2,3,26[A]-26[C]]	---	---
• Osteoarthritis	---	---	[19]	[D[2]]	[F]
• No trauma patients	[15]	[8]	---	---	---
• Medicare patients	[6[A],6[B],23[A],23[B]]	[22[A],22[B]]	[2,3,17[A],17[B],26[A]-26[C]]	---	---
• Elective surgery	[7[A],7[B],7[C]]	[7[A]-7[C]]	---	---	---
• If LOS ≥2 days	[5[A],5[B]]	[5[A],5[B]]	[10[A],10[B]]	---	---
• Minimum LOS of readmission	---	---	---	---	[F]
• Matching of patient groups	[15]	[8]	---	---	---
• Fracture patients	---	---	---	[D[3]]	---
• No selections	---	---	---	[D[1]]	---

Table 3 Continued

Readmission	Studies (*n*=13)			Registry reports (*n*=2)	
	THA (*n*=10) [5[A],5[B],6[A],6[B],7[A],7[B],7[C],15,23[A],23[B]]	**TKA (*n*=8)** [5[A],5[B],7[A],7[B],7[C],8,22[A],22[B]]	**THA&TKA (*n*=10)** [2,3,10[A],10[B],17[A],17[B],19,26[A],26[B],26[C]]	**THA (*n*=3)** [D[1],D[2],D[3]]	**TKA (*n*=1)** [F]
4b) Type of hospitals selected					
• Number of procedures limit	---	---	[3-17[B]]	---	---
• Veteran Affairs Hospitals	[5[A],5[B]]	[5[A],5[B]]	[10[A],10[B]]	---	---
• Government hospitals	---	---	[26[A]]	---	---
• Proprietary hospitals	---	---	[26[B]]	---	---
• Non-profit hospitals	---	---	[26[C]]	---	---
• Honor roll hospitals	[6[A]]	---	---	---	---
• Affiliated honor roll hospitals	[6[B]]	---	---	---	---
• Physician-owned	---	---	17[A]	---	---
• Non-physician owned	---	---	17[B]	---	---
• No selections	[7[A]-23[B]]	[7[A]-22[B]]	[2,19]	---	---

The definitions for readmission were defined for 6 domains. The numbers in brackets correspond to the study number from Table 1A and the letters in brackets to the report codes from Table 1B.

Fu=Follow-up; LOS=length-of-stay; THA=total hip arthroplasty; TKA=total knee arthroplasty. No=negative outlier; Po=positive outlier.

For complications, between-hospital variations were case-mix adjusted for age(9,10,14-16,21,27,42,43,49,51), gender(9,10,14,15,21,27,42,43,49,51), ethnicity(21,42,43), Elixhauser comorbidities(9,42,49), patient comorbidities(14,16,27,39,43), ASA score(10,21), procedure (THA or TKA) when THA&TKA are combined(14,16,51), payer(42), admission status(42), functional status(21), history of acute myocardial infarction(21), history of peripheral vascular disease(21), depression(21), diabetes mellitus(21), surgical time(21), work relative value unit(21), emergency surgery(21), BMI(10), smoking(10), smoking status(10), diagnosis (osteoarthritis versus other) (10), preoperative Hb(10), clinical comorbidities(15) and bilateral surgery (14).

Context for benchmarking hospitals

Between-hospital variation was generated mostly as feedback for quality improvement purposes(9,10,21,30,32,33,42,45-47), but also to assess variation by structural hospital characteristics (e.g., ownership structure or teaching status)(28,31,34,48,51-53), to assess outcome associations between specialisms and hospitals(40) and to assess the impact of coding schemes(43). Regardless of the purpose of the studies, 19 studies (58% of studies) informed individual hospitals about their performance (i.e., 5 for revision(30-34), 6 for readmission(9,21,28,31,34,40) and 12 for complications(9,10,21,33,34,42,43,45-48,51)). The remaining 14 studies (42% of studies) reported the variation in one overall estimate (i.e., mean (sd), median (IQR) or range) from which hospitals are unable to infer how they are performing compared with other hospitals.(14-16,27,29,36-39,41,44,49,50,54) All registry reports gave outcomes at the individual hospital level when outcomes were collected (i.e., 8 for revision(2-8,35), 2 for readmission(4,6), 3 for complications(3-5), 1 for LOS(6) and 2 for mortality(3,5)).

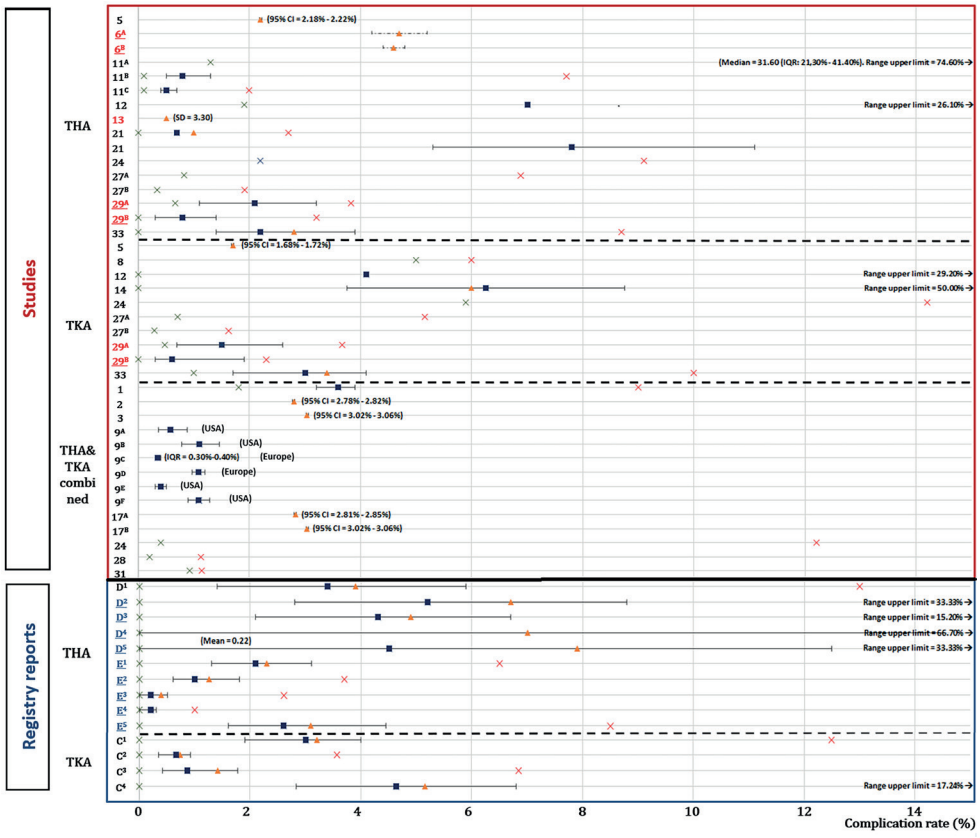

Figure 4 Between-hospital variation for complications

The numbers on the *y*-axis correspond with the study numbers from Table 1A and the letters on the *y*-axis with the report codes from Table 1B. A letter in superscript was added to a study number or a number in superscript to a report code when the complication rate was reported more than once with different definitions. Study numbers were underlined and red coloured when complications within 30 days was reported and registry reports were underlined and blue coloured when complications within 2 years was reported. The green and red cross represent the upper and lower range, respectively. The blue square represents the median and the yellow triangle the mean. The interquartile range is shown in a solid line through the median. The 95% confidence interval is shown with a dashed line through the mean. Results of outlier procedures are shown below.

THA studies: 12=No:2, Po:0, Others:21; 27^{A}=No:5, Po:4, Others:8; 27^{A}=No:4, Po:4, Others:9; 29^{A}=No:1, Po:2, Others:7; 27^{B}=No:1, Po:4, Others:5. **TKA studies:** 27^{A}=No:4, Po:2, Others:12; 27A=No:3, Po:1, Others:14; 29^{A}=No:0, Po:2, Others:7; 29^{B}=No:0, Po:3, Others:6. **THA reports:** D^{1}=No:0, Po:22, Others:16; D^{2}=No:4, Po:4, Others:31; D^{3}=No:4, Po:5, Others:29; D^{4}=No:0, Po:1, Others:19; D^{5}=No:0, Po:3, Others:33; E^{6}=No:14, Po:14, Others:48; E^{7}=No:0, Po:18, Others:58; E^{8}=No:6, Po:6, Others:57; E^{9}=No:7, Po:3, Others:47; E^{10}=No:2, Po:8, Others:46; E^{11}=No:2, Po:6, Others:48.

No=negative outlier; O/E=observed divided by expected; Po=positive outlier; THA=total hip arthroplasty; TKA=total knee arthroplasty; 95% CI=95% confidence interval.

