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REVIEW ARTICLE

Comparable dislocation and revision rates for patients undergoing total hip arthroplasty with subsequent or prior lumbar spinal fusion: a meta-analysis and systematic review

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Abstract

Background There is a known correlation between the procedures of lumbar spinal fusion (LSF), total hip arthroplasty (THA) and the complication of hip dislocation and revision occurring in patients. However there is no consensus as to whether the risk of this complication is higher if THA is performed before or after LSF. This meta-analysis aims to determine the influence of surgical sequence of lumbar spinal fusion and total hip arthroplasty on the rates of hip dislocation and revisions.

Methods A meta-analysis was conducted with a multi-database search (PubMed, OVID, EMBASE, Medline) according to PRISMA guidelines on 27th May 2020. Data from all published literature meeting inclusion criteria were extracted and analyzed with an inverse variance statistical model.

Findings A total of 25,558 subsequent LSF and 43,880 prior LSF THA patients were included in this study. There was no statistically significant difference in all-cause revisions (OR = 0.86, 95%CI: 0.48–1.54, $p = 0.61$), dislocation (OR = 0.82, 95%CI: 0.25–2.72, $p = 0.75$) or aseptic loosening (OR = 1.14, 95%CI: 0.94–1.38, $p = 0.17$) when comparing patients receiving LSF subsequent versus prior to THA.

Conclusion Lumbar spinal fusion remains a risk factor for dislocation and revision of total hip arthroplasties regardless of whether it is performed prior to or after THA. Further preoperative assessment and altered surgical technique may be required in patients having THA who have previously undergone or are likely to undergo LSF in the future.

Evidence level Level II, Meta-analysis of homogeneous studies.

Keywords Total hip arthroplasty · Total hip replacement · Spinal fusion · Dislocation · Revision

Location: This work was primarily performed in Box Hill Hospital, Victoria, Australia.

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Introduction

Total hip arthroplasty (THA) is one of the most successful elective operations in orthopaedic surgery [1]. A major indication for THA is degenerative arthritis of the hip, and THA aims to alleviate pain and restore mobility and function of patients [2]. A known major complication of THA is prosthetic hip dislocation, which may lead to revision hip surgery. Risk factors for hip dislocation are multifactorial, and can relate to patient, implant and operative factors [3].

There is a known correlation between THA dislocation and lumbar spine fusion (LSF) [3, 4]. This is due to the close relationship between lumbar spine and pelvic mobility. Lumbar spine fusion or a stiff lumbar spine can result in decreased pelvic mobility, leading to a compensatory change in femoral biomechanics in order to maintain balance and posture. This in turn can predispose to impingement and dislocation [5–7].

Studies describe dislocation in THAs that have been performed after LSF, and also dislocation when LSF is performed on patients that have previously undergone THA [3, 4, 8]. The aim of our study is to assess whether there is a difference in the incidence of dislocation and revision when THA is performed before or after LSF, hence helping to establish a clinical pathway for patients who present with both symptomatic lumbar spine and hip degenerative disease.

Methods

Literature search

This meta-analysis was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) criteria [9]. A comprehensive multi-database search (PubMed, OVID Medline, EMBASE) was conducted from date of database inception to 27th May 2020. The Medical Subject Headings and Boolean operators utilised for this search were: [('Total hip arthroplasty' OR 'THA' OR 'Total hip replacement' OR 'THR') AND (Spinal fusion OR Spinal arthrodesis)]. Identified articles and their corresponding references were reviewed and considered for inclusion according to the selection criteria.

Selection criteria

All articles of any study design comparing the complications of THA patients receiving prior or subsequent LSF were considered for inclusion. Patients receiving LSF subsequent to THA can only be included if they do not experience any dislocation or revision from time of index THA to LSF. All patients did not have any LSF revision. Non-English language studies, non peer-reviewed studies, unpublished manuscripts, conference abstracts, and studies not directly comparing the complications of THA with subsequent versus prior LSF were excluded. Two independent authors reviewed records retrieved from the initial search twice and excluded those that did not meet criteria for analysis. Titles and abstracts of remaining articles were then screened against the inclusion criteria. Included articles were critically reviewed according to a predefined data extraction form. Any difference in opinions was resolved by open discussion between the first three authors.

