The safety of bilateral simultaneous hip and knee arthroplasty versus staged arthroplasty in a high volume center comparing blood loss, peri- and postoperative complications, and early functional outcome.

Michael Najfeld [1], Thomas Kalteis [1], Christian Spiegler [1], Christophe Ley [2], Robert Hube [1]

[1] OCM Orthopädische Chirurgie München

[2] Ghent University

Kontaktautor:

Michael Najfeld Dr. med.

OCM München

Steinerstr. 6

81369 München

Deutschland

E-mail: michael.najfeld@ocm-muenchen.de

Tel.: + 49 – 89 – 20608242 Fax : + 49 – 89 – 206082333

Abstract:

Purpose: In recent years, there has been an increasing interest in simultaneous hip and knee arthroplasty compared to staged procedures. The aim of this study was to clarify some controversies and show the safety for the patients by comparing the transfusion rate, postoperative hemoglobin drop, length of stay (LOS), in hospital complications, 30-days readmissions and early functional outcome after simultaneous and staged hip and knee arthroplasty.

Methods: We conducted a retrospective trial that included all patients who were undergoing primary TKA, THA and UKA by one single surgeon in a high-volume arthroplasty center between 2015 and 2020 as simultaneous or staged procedure. Staged bilateral arthroplasties were performed within 12 months and were stratified by the time between procedures. Data was acquired through the electronic files at the OCM. For functional outcome we compared the ability of the patients to walk independently on the ward and the ability to walk a set of stairs alone which was daily recorded by the attending physiotherapist.

Results: In total 305 patients were assessed for eligibility and included in this clinical trial. 145 patients were allocated to the staged arthroplasty group. That group was subdivided in a hip and a knee group, whereas the knee group was split in TKA and unicompartimental knee arthroplasty (UKA). The second staged procedure was performed within 12 months of the first procedure.160 patients were allocated to the simultaneous arthroplasty group. This group was also subdivided into a hip and knee group, whereas the knee group was split again in a TKA and UKA group. No statistical difference was found between the two groups regarding demographic data. Primary outcome measurements: There is no significant difference in transfusion rate or complication rate.

Secondarily: No correlation was found between the Hb-drop and the functional outcome as well as the length of stay (LOS). Walking the stairs showed a significant difference in the knee group.

Conclusion: We observed no significant differences in transfusion rate, in hospital complications, as well as readmission rate. The early functional outcome showed no significant difference in mobility for all groups. Simultaneous arthroplasty for knee or hip is as safe as a staged procedure, with no higher risk for the patient and his outcome, in a high volume center.

Level of evidence: Level IV

Key words: Bilateral simultaneous; Arthroplasty; Hip; Replacement; Knee; Staged; Complications

Introduction

Bilateral simultaneous total hip arthroplasty (THA), as well as bilateral simultaneous total knee arthroplasty (TKA) has been on the rise for the past couple of years. Initial data suggested however that simultaneous bilateral hip arthroplasty is associated with an increased rate of complications, including occurrences of deep-vein thrombosis (DVT)[1], as well as increased medical morbidities, thus leading to suboptimal functional outcomes[3]. Other studies found increased postoperative mortality and complications after simultaneous bilateral TKA compared to staged bilateral TKA, with pulmonary embolism and cardiac complications as the major complications[4][5][6][7]. In contrast, other studies reported no differences in mortality and complications between simultaneous and staged procedures[8][9][10].

This has led to the evaluation of the best strategy to operate a bilateral hip or knee replacement without increasing the risk of perioperative comorbidities, having as options a simultaneous bilateral hip or knee replacement or a sequential surgery[11]. From the perspective of fast-track surgery, it is ideal to offer a simultaneous bilateral procedure instead of a staged procedure. However, only if the simultaneous procedure is as safe as the staged alternative. Promising results with low postoperative morbidity and mortality after simultaneous bilateral TKA in selected patients have been reported[12][13][14]

Systemic reviews for hip and knee arthroplasty are not always conclusive for simultaneous versus staged arthroplasty in recent years [15][16]. The aim of this study was to show that simultaneous hip and knee arthroplasty can achieve similar results as the staged arthroplasty and the fact, that the surgery is performed in a high volume center is contributing to the safety of the patients.

Patients and methods

The regional ethics committee waived the need for approval on January 20th 2021, as this was an observational non-interventional study. We conducted a non-randomized, non-blinded retrospective trial that included all patients that were scheduled to undergo primary TKA, THA and UKA by one single surgeon (R.H.) in a high-volume arthroplasty center between January 2017 and December 2020. The inclusion criteria were any patient undergoing a primary TKA, THA and UKA for primary or secondary knee osteoarthritis without previous joint arthrotomy. Exclusion criteria were based on patients that lacked capacity to consent to the study or patients who were unwilling to consent and patients who have previous joint arthrotomy, as well as revision cases were also excluded.

All surgeries were performed without a tourniquet with the medial parapatellar approach for TKA, OCM-approach (muscle sparing anterolateral approach) for THA and a modified minimal invasive

parapatellar approach for the UKA. All departments have implemented protocols, including anaesthesia, tranexamic acid, opioid-sparing analgesia with acetaminophen, non-steroid anti-inflammatory drugs (NSAIDs), and early mobilization, regardless of age or preexisting comorbidity. The postoperative rehabilitation regimens were the same for both groups simultaneous and staged for hips and knees and started the day of surgery. The first mobilization of the patient for all joints was performed under the supervision of physiotherapy in the postoperative area or on the regular ward. Transfer from the bed to the floor and quadriceps setting exercise were started on day 1 after surgery. Ambulatory training with weight bearing as tolerated and active-assisted range of motion exercises were started on the day of surgery as well as gait training using a walker. Walking outside on the ward was facilitated as soon as the patient was safely ambulating in his room and stairs were performed as soon as free outside walking was performed.

Demographic data as age, sex, height, weight and the resulting body mass index and operated side were protocolled. operation time (OR time), surgical and medical complications were collected from the patient's electronic file, as well as every visit of the patient within 90 days postoperatively in our clinic. The OR time was defined by the incision of the skin and the closure of the skin by the last suture.

In total 305 patients were included in the study. The included patients were divided into 2 groups according to how the arthroplasty was performed, simultaneous 160 (52,46%) versus staged 145 (47,54%). Within each group patients were differentiated between THA, TKA and UKA. Figure 1 shows the separation into the specific groups.

Correlations have been calculated via the classical Pearson correlation coefficient and the associated uncertainty is conveyed via confidence intervals.

Hb drop between the two groups has been compared via the Kolmogorov-Smirnov two-sample test, while all other comparisons have been achieved via the Mann-Whitney U test (also known as Wilcoxon rank-sum test). We made this distinction because Hb drop values were given at a continuous scale, contrary to the discrete ordinal scale of all other values (LOS, Stairs POD, free moving PPOD, OR time). The significance level of all tests was 5%.