Table 4 Definitions to report between-hospital variation for complications

Complications	Studies (*n*=20)			Registry reports (*n*=3)	
	THA (*n*=16) [5,6[A],6[B],11[A],11[B],11[C],12, 13,20,21,24,27[A],27[B],29[A] ,29[B],33]	**TKA (*n*=10)** [5,8,12,14,24,27[A],27[B],29[A] ,29[B],33]	**THA&TKA (*n*=14)** [1,2,3,9[A],9[B],9[C],9[D],9[E],9[F],17[A] ,17[B],24,28,31]	**THA (*n*=16)** [D[1],D[2],D[3],D[4],D[5],E[1], E[2],E[3],E[4],E[5],E[6],E[7],E[8], E[9],E[10],E[11]]	**TKA (*n*=4)** [C[1],C[2],C[3],C[4]]
1) Outcome definition					
• NQF complication rate*	---	---	[1-3,17[A],17[B]]	---	---
• VASQIP complication**	[5]	[5]	---	---	---
• Study/report specific composite	[6[A],6[B],24]	[14,24]	[24]	---	---
• Early prosthetic joint infections	---	---	[9[A],9[C],9[E]]	---	---
• Late prosthetic joint infections	---	---	[9[B],9[D],9[F]]	---	---
• Blood transfusion	---	---	---	[D[1]]	---
• Blood transfusion (red blood cells)	[11[A]]	[12]	---	---	---
• Blood transfusion (fresh frozen plasma)	[11[B]]	---	---	---	---
• Blood transfusion (platelets)	[11[C]]	---	---	---	---
• Allogeneic transfusion	[12]	---	---	---	---
• DVT and/or PE	[13]	---	---	---	---
• Reoperation	[20]	---	---	[D[2]-E[1], E[5]]	[C[1]]
• Reoperation due to deep infection	---	---	---	[E[2]]	---
• Reoperation due to dislocation	---	---	---	[E[3]]	---
• Reoperation due to a fracture	---	---	---	[E[4]]	---
• Surgical site infection	[21,27[A],29[A],33]	[27[A],29[A],33]	[28,31]	---	---
• Deep Surgical site infection	[27[B],29[B]]	[27[B],29[B]]	---	---	---
• Cardiovascular events	---	---	---	---	[C[2]]
• May be related to the surgery	---	---	---	---	[C[3]]
• All adverse events, including death	---	---	---	---	[C[4]]
• Not specified	---	[8]	---	---	---

Table 4 Continued

Complications	Studies (*n*=20)				
	THA (*n*=16) [5,6[A],6[B],11[A],11[B],11[C],12, 13,20,21,24,27[A],27[B],29[A] ,29[B],33]	**TKA (*n*=10)** [5,8,12,14,24,27[A],27[B],29[A] ,29[B],33]	**THA&TKA (*n*=14)** [1,2,3,9[A],9[B],9[C],9[D],9[E],9[F],17[A] ,17[B],24,28,31]	**THA (*n*=16)** [D[1],D[2],D[3],D[4],D[5],E[1], E[2],E[3],E[4],E[5],E[6],E[7],E[8], E[9],E[10],E[11]]	**TKA (*n*=4)** [C[1],C[2],C[3],C[4]]
2a) Follow-up					
Within hospital stay	[11[A]-11[C],12,20]	[12]	---	---	---
Within 7 days	---	---	---	[D[1]]	---
Within 14 days	[5]	[5]	---	---	---
Within 4 weeks	---	---	[9[A],9[C],9[E]]	---	---
Within 30 days	[6[A],6[B],13,29[A],29[B]]	[29[A],29[B]]	---	---	---
Within 90 days	---	[14]	---	---	[C[1]-C[4]]
Within 1 year	[21,33]	[33]	[28,31]	---	---
Within 2 years	[24]	[24]	[9[B],9[D],9[F],24]	[D[2]-E[5]]	---
Composite	---	---	[1-3,17[A],17[B]]	---	---
Not specified	[27[A],27[B]]	[8,27[A],27[B]]	---	---	---
2b) Follow-up starting point					
Post-admission	[13]	---	[1-17[B]]	---	---
Post-operative	[6[A],6[B],21,24,29[A]-33]	[14,24,29A,29B,33]	[24-31]	[D[1]-E[5]]	[C[1]-C[4]]
Post-discharge	[5]	[5]	---	---	---
Not specified	[27[A],27[B]]	[8,27[A],27[B]]	---	---	---
Not applicable	[11[A]-11[C],12,20]	[12]	---	---	---
3) Case-mix adjusted					
Yes	[5-20]	[5,12,14]	[1-3,17[A],17[B],28]	---	---
No	[21-33]	[8, 24-33]	[9[A]-9[F], 24,31]	[D[1]-E[5]]	[C[1]-C[4]]

Table 4 Continued

Complications	Studies (*n*=20)			Registry reports (*n*=3)	
	THA (*n*=16) [5,6[A],6[B],11[A],11[B],11[C],12, 13,20,21,24,27[A],27[B],29[A] ,29[B],33]	**TKA (*n*=10)** [5,8,12,14,24,27[A],27[B],29[A] ,29[B],33]	**THA&TKA (*n*=14)** [1,2,3,9[A],9[B],9[C],9[D],9[E],9[F],1 7[A],17[B],24,28,31]	**THA (*n*=16)** [D[1],D[2],D[3],D[4],D[5],E[1], E[2],E[3],E[4],E[5],E[6],E[7],E[8], E[9],E[10],E[11]]	**TKA (*n*=4)** [C[1],C[2],C[3],C[4]]
4a) Type of patient selected					
Age selection(s)	[6[A],6[B]]	[14]	[1-29]	---	---
Osteoarthritis	---	---	---	[D[1],D[3]]	---
No trauma patients	[13]	---	[28]	---	---
Fracture	---	---	---	[D[4], E[5]]	---
Proximal femoral fracture	---	---	---	[D[5]]	---
Medicare patients	[6[A],6[B],21]	[14]	[1-29,17[A],17[B]]	---	---
Elective surgery	[12,33]	[12,33]	[1]	---	---
Matching of patient groups	---	[8]	---	[D[2]]	---
No selections, all patients included	[5,11[A]-11[C],20,24-29[B]]	[5,24-29[B]]	[9[A]-9[F],24,31]	[E[1]-E[4]]	[C[1]-C[4]]
4b) Type of hospitals selected					---
Number of procedures limit	[33]	[33]	[1,3,17[A],17[B]]	[D[1]-E[5]]	---
Academic hospitals	---	---	[9[A]-9[F]]	---	---
Academic and affiliated hospitals	[11[A]-11[C]]	---	---	---	---
Non-academic hospitals	[12]	[12]	---	---	---
Honor roll hospitals	[6[A]]	---	---	---	---
Affiliated honor roll hospitals	[6[B]]	---	---	---	---
Veteran Affairs Hospitals	[5]	[5]	---	---	---
Physician owned	---	---	17[A]	---	---
Non-physician owned	---	---	17[B]	---	---
No selections, all patients included	[13-29[B]]	[8,14-29[B]]	[2,24-31]	---	[C[1]-C[4]]

The definitions for complications were defined for 6 domains. The numbers in brackets correspond to the study number from Table 1A, and the letters in brackets correspond to the report codes from Table 1B.

*National Quality Forum (NQF)-endorsed hospital-level risk-standardized complication rate developed by the Centres for Medicare and Medicaid Services. **Veterans Affairs Surgical Quality Improvement Programme (VASQIP) nurse-identified postoperative complications.

DVT=deep venous thrombosis; No=negative outlier; PE=pulmonary embolism; Po=positive outlier; THA=total hip arthroplasty; TKA=total knee arthroplasty.

Discussion

The present study showed that between-hospital variation for revision, readmission, and complications is often reported in arthroplasty cohort studies and registry reports, with considerable differences between hospitals present for both THA and TKA. Large heterogeneity was found in definitions of variables and methods used, which likely explains at least part of the variation but obscures the ability to compare results and pool data. For revision, most studies reported revision within one year and most registry reports revision within 5 years. Most studies and reports reported on readmission within 30 days. As for complications, most studies reported complications within 30 days, with reports evaluating complications up to 2 years. The between-hospital variation was generally reported in the context of quality improvement purposes, but also the association with structural characteristics like ownership or teaching status.

Data currently available in literature and registry reports therefore do not facilitate an international comparison between hospital outcomes for THA and TKA, due to heterogeneity in definitions and methods used and it is impossible to pool data to enable, for example, earlier detection of safety issues. A well-known example where earlier detection would have prevented many patients from unnecessary suffering was the metal-on-metal hip arthroplasty disaster, in which 20% of patients had to undergo a revision within 10 years, compared with 4% in metal-on-polyethylene arthroplasties.(55,56) The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) identified these implants as having an outlier performance in 2007, more than three years before retraction from the market.(57) In addition, the mortality risk increased by 8.5% (95%-CI: 5.8%-11.2%) due to these implants.(58) To pool data and enable international comparison of between-hospital variation, two steps must be taken.

First, worldwide agreement on definitions is needed for the outcome, follow-up (starting time), case-mix adjustment, and patients/hospitals that should be selected. An example of this on a smaller scale is, the Nordic Arthroplasty Register Association (NARA). They previously merged revision data with matching definitions to identify differences in revision rates between Sweden, Denmark, Norway, and Finland in 2014.(59) However, as shown in the present study, the definitions in their published annual reports do not match exactly when patient- and hospital selections are considered. A collaboration of arthroplasty registries such as the International Society of Arthroplasty Registries and NORE (EFORT) could play a leading role in assessing the feasibility of a unified global system to evaluate delivered care and benchmark hospital performance using the same definitions.(60) Since 2012, the International Consortium of Orthopaedic Registries (ICOR) has been working to implement a

global surveillance system for monitoring medical devices throughout their life. They already have several tools available to facilitate collaboration at different stages.(61,62) In this context, it is essential to distinguish between suitable indicators for monitoring quality of care or implant survival. Revision of an implant within 1 year, for example, gives a better reflection of the quality of care delivered as it is closer to (and therefore more likely to be related with) the surgery performed, whereas a revision within 5 years is highly relevant to monitor implant survival. Even if definitions match in the future, it will often remain difficult to compare hospitals from different healthcare systems in a fair way. For example, differences in LOS and readmissions between hospitals in different healthcare systems can be caused by the availability of outpatient clinics, hospitalization shorter than 24 hours imposed by health insurance policies, cooperation agreements with general practitioners, and other financial incentives.