Data extraction

Extracted data parameters included details on study designs, publication year, number of THA, time between THA and LSF and complications. Metrics evaluated encompassed all-cause revisions, aseptic loosening, dislocations and periprosthetic joint infections (PJI). Data extracted was copied and organised into a Microsoft Excel spreadsheet.

Methodology assessment

Methodology quality of included studies was assessed with the Methodological Index for Non-Randomised Studies (MINORS) [10]. MINORS uses 12 criteria to assess non-randomised comparative studies. Each criterion was scored with a 3-point system from 0 to 2 (0: not reported, 1: inadequately reported and 2: adequately reported). The ideal score is 24 points.

Statistical analysis

The odds ratio (OR) and 95% confidence intervals were primarily used as summary statistics. In this meta-analysis, both fixed- and random-effects models were tested. Fixed-effects model assumed that treatment effects in each study were identical, while random-effects model assumed that variations were present between studies. X^2 tests were used to study heterogeneity between studies. I^2 statistic was used to estimate the percentage of total variation across studies, owing to heterogeneity rather than chance. Values greater than 50% was regarded as substantial heterogeneity. I^2 can be calculated as: $I^2 = 100\% \times (Q - df)/Q$. Q was defined as Cochrane's heterogeneity statistics and df defined as degree of freedom. If substantial heterogeneity was present, the possible clinical and methodological reasons were explored qualitatively. This meta-analysis presented results with a random-effects model to account for clinical diversity and methodological variation between studies. Specific analyses to adjust for possible confounding factors including time between THA and LSF, as well as number of spinal levels were not possible because raw data was unavailable. All *p* values were two-sided. Review Manager (version 5.3, Copenhagen, The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) was used for statistical analysis.

Results

Literature Search

A selection process flowchart to include relevant studies is illustrated in Fig. 1. A total of 427 studies were identified from the initial search, of which 137 duplicates and 17 non-English language articles were removed. Titles and abstracts of 273 remaining studies were screened according to the pre-defined inclusion criteria and 252 studies were excluded. Twenty-one full-text articles were assessed for eligibility. In total, five studies were included, including one prospective [11] and four retrospective studies [4, 8, 12, 13].

Methodology assessment

Aggregate MINORS score for included studies ranged from 14 [12] to 20 [11], with an average of 16.8. Individual scores are detailed in "Appendix".

Demographics

A total of 25,558 subsequent LSF and 43,880 prior LSF THA patients were included in this study. Only Gramamtopoulos [11] reported mean number of spinal levels fused, with a mean of 1.4 and 1.7 levels in the subsequent and prior LSF groups respectively. Time period between procedures ranged from 1.4 [8] to 4.1 [11] years. Further details are available in Table 1.

Complications

There was no statistically significant difference in all-cause revisions (OR = 0.86, 95%CI: 0.48–1.54, $p = 0.61$), dislocation (OR = 0.82, 95%CI: 0.25–2.72, $p = 0.75$), aseptic loosening (OR = 1.14, 95%CI: 0.94–1.38, $p = 0.17$) or aseptic loosening (OR = 1.14, 95%CI: 0.94–1.38, $p = 0.17$) when comparing between patients receiving LSF subsequent and prior to THA. (Figs. 2, 3, 4 and 5 respectively).

Discussion

This is the first systematic review and meta-analysis comparing the complication profile of THA in patients receiving LSF subsequent or prior to THA. This analysis revealed no statistically significant difference in complications of THA with subsequent or prior LSF. A previous meta-analysis by