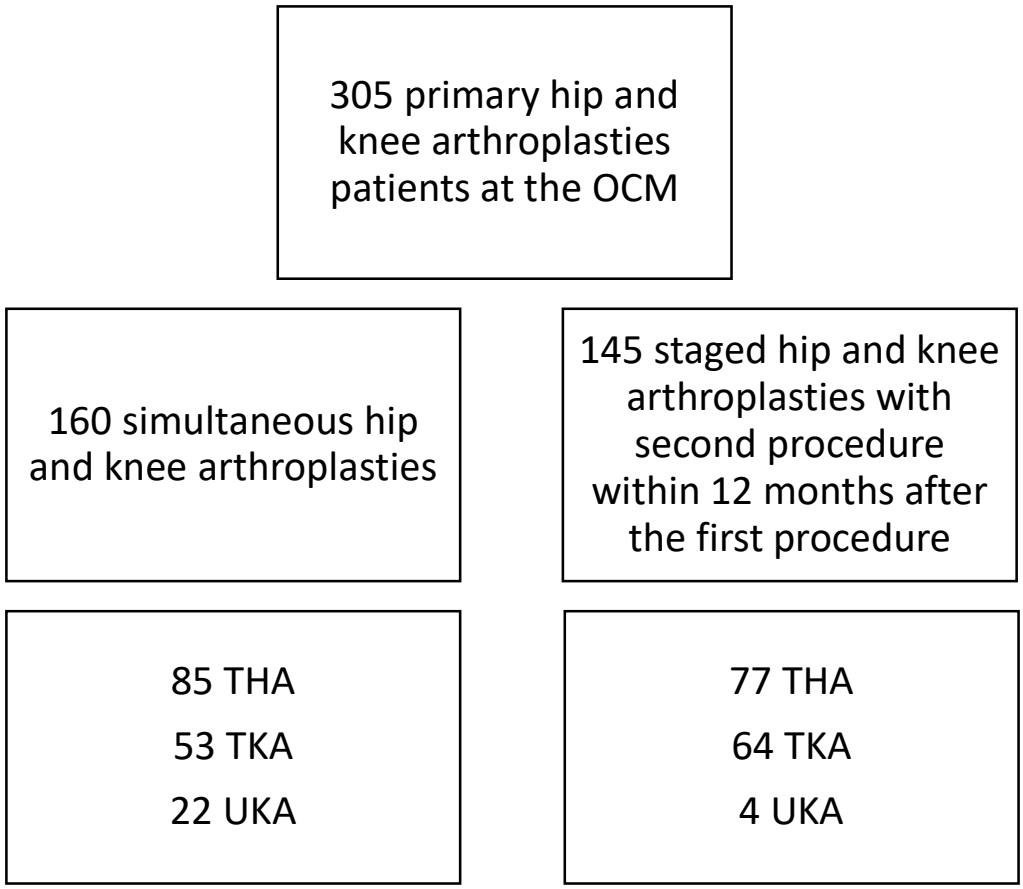

Figure 1 Flowchart of the study's selected patients

Pre-operative characteristics $n(\%)$	THA $n = 85$	TKA $n = 53$	UKA $n = 22$
Age mean (range)	62.8 (32-81)	69.6 (49-84)	65.5 (52-82)
< 50	10 (11.76)	1 (1.89)	0 (0)
50-60	27 (31.76)	5 (9.43)	7 (31.82)
61-65	15 (17.65)	9 (16.98)	5 (22.73)
66-70	8 (9.41)	10 (18.87)	3 (13.64)
71-75	11 (12.94)	18 (33.96)	3 (13.64)
76-80	12 (14.12)	6 (11.32)	3 (13.64)
> 80	2 (2.35)	4 (7.55)	1 (4.55)
BMI mean (range)	26.3 (18-40)	28.1 (18.9-43.2)	27.7 (22.7-33.5)
< 18.5	1 (1.18)	0 (0)	0 (0)
18.5-24.9	35 (41.18)	13 (24.53)	4 (18.18)
25-29.9	35 (41.18)	27 (50.94)	14 (63.64)
30-34.9	8 (9.41)	9 (16.98)	4 (18.18)
35-39.9	5 (5.88)	3 (5.66)	0 (0)
> 40	1 (1.18)	1 (1.89)	0 (0)
Female	36 (42.35)	22 (41.51)	3 (13.64)
Male	49 (57.65)	31 (58.49)	19 (86.36)

Figure 2 Characteristics of patients having received a simultaneous arthroplasty

Pre-operative characteristics $n(\%)$	THA $n = 77$	TKA $n = 64$	UKA $n = 4$
Age mean (range)	64 (37-86)	69.7 (51-87)	75.8 (64-81)
< 50	8 (10.39)	0 (0)	0 (0)
50-60	21 (27.27)	11 (17.19)	0 (0)
61-65	13 (16.88)	11 (17.19)	1 (25.00)
66-70	14 (18.18)	10 (15.63)	0 (0)
71-75	9 (11.69)	13 (20.31)	0 (0)
76-80	8 (10.39)	14 (21.88)	1 (25.00)
> 80	4 (5.19)	5 (7.81)	2 (50.00)
BMI mean (range)	26.2 (17.6-39.7)	28.4 (20-42.7)	25.1 (21.4-27.5)
< 18.5	1 (1.30)	0 (0)	0 (0)
18.5-24.9	40 (51.95)	21 (32.81)	1 (25.00)
25-29.9	19 (24.68)	18 (28.13)	3 (75.00)
30-34.9	11 (14.29)	18 (28.13)	0 (0)
35-39.9	6 (7.79)	5 (7.81)	0 (0)
> 40	0 (0)	2 (3.13)	0 (0)
Female	48 (62.34)	37 (57.81)	0 (0)
Male	29 (37.66)	27 (42.19)	4 (100)

Figure 3 Characteristics of patients having received a staged arthroplasty

Results

The study population consisted of 305 patients. 160 received a simultaneous procedure versus 145 with staged arthroplasty. In the THA group 85 (53%) simultaneous versus 77 (53%) staged arthroplasties were performed. The average length of stay (LOS) for the simultaneous THA group was 7 days (± 2 days) with a range of 4-12 days, versus the staged THA group 7 days (± 1,5 days) with a range of 3-15 days. The hemoglobin drop in the simultaneous group was on average 2,2 g/dl (± 0,9) compared to 1,9 g/dl (±0,9) in the staged group. The transfusion rate for both groups was 0% and no significant difference was found in the Hb-drop after the first staged procedure (p= 0,1147) compared to a significant difference after the second procedure (p= 0,0271) in comparison with the simultaneous procedure. The mean OR time for the simultaneous group was 79 min (±13) versus 29 min (± 5) for one hip of the staged group. Statistical analysis of OR time showed a significant difference for the hip group $p<0,05$ with dividing the OR time in half for the simultaneous procedures compared to the average of the staged procedures. The 30 day readmission rate was 0,02% after simultaneous versus 0,01% after staged THA arthroplasty. 1 patient had to be re-operated for a hematoma in the simultaneous group and 1 had to be readmitted for swelling and hematoma compared to 1 readmission for fracture in the staged group. No medical complications, as well as no deaths, occurred within 30 days of surgery for the THA group. Independent mobilization of the patient on the ward was achieved after 2,5 (±0,7) days and the ability to walk stairs alone after 4 (±1) for the simultaneous THA, compared to 2,5 (±0,7) respectively stairs after 3,5 (±1) in the staged THA group. No significant difference were found in the early functional outcome for mobility and ability to walk stairs for the hip group. In the correlation examination no significant difference could be found for Hb-drop, age and BMI in relation to LOS, functional outcome for the simultaneous group figure 4,5 and 6. In the staged group a positive correlation with significance was described between Hb-drop and the ability to walk stairs (figure 9).