Second, to allow for fair hospital comparison between hospitals, it is important to adjust for differences in case-mix.(63) Hospitals that tend to treat mainly patients without comorbidities (e.g., ASA I patient with osteoarthritis and no hip deformities) are expected to have a lower frequency of adverse events (e.g., revision, infection) than hospitals treating patients with multiple comorbidities (e.g., ASA III and congenital hip deformities).(64-66) As shown in this study, there is no consensus on whether or not to adjust for case-mix, let alone for which patient characteristics should be adjusted. Adjustments were made for 35 different patient characteristics, mainly for age and gender, followed by ethnicity, BMI, ASA score, and Elixhauser comorbidities; these patient characteristics are readily available in routinely collected data. In 3 studies and 1 report, hospital variation was adjusted for surgery- or hospital-specific determinants (e.g., hospital and surgeon volume) in addition to patient characteristics. However, these determinants could also be a proxy for experience and thereby an intermediate variable in the causal pathway to achieve good patient outcomes, that should not be adjusted for.

Consensus in data definitions and case-mix adjustment definitions enables international hospital comparison, such that (global) feedback can be given in relation to others as this has been shown effective to improve care. A previous study showed a 0.89% (95%-CI:0.83%-0.96%) reduction in serious adverse events for THA and TKA when hospitals receiving feedback were compared with control hospitals.(67) In addition, a Cochrane review showed a median absolute improvement of 4.3% associated with audit and feedback (IQR:0.5%-16.0%).(68) Studies have also shown that feedback is more effective when given monthly in an active way by a senior colleague, both verbal and written, with specific goals and actions planned rather than in a passive way (e.g., registry reports).(68-71) Feedback is often reactive and only targeted at underperforming hospitals (i.e., negative outliers), sometimes

with financial consequences. Feedback could, however, be more effective if not only underperforming hospitals feel addressed, but if normal or good performing hospitals are also actively motivated to improve further, which could be achieved by international comparisons.

Several limitations should be noted. First, completeness of data was reported for only 8 studies (24% of studies), making it impossible to assess whether selection bias affected hospital outcomes and thus generalizability of our results (Appendix IIIA&B). To allow for a correct interpretation, it is therefore essential to state the variation in completeness of data across hospitals in a study or report. Second, when indicator outcomes occurred but in another hospital, this underestimates the outcome in the first hospital and also the variation between hospitals if this happens systematically for some hospitals. However, this does not apply to registries included in this study because they use a unique personal code, linking outcomes in other hospitals to the primary procedure. Third, between-hospital variation may have been overestimated when outcomes were not adjusted for case-mix or only by a limited number of variables, resulting in possible residual confounding which is now attributed to the hospital. Finally, some studies and reports have not reported the definitions across all 4 domains so that the agreement may have been higher for some domains (Table 2, 3, and 4).

Conclusion

To benchmark hospital performance or pool data for earlier detection of safety problems across countries, it is necessary to collaborate internationally and strive for more uniformity in indicator definitions and methods used.

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Supplemental data

Appendix I Literature search strategy

1. PubMed (http://www.ncbi.nlm.nih.gov/pubmed?otool=leiden)

(((("tha"[ti] OR "total hip"[ti] OR "Arthroplasty, Replacement, Hip"[majr] OR "Hip Prosthesis"[majr] OR "Hip Prosthesis"[ti] OR "Hip Replacement"[ti] OR "Hip Arthroplasty"[ti] OR "Prosthetic Hip"[ti] OR "Prosthetic Hip"[ti] **OR** "tka"[ti] OR "total knee"[ti] OR "Arthroplasty, Replacement, Knee"[majr] OR "Knee Prosthesis"[majr] OR "Knee Prosthesis"[ti] OR "Knee Replacement"[ti] OR "Knee Arthroplasty"[ti] OR "Prosthetic Knee"[ti] OR "Prosthetic Knees"[ti] OR (("Arthroplasty, Replacement"[majr] OR "Joint Prosthesis"[majr] OR "Joint Arthroplasty"[ti] OR "Joint Replacement"[ti] OR "Joint Prosthesis"[ti] OR "Prosthetic Joint"[ti] OR "Prosthetic Joints"[ti]) AND ("Hip"[majr] OR "Hip Joint"[majr] OR "hip"[ti] OR "hips"[ti] OR "Knee"[majr] OR "Knee Joint"[majr] OR "knee"[ti] OR "knees"[ti])))) AND ("revision rate"[ti] OR "revision rates"[ti] OR (("revision"[ti] OR "revisions"[ti]) AND ("rate"[ti] OR "rates"[ti] OR "median"[ti] OR "mean"[ti] OR "percentage"[ti] OR "percent"[ti] OR percent*[ti])) OR "revision"[ti] OR "Repeat Surgery"[ti] OR "Joint Revision"[ti] OR "Reoperation"[majr] OR "Reoperation"[ti] OR Reoperat*[ti] OR "Re-operation"[ti] OR Re-operat*[ti] OR "Length of Stay"[majr] OR "length of stay"[ti] OR "lengths of stay"[ti] OR "length of stays"[ti] OR "lengths of stays"[ti] OR "stay length"[ti] OR "stay lengths"[ti] OR "Patient Readmission"[majr] OR "patient readmission"[ti] OR "hospital readmission"[ti] OR "patient re-admission"[ti] OR "hospital re-admission"[ti] OR "readmission"[ti] OR "re-admission"[ti] OR readmit*[ti] OR re-admit*[ti] OR "Mortality"[majr] OR "mortality"[Subheading] OR "mortality"[ti] OR mortalit*[ti] OR "death"[ti] OR "deaths"[ti] OR "Cause of Death"[ti] OR "fatality rate"[ti] OR "fatality rates"[ti] OR "Fatal Outcome"[ti] OR "Fatal Outcomes"[ti] OR "Survival Rate"[majr] OR "complications"[Subheading:noexp] OR "Postoperative Complications"[majr:noexp] OR "Prosthesis Failure"[majr] OR "Prosthesis-Related Infections"[majr] OR "Surgical Wound Infection"[majr] OR "Prosthesis Failure"[ti] OR "Prosthesis-Related Infections"[ti] OR "Prosthesis-Related Infection"[ti] OR "Prosthesis Infections"[ti] OR "Prosthesis Infection"[ti] OR "Surgical Wound Infection"[ti] OR "Surgical Infection"[ti] OR "Surgical Wound Infections"[ti] OR "Surgical Infections"[ti] OR "surgical injury"[ti] OR "surgical injuries"[ti] OR "complication"[ti] OR "complications"[ti] OR "Joint Dislocations"[majr] OR "Dislocations"[ti] OR "Dislocation"[ti] OR dislocat*[ti] OR Subluxat*[ti] OR "Prosthesis-Related Infections"[majr] OR "Prosthesis-Related Infection"[ti] OR "Prosthesis-Related Infections"[ti] OR "Infections"[majr:noexp] OR "infection"[ti]