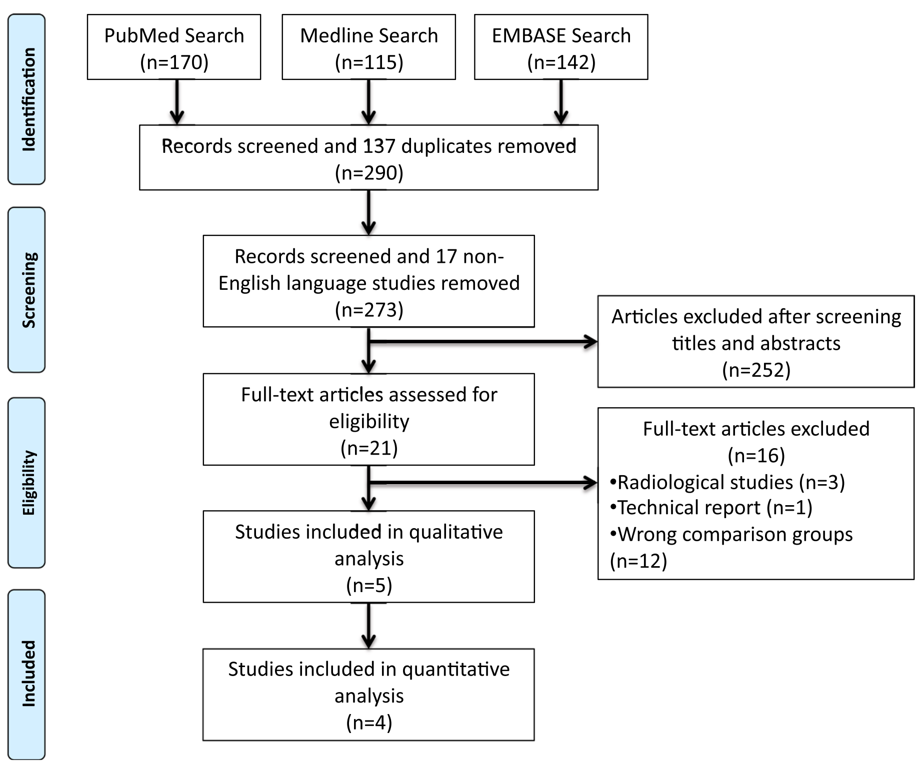

Fig. 1 PRISMA selection process flowchart

Table 1 Basic demographics

Article	Year	Study design	Number of THA		Sex distribution				Mean Time period between procedures		Number of Spinal levels fused		Follow-up/year
			Subsequent-SF	Prior-SF	Subsequent-SF		Prior-SF		Subsequent-SF	Prior-SF	Subsequent-SF	Prior-SF	
					Male	Female	Male	Female					
Bala	2019	Registry	10,482	13,102	4005	6477	5006	8096	–	–	–	–	2
Grammatopoulos	2019	Prospective	26	21	7	19	7	14	4.1	2.8	1.4	1.9	3.7
Malkani	2019	Registry	13,632	28,668	–	–	–	–	–	–	–	–	–
Parilla	2019	Retrospective	62	73	–	–	–	–	2.2	2.6	–	–	–
Yang	2020	Registry	1356	2016	–	–	–	–	1.7*	1.4*	–	–	–

* = Values presented in median

[3] revealed a higher dislocation and revision rate in patients receiving THA with prior LSF compared to those receiving THA only. Together, this suggests that the timing of LSF surrounding THA does not influence complication rates, and that LSF continues to be a risk factor for THA dislocation and revision regardless of the sequence in which the procedures are performed. This can be clinically relevant when discussing the risks of surgery with patients who may need to undergo both procedures and when planning these procedures.

Limitations in spino-pelvic mobility can present in two main forms, either as stuck-standing or stuck-sitting [14]. Stuck-standing refers to excess anterior pelvic tilting and hyper-lordosis of the lumbar spine when sitting. This leads to an increased risk of anterior impingement and possible posterior dislocation of the femoral head in a flexed hip position [14]. The stuck-sitting phenomenon occurs predominantly in LSF patients, characterised by excessive posterior pelvic tilting and hypo-lordosis of the lumbar spine when standing [15]. Clinically, this limitation in spino-pelvic mobility necessitates further compensatory movements of the femoral side of the hip in postural and functional movement such as walking and lying supine. With every 1° decrease in spino-pelvic motion, there was a 0.9° increase in femoral motion [16]. Hence, stuck sitting phenomenon increases the risk of posterior osseous impingement and subsequent anterior dislocation of the femoral head in an extended hip position [7, 14].

Bala et al. [4] suggests performing THA prior to LSF. They hypothesised that patients undergoing subsequent LSF after THA were likely to have a stable THA with an already stiff and immobile degenerative spine. Hence, the subsequent correction of lumbar lordosis and added stiffness from LSF is unlikely to significantly alter functional anteversion and hence dislocation risks [17]. Furthermore, strict patient selection is a strong consideration for LSF post THA. THA patients with recurrent hip dislocations are often deemed to be unsafe surgical candidates for LSF [4]. Interestingly, Bala et al. [4] noted that patients undergoing THA with prior LSF had a higher proportion of early dislocations (2.8% at 90-days and 4.6% at 2-years; 1.6 times increase between 90-days and 2-years dislocation rates), while patients with a THA with subsequent LSF had higher levels of late dislocations (0.2% at 90-days and 1.7% at 2-years; 8.5 times increase between 90-days and 2-years dislocation rates). Bala et al. [4] postulates that stable well-functioning THA patients that had adequate time for bony ingrowth in cementless THA, tissue healing and scarring, as well as muscle strengthening are more likely to tolerate alterations in spinopelvic mobility imposed by LSF. However, in THA performed after LSF, a new hip prosthesis is inserted in a pelvis with already limited spino-pelvic mobility. Furthermore, the THA procedure results in iatrogenic damage to

