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ORIGINAL PAPER

Blood loss and allogeneic transfusion for surgical treatment of periprosthetic joint infection: a comparison of one- vs. two-stage exchange total hip arthroplasty

Ahmad Shoib Sharqzad[1] · Camila Cavalheiro[1] · Akos Zahar[1] · Christian Lausmann[1] · Thorsten Gehrke[1] · Daniel Kendoff[2] · Javad Parvizi[3] · Mustafa Citak[1]

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Abstract

Purpose The purpose of the current study was to compare the blood loss and the need for allogeneic transfusion after one- and two-stage exchange arthroplasty for periprosthetic joint infection (PJI) of THA.

Methods We performed a retrospective review of all patients undergoing either one-stage or two-stage septic exchange arthroplasty at two high-volume infection referral centres. The study cohort consists of 90 patients undergoing the two-stage and 184 patients the one-stage exchange arthroplasty. The difference between pre- and post-operative haemoglobin (Hb) and total blood loss as well as the allogeneic transfusion rate were compared between both groups.

Results Both procedures together of the two-stage septic exchange arthroplasty had higher intra-operative blood loss and allogeneic blood transfusion rate compared to the one-stage septic exchange arthroplasty group. However, among the patients of the two-stage group, there were more smokers and had worse physical status (ASA) and higher mortality risk (CCI) than patients in the one-stage group.

Conclusions Two-stage septic revision of total hip arthroplasty has higher rates of blood loss and transfusion rates than one-stage revision. Therefore, the authors believe that blood loss rate, including its complications, should be considered when decision for the type of staged septic exchange is made.

Keywords Blood loss · Allogeneic blood transfusion · One-stage exchange · Two-stage exchange

Introduction

Periprosthetic joint infection (PJI) is an uncommon but serious complication, affecting approximately 1 to 3% of patients who undergo primary total hip arthroplasty (THA) and is one of the leading causes of hip revision surgery [1–3]. Management of PJI often requires surgical intervention in the form of resection arthroplasty and reimplantation.

A two-stage exchange arthroplasty is the most preferred surgical treatment in North America for management of chronic PJI [1, 4–6]. The two-stage approach allows two chances to debride the tissues, and reduce bioburden, and the interval period allows an opportunity to assess the response to antibiotics and perform further microbiologic analysis of tissue samples [7]. However, prolonged treatment duration, requirement of at least two major surgical interventions, increased loss of function, and high morbidity and higher mortality are important drawbacks of two stage exchange arthroplasty [1, 4, 5, 8]. One-stage exchange arthroplasty, on the other hand, has advantages of decreased patient morbidity, no need for second stage major surgery, shorter treatment duration, early functional recovery, and may confer less hospital costs, at least in 80–90% of the patients [4, 5, 7, 9].

Although infection control of both techniques presented similar success rates [4, 6, 7, 9], the decision to do one- or two-stage revision should take into account other parameters

✉ Mustafa Citak
mustafa.citak@helios-gesundheit.de

[1] Helios ENDO-Klinik Hamburg, Department of Orthopaedic Surgery, Holstenstraße 2, 22767 Hamburg, Germany

[2] Helios Klinikum Berlin-Buch, Department of Orthopaedic Surgery, Berlin, Germany

[3] Rothman Institute at Thomas Jefferson University Hospital, Philadelphia, PA, USA

as well, such as morbidity and mortality, functional outcomes, and hospital costs. One of the major issues in terms of morbidity of either surgical treatment are the blood loss and transfusion rates, which can lead to a deterioration of general state of the patient and make the already complicated treatment even more demanding [10].

Despite the advances in the surgical techniques, severe blood loss and transfusion remain still a challenge after revision THA [10–12]. Revision surgery is usually complex, regardless of being one- or two-stage procedure, these are associated with higher blood loss and subsequent perioperative blood transfusion [10, 11]. Several other factors may influence peri-operative blood loss in these patients. These include gender, age, physical status of the patient, hypertension, body mass index, coagulation factors, type of anaesthesia, and surgical procedure [13].

There is some data about the morbidity of one- or two-stage exchange arthroplasty [6]. The main purpose of the current study was to compare the blood loss and the need for allogeneic transfusion following one- and two-stage exchange arthroplasty for PJI of THA. We hypothesized that blood loss might be lower in the setting of the one-stage septic exchange compared to the two-stages of the two-stage exchange revision total hip arthroplasty.