OR "infections"[ti] OR "infected"[ti] OR "loosening"[ti] OR "malalignment"[ti] OR "malalignments"[ti] OR "malaligned"[ti] OR "Joint Instability"[majr] OR "Instability"[ti] OR "Instabilities"[ti] OR "Patellar Dislocation"[majr] OR "Patellar Dislocation"[ti] OR "Patella Dislocation"[ti] OR "Patellar Dislocations"[ti] OR "Patella Dislocations"[ti]) AND ((("variation"[tw] OR "variations"[tw] OR "difference"[tw] OR "differences"[tw]) AND ("Hospitals"[mesh] OR "hospital"[tw] OR "hospitals"[tw])) OR "hospital characteristics"[tw] OR "hospital outcome"[tw] OR "hospital outcomes"[tw] OR "Hospitals/statistics and numerical data"[mesh] OR "Practice Patterns, Physicians'/statistics and numerical data"[mesh] OR "international variation"[tw] OR "international variations"[tw] OR "ranking hospitals"[tw] OR "hospital rank"[tw] OR "hospital ranking"[tw] OR "hospital rankings"[tw] OR "hospital ranks"[tw])) **OR** (("tha"[tiab] OR "total hip"[tiab] OR "Arthroplasty, Replacement, Hip"[mesh] OR "Hip Prosthesis"[mesh] OR "Hip Prosthesis"[tiab] OR "Hip Replacement"[tiab] OR "Hip Arthroplasty"[tiab] OR "Prosthetic Hip"[tiab] OR "Prosthetic Hip"[tiab] **OR** "tka"[tiab] OR "total knee"[tiab] OR "Arthroplasty, Replacement, Knee"[mesh] OR "Knee Prosthesis"[mesh] OR "Knee Prosthesis"[tiab] OR "Knee Replacement"[tiab] OR "Knee Arthroplasty"[tiab] OR "Prosthetic Knee"[tiab] OR "Prosthetic Knees"[tiab] OR (("Arthroplasty, Replacement"[mesh] OR "Joint Prosthesis"[mesh] OR "Joint Arthroplasty"[tiab] OR "Joint Replacement"[tiab] OR "Joint Prosthesis"[tiab] OR "Prosthetic Joint"[tiab] OR "Prosthetic Joints"[tiab]) AND ("Hip"[mesh] OR "Hip Joint"[mesh] OR "hip"[tiab] OR "hips"[tiab] OR "Knee"[mesh] OR "Knee Joint"[mesh] OR "knee"[tiab] OR "knees"[tiab]))) AND ("revision rate"[tw] OR "revision rates"[tw] OR (("revision"[tw] OR "revisions"[tw]) AND ("rate"[tw] OR "rates"[tw] OR "median"[tw] OR "mean"[tw] OR "percentage"[tw] OR "percent"[tw] OR percent*[tw])) OR "revision"[tw] OR "Repeat Surgery"[tw] OR "Joint Revision"[tw] OR "Reoperation"[mesh] OR "Reoperation"[tw] OR Reoperat*[tw] OR "Re-operation"[tw] OR Re-operat*[tw] OR "Length of Stay"[mesh] OR "length of stay"[tw] OR "lengths of stay"[tw] OR "length of stays"[tw] OR "lengths of stays"[tw] OR "stay length"[tw] OR "stay lengths"[tw] OR "Patient Readmission"[mesh] OR "patient readmission"[tw] OR "hospital readmission"[tw] OR "patient re-admission"[tw] OR "hospital re-admission"[tw] OR "readmission"[tw] OR "re-admission"[tw] OR readmit*[tw] OR re-admit*[tw] OR "Mortality"[mesh] OR "mortality"[Subheading] OR "mortality"[tw] OR mortalit*[tw] OR "death"[tw] OR "deaths"[tw] OR "Cause of Death"[tw] OR "fatality rate"[tw] OR "fatality rates"[tw] OR "Fatal Outcome"[tw] OR "Fatal Outcomes"[tw] OR "Survival Rate"[mesh] OR "complications"[Subheading:noexp] OR "Postoperative Complications"[mesh:noexp] OR "Prosthesis Failure"[mesh] OR "Prosthesis-Related Infections"[mesh] OR "Surgical Wound Infection"[mesh] OR "Prosthesis Failure"[tw] OR "Prosthesis-Related Infections"[tw] OR "Prosthesis-Related Infection"[tw] OR "Prosthesis Infections"[tw] OR "Prosthesis Infection"[tw]

OR "Surgical Wound Infection"[tw] OR "Surgical Infection"[tw] OR "Surgical Wound Infections"[tw] OR "Surgical Infections"[tw] OR "surgical injury"[tw] OR "surgical injuries"[tw] OR "complication"[tw] OR "complications"[tw] OR "Joint Dislocations"[mesh] OR "Dislocations"[tw] OR "Dislocation"[tw] OR dislocat*[tw] OR Subluxat*[tw] OR "Prosthesis-Related Infections"[mesh] OR "Prosthesis-Related Infection"[tw] OR "Prosthesis-Related Infections"[tw] OR "Infections"[mesh:noexp] OR "infection"[tw] OR "infections"[tw] OR "infected"[tw] OR "loosening"[tw] OR "malalignment"[tw] OR "malalignments"[tw] OR "malaligned"[tw] OR "Joint Instability"[mesh] OR "Instability"[tw] OR "Instabilities"[tw] OR "Patellar Dislocation"[mesh] OR "Patellar Dislocation"[tw] OR "Patella Dislocation"[tw] OR "Patellar Dislocations"[tw] OR "Patella Dislocations"[tw]) AND ((("variation"[ti] OR "variations"[ti] OR "difference"[ti] OR "differences"[ti]) AND ("Hospitals"[majr] OR "hospital"[ti] OR "hospitals"[ti])) OR "hospital characteristics"[ti] OR "hospital outcome"[ti] OR "hospital outcomes"[ti] OR "Hospitals/statistics and numerical data"[majr] OR "Practice Patterns, Physicians'/statistics and numerical data"[majr] OR "international variation"[ti] OR "international variations"[ti] OR "ranking hospitals"[ti] OR "hospital rank"[ti] OR "hospital ranking"[ti] OR "hospital rankings"[ti] OR "hospital ranks"[ti])) AND ("2009/01/01"[PDAT] : "3000/12/31"[PDAT])

2. Embase (http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=main&MODE=ovid&D=oemezd)

((("tha".ti OR "total hip".ti OR exp *"Hip Replacement"/ OR exp *"hip arthroplasty"/ OR exp *"Hip Prosthesis"/ OR "Hip Prosthesis".ti OR "Hip Replacement".ti OR "Hip Arthroplasty".ti OR "Prosthetic Hip".ti OR "Prosthetic Hip".ti **OR** "tka".ti OR "total knee".ti OR exp *"Knee Replacement"/ OR exp *"knee arthroplasty"/ OR exp *"Knee Prosthesis"/ OR "Knee Prosthesis".ti OR "Knee Replacement".ti OR "Knee Arthroplasty".ti OR "Prosthetic Knee".ti OR "Prosthetic Knees".ti OR ((*"Arthroplasty"/ OR *"Joint Prosthesis"/ OR "Joint Arthroplasty".ti OR "Joint Replacement".ti OR "Joint Prosthesis".ti OR "Prosthetic Joint".ti OR "Prosthetic Joints".ti) AND (exp *"Hip"/ OR "hip".ti OR "hips".ti OR exp *"Knee"/ OR "knee".ti OR "knees".ti))) AND ("revision rate".ti OR "revision rates".ti OR (("revision".ti OR "revisions".ti) AND ("rate".ti OR "rates".ti OR "median".ti OR "mean".ti OR "percentage".ti OR "percent".ti OR percent*.ti)) OR "revision".ti OR "Repeat Surgery".ti OR "Joint Revision".ti OR *"Reoperation"/ OR "Reoperation".ti OR Reoperat*.ti OR "Re-operation".ti OR "Re-operat*".ti OR *"Length of Stay"/ OR "length of stay".ti OR "lengths of stay".ti OR "length of stays".ti OR "lengths of stays".ti OR "stay length".ti OR "stay lengths".ti OR *"Hospital Readmission"/ OR "patient readmission".ti OR "hospital readmission".ti OR "patient re-admission".ti OR "hospital re-admission".ti OR "readmission".ti OR "re-admission".ti OR

readmit*.ti OR "re-admit*".ti OR exp *"Mortality"/ OR "mortality".ti OR mortalit*.ti OR "death".ti OR "deaths".ti OR "Cause of Death".ti OR "fatality rate".ti OR "fatality rates".ti OR "Fatal Outcome".ti OR "Fatal Outcomes".ti OR *"Survival Rate"/ OR *"complication"/ OR "Postoperative Complication"/ OR exp *"Prosthesis Complication"/ OR "Surgical Infection"/ OR *"infectious complication"/ OR "Prosthesis Failure".ti OR "Prosthesis-Related Infections".ti OR "Prosthesis-Related Infection".ti OR "Prosthesis Infections".ti OR "Prosthesis Infection".ti OR "Surgical Wound Infection".ti OR "Surgical Infection".ti OR "Surgical Wound Infections".ti OR "Surgical Infections".ti OR *"Infection"/ OR "infection".ti OR "infections".ti OR "infected".ti OR "surgical injury".ti OR "surgical injuries".ti OR "complication".ti OR "complications".ti OR *"Joint Dislocation"/ OR "Dislocations".ti OR "Dislocation".ti OR dislocat*.ti OR *"subluxation"/ OR Subluxat*.ti OR *"prosthesis loosening"/ OR "loosening".ti OR "malalignment".ti OR "malalignments".ti OR "malaligned".ti OR exp *"Joint Instability"/ OR "Instability".ti OR "Instabilities".ti OR *"Patella Dislocation"/ OR "Patellar Dislocation".ti OR "Patella Dislocation".ti OR "Patellar Dislocations".ti OR "Patella Dislocations".ti) AND ((("variation".mp OR "variations".mp OR "difference".mp OR "differences".mp) ADJ5 ("hospital".mp OR "hospitals".mp)) OR (("variation".mp OR "variations".mp OR "difference".mp OR "differences".mp) AND exp "Hospital"/) OR "hospital characteristics".mp OR "hospital outcome".mp OR "hospital outcomes".mp OR "international variation".mp OR "international variations".mp OR "ranking hospitals".mp OR "hospital rank".mp OR "hospital ranking".mp OR "hospital rankings".mp OR "hospital ranks".mp)) **OR** (("tha".ti,ab OR "total hip".ti,ab OR exp "Hip Replacement"/ OR exp "hip arthroplasty"/ OR exp "Hip Prosthesis"/ OR "Hip Prosthesis".ti,ab OR "Hip Replacement".ti,ab OR "Hip Arthroplasty".ti,ab OR "Prosthetic Hip".ti,ab OR "Prosthetic Hip".ti,ab **OR** "tka".ti,ab OR "total knee".ti,ab OR exp "Knee Replacement"/ OR exp "knee arthroplasty"/ OR exp "Knee Prosthesis"/ OR "Knee Prosthesis".ti,ab OR "Knee Replacement".ti,ab OR "Knee Arthroplasty".ti,ab OR "Prosthetic Knee".ti,ab OR "Prosthetic Knees".ti,ab OR ((*"Arthroplasty"/ OR *"Joint Prosthesis"/ OR "Joint Arthroplasty".ti OR "Joint Replacement".ti OR "Joint Prosthesis".ti OR "Prosthetic Joint".ti OR "Prosthetic Joints".ti) AND (exp *"Hip"/ OR "hip".ti OR "hips".ti OR exp *"Knee"/ OR "knee".ti OR "knees".ti))) AND ("revision rate".mp OR "revision rates".mp OR (("revision".mp OR "revisions".mp) ADJ5 ("rate".mp OR "rates".mp OR "median".mp OR "mean".mp OR "percentage".mp OR "percent".mp OR percent*.mp)) OR "revision".mp OR "Repeat Surgery".mp OR "Joint Revision".mp OR "Reoperation"/ OR "Reoperation".mp OR Reoperat*.mp OR "Re-operation".mp OR "Re-operat*".mp OR "Length of Stay"/ OR "length of stay".mp OR "lengths of stay".mp OR "length of stays".mp OR "lengths of stays".mp OR "stay length".mp OR "stay lengths".mp OR "Hospital Readmission"/ OR "patient readmission".mp OR "hospital readmission".mp OR "patient re-admission".