Study or Subgroup	Subsequent LSF Events	Subsequent LSF Total	Prior LSF Events	Prior LSF Total	Weight	Odds Ratio IV, Random, 95% CI
Bala 2019	384	10482	745	13102	47.9%	0.63 [0.56, 0.72]
Grammatopoulos 2019	2	26	2	21	7.1%	0.79 [0.10, 6.15]
Yang 2020	121	1356	152	2016	45.0%	1.20 [0.94, 1.54]
Total (95% CI)		**11864**		**15139**	**100.0%**	**0.86 [0.48, 1.54]**
Total events	507		899			

Heterogeneity: Tau^2 = 0.18; Chi^2 = 20.45, df = 2 (P < 0.0001); I^2 = 90%
Test for overall effect: Z = 0.51 (P = 0.61)

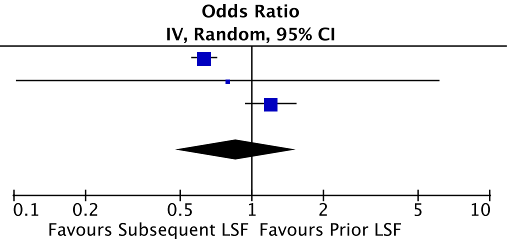

Fig. 2 All cause revisions

Study or Subgroup	Subsequent LSF Events	Subsequent LSF Total	Prior LSF Events	Prior LSF Total	Weight	Odds Ratio IV, Random, 95% CI
Bala 2019	174	10482	608	13102	33.3%	0.35 [0.29, 0.41]
Grammatopoulos 2019	1	26	0	21	9.7%	2.53 [0.10, 65.34]
Parilla 2019	4	62	7	73	24.3%	0.65 [0.18, 2.33]
Yang 2020	73	1356	66	2016	32.7%	1.68 [1.20, 2.36]
Total (95% CI)		**11926**		**15212**	**100.0%**	**0.82 [0.25, 2.72]**
Total events	252		681			

Heterogeneity: Tau^2 = 1.12; Chi^2 = 67.28, df = 3 (P < 0.00001); I^2 = 96%
Test for overall effect: Z = 0.32 (P = 0.75)

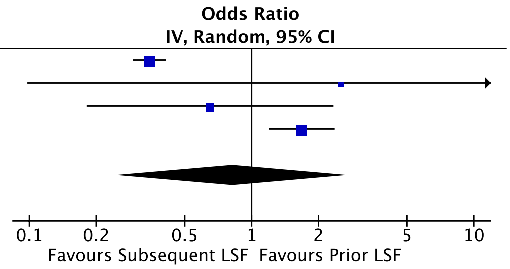

Fig. 3 Dislocations

Study or Subgroup	Subsequent LSF Events	Subsequent LSF Total	Prior LSF Events	Prior LSF Total	Weight	Odds Ratio IV, Random, 95% CI
Bala 2019	174	10482	352	13102	41.9%	0.61 [0.51, 0.73]
Grammatopoulos 2019	2	26	2	21	17.2%	0.79 [0.10, 6.15]
Yang 2020	89	1356	63	2016	40.9%	2.18 [1.56, 3.03]
Total (95% CI)		**11864**		**15139**	**100.0%**	**1.07 [0.36, 3.24]**
Total events	265		417			

Heterogeneity: Tau^2 = 0.75; Chi^2 = 43.40, df = 2 (P < 0.00001); I^2 = 95%
Test for overall effect: Z = 0.13 (P = 0.90)