Whereas the age and Hb-drop was a significant negative correlation. (figure 7)

In the TKA group 53 (33%) simultaneous versus 64 (44%) staged arthroplasties were performed. The average LOS after simultaneous TKA was 8 days (± 2 days) versus 7 (± 2 days) after staged procedure with a range of 4-16 days respectively 3-13 days. The mean hemoglobin drop after simultaneous procedure was 2,4 g/dl (±0,8) versus 1,9 g/dl (±0,7) after staged procedure. No transfusion was performed in both groups. The Hb-drop difference after the first and second staged procedure was significant compared to the simultaneous procedure (p= 0,0013 and p= 0,0220) The mean OR time after simultaneous TKA was 85min (±17) compared to 40min (±10) for one TKA in the staged group. Statistical analysis showed no difference between the half of a simultaneous procedure and the time of a staged procedure. The 30 day readmission rate 0,02% after simultaneous TKA versus 0,01% after staged TKA. 1 patient in the simultaneous group had to be readmitted for wound issues with no surgical treatment and 1 patient in the staged group was readmitted for early infection with surgical debridement. Within the first 2 months post-surgery 2 patients from the simultaneous TKA group had to undergo a mobilization of the knee and an arthroscopic debridement. No medical complications, as well as no deaths occurred within 30 days of surgery for the TKA groups. The independent mobilization of the simultaneous TKA patients was achieved after 3 days (±1,5) and the ability to walk stairs alone after 4 days (±1) versus independent mobilization after 2,5 days (±0,7) and stairs after 3,5 days (±1) in the staged TKA group. The was no difference for the independent mobilization but a significant one for the ability to walk stairs comparing to the first and second staged procedure to the simultaneous group (p= 0,0020 and p= 0,00001). In the correlation examination no significant difference could be found for Hb-drop, age and BMI in relation to LOS, functional outcome in the simultaneous group. (figure 4,5,6) In the staged group a positive significant correlation between age and the ability to walk stairs was found (figure 7) and a negative significant correlation between BMI and the ability to walk independently. (figure 8)

In the UKA group 22 (14%) procedures were performed simultaneously compared to 4 (3%) staged. The average LOS after simultaneous UKA was 6,5 days (± 2 days) versus 5,5 (± 1,5 days) after staged procedure with a range of 4-11 days respectively 4-8 days. The mean hemoglobin drop after simultaneous procedure was 2 g/dl (±1) versus 1,5 g/dl (±0,6) after staged procedure. No transfusion was performed in both groups. The mean OR time after simultaneous UKA was 75min (±21) compared to 35min (±3) for one UKA in the staged group. No patient had to be readmitted 30 days post-surgery. 1 patient in the simultaneous UKA group had to be treated by intern medicine for hemorrhagic gastritis postoperatively. Early independent mobilization was achieved after 2,5 days (±1) and independent mobility on stairs after 4 days (±1) in the simultaneous UKA group versus after 2 days (±1) respectively stairs after 3,5 days (±1) in the staged UKA group. No statistical analysis comparing the difference of Hb-drop, LOS and functional outcome could be performed due to the limited number of patients. In the correlation analysis no significance could be found between age, BMI, Hb-drop compared to LOS and functional outcome for the simultaneous group. In the staged group only a significant positive correlation was found between BMI and LOS. (figure 8)

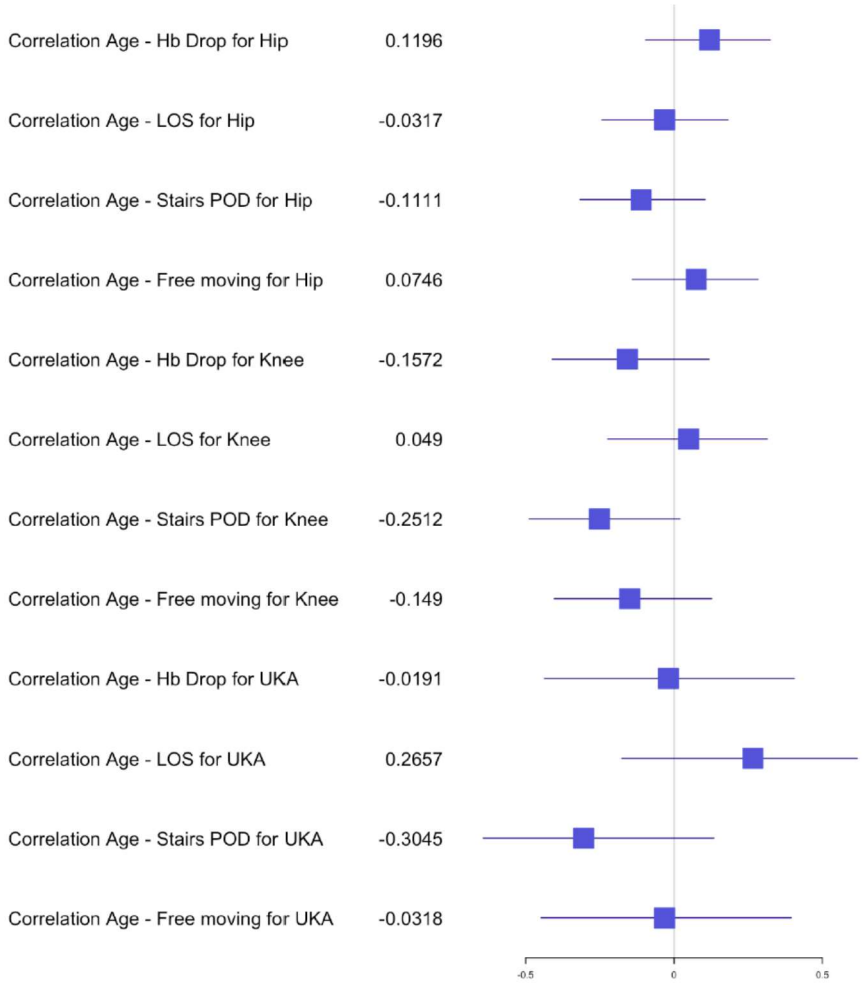

Figure 4 Forest plot for the effect of age on Hb-drop, LOS and functional outcome for simultaneous arthroplasty