mp OR "hospital re-admission".mp OR "readmission".mp OR "re-admission".mp OR readmit*.mp OR "re-admit*".mp OR exp "Mortality"/ OR "mortality".mp OR mortalit*.mp OR "death".mp OR "deaths".mp OR "Cause of Death".mp OR "fatality rate".mp OR "fatality rates".mp OR "Fatal Outcome".mp OR "Fatal Outcomes".mp OR "Survival Rate"/ OR *"complication"/ OR "Postoperative Complication"/ OR exp "Prosthesis Complication"/ OR "Surgical Infection"/ OR "infectious complication"/ OR "Prosthesis Failure".mp OR "Prosthesis-Related Infections".mp OR "Prosthesis-Related Infection".mp OR "Prosthesis Infections".mp OR "Prosthesis Infection".mp OR "Surgical Wound Infection".mp OR "Surgical Infection".mp OR "Surgical Wound Infections".mp OR "Surgical Infections".mp OR "Infection"/ OR "infection".mp OR "infections".mp OR "infected".mp OR "surgical injury".mp OR "surgical injuries".mp OR "complication".mp OR "complications".mp OR "Joint Dislocation"/ OR "Dislocations".mp OR "Dislocation".mp OR dislocat*.mp OR "subluxation"/ OR Subluxat*.mp OR "prosthesis loosening"/ OR "loosening".mp OR "malalignment".mp OR "malalignments".mp OR "malaligned".mp OR exp "Joint Instability"/ OR "Instability".mp OR "Instabilities".mp OR "Patella Dislocation"/ OR "Patellar Dislocation".mp OR "Patella Dislocation".mp OR "Patellar Dislocations".mp OR "Patella Dislocations".mp) AND ((("variation".ti OR "variations".ti OR "difference".ti OR "differences".ti) AND (exp *"Hospital"/ OR "hospital".ti OR "hospitals".ti)) OR "hospital characteristics".ti OR "hospital outcome".ti OR "hospital outcomes".ti OR "international variation".ti OR "international variations".ti OR "ranking hospitals".ti OR "hospital rank".ti OR "hospital ranking".ti OR "hospital rankings".ti OR "hospital ranks".ti)) AND (2009 OR 201* OR 202*).yr

3. Web of Science (http://isiknowledge.com/wos)

((ti=("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND ti=("revision rate" OR "revision rates" OR (("revision" OR "revisions") AND ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital

re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND ts=((("variation" OR "variations" OR "difference" OR "differences") NEAR5 ("hospital" OR "hospitals")) OR (("variation" OR "variations" OR "difference" OR "differences") AND "Hospital") OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks")) **OR** (ts=("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND ts=("revision rate" OR "revision rates" OR (("revision" OR "revisions") NEAR/5 ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis

Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND ti=((("variation" OR "variations" OR "difference" OR "differences") AND ("Hospital" OR "hospital" OR "hospitals")) OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"))) AND py=(2009 OR 2010 OR 2011 OR 2012 OR 2013 OR 2014 OR 2015 OR 2016 OR 2017 OR 2018 OR 2019 OR 2020)

4. Cochrane library (http://www.cochranelibrary.com/)

(("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR ((*"Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))):ti AND ("revision rate" OR "revision rates" OR (("revision" OR "revisions") AND ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat*" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit*" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related

Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations"):ti AND ((("variation" OR "variations" OR "difference" OR "differences") NEAR/5 ("hospital" OR "hospitals")) OR (("variation" OR "variations" OR "difference" OR "differences") AND "Hospital") OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"):ti,ab,kw) **OR** (("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR ((*"Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))):ti,ab,kw AND ("revision rate" OR "revision rates" OR (("revision" OR "revisions") NEAR/5 ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat*" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit*" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation"

OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations"):ti,ab,kw AND ((("variation" OR "variations" OR "difference" OR "differences") NEAR/5 ("Hospital" OR "hospital" OR "hospitals")) OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"):ti)

AND py=(2009 OR 2010 OR 2011 OR 2012 OR 2013 OR 2014 OR 2015 OR 2016 OR 2017 OR 2018 OR 2019 OR 2020)

5. Emcare (http://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=n&CSC=Y&PAGE=main&D=emcr)

(((("tha".ti OR "total hip".ti OR exp *"Hip Replacement"/ OR exp *"hip arthroplasty"/ OR exp *"Hip Prosthesis"/ OR "Hip Prosthesis".ti OR "Hip Replacement".ti OR "Hip Arthroplasty".ti OR "Prosthetic Hip".ti OR "Prosthetic Hip".ti **OR** "tka".ti OR "total knee".ti OR exp *"Knee Replacement"/ OR exp *"knee arthroplasty"/ OR exp *"Knee Prosthesis"/ OR "Knee Prosthesis".ti OR "Knee Replacement".ti OR "Knee Arthroplasty".ti OR "Prosthetic Knee".ti OR "Prosthetic Knees".ti OR ((*"Arthroplasty"/ OR *"Joint Prosthesis"/ OR "Joint Arthroplasty".ti OR "Joint Replacement".ti OR "Joint Prosthesis".ti OR "Prosthetic Joint".ti OR "Prosthetic Joints".ti) AND (exp *"Hip"/ OR "hip".ti OR "hips".ti OR exp *"Knee"/ OR "knee".ti OR "knees".ti))) AND ("revision rate".ti OR "revision rates".ti OR (("revision".ti OR "revisions".ti) AND ("rate".ti OR "rates".ti OR "median".ti OR "mean".ti OR "percentage".ti OR "percent".ti OR percent*.ti)) OR "revision".ti OR "Repeat Surgery".ti OR "Joint Revision".ti OR *"Reoperation"/ OR "Reoperation".ti OR Reoperat*.ti OR "Re-operation".ti OR "Re-operat*".ti OR *"Length of Stay"/ OR "length of stay".ti OR "lengths of stay".ti OR "length of stays".ti OR "lengths of stays".ti OR "stay length".ti OR "stay lengths".ti OR *"Hospital Readmission"/ OR "patient readmission".ti OR "hospital readmission".ti OR "patient re-admission".ti OR "hospital re-admission".ti OR "readmission".ti OR "re-admission".ti OR readmit*.ti OR "re-admit*".ti OR exp *"Mortality"/ OR "mortality".ti OR mortalit*.ti OR "death".ti OR "deaths".ti OR "Cause of Death".ti OR "fatality rate".ti OR "fatality rates".ti OR "Fatal Outcome".ti OR "Fatal Outcomes".ti OR *"Survival Rate"/ OR *"complication"/ OR "Postoperative Complication"/ OR exp *"Prosthesis Complication"/ OR "Surgical Infection"/ OR *"infectious complication"/ OR "Prosthesis Failure".ti OR "Prosthesis-Related Infections".ti OR "Prosthesis-Related