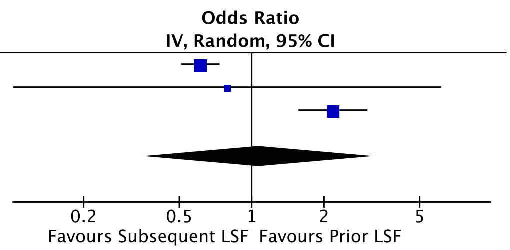

Fig. 4 Peri-prosthetic joint infections

Study or Subgroup	Subsequent LSF Events	Subsequent LSF Total	Prior LSF Events	Prior LSF Total	Weight	Odds Ratio IV, Random, 95% CI
Bala 2019	200	10482	220	13102	98.4%	1.14 [0.94, 1.38]
Grammatopoulos 2019	1	26	1	21	0.5%	0.80 [0.05, 13.60]
Parilla 2019	3	62	2	73	1.1%	1.81 [0.29, 11.17]
Total (95% CI)		**10570**		**13196**	**100.0%**	**1.14 [0.94, 1.38]**
Total events	204		223			

Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.30, df = 2 (P = 0.86); I^2 = 0%
Test for overall effect: Z = 1.37 (P = 0.17)

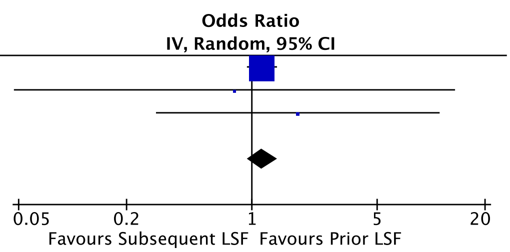

Fig. 5 Aseptic loosening

soft tissue and muscular structures, which in a patient with limited spinopelvic mobility can increase the risk of early dislocation [4]. This concept is further backed by a longer mean time to dislocation in the subsequent LSF than prior LSF group (subsequent LSF: 15.33 ± 5.86 months vs prior LSF: 11.71 ± 18.23 months) as reported by Parilla et al. [13]. Malkani et al. [12] also reported a decreasing percentage of revisions indicated for dislocations as the time from THA to subsequent LSF increases (1 year: 24% vs 2 years: 23.8% vs 5 years: 20%). This suggests that soft tissue and muscle healing after THA are important considerations in the setting of patients with altered spino-pelvic biomechanics.

Critics of performing THA prior to LSF, argue that the subsequent LSF in patients with spinal pathology may in fact further limit spino-pelvic mobility derived from added stiffness from the fusion construct [8], hence imposing further postural and functional limitations as well as dislocation risks. In contrast, supporters of THA with prior LSF argues that there is significant biomechanical advantage to correct pre-existing spine pathology prior to THA so that the optimum cup position can be determined prior to THA, contributing to hip stability. Patients with prior LSF of at least 2 years were also found to have statistically significant lower dislocation rates when compared to those with subsequent LSF [8]. This raises the question regarding the presence of a long-term compensatory mechanism that would mitigate the effect of LSF on spino-pelvic parameters as well as the presence of a threshold time interval between prior LSF and subsequent THA to allow for a stable hip. Parilla et al. [13] conducted a retrospective radiographic analysis of 135 patients receiving both surgeries and compared various spino-pelvic parameters and dislocation rates. Neither metric revealed any significant difference when comparing the sequence in which procedures were performed. When comparing patients who had dislocations and those without, dislocators had a lower lumbar lordosis (− 10.9°), sacral slope (− 7.8°) and a higher pelvic tilt (+ 4.3°) and pelvic incidence (+ 7.3°) [13], in keeping with a "stuck sitting" phenomenon that is consistent with changes attributed to spinal fusion [18]. This may indicate that compensatory mechanisms derived from surgical sequence and time between procedures are insufficient to provide benefit one way or another, and that dislocation in THA with LSF or concurrent spine pathology is instead dependent on the deviation of spino-pelvic parameters from normal values and acetabular cup position.

The correlation between LSF and THA dislocation has significant implications for surgeons and their patients planning to undergo THA who may also have concurrent lumbar spine pathology. Identification of at-risk patients is crucial to avoid poor THA outcomes. This can involve use of preoperative dynamic analysis with either sitting and standing radiographs, or newer techniques such as the use of multiwire chamber imaging which can limit radiation exposure [19]. Innmann et al. [20] recently reported the utility of lateral standing radiographs to screen for significant hip users (compensatory femoral movements) in context of reduced lumbar spine mobility when a standing pelvic tilt of ≥ 19° is observed, with a sensitivity of 90% and specificity of 71%. This can be further verified by lateral sitting radiographs portraying a deep flexed seated position with a reported 100% accuracy.