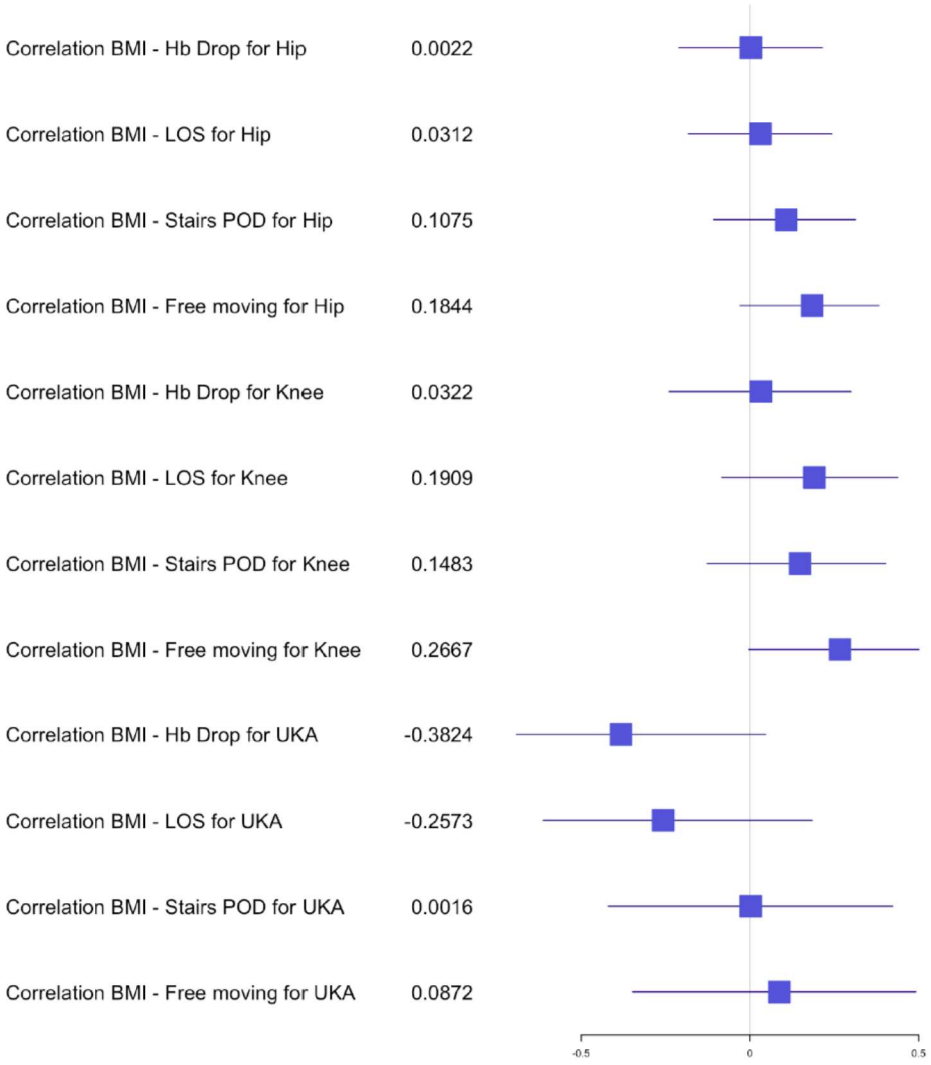

Figure 5 Forest plot for the effects of BMI on Hb-drop, LOS and functional outcome for simultaneous arthroplasty

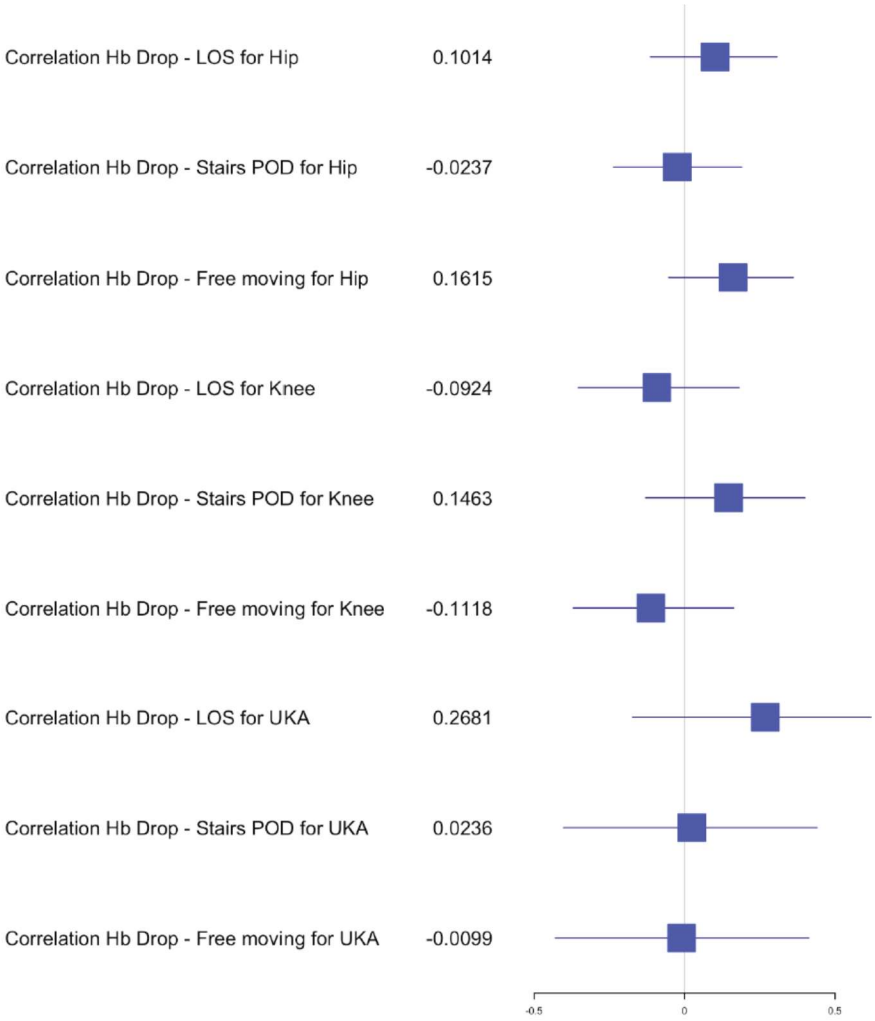

Figure 6 Forest plot for the effects of Hb-drop on LOS and functional outcome for simultaneous arthroplasty