Infection".ti OR "Prosthesis Infections".ti OR "Prosthesis Infection".ti OR "Surgical Wound Infection".ti OR "Surgical Infection".ti OR "Surgical Wound Infections".ti OR "Surgical Infections".ti OR *"Infection"/ OR "infection".ti OR "infections".ti OR "infected".ti OR "surgical injury".ti OR "surgical injuries".ti OR "complication".ti OR "complications".ti OR *"Joint Dislocation"/ OR "Dislocations".ti OR "Dislocation".ti OR dislocat*.ti OR *"subluxation"/ OR Subluxat*.ti OR *"prosthesis loosening"/ OR "loosening".ti OR "malalignment".ti OR "malalignments".ti OR "malaligned".ti OR exp *"Joint Instability"/ OR "Instability".ti OR "Instabilities".ti OR *"Patella Dislocation"/ OR "Patellar Dislocation".ti OR "Patella Dislocation".ti OR "Patellar Dislocations".ti OR "Patella Dislocations".ti) AND ((("variation".mp OR "variations".mp OR "difference".mp OR "differences".mp) ADJ5 ("hospital".mp OR "hospitals".mp)) OR (("variation".mp OR "variations".mp OR "difference".mp OR "differences".mp) AND exp "Hospital"/) OR "hospital characteristics".mp OR "hospital outcome".mp OR "hospital outcomes".mp OR "international variation".mp OR "international variations".mp OR "ranking hospitals".mp OR "hospital rank".mp OR "hospital ranking".mp OR "hospital rankings".mp OR "hospital ranks".mp)) **OR** (("tha".ti,ab OR "total hip".ti,ab OR exp "Hip Replacement"/ OR exp "hip arthroplasty"/ OR exp "Hip Prosthesis"/ OR "Hip Prosthesis".ti,ab OR "Hip Replacement".ti,ab OR "Hip Arthroplasty".ti,ab OR "Prosthetic Hip".ti,ab OR "Prosthetic Hip".ti,ab **OR** "tka".ti,ab OR "total knee".ti,ab OR exp "Knee Replacement"/ OR exp "knee arthroplasty"/ OR exp "Knee Prosthesis"/ OR "Knee Prosthesis".ti,ab OR "Knee Replacement".ti,ab OR "Knee Arthroplasty".ti,ab OR "Prosthetic Knee".ti,ab OR "Prosthetic Knees".ti,ab OR ((*"Arthroplasty"/ OR *"Joint Prosthesis"/ OR "Joint Arthroplasty".ti OR "Joint Replacement".ti OR "Joint Prosthesis".ti OR "Prosthetic Joint".ti OR "Prosthetic Joints".ti) AND (exp *"Hip"/ OR "hip".ti OR "hips".ti OR exp *"Knee"/ OR "knee".ti OR "knees".ti))) AND ("revision rate".mp OR "revision rates".mp OR (("revision".mp OR "revisions".mp) ADJ5 ("rate".mp OR "rates".mp OR "median".mp OR "mean".mp OR "percentage".mp OR "percent".mp OR percent*.mp)) OR "revision".mp OR "Repeat Surgery".mp OR "Joint Revision".mp OR "Reoperation"/ OR "Reoperation".mp OR Reoperat*.mp OR "Re-operation".mp OR "Re-operat*".mp OR "Length of Stay"/ OR "length of stay".mp OR "lengths of stay".mp OR "length of stays".mp OR "lengths of stays".mp OR "stay length".mp OR "stay lengths".mp OR "Hospital Readmission"/ OR "patient readmission".mp OR "hospital readmission".mp OR "patient re-admission".mp OR "hospital re-admission".mp OR "readmission".mp OR "re-admission".mp OR readmit*.mp OR "re-admit*".mp OR exp "Mortality"/ OR "mortality".mp OR mortalit*.mp OR "death".mp OR "deaths".mp OR "Cause of Death".mp OR "fatality rate".mp OR "fatality rates".mp OR "Fatal Outcome".mp OR "Fatal Outcomes".mp OR "Survival Rate"/ OR *"complication"/ OR "Postoperative Complication"/ OR exp "Prosthesis Complication"/ OR "Surgical Infection"/ OR "infectious complication"/

OR "Prosthesis Failure".mp OR "Prosthesis-Related Infections".mp OR "Prosthesis-Related Infection".mp OR "Prosthesis Infections".mp OR "Prosthesis Infection".mp OR "Surgical Wound Infection".mp OR "Surgical Infection".mp OR "Surgical Wound Infections".mp OR "Surgical Infections".mp OR "Infection"/ OR "infection".mp OR "infections".mp OR "infected".mp OR "surgical injury".mp OR "surgical injuries".mp OR "complication".mp OR "complications".mp OR "Joint Dislocation"/ OR "Dislocations".mp OR "Dislocation".mp OR dislocat*.mp OR "subluxation"/ OR Subluxat*.mp OR "prosthesis loosening"/ OR "loosening".mp OR "malalignment".mp OR "malalignments".mp OR "malaligned".mp OR exp "Joint Instability"/ OR "Instability".mp OR "Instabilities".mp OR "Patella Dislocation"/ OR "Patellar Dislocation".mp OR "Patella Dislocation".mp OR "Patellar Dislocations".mp OR "Patella Dislocations".mp) AND ((("variation".ti OR "variations".ti OR "difference".ti OR "differences".ti) AND (exp *"Hospital"/ OR "hospital".ti OR "hospitals".ti)) OR "hospital characteristics".ti OR "hospital outcome".ti OR "hospital outcomes".ti OR "international variation".ti OR "international variations".ti OR "ranking hospitals".ti OR "hospital rank".ti OR "hospital ranking".ti OR "hospital rankings".ti OR "hospital ranks".ti)) AND (2009 OR 201* OR 202*).yr

6. Academic Search Premier (http://search.ebscohost.com/login.aspx?authtype=ip,uid&profile=lumc&defaultdb=aph)

((TI("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND TI("revision rate" OR "revision rates" OR (("revision" OR "revisions") AND ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication"

OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND SU((("variation" OR "variations" OR "difference" OR "differences") NEAR5 ("hospital" OR "hospitals")) OR (("variation" OR "variations" OR "difference" OR "differences") AND "Hospital") OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks")) **OR** (SU("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND SU("revision rate" OR "revision rates" OR (("revision" OR "revisions") NEAR/5 ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR

"surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND TI((("variation" OR "variations" OR "difference" OR "differences") AND ("Hospital" OR "hospital" OR "hospitals")) OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"))

((TI("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND TI("revision rate" OR "revision rates" OR (("revision" OR "revisions") AND ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation"

OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND AB((("variation" OR "variations" OR "difference" OR "differences") NEAR5 ("hospital" OR "hospitals")) OR (("variation" OR "variations" OR "difference" OR "differences") AND "Hospital") OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks")) **OR** (AB("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND AB("revision rate" OR "revision rates" OR (("revision" OR "revisions") NEAR/5 ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND TI((("variation" OR "variations" OR "difference" OR "differences") AND ("Hospital" OR "hospital" OR "hospitals")) OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR

"international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"))**)**

((TI("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND TI("revision rate" OR "revision rates" OR (("revision" OR "revisions") AND ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND KW((("variation" OR "variations" OR "difference" OR "differences") NEAR5 ("hospital" OR "hospitals")) OR (("variation" OR "variations" OR "difference" OR "differences") AND "Hospital") OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks")) **OR** (KW("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR

"Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND KW("revision rate" OR "revision rates" OR (("revision" OR "revisions") NEAR/5 ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND TI((("variation" OR "variations" OR "difference" OR "differences") AND ("Hospital" OR "hospital" OR "hospitals")) OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"))

((TI("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint

Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND TI("revision rate" OR "revision rates" OR (("revision" OR "revisions") AND ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision" OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND TI((("variation" OR "variations" OR "difference" OR "differences") NEAR5 ("hospital" OR "hospitals")) OR (("variation" OR "variations" OR "difference" OR "differences") AND "Hospital") OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks")) **OR** (TI("tha" OR "total hip" OR "Hip Replacement" OR "hip arthroplasty" OR "Hip Prosthesis" OR "Hip Prosthesis" OR "Hip Replacement" OR "Hip Arthroplasty" OR "Prosthetic Hip" OR "Prosthetic Hip" **OR** "tka" OR "total knee" OR "Knee Replacement" OR "knee arthroplasty" OR "Knee Prosthesis" OR "Knee Prosthesis" OR "Knee Replacement" OR "Knee Arthroplasty" OR "Prosthetic Knee" OR "Prosthetic Knees" OR (("Arthroplasty" OR "Joint Prosthesis" OR "Joint Arthroplasty" OR "Joint Replacement" OR "Joint Prosthesis" OR "Prosthetic Joint" OR "Prosthetic Joints") AND ("Hip" OR "hip" OR "hips" OR "Knee" OR "knee" OR "knees"))) AND TI("revision rate" OR "revision rates" OR (("revision" OR "revisions") NEAR/5 ("rate" OR "rates" OR "median" OR "mean" OR "percentage" OR "percent" OR percent*)) OR "revision"

OR "Repeat Surgery" OR "Joint Revision" OR "Reoperation" OR "Reoperation" OR Reoperat* OR "Re-operation" OR "Re-operat" OR "Length of Stay" OR "length of stay" OR "lengths of stay" OR "length of stays" OR "lengths of stays" OR "stay length" OR "stay lengths" OR "Hospital Readmission" OR "patient readmission" OR "hospital readmission" OR "patient re-admission" OR "hospital re-admission" OR "readmission" OR "re-admission" OR readmit* OR "re-admit" OR "Mortality" OR "mortality" OR mortalit* OR "death" OR "deaths" OR "Cause of Death" OR "fatality rate" OR "fatality rates" OR "Fatal Outcome" OR "Fatal Outcomes" OR "Survival Rate" OR "complication" OR "Postoperative Complication" OR "Prosthesis Complication" OR "Surgical Infection" OR "infectious complication" OR "Prosthesis Failure" OR "Prosthesis-Related Infections" OR "Prosthesis-Related Infection" OR "Prosthesis Infections" OR "Prosthesis Infection" OR "Surgical Wound Infection" OR "Surgical Infection" OR "Surgical Wound Infections" OR "Surgical Infections" OR "Infection" OR "infection" OR "infections" OR "infected" OR "surgical injury" OR "surgical injuries" OR "complication" OR "complications" OR "Joint Dislocation" OR "Dislocations" OR "Dislocation" OR dislocat* OR "subluxation" OR Subluxat* OR "prosthesis loosening" OR "loosening" OR "malalignment" OR "malalignments" OR "malaligned" OR "Joint Instability" OR "Instability" OR "Instabilities" OR "Patella Dislocation" OR "Patellar Dislocation" OR "Patella Dislocation" OR "Patellar Dislocations" OR "Patella Dislocations") AND TI((("variation" OR "variations" OR "difference" OR "differences") AND ("Hospital" OR "hospital" OR "hospitals")) OR "hospital characteristics" OR "hospital outcome" OR "hospital outcomes" OR "international variation" OR "international variations" OR "ranking hospitals" OR "hospital rank" OR "hospital ranking" OR "hospital rankings" OR "hospital ranks"))