Determining the optimum acetabular cup position in patients with stiff spinal pathology or LSF is challenging. The concept of "acetabular safe zone" has been previously well described, but has subsequently been questioned with increasing evidence to suggest that the safe zone may differ in different patients [21]. Abdel et al. [22] conducted a cohort study of 9784 primary THA and found the majority (58%) of dislocated THAs to have cup placement within the Lewinnek "safe zone", while Esposito et al. [23] examined 147 dislocators from 7040 primary THA and found no difference among the radiographic zones. In conjunction with CT anatomical studies, it is postulated that the ideal cup position for some patients may lie outside this "safe zone", especially in patients with abnormal pelvic tilt and posture [7, 24]. Current research also demonstrates that dynamic pelvic rotation during physiological postural changes can correspond up to 10-degree variations in acetabular cup version. These findings further highlight the need for more research to develop targets for kinematic cup positioning.

It is thought that patients with altered spino-pelvic biomechanics could benefit from patient specific instrumentation, navigation or robotic-assisted surgeries since these techniques are capable of achieving more accurate implant cup positioning [25–27]. While a recent meta-analysis comparing robotic-assisted and conventional THA revealed superior cup positioning alignment accuracy for robotic-assisted THA, the robotic-assisted group paradoxically had higher, albeit not statistically significant ($p = 0.08$) dislocation rates than the conventional group [28]. Unfortunately, Chen et al. [28] did not explore this finding. Alternatively, the use of dual mobility prosthesis in this high risk patient cohort has shown promising results. A retrospective study of 93 THA patients with prior LSF receiving dual mobility cup prosthesis reported no cases of hip instability or dislocation at a minimum follow-up of 1 year [29].

Limitations

There are some limitations to this study. The lack of randomised prospective studies meant that selection and recall bias cannot be excluded completely. It is acknowledged that only five studies were included in the study. However, given that this is a new area of research, the limited number of studies is not unexpected. Furthermore, three out of five studies are based on institutional database records, which have been suggested to have a lower detection rate of complications. The presence of type-2 errors may lead to falsely lowered quantitative results. Adjustments for potential confounders such as number of spinal levels fused, types of LSF, prosthesis designs, approach for THA and length of time between both procedures were not possible due to the lack of information available. Subgroup analysis based on direction of dislocations and approach of THA was also not possible due to lack of reporting by individual studies.

Conclusion

Lumbar spinal fusion remains a risk factor for THA dislocation and revision regardless of whether it is performed prior or subsequent to total hip arthroplasty. Further preoperative assessment and altered surgical technique may be required in patients having THA who have previously undergone or are likely to undergo LSF in the future.

Author contributions The contribution of each author is as follows: James Randolph Onggo: Conception and design, collection and assembly of data, analysis and interpretation of data, statistical expertise, drafting of article, critical revision of article, final approval of article; Mithun Nambiar: Conception and design, interpretation of data, drafting of article, critical revision of article, final approval of article; Jason Derry Onggo: Collection and assembly of data, analysis and interpretation of data, statistical expertise, drafting of article, critical revision of article, final approval of article; Kevin Phan: Collection and assembly of data, analysis and interpretation of data, statistical expertise, drafting of article, final approval of article; Anuruban Ambikaipalan: Interpretation of data, drafting of article, critical revision of article, final approval of article; Sina Babazadeh: Conception and design, interpretation of data, drafting of article, critical revision of article, final approval of article; Raphael Hau: Conception and design, interpretation of data, drafting of article, critical revision of article, final approval of article.

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Compliance with ethical standards

Conflict of interest Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Appendix

See appendix Table 2.

Table 2 MINORS scores

Articles	Year	Clearly stated aim	Inclusion of consecutive patients	Prospective collection of data	Endpoints appropriate to study aims	Unbiased assessment of endpoints	Follow-up period appropriate	Loss to follow-up less than 5%	Prospective calculation of study size	Adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses	Total
Bala	2019	2	2	1	2	1	2	0	0	2	2	1	2	17
Grammatopoulos	2019	2	2	2	2	2	2	0	0	2	2	2	2	20
Malkani	2019	2	1	1	1	0	2	0	0	2	2	1	2	14
Parilla	2019	2	2	1	2	1	2	1	0	2	2	0	2	17
Yang	2020	2	2	1	2	0	2	0	0	2	2	1	2	16

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