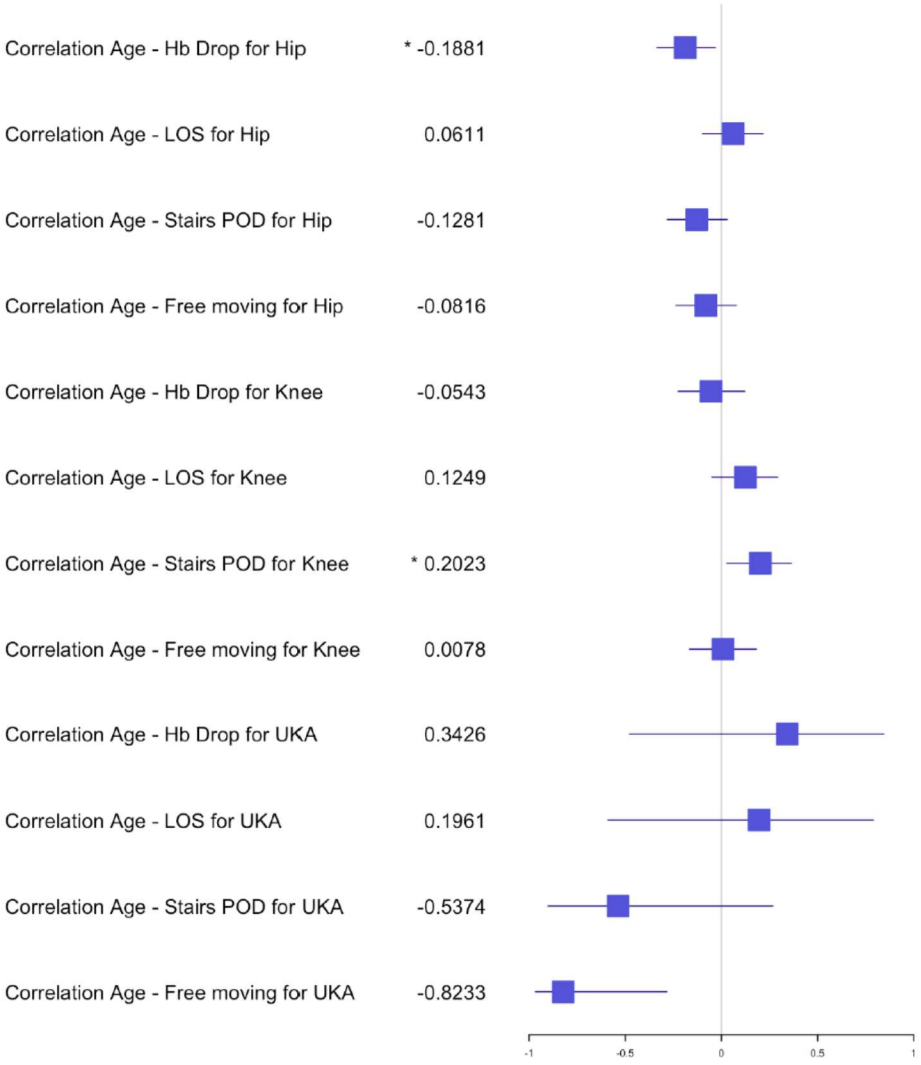

Figure 7 Forest plot for the effects of age on Hb-drop, LOS and functional outcome for staged arthroplasty

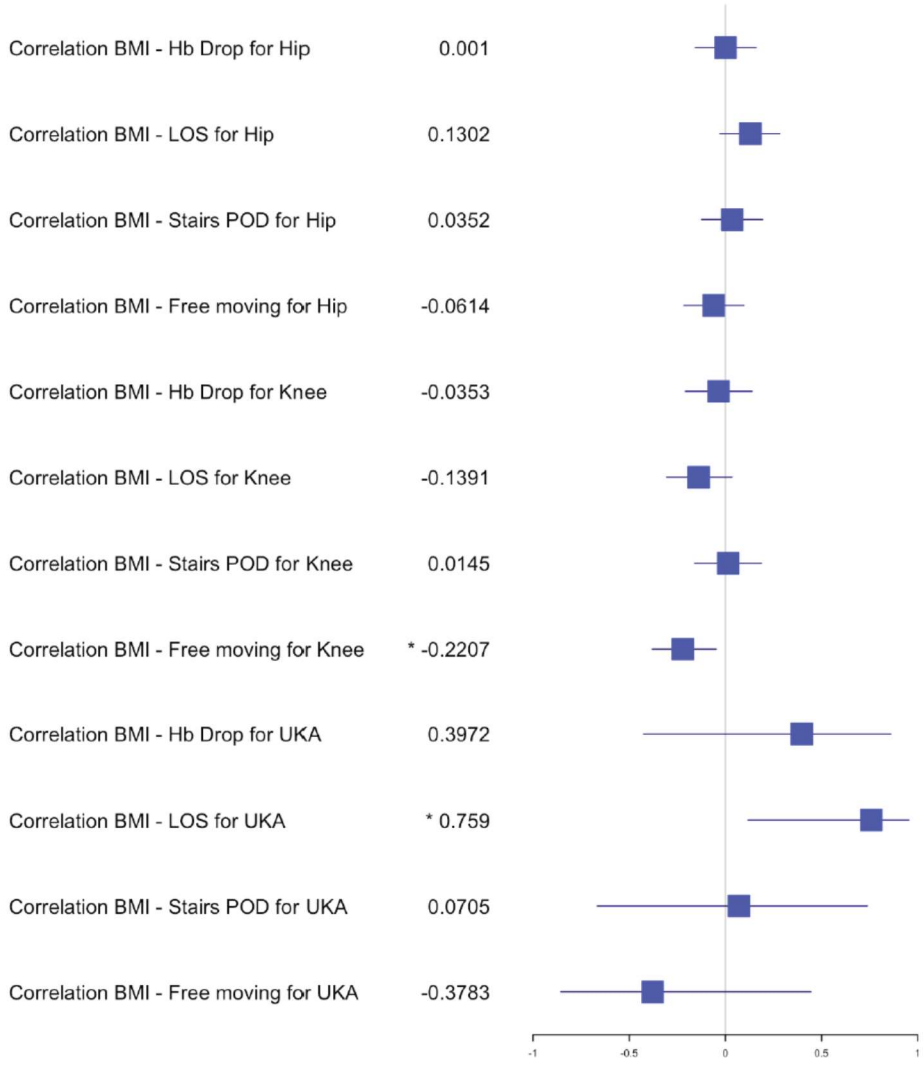

Figure 8 Forest plot for the effects of BMI on Hb-drop, LOS and functional outcome for staged arthroplasty