AND py=(2009 OR 2010 OR 2011 OR 2012 OR 2013 OR 2014 OR 2015 OR 2016 OR 2017 OR 2018 OR 2019 OR 2020)

Appendix IIA Study details

Authors	Arthroplasty	Number of patients	Number of hospitals	Time period	Data category	Data collection method	Data completeness	Indicator(s) reported
Bozic(14) *USA, 2014*	THA&TKA *Combined*	THA: 251199 TKA: 626781 THA + TKA: 118	3479	2008 to 2010	Administrative	Routinely	---	Complications
Thirukumaran(15) *USA, 2020*	THA + TKA *Combined*	---	2326	2009 to 2012 & 2013 to 2016	Administrative	Routinely	---	Readmission Complications
Courtney(39) *USA, 2018*	THA + TKA *Combined*	458259	2702	April 1, 2012 to March 31, 2015 & July 1, 2012 to June 30, 2015	Administrative	Routinely	>75%	Readmission Complications
van Schie(30) *The Netherlands, 2020*	THA&TKA *Separately*	THA: 86468 TKA: 73077	THA:97 TKA:98	2014 to 2016	Clinical	Clinician-reported	THA&TKA: 98% Revisions: 96%	Revision
Graham(21) *USA, 2019*	THA&TKA *Separately*	THA: 45833 TKA: 24338	THA: 96 TKA: 95	October 1, 2007 to September 30, 2014	Clinical	Clinician-reported	THA&TKA: 83%	Readmission Complications
Sheetz(9) *USA, 2019*	THA	143174	106	2005 to 2014	Administrative	Routinely	---	Readmission Complications Mortality
Bottle(36) *The United Kingdom, 2018*	THA&TKA *Separately*	THA: 259980 TKA: 311033	---	April 2010 to March 2015	Administrative	Routinely	---	Readmission
Padegimas(34) *USA, 2018*	TKA	430	2	2014	Administrative	Routinely	---	Revision Readmission Complications LOS
Marang-vd Mheen(50) *The Netherlands, 2017*	THA + TKA *Combined*	41397	22	July 2007 to December 2010	Administrative	Routinely	---	Complications LOS

Appendix IIA Continued

Authors	Arthroplasty	Number of patients	Number of hospitals	Time period	Data category	Data collection method	Data completeness	Indicator(s) reported
Hollis(40) *USA, 2017*	THA + TKA *Combined*	THA: 22797 TKA: 41927	84	October 1, 2007 to September 30, 2014	Clinical	Clinician-reported	---	Readmission
Qian(42) *USA, 2013*	THA	54405	77	June 2006 to September 2010	Administrative	Routinely	---	Complications
Voorn(10) *The Netherlands, 2017*	THA&TKA *Separately*	THA: 1163 TKA: 986	THA: 23 TKA: 23	May 2013 to October 2013	Clinical	Routinely	---	Complications LOS
Cram(43) *USA, 2012*	THA	202773	---	2007 to 2008	Administrative	Routinely	---	Complications
Cai(49) *USA, 2012*	TKA	610285	3101	July 1, 2002 to June 30, 2005	Administrative	Routinely	---	Complications
Padegimas(31) *USA, 2017*	THA	658	2	2014	Administrative	Routinely	---	Revision Readmission LOS
Chen(52) *USA, 2017*	THA&TKA *Separately*	THA: 122 TKA: 84	THA: 2 TKA: 2	January 2010 to August 2014	Clinical	Routinely	---	LOS
Courtney(16) *USA, 2017*	THA + TKA *Combined*	458259	2702	April 1, 2012 to March 31, 2015 & July 1, 2012 to June 30, 2015	Administrative	Routinely	>75%	Readmission Complications
Husni(54) *USA, 2010*	TKA	9157	295	2000	Administrative	Routinely	---	LOS
Hofstede(41) *The Netherlands, 2018*	THA + TKA *Combined*	120106	61	2007 to 2012	Administrative	Routinely	2007: 88% 2012: 76%	Readmission LOS
Pross(27) *Germany, 2017*	THA	---	551 to 1117	2006 to 2014	Clinical	Clinician-reported	35%	Revision Complications
Calderwood(44) *USA, 2013*	THA	524892	3296	2005 to 2007	Administrative	Routinely	≥95%	Complications
Kurtz(38) *USA, 2016*	TKA	952593	3848	2010 to 2013	Administrative	Routinely	---	Readmission

Appendix IIA Continued

Authors	Arthroplasty	Number of patients	Number of hospitals	Time period	Data category	Data collection method	Data completeness	Indicator(s) reported
Kurtz(37) *USA, 2016*	THA	442333	3730	2010 to 2013	Administrative	Routinely	---	Readmission
Jergesen(48) *USA, 2016*	THA&TKA *Separately*	THA: 272 TKA: 261	THA: 2 TKA: 2	2008 to 2012	Administrative	Routinely	---	Complications
Makela(32) *USA, 2011*	THA&TKA *Separately*	Total: 12187	THA: 60 TKA: 60	2005 to 2007	Administrative	Clinician-reported	---	Revision
Mittal(28) *USA, 2018*	THA + TKA *Combined*	---	2461	2012 to 2015	Administrative	Routinely	---	Readmission
Skufca(45) *Finland, 2017*	THA&TKA *Separately*	THA: 73227 TKA: 56860	THA: 17 TKA: 18	1999 to 2014	Clinical	Clinician-reported	---	Complications
Asaid(51) *Australia, 2013*	THA + TKA *Combined*	THA: 938 TKA: 658	2	June 28, 2002 to September 3, 2007	Clinical	Routinely	---	Complications
Dailey(46) *Australia, 2009*	THA&TKA *Separately*	THA: 4131 TKA: 4858	THA: 10 TKA: 9	July 1, 2005 to June 30, 2007	Clinical	Clinician-reported	THA: 83% TKA: 78%	Complications
Martino(53) *USA, 2018*	THA&TKA *Separately*	THA: 495 TKA: 796	THA: 2 TKA: 2	June 2013 to December 2014	Clinical	Routinely	---	LOS
Singh(33) *United Kingdom, 2017*	THA + TKA *Combined*	THA: 4915 TKA: 5928	2	April 2003 to October 2014	Clinical	Clinician-reported	---	Revision Complications
Husted(29) *Denmark, 2010*	THA&TKA *Separately*	---	THA: 48 TKA: 43	2004	Clinical	Clinician-reported	---	LOS
Lopez-Contreras(47) *Spain, 2012*	THA&TKA *Separately*	THA: 7804 TKA: 16781	THA: 49 TKA: 51	2007 to 2009	Clinical	Clinician-reported	---	Complications