Patients and methods

We performed a retrospective review of all patients undergoing either one-stage or two-stage hip exchange arthroplasty at two high-volume infection referral centers. At the Rothman Institute (RI) (Philadelphia, PA, USA), 90 patients, operated from 1997 to 2009, were enrolled into one group who met the inclusion criteria and underwent a two-stage revision as treatment of PJI of THA. In the setting of the two-stage revision arthroplasty, a surgeon-made articulating spacer was used for the interim period. At the Endo-Klinik (EK) (Hamburg, Germany), 184 patients, who met inclusion criteria and underwent a one-stage revision from 2006 to 2012, were enrolled into the other group. Anaemia, malignancy, surgeries within the last six months, and haematologic or cardiac disorders were defined as exclusion criteria for this study. According to the protocol of the Endo-Klinik in all septic one-stage cases, the causative germ was identified by a preoperative aspiration. After receiving the germ and its susceptibility, the one-stage procedure was planned and a microbiologist was consulted for a recommendation for topic and systemic antibiotics. Meanwhile, the surgery all foreign material was removed and a radical debridement was performed. Afterwards, a cemented prosthesis with antibiotic-loaded bone cement was implanted.

The following patient parameters were collected in both study groups: age, gender, weight (kg), height (cm), body mass index (BMI, kg/m2), smoking status, surgical diagnosis, Charlson Comorbidity Index (CCI) [14], and American Society of Anesthesiologists (ASA) classification score. The difference between pre- and post-operative haemoglobin (Hb), amount of peri-operative blood loss, and amount of blood transfusion were also recorded. Several parameters were applied to calculate the blood loss: the total blood volume, total Hb count and decrease in Hb count were taken into account. Blood loss was calculated using the formula presented by Hawi et al. [11]:

$$\left(\left(\text{Decrease in Hb}^{*}\text{total blood volume}\right)/\text{total Hb count}\right)$$

The final formula to calculate the blood loss was [11]:

$$\text{Blood loss (L)} = \text{decrease in Hb count (g)}/\text{initial Hb value (g/L)}$$

The post-operative haemoglobin was checked on post-operative day three. All drains were opened immediately after surgery and were removed 48 hours post-operatively. None of the groups received blood supplements as erythropoietin, iron substitution or pharmacological substances like tranexamic acid, acetylsalicylic acid, and other anticoagulants were stopped at least five days before surgery and INR (international normalized ratio) and PTT (partial thromboplastin time) parameters were measured to exclude coagulopathies. Each institution had the same transfusion criteria. In case of anaemia symptoms or a haemoglobin value lower than 6 g/dL, a transfusion of two units of erythrocyte concentrates was given. Each unit had a volume of 300 ml. In both institutions, the post-operative DVT prophylaxis was performed with a subcutaneous injection of low-dose molecular heparin according to the current guidelines.

The primary outcome measures were to compare the difference between pre- and post-operative Hb and total blood loss in both groups. The secondary outcome measure was to determine the allogeneic transfusion rate between the two groups.

Statistical analysis

All data were processed using GraphPad Prism (Prism 5 for Mac OS X, Version 5.0d, La Jolla, CA, USA). All variables were expressed in terms of mean and standard deviation (SD) of the mean. The Shapiro-Wilk normality test was performed to ascertain whether the data were normally distributed. Student's *t* test was performed when the data demonstrated a normal Gaussian distribution; otherwise, the Mann-Whitney test was employed for non-parametric data. Statistical significance for these analyses was set at a p value less than 0.05.

Table 1 This table shows the demographic data and outcome measures of the study cohorts