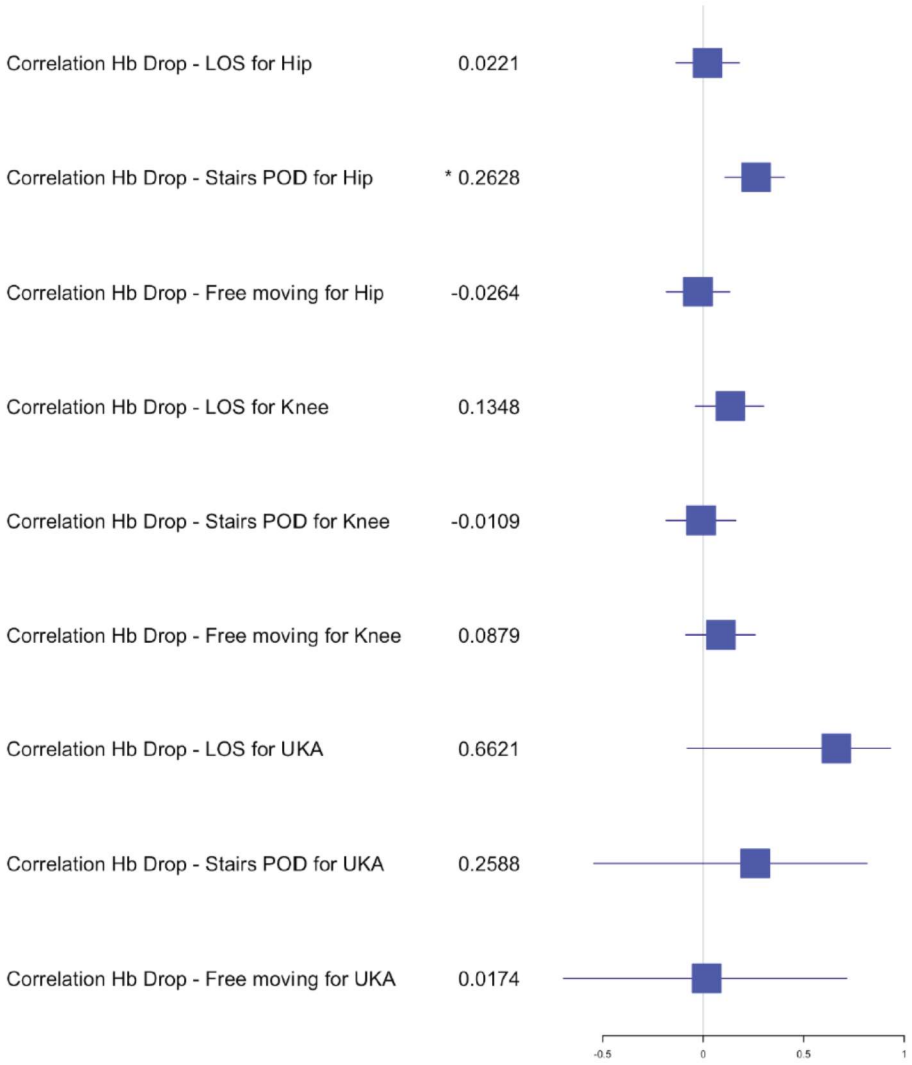

Figure 9 Forest plot of the effects of Hb-drop on LOS and functional outcome for staged arthroplasty

Discussion

Our study found no significant differences between transfusion rate, peri- and postoperative complications, early functional outcome except stairs for knees, and 30 day readmission rate in total hip and knee arthroplasty as well as unicompartmental knee arthroplasty. The Hb-drop was significantly different for knee arthroplasty comparing staged to simultaneous procedure. Nevertheless, the clinical outcome for mobility showed no difference. The ability to walk independently stairs was significantly delayed for knees and the positive correlation between age and stairs shows that older people have more difficulties. These finding reflect previous published

literature[17][18][19][20].The transfusion rate, was for all patients of this study 0%. Most likely the early mobilization on the same day of surgery contributed to these findings[12]. Nevertheless for THA patients a higher Hb-drop delays the ability to walk stairs in the correlation analysis. Age on the other hand influences the Hb-drop negatively for THA patients. No higher in-hospital complications could be found for THA, TKA and UKA.

Within the first 12 month, only (n=2) patients needed additional surgery for mobilization and arthroscopic debridement in the simultaneous group compared to the staged TKA. No higher morbidity or mortality rate was found in either group. No medical complication, consisting of a pulmonary embolism, deep venous thrombosis or respiratory distress could be found. These findings are confirming the previous meta-analysis by Haverkamp et al.[21] Only (n=1) patient developed a hemorrhagic gastritis in the early postoperative phase in the simultaneous UKA group.

The LOS in this study cannot be compared to previous studies as the German health system has a minimum stay criteria of 3-4 days for full remuneration. Nevertheless, within this study, no significant difference could be shown within all the groups and the length of stay and no correlation was found with the BMI, age or Hb-drop. Therefore the cumulated postoperative rehabilitation period after simultaneous procedure can be considered as shorter than the staged procedure. Early independent mobilization could be achieved at similar time. An earlier return to normal physical activity and better quality of life can be assumed. Further investigations about the quality of life and the mobilization with 12 months post-surgery should be investigated[17].

No higher infection rate has been observed for THA, TKA and the UKA group. Interestingly the OR time for knee arthroplasty per single staged procedure showed no significant difference compared to the simultaneous group and the fact that the average OR time doesn’t exceed the 100 min windows for increased infection rate[22], it is safe to be performed. For hip arthroplasty the significant difference can be explained by the fact that the hip is in lateral positioning and for

the second procedure in the simultaneous group, the patient had to be repositioned and re-draped for the second procedure. The OR time was still running at that time. Nevertheless, in these cases the average OR time still didn't exceed the 100min window. Different perioperative implantation, as well as the fact that these surgeries are performed by a high volume surgeon, are contributing to the reduced OR time and also to the mobilization on the same day of surgery.

The limitation of the study is the retrospective data collection and the number of patients in each group. Specific comorbidities are not registered and should have been ideally incorporated. The UKA group was limited in its statistical analysis due to the reduced number of patients in one group. A strength is a standardized fast track setup for one high volume surgeon for all procedures, with data collected till recently. Similar to Sheth et al.[18] the second procedure of the staged group could have been perform up to 12 month after the first procedure. This allowed to include a higher number of patients.

Conclusion

In conclusion we found no higher rate of transfusion, hemoglobin drop, peri- and postoperative complications. The early mobilization had no significant difference in each group. It is safe to perform bilateral simultaneous arthroplasty procedures for hips and knees in the context of a fast track setting in a high-volume institution. However further investigations are needed for more precise clinical outcomes in the early postoperative phase and long term results.

Abbreviations

BMI	Body mass index
DVT	Deep venous thrombosis
Hb	Hemoglobin

UKA	unicompartmental knee arthroplasty
LOS	Length of stay
NSAIDs	Nonsteroidal anti-inflammatory drugs
OR time	Operation time
THA	Total hip arthroplasty
TKA	Total knee arthroplasty

Conflict of interest:

The authors declare no conflicts of interest.

References

1. Ritter, M.A.; Stringer, E.A. Bilateral total hip arthroplasty: A single procedure. *Clin. Orthop. Relat. Res.* **1980**, *NO 149*, 185–190, doi:10.1097/00003086-198006000-00025.

2. Ritter MA, S.E. Bilateral total hip arthroplasty: a single procedure - PubMed Available online: https://pubmed.ncbi.nlm.nih.gov/7408301/ (accessed on Feb 28, 2021).