Appendix IIB Registry reports details

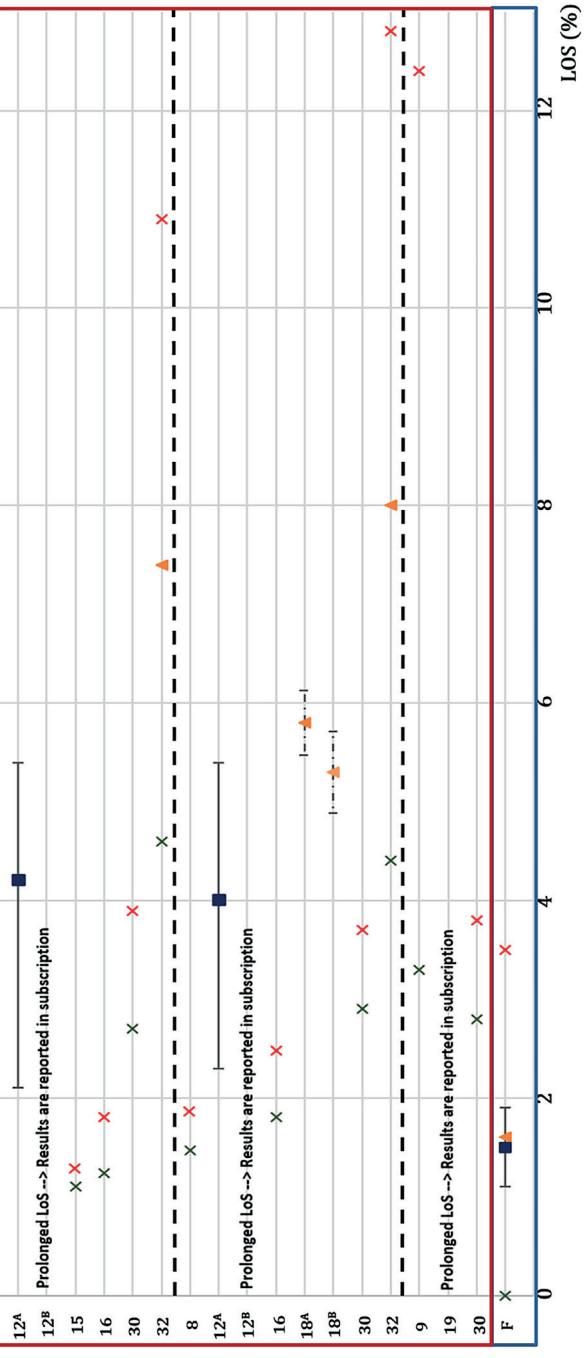
Register reports	Arthroplasty	Number of patients	Number of hospitals	Completeness of data		Indicator(s) reported
				Overall	Individual hospitals	
Norwegian Arthroplasty Registry(1) *Norway, 2020* *Founded in 1987*	THA & TKA	THA (2019): 9879 TKA (2019): 7161	THA: 57 TKA: 58	THA (2017-2018): 97.5% THA revision: 93.1% TKA (2017-2018): 97.6% TKA revision: 93.2%	Yes	Revision
Dutch Arthroplasty Registry(2) *The Netherlands, 2020* *Founded in 2007*	THA & TKA	THA (2019): 33248 TKA (2019): 25859	THA: 95 TKA: 91	THA (2018): 99% THA revision (2018): 97% TKA (2018): 99% TKA revision (2018): 97%	No	Revision
Swedish Knee Arthroplasty Registry(3) *Sweden, 2020* *Founded in 1975*	TKA	2019: 14977	72	2018: 97.1%	Yes	Revision Complications Mortality
Danish Hip Arthroplasty Registry(4) *Denmark, 2020* *Founded in 1995*	THA	2019: 11193	47	2019: 96.5% Revision (2019): 86.2%	Yes	Revision Readmission Complications
Swedish Hip Arthroplasty Registry(5) *Sweden, 2019* *Founded in 1979*	THA	2018: 18629	81	2017: 98%	Yes	Revision Complications Mortality
Danish Knee Arthroplasty Registry(6) *Denmark, 2020* *Founded in 1997*	TKA	2019: 11124	39	2019: 95.7% Revision (2019): 89.7%.	Yes	Revision Readmission LOS

Appendix IIB Continued

Register reports	Arthroplasty	Number of patients	Number of hospitals	Completeness of data		Indicator(s) reported
				Overall	Individual hospitals	
Finnish Arthroplasty Registry(7) *Finland, 2020* *Founded in 1980*	THA & TKA	THA (2019): 10495 TKA (2019): 13460	THA: 51 TKA: 51	THA (2019): 94.9% TKA (2019): 97.1%	Yes	Revision
Swiss Arthroplasty Registry(8) *Switzerland, 2020* *Founded in 2012*	THA & TKA	THA (2019): 19897 TKA (2019): 15378	THA: 152 TKA: 148	THA and TKA combined (2019): >95%	Yes	Revision

LOS=length-of-stay; THA=total hip arthroplasty; TKA=total knee arthroplasty; USA=United States of America.

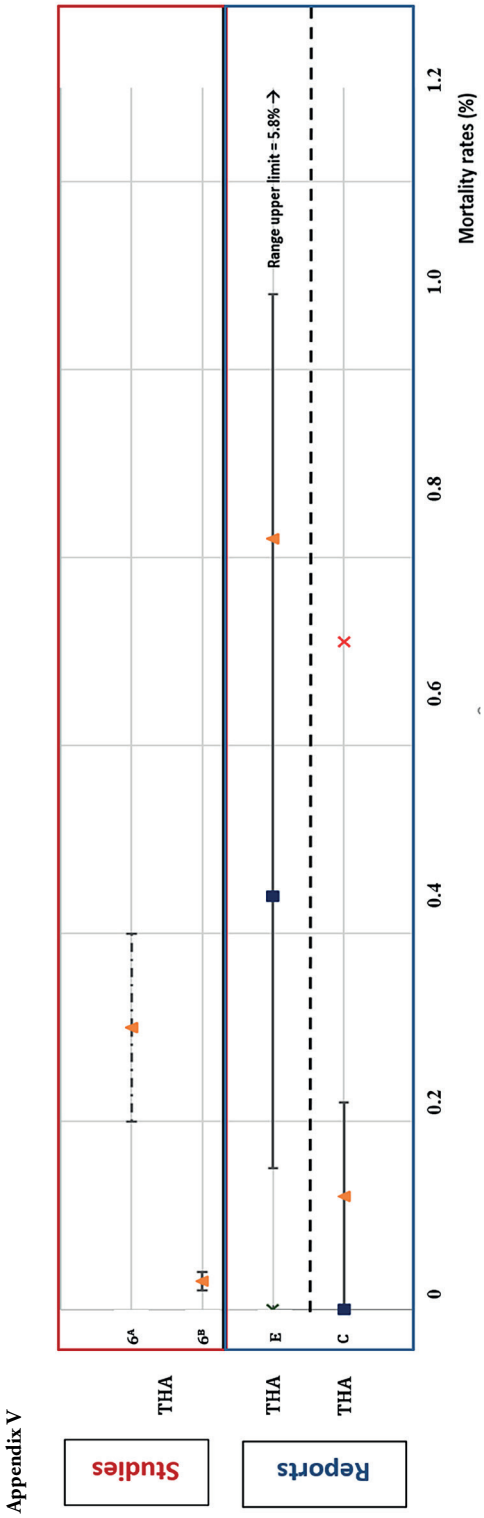
Appendix III



Appendix IV Measurements to report between-hospital variation for length-of-stay

Length-of-stay	Studies (*n*=9)			Registry reports (*n*=1)
	THA (*n*=6) [12[A],12[B],15, 16,30,32]	**TKA (*n*=8)** [8,12[A],12[B],16,18[A], 18[B],30,32]	**THA&TKA (*n*=3)** [9,19,30]	**TKA (*n*=1)** [F]
1a) Outcome definition I				
Nights spent in hospital	[15,30]	[8,30]	[30]	---
Post-operative stay	[12[A],12[B]]	[12[A],12[B],18[A],18[B]]	---	[F]
Total LOS	[16]	[16]	---	---
+LOS rehabilitation centre	[32]	[32]	---	---
Unclear	---	---	[9,19]	---
1b) Outcome definition II				
LOS (days)	[12[A],15,16,30,32]	[8,12[A],16-32]	[9,30]	[F]
Extended LOS (%)	[12[B]]	[12[B]]	[19]	---
2) Case-mix adjusted				
Yes	[12[B]]	[12[B]]	---	---
No	[12[A],15,16,30,32]	[8,12[A],16-32]	[9-30]	[F]
3a) Type of patient selected				
Age selection(s)	[12[A],12[B],30]	[12[A],12[B],30]	[30]	---
Osteoarthritis	---	---	[19]	---
No trauma patients	[15]	[8]	---	---
Medicare patients	---	[18[A],18[B]]	---	---
Elective surgery	[12[A],12[B]]	[12[A],12[B]]	---	---
Matching of patient groups	[15,16]	[8,16]	---	---
No selections	32	[32]	[9]	[F]
3b) Type of hospitals selected				
Academic hospitals	---	---	[9]	---
Non-academic hospitals	[12[A],12[B]]	[12[A],12[B]]	---	---
Critical pathway hospitals	---	[18[A]]	---	---
Non-critical pathway hospitals	---	[18[B]]	---	---
Unclear	[32]	[32]	---	---
No selections	[15,16,30]	[8,16,30]	[19,30]	[F]

The definitions for length-of-stay were defined for 5 domains. The numbers in brackets correspond to the study numbers from Table 1A and the letters in brackets correspond to the report codes from Table 1B.
LOS=length-of-stay ; THA=total hip arthroplasty; TKA=total knee arthroplasty.


Studies
Reports
THA
THA
THA
6A
6B
E
C
Range upper limit = 5.8% →
0
0.2
0.4
0.6
0.8
1.0
1.2
Mortality rates (%)

Appendix V

Appendix VI Measurements to report between-hospital variation for mortality

	Studies (*n*=1)	Registry reports (*n*=2)	
	THA (*n*=2)	THA (*n*=1)	TKA (*n*=1)
Mortality	[6[A],6[B]]	[E]	[C]
1) Outcome definition			
Post-operative	[6[A],6[B]]	[E]	[C]
2) Follow-up			
Within 30 days	[6[A],6[B]]	---	---
Within 90 days	---	[E]	[C]
3) Case-mix adjusted			
Yes	[6[A],6[B]]	---	---
No	---	[E]	[C]
4a) Type of patient selected			
Age	[6[A],6[B]]	---	---
Medicare patients	[6[A],6[B]]	---	---
Multiple selections were made	---	[E]	---
4b) Type of hospitals selected			
Honor roll hospitals	[6[A]]	---	---
Affiliated honor roll hospitals	[6[B]]	---	---

The definitions for mortality were defined for 5 domains. The numbers in brackets correspond to the study numbers from Table 1A, and the letters in brackets correspond to the report codes from Table 1B.