Variable	Cohort	*N*	Mean	SD	*p*
Age [years]	ENDO	184	70.5	10.0	< 0.001
	Rothman 1	90	63.3	12.4	
	Rothman 2	90	63.6	12.4	
BMI [kg/m^2]	ENDO	184	28.11	5.16	0.185
	Rothman 1	90	29.99	8.19	
	Rothman 2				
HGB initial	ENDO	183	12.87	1.86	< 0.001
	Rothman 1	90	11.32	1.90	
	Rothman 2	90	12.00	1.57	
HCT initial	ENDO	184	39.44	5.16	< 0.001
	Rothman 1	90	34.62	5.65	
	Rothman 2	90	36.82	4.88	
INR initial	ENDO	181	1.009	0.092	< 0.001
	Rothman 1	85	1.199	0.257	
	Rothman 2	71	1.138	0.350	
PTT initial	ENDO	182	29.52	4.07	< 0.001
	Rothman 1	85	35.36	8.06	
	Rothman 2	71	33.29	8.62	
Surgery time [min]	ENDO	179	164.8	57.1	0.006
	Rothman 1	80	143.1	44.2	
	Rothman 2	75	150.7	40.9	
Time interval between stage 1 and 2	ENDO				
	Rothman 1				
	Rothman 2	90	111.4	83.4	
Allogenic transfusion	ENDO	165	3.8	3.1	< 0.001
	Rothman 1	90	3.3	1.9	
	Rothman 2	90	4.0	3.1	
	Rothman 1+2	90	7.3	4.2	
Total blood loss	ENDO	184	4644.4	2981.3	< 0.001
	Rothman 1	90	3280.8	1338.4	
	Rothman 2	90	4642.2	2554.7	
	Rothman 1+2	90	7923.0	3158.1	

ENDO Endo-Klinik, *Rothman 1* first stage of two stage procedure with removal of the infected prosthesis and spacer implantation at the Rothman Institute, *Rothman 2* second stage of two stage procedure with removal of the spacer and reimplantation at the Rothman Institute, *BMI* body mass index, *HGB initial* preoperative hemoglobin value in g/dl, *HCT initial* preoperative hematocrit, *INR initial* preoperative international normalized ratio, *PTT initial* preoperative partial thromboplastin time. Significance level $p < 0.05$

Results

The demographic parameters and measured data outcomes are described in Table 1. Patients undergoing one-stage exchange were statistically significantly older than patients of two-stage group and presented slightly lower coagulation parameters. Also, the average surgical time of the one-stage procedures was significantly longer compared with the two-stage procedures (Table 1).

The mean intra-operative blood loss and allogeneic blood transfusion rate in the one-stage group were lower than in the two-stage group, counting the mean of the first and second procedures (Table 1). The difference of both parameters was statistically significant ($p < 0.001$) (Figs. 1 and 2; Table 1).

Table 2 demonstrates patient conditions in both groups. Despite there were no statistically significant differences analyzing gender or comorbidities, among the patients of the two-stage group, there were more smokers and had worse physical status (ASA) and higher mortality risk (CCI) than patients in the one-stage group (Table 2).

Discussion

Despite the advances in the surgical techniques, severe blood loss and transfusion remains as an important cause of complications after revision THA [10–12]. Despite the general complexity of revision arthroplasty, several other factors such as gender, age, physical status of the patient, hypertension, body mass index, coagulation factors, type of anaesthesia, and surgical procedure may influence peri-operative blood loss in these patients [13].

It is known that elderly patients' medical condition is not always suitable for repeated extensive surgery and patients with PJI usually have poor overall health. From this point of view, one-stage revision for infected THA can be an excellent option because there is no need for extensive second stage operation, decreased morbidity and early functional recovery are to be expected [7].

Our results are in agreement with the suggestion that the one-stage revision may be more suitable for treatment of selected infected THAs. The patients in the two-stage group had

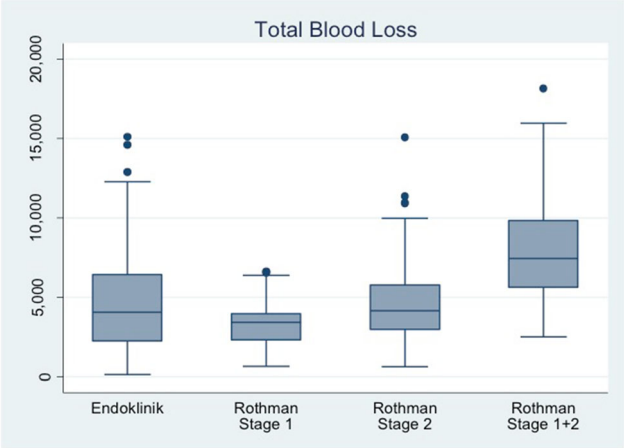

Fig. 1 Box-plot analysis of total blood loss of the two surgical approaches. The dots reveal the outliers of blood loss in ml

more blood loss and more transfusion rates than the patients in the one-stage group, mainly because of the two surgical procedures that are necessary when this treatment option is chosen. If we analyze single surgical procedures, we can notice that the differences of blood loss and transfusion rates are not significant. It is quite obvious that the double procedure makes these parameters worse in the two-stage group.