3. Wykman, A.; Olsson, E. Walking ability after total hip replacement: A comparison of gait analysis in unilateral and bilateral cases. *J. Bone Jt. Surg. - Ser. B* **1992**, *74*, 53–56, doi:10.1302/0301-620x.74b1.1732266.

4. Bolognesi, M.P.; Watters, T.S.; Attarian, D.E.; Wellman, S.S.; Setoguchi, S. Simultaneous vs Staged bilateral total knee arthroplasty among medicare beneficiaries, 2000-2009. *J. Arthroplasty* **2013**, *28*, 87–91, doi:10.1016/j.arth.2013.05.039.

5. Meehan, J.P.; Danielsen, B.; Tancredi, D.J.; Kim, S.; Jamali, A.A.; White, R.H. A population-based comparison of the incidence of adverse outcomes after simultaneous-bilateral and staged-bilateral total knee arthroplasty. *J. Bone Jt. Surg. - Ser. A* **2011**, *93*, 2203–2213, doi:10.2106/JBJS.J.01350.

6. Peskun, C.; Mayne, I.; Malempati, H.; Kosashvili, Y.; Gross, A.; Backstein, D. Cardiovascular disease predicts complications following bilateral total knee arthroplasty under a single anesthetic. *Knee* **2012**, *19*, 580–584, doi:10.1016/j.knee.2011.09.010.

7. Shao, H.; Chen, C.L.; Maltenfort, M.G.; Restrepo, C.; Rothman, R.H.; Chen, A.F. Bilateral Total Hip Arthroplasty: 1-Stage or 2-Stage? A Meta-Analysis. *J. Arthroplasty* 2017, *32*, 689–695.

8. Hooper, G.J.; Hooper, N.M.; Rothwell, A.G.; Hobbs, T. Bilateral Total Joint Arthroplasty. The Early Results from the New Zealand National Joint Registry. *J. Arthroplasty* **2009**, *24*, 1174–1177, doi:10.1016/j.arth.2008.09.022.

9. Bini, S.A.; Khatod, M.; Inacio, M.C.S.; Paxton, E.W. Same-Day Versus Staged Bilateral Total Knee Arthroplasty Poses No Increase in Complications in 6672 Primary

Procedures. *J. Arthroplasty* **2014**, *29*, 694–697, doi:10.1016/j.arth.2012.09.009.

10. Lindberg-Larsen, M.; Jørgensen, C.C.; Husted, H.; Kehlet, H. Early morbidity after simultaneous and staged bilateral total knee arthroplasty. *Knee Surgery, Sport. Traumatol. Arthrosc.* **2015**, *23*, 831–837, doi:10.1007/s00167-014-2880-1.

11. Alfaro-Adrián, J.; Bayona, F.; Rech, J.A.; Murray, D.W. One- or two-stage bilateral total hip replacement. *J. Arthroplasty* **1999**, *14*, 439–445, doi:10.1016/S0883-5403(99)90099-2.

12. Gromov, K.; Troelsen, A.; Stahl Otte, K.; Ørsnes, T.; Husted, H. Morbidity and mortality after bilateral simultaneous total knee arthroplasty in a fast-track setting. *Acta Orthop.* **2016**, *87*, 286–290, doi:10.3109/17453674.2016.1141631.

13. Hart, A.; Antoniou, J.; Brin, Y.S.; Huk, O.L.; Zukor, D.J.; Bergeron, S.G. Simultaneous Bilateral Versus Unilateral Total Knee Arthroplasty: A Comparison of 30-Day Readmission Rates and Major Complications. *J. Arthroplasty* **2016**, *31*, 31–35, doi:10.1016/j.arth.2015.07.031.

14. Husted, H.; Troelsen, A.; Otte, K.S.; Kristensen, B.B.; Holm, G.; Kehlet, H. Fast-track surgery for bilateral total knee replacement. *J. Bone Jt. Surg. - Ser. B* **2011**, *93 B*, 351–356, doi:10.1302/0301-620X.93B3.25296.

15. Muskus, M.; Rojas, J.; Gutiérrez, C.; Guio, J.; Bonilla, G.; Llinás, A. Bilateral Hip Arthroplasty: When Is It Safe to Operate the Second Hip? A Systematic Review. *Biomed Res. Int.* 2018, *2018*.

16. Liu, L.; Liu, H.; Zhang, H.; Song, J.; Zhang, L. Bilateral total knee arthroplasty Simultaneous or staged?: A systematic review and meta-analysis. *Med. (United States)* 2019, *98*.

17. Lindberg-Larsen, M.; Pitter, F.T.; Husted, H.; Kehlet, H.; Jørgensen, C.C.; Madsen, F.; Hansen, T.B.; Solgaard, S.; Laursen, M.B.; Hansen, L.T.; et al. Simultaneous vs staged bilateral total knee arthroplasty: a propensity-matched case–control study from nine fast-track centres. *Arch. Orthop. Trauma Surg.* **2019**, *139*, 709–716, doi:10.1007/s00402-019-03157-z.

18. Sheth, D.S.; Cafri, G.; Paxton, E.W.; Namba, R.S. Bilateral Simultaneous vs Staged Total Knee Arthroplasty: A Comparison of Complications and Mortality. *J. Arthroplasty* **2016**, *31*, 212–216, doi:10.1016/j.arth.2016.03.018.

19. Huang, L.; Xu, T.; Li, P.; Xu, Y.; Xia, L.; Zhao, Z. Comparison of mortality and complications between bilateral simultaneous and staged total hip arthroplasty: A systematic review and meta-analysis. *Med. (United States)* 2019, *98*.

20. Malahias, M.A.; Manolopoulos, P.P.; Mancino, F.; Jang, S.J.; Gu, A.; Giotis, D.; Denti, M.; Nikolaou, V.S.; Sculco, P.K. Safety and outcome of simultaneous bilateral unicompartmental knee arthroplasty: A systematic review. *J. Orthop.* 2021, *24*, 58–64.

21. Haverkamp, D.; van den Bekerom, M.P.J.; Harmse, I.; Schafroth, M.U. One stage bilateral total hip arthroplasty, is it safe? A meta-analysis. *HIP Int.* **2010**, *20*, 440–446, doi:10.1177/112070001002000405.

22. Ravi, B.; Jenkinson, R.; O'heireamhoin, S.; Austin, P.C.; Aktar, S.; Leroux, T.S.; Paterson, M.; Redelmeier, D.A.; Ravi, B.; Jenkinson, R. Surgical duration is associated with an increased risk of periprosthetic infection following total knee arthroplasty: A population-based retrospective cohort study-NC-ND license. (http://creativecommons.org/licenses/by-nc-nd/4.0/). *EClinicalMedicine* **2019**, *16*, 74–80, doi:10.1016/j.eclinm.2019.09.015.

1. Ritter, M.A.; Stringer, E.A. Bilateral total hip arthroplasty: A single procedure. *Clin.*

Orthop. Relat. Res. **1980**, *NO 149*, 185–190, doi:10.1097/00003086-198006000-00025.