Blood loss may be accompanied by serious clinical complications and therefore, it has protocols for managing it, mainly with allogeneic blood transfusion [15, 16]. Carson et al. [17] documented in a study of 1958 surgical patients who refused blood transfusion for religious reasons. Patients with pre-existing cardiovascular disease had higher rates of both morbidity and mortality when the haemoglobin level was 10 g/dL or less.

Besides increasing the mortality rate, severe blood loss may lead to other complications particularly relevant for orthopedic surgery. Lawrence et al. [18] showed in a retrospective study performed in 5973 patients at least 60 years old

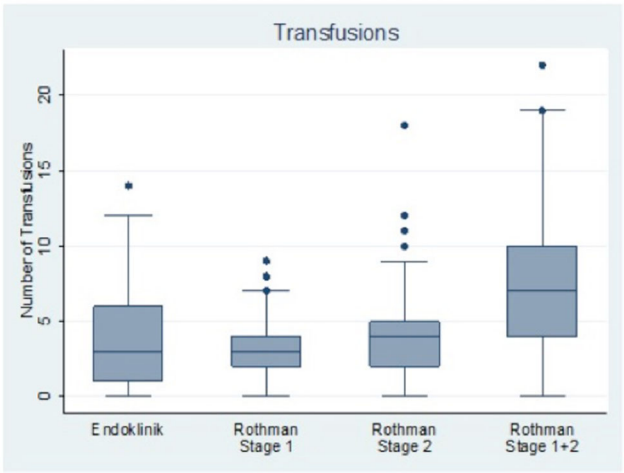

Fig. 2 Numbers of units of allogeneic transfusion rates between both procedures are presented. Significant differences are shown by the stars

undergoing hip fracture fixation that higher Hb levels in the post-operative period are associated with better early functional recovery. Young et al. [19] stated that complications of anaemia such as fatigue can limit participation in rehabilitation programs, potentially resulting in longer hospital stay and poorer long-term outcome for post-arthroplasty patients.

Besides all the downsides, the main treatment for blood loss has its own risks. Allogeneic transfusion may be associated with increased risk of serious and potentially fatal complications, including cross-match errors, disease transmission, bacterial contamination, and immunomodulation, increasing the risk of post-operative infection. This could complicate the post-operative course, especially in septic revisions where stringent infection control is desired, potentially increasing the risk of failure of the revision procedure [10, 20].

Comparison of one- vs. two-stage revisions has been for long-time controversial, but several current studies showed improved infection control rates in one-stage septic exchange of THA. Since 1981, when Buchholz proposed [21] one-stage revision with a success rate of 77%, the procedure has slowly gained popularity as a treatment option for PJI in selected patients [6]. Along the years, protocols for staged revisions have improved including culture-negative infections or partial component-retained two-stage procedure, enhancing with that of the infection control rates [5, 22, 23].

Current systematic reviews [1, 5, 7] were also published comparing one- and two-stage revisions and they suggest that the results are comparable. In general, there are several studies comparing infection rates [4, 6, 7, 9], but functional outcomes or clinical evaluation are rarely analyzed.

To the best of our knowledge, this is the first study comparing blood loss or transfusion rates between these two procedures. The most important findings of the present study were that the blood loss and the rate of allogeneic transfusion were higher in the two-stage revision arthroplasty group compared to that in the one-stage procedure. The main focus of our study was to elucidate those two factors. We did not analyze the complication and mortality rates of the both groups, which is one of the limitations of our study. Furthermore, it is a retrospective study design and the selection criteria for performing one- or two-stage procedure was made exclusively by the treatment center. Also, could be other variables influencing the results between the groups, since they are composed of different populations and may not be homogeneous. Another limitation was that intra- and post-operative blood loss was not measured but a calculated estimation by pre- and post-operative Hb levels was performed. It is well known that intra-operative blood loss cannot be measured precisely because of swabs, drapes, and other items that may contain blood which is difficult to measure.

In conclusion, our data suggest that two-stage septic revision of total hip arthroplasty including both stages of this procedure has higher rates of blood loss and transfusion rates

Table 2 Detailed information of demographic data and patients' conditions of both groups are shown

		Endo-Klinik ($n = 184$)		Rothman Institute stage 1 ($n = 90$)		Rothman Institute stage 2 ($n = 90$)		
Variable	Value	*n*	%	*n*	%	*n*	%	*p* value
Gender	Female	82	44.6	45	50.0	–	–	0.440
	Male	102	55.4	45	50.0	–	–	
High blood pressure	No	79	42.9	35	38.9	–	–	0.602
	Yes	105	57.1	55	61.1	–	–	
Diabetes mellitus	No	162	88.0	72	80.0	–	–	0.100
	Yes	22	12.0	18	20.0	–	–	
Smoker	Not available		6			–	–	
	No	157	88.2	64	71.1	–	–	0.001
	Yes	21	11.8	26	28.9	–	–	
ASA score	Not available			25		20		
	1	4	2.2			1	1.4	0.002
	2	97	52.7	19	29.2	11	15.7	
	3	80	43.5	43	66.2	56	80.0	
	4	3	1.6	3	4.6	2	2.9	
Charlson Comorbidity Index	Not available			1		1		
	0	98	53.3	4	4.5	4	4.5	< 0.001
	1	37	20.1	8	9.0	8	9.0	
	2	22	12.0	20	22.5	21	23.6	
	3	17	9.2	24	27.0	23	25.8	
	4	6	3.3	13	14.6	13	14.6	
	5	2	1.1	7	7.9	7	7.9	
	6	2	1.1	4	4.5	4	4.5	
	7			3	3.4	3	3.4	
	8			4	4.5	4	4.5	
	9			2	2.3	2	2.3	

ASA American Society of Anesthesiologists. Significance level $p < 0.05$

than one-stage revision. Therefore, patients undergoing a two-stage hip revision may be subject to greater risk of clinical complications and higher rates of morbidity and mortality. The authors believe that blood loss rate, including its complications, should be considered when decision for the type of staged septic hip exchange is made.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest regarding this manuscript.

Outside the manuscript, one or more of the authors of this paper have disclosed the following disclosures:

- Waldemar Link, Hamburg, Germany
- Zimmer
- ConvaTec
- TissueGene
- Ceramtec
- Corentec
- Ethicon
- Tenor
- Heron

Ethical approval This study was performed after obtaining approval from the institutional review board. The PV number is "WF-007/15."

References

1. Munoz-Mahamud E, Gallart X, Soriano A (2013) One-stage revision arthroplasty for infected hip replacements. Open Orthop J 7: 184–189. https://doi.org/10.2174/1874325001307010184
2. Reina N, Delaunay C, Chiron P, Ramdane N, Hamadouche M, Societe francaise de chirurgie orthopedique et t (2013) Infection as a cause of primary total hip arthroplasty revision and its predictive factors. Orthop Traumatol Surg Res 99:555–561. https://doi.org/10.1016/j.otsr.2013.07.001
3. Strange S, Whitehouse MR, Beswick AD, Board T, Burston A, Burston B, Carroll FE, Dieppe P, Garfield K, Gooberman-Hill R, Jones S, Kunutsor S, Lane A, Lenguerrand E, MacGowan A,

Moore A, Noble S, Simon J, Stockley I, Taylor AH, Toms A, Webb J, Whittaker JP, Wilson M, Wylde V, Blom AW (2016) One-stage or two-stage revision surgery for prosthetic hip joint infection–the INFORM trial: a study protocol for a randomised controlled trial. Trials 17:90. https://doi.org/10.1186/s13063-016-1213-8