2. Ritter MA, S.E. Bilateral total hip arthroplasty: a single procedure - PubMed Available online: https://pubmed.ncbi.nlm.nih.gov/7408301/ (accessed on Feb 28, 2021).

3. Wykman, A.; Olsson, E. Walking ability after total hip replacement: A comparison of gait analysis in unilateral and bilateral cases. *J. Bone Jt. Surg. - Ser. B* **1992**, *74*, 53–56, doi:10.1302/0301-620x.74b1.1732266.

4. Bolognesi, M.P.; Watters, T.S.; Attarian, D.E.; Wellman, S.S.; Setoguchi, S. Simultaneous vs Staged bilateral total knee arthroplasty among medicare beneficiaries, 2000-2009. *J. Arthroplasty* **2013**, *28*, 87–91, doi:10.1016/j.arth.2013.05.039.

5. Meehan, J.P.; Danielsen, B.; Tancredi, D.J.; Kim, S.; Jamali, A.A.; White, R.H. A population-based comparison of the incidence of adverse outcomes after simultaneous-bilateral and staged-bilateral total knee arthroplasty. *J. Bone Jt. Surg. - Ser. A* **2011**, *93*, 2203–2213, doi:10.2106/JBJS.J.01350.

6. Peskun, C.; Mayne, I.; Malempati, H.; Kosashvili, Y.; Gross, A.; Backstein, D. Cardiovascular disease predicts complications following bilateral total knee arthroplasty under a single anesthetic. *Knee* **2012**, *19*, 580–584, doi:10.1016/j.knee.2011.09.010.

7. Shao, H.; Chen, C.L.; Maltenfort, M.G.; Restrepo, C.; Rothman, R.H.; Chen, A.F. Bilateral Total Hip Arthroplasty: 1-Stage or 2-Stage? A Meta-Analysis. *J. Arthroplasty* 2017, *32*, 689–695.

8. Hooper, G.J.; Hooper, N.M.; Rothwell, A.G.; Hobbs, T. Bilateral Total Joint Arthroplasty. The Early Results from the New Zealand National Joint Registry. *J. Arthroplasty* **2009**, *24*, 1174–1177, doi:10.1016/j.arth.2008.09.022.

9. Bini, S.A.; Khatod, M.; Inacio, M.C.S.; Paxton, E.W. Same-Day Versus Staged Bilateral

Total Knee Arthroplasty Poses No Increase in Complications in 6672 Primary Procedures. *J. Arthroplasty* **2014**, *29*, 694–697, doi:10.1016/j.arth.2012.09.009.

10. Lindberg-Larsen, M.; Jørgensen, C.C.; Husted, H.; Kehlet, H. Early morbidity after simultaneous and staged bilateral total knee arthroplasty. *Knee Surgery, Sport. Traumatol. Arthrosc.* **2015**, *23*, 831–837, doi:10.1007/s00167-014-2880-1.

11. Alfaro-Adrián, J.; Bayona, F.; Rech, J.A.; Murray, D.W. One- or two-stage bilateral total hip replacement. *J. Arthroplasty* **1999**, *14*, 439–445, doi:10.1016/S0883-5403(99)90099-2.

12. Gromov, K.; Troelsen, A.; Stahl Otte, K.; Ørsnes, T.; Husted, H. Morbidity and mortality after bilateral simultaneous total knee arthroplasty in a fast-track setting. *Acta Orthop.* **2016**, *87*, 286–290, doi:10.3109/17453674.2016.1141631.

13. Hart, A.; Antoniou, J.; Brin, Y.S.; Huk, O.L.; Zukor, D.J.; Bergeron, S.G. Simultaneous Bilateral Versus Unilateral Total Knee Arthroplasty: A Comparison of 30-Day Readmission Rates and Major Complications. *J. Arthroplasty* **2016**, *31*, 31–35, doi:10.1016/j.arth.2015.07.031.

14. Husted, H.; Troelsen, A.; Otte, K.S.; Kristensen, B.B.; Holm, G.; Kehlet, H. Fast-track surgery for bilateral total knee replacement. *J. Bone Jt. Surg. - Ser. B* **2011**, *93 B*, 351–356, doi:10.1302/0301-620X.93B3.25296.

15. Muskus, M.; Rojas, J.; Gutiérrez, C.; Guio, J.; Bonilla, G.; Llinás, A. Bilateral Hip Arthroplasty: When Is It Safe to Operate the Second Hip? A Systematic Review. *Biomed Res. Int.* 2018, *2018*.

16. Liu, L.; Liu, H.; Zhang, H.; Song, J.; Zhang, L. Bilateral total knee arthroplasty Simultaneous or staged?: A systematic review and meta-analysis. *Med. (United States)*

2019, *98*.

17. Lindberg-Larsen, M.; Pitter, F.T.; Husted, H.; Kehlet, H.; Jørgensen, C.C.; Madsen, F.; Hansen, T.B.; Solgaard, S.; Laursen, M.B.; Hansen, L.T.; et al. Simultaneous vs staged bilateral total knee arthroplasty: a propensity-matched case–control study from nine fast-track centres. *Arch. Orthop. Trauma Surg.* **2019**, *139*, 709–716, doi:10.1007/s00402-019-03157-z.

18. Sheth, D.S.; Cafri, G.; Paxton, E.W.; Namba, R.S. Bilateral Simultaneous vs Staged Total Knee Arthroplasty: A Comparison of Complications and Mortality. *J. Arthroplasty* **2016**, *31*, 212–216, doi:10.1016/j.arth.2016.03.018.

19. Huang, L.; Xu, T.; Li, P.; Xu, Y.; Xia, L.; Zhao, Z. Comparison of mortality and complications between bilateral simultaneous and staged total hip arthroplasty: A systematic review and meta-analysis. *Med. (United States)* 2019, *98*.

20. Malahias, M.A.; Manolopoulos, P.P.; Mancino, F.; Jang, S.J.; Gu, A.; Giotis, D.; Denti, M.; Nikolaou, V.S.; Sculco, P.K. Safety and outcome of simultaneous bilateral unicompartmental knee arthroplasty: A systematic review. *J. Orthop.* 2021, *24*, 58–64.

21. Haverkamp, D.; van den Bekerom, M.P.J.; Harmse, I.; Schafroth, M.U. One stage bilateral total hip arthroplasty, is it safe? A meta-analysis. *HIP Int.* **2010**, *20*, 440–446, doi:10.1177/112070001002000405.

22. Ravi, B.; Jenkinson, R.; O'heireamhoin, S.; Austin, P.C.; Aktar, S.; Leroux, T.S.; Paterson, M.; Redelmeier, D.A.; Ravi, B.; Jenkinson, R. Surgical duration is associated with an increased risk of periprosthetic infection following total knee arthroplasty: A population-based retrospective cohort study-NC-ND license. (http://creativecommons.org/licenses/by-nc-nd/4.0/). *EClinicalMedicine* **2019**, *16*, 74–80, doi:10.1016/j.eclinm.2019.09.015.