4. Choi HR, Kwon YM, Freiberg AA, Malchau H (2013) Comparison of one-stage revision with antibiotic cement versus two-stage revision results for infected total hip arthroplasty. J Arthroplast 28:66–70. https://doi.org/10.1016/j.arth.2013.02.037
5. Leonard HA, Liddle AD, Burke O, Murray DW, Pandit H (2014) Single- or two-stage revision for infected total hip arthroplasty? A systematic review of the literature. Clin Orthop Relat Res 472:1036–1042. https://doi.org/10.1007/s11999-013-3294-y
6. Nguyen M, Sukeik M, Zahar A, Nizam I, Haddad FS (2016) One-stage exchange arthroplasty for periprosthetic hip and knee joint infections. Open Orthop J 10:646–653. https://doi.org/10.2174/1874325001610010646
7. Negus JJ, Gifford PB, Haddad FS (2017) Single-stage revision arthroplasty for infection-an underutilized treatment strategy. J Arthroplast 32:2051–2055. https://doi.org/10.1016/j.arth.2017.02.059
8. Ilchmann T, Zimmerli W, Ochsner PE, Kessler B, Zwicky L, Graber P, Clauss M (2016) One-stage revision of infected hip arthroplasty: outcome of 39 consecutive hips. Int Orthop 40:913–918. https://doi.org/10.1007/s00264-015-2833-4
9. Zahar A, Gehrke TA (2016) One-stage revision for infected total hip arthroplasty. Orthop Clin North Am 47:11–18. https://doi.org/10.1016/j.ocl.2015.08.004
10. George J, Sikora M, Masch J, Farias-Kovac M, Klika AK, Higuera CA (2017) Infection is not a risk factor for perioperative and postoperative blood loss and transfusion in revision total hip arthroplasty. J Arthroplast 32:214–219 e211. https://doi.org/10.1016/j.arth.2016.06.046
11. Hawi N, Kendoff DO, Hessling U, Haasper C, Gehrke T, Citak M (2014) Effectiveness of an autologous transfusion system following cemented and non-cemented revisions of total hip arthroplasty. Int Orthop 38:1603–1608. https://doi.org/10.1007/s00264-014-2359-1
12. Pierson JL, Hannon TJ, Earles DR (2004) A blood-conservation algorithm to reduce blood transfusions after total hip and knee arthroplasty. J Bone Joint Surg Am 86-A:1512–1518
13. Pola E, Papaleo P, Santoliquido A, Gasparini G, Aulisa L, De Santis E (2004) Clinical factors associated with an increased risk of perioperative blood transfusion in nonanemic patients undergoing total hip arthroplasty. J Bone Joint Surg Am 86-A:57–61
14. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40:373–383
15. Adams RC, Lundy JS (1942) Anesthesia in cases of poor surgical risk: some suggestions for decreasing the risk. Anesthesiology 3:603–607
16. Adams RC, Lundy JS (1942) Anesthesia in cases of poor surgical risk: some suggestions for decreasing the risk. Surg Gynecol Obstet 74:1011–1019
17. Carson JL, Duff A, Poses RM, Berlin JA, Spence RK, Trout R, Noveck H, Strom BL (1996) Effect of anaemia and cardiovascular disease on surgical mortality and morbidity. Lancet 348:1055–1060. https://doi.org/10.1016/S0140-6736(96)04330-9
18. Lawrence VA, Silverstein JH, Cornell JE, Pederson T, Noveck H, Carson JL (2003) Higher Hb level is associated with better early functional recovery after hip fracture repair. Transfusion 43:1717–1722
19. Young SW, Marsh DJ, Akhavani MA, Walker CG, Skinner JA (2008) Attitudes to blood transfusion post arthroplasty surgery in the United Kingdom: a national survey. Int Orthop 32:325–329. https://doi.org/10.1007/s00264-007-0330-0
20. Greenky M, Shaner J, Rasouli MR, Han SB, Parvizi J, Hozack WJ (2014) Intraoperative blood salvage in revision total hip arthroplasty: who benefits most? J Arthroplast 29:1298–1300. https://doi.org/10.1016/j.arth.2013.12.009
21. Buchholz HW, Elson RA, Engelbrecht E, Lodenkamper H, Rottger J, Siegel A (1981) Management of deep infection of total hip replacement. J Bone Joint Surg (Br) 63-B:342–353
22. Wang J, Wang Q, Shen H, Zhang X (2018) Comparable outcome of culture-negative and culture-positive periprosthetic hip joint infection for patients undergoing two-stage revision. Int Orthop 42:469–477. https://doi.org/10.1007/s00264-018-3783-4
23. Yan Z, Fang R, Liu T (2018) Partial component-retained two-stage reconstruction for chronic infection after uncemented total hip arthroplasty: good or bad? Int Orthop 42:729–730. https://doi.org/10.1007/s00264-017-3748-z