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ORIGINAL ARTICLE • HIP - FRACTURES

A systematic review and meta-analysis of the direct anterior approach for hemiarthroplasty for femoral neck fracture

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Abstract
Background We performed a systematic review and meta-analysis to assess whether the direct anterior approach (DAA) is associated with improved functional and clinical outcomes compared to other surgical approaches for hemiarthroplasty for displaced femoral neck fractures.
Materials and methods Randomized trials and cohort studies of hemiarthroplasty performed via DAA versus another surgical approach (anterolateral, lateral, posterolateral, posterior) were included. Our primary outcome was postoperative functional mobility. Secondary outcomes included overall complication rate, dislocation rate, perioperative fracture, infection rate, re-operation rate, overall mortality, operative time, pain, intra-operative blood loss, and length of stay.
Results Nine studies met inclusion criteria, comprising a total of 698 hips (330 direct anterior, 57 anterolateral, 89 lateral, 114 posterolateral, 108 posterior approach). With regard to functional mobility, DAA was favored in 4 studies, and no study favored another approach over DAA. DAA had a significantly lower dislocation rate compared to posterior capsular approaches. Analysis of other secondary outcomes did not identify statistically significant differences.
Conclusion This is the first systematic review and meta-analysis of the DAA for hemiarthroplasty. Available evidence suggests superior early functional mobility with the DAA. The DAA is associated with a significantly lower dislocation rate compared to posterior capsular approaches for hemiarthroplasty.

Keywords Hemiarthroplasty · Femoral neck fracture · Hip fracture · Direct anterior approach · Meta-analysis · Systematic review

Introduction

Femoral neck fractures are common injuries among the elderly and represent a major source of morbidity and mortality [1, 2]. While some non-displaced fractures can be managed non-surgically, displaced femoral neck fractures generally require surgical treatment [3]. For elderly patients with multiple comorbidities, physiologic compromise, and decreased functional demands, hemiarthroplasty is often performed. The benefits of hemiarthroplasty include early ambulation, minimization of operative time, and improved stability [4–6].

Two important considerations when managing displaced femoral neck fractures are early mobilization and minimization of perioperative complications [1, 2, 7]. These parameters may be affected by choice of surgical approach. The direct anterior approach (DAA) is a popular technique for elective total hip arthroplasty (THA), with a growing body of literature supporting its association with reduced risk of dislocation, decreased postoperative pain, faster rehabilitation, and shorter length of hospital stay compared to other

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surgical approaches [5, 8–10]. Despite this trend in THA, most hemiarthroplasties for the treatment of femoral neck fractures are done through lateral or posterior approach variations [11, 12]. We performed a systematic review and meta-analysis to evaluate whether treatment of displaced femoral neck fractures with hemiarthroplasty using the DAA is associated with improved functional and clinical outcomes when compared with hemiarthroplasty performed using other surgical approaches.

Materials and methods

Prior to our literature search, we drafted a protocol outlining our search strategy, inclusion/exclusion criteria, and outcomes of interest. The study protocol was registered on PROSPERO, an international prospective register of systematic reviews and meta-analyses [13]. We conducted our review utilizing standard methodology as outlined in the Cochrane Handbook and reported results in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [14, 15].

Eligible studies included randomized control trials and observational, comparative studies of hemiarthroplasty performed via direct anterior approach versus hemiarthroplasty performed through another surgical approach (anterolateral, lateral, posterolateral, posterior) for treatment of femoral neck fractures, in which at least one quantifiable pre-specified outcome measure was reported. Our primary outcome was postoperative functional mobility. Secondary outcomes included overall complication rate, dislocation rate, perioperative fracture rate, infection rate, re-operation rate, overall mortality, operative time, pain, perioperative blood loss, and length of stay.

We searched Medline [Ovid], EMBASE [Ovid], CINAHL [Ovid], and the Cochrane Library databases, from their date of inception until October 2016. No limits were applied to searches regarding time, publication status, or language. Google Scholar was searched using similar criteria, and the first 20 pages of search results were reviewed. To identify studies from unpublished sources, we searched for registered trials on ClinicalTrials.gov and reviewed publicly available abstract archives from the Orthopaedic Research Society (ORS), Orthopaedic Trauma Association (OTA), American Academy of Orthopaedic Surgeons (AAOS), and the American Association of Hip and Knee Surgeons (AAHKS). If no full manuscript could be located for identified abstracts, attempts were made via email to contact the authors and obtain full study datasets. Manuscripts written in a language other than English were translated by a medically trained individual fluent in that language.

Studies were selected for inclusion, in accordance with our pre-specified criteria, by two reviewers (SK, MS). Both reviewers performed data extraction independently, using a standardized data collection form. Discrepancies regarding study inclusion or data extraction were resolved through discussion and consensus by the reviewers. The surgical technique described in each manuscript was confirmed by blinded evaluation by a fellowship-trained arthroplasty surgeon (WM).

Risk of bias assessment was performed independently by two reviewers (SK, MS). An additional risk of bias assessment was performed by a third reviewer (RK) blinded to study title, authors, year, and journal of publication. Discrepancies were resolved through discussion and consensus by the reviewers. The Cochrane Collaboration risk-of-bias assessment tool was utilized for randomized trials, and the Newcastle–Ottawa Scale risk-of-bias assessment tool was utilized for non-randomized studies [16, 17].

Analysis

Qualitative analysis was used to evaluate outcomes for which substantial variability in method or timing of assessment among studies precluded meaningful quantitative analysis. Quantitative analysis was performed for comparably assessed outcomes if substantial heterogeneity of the data element was not present. Heterogeneity was assessed using the I^2 statistic, with the limit for substantial heterogeneity pre-defined as $I^2 > 60\%$ [14]. Quantitative analysis was performed using Review Manager 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration). When necessary for statistical comparison, conversion of median and range to mean and standard deviation was performed using the method of Hozo et al. [18]. Fixed effect odds ratios (OR) and 95% confidence intervals (CI) were used to analyze dichotomous variables; mean differences were used to analyze continuous variables [14]. Statistical significance was set at $p < 0.05$.

Subgroup analysis was performed to evaluate outcomes among approaches grouped by direction of intra-operative, surgical dislocation. Defined subgroups include DAA versus other approaches involving anterior intra-operative dislocation (anterolateral approach and lateral approach), and DAA versus posterior intra-operative dislocation (posterolateral approach and posterior approach).

Results

Eleven studies were identified that met inclusion criteria; however, two studies were excluded due to inability to obtain full text (Fig. 1). A summary of the 9 studies included in our analysis, including a total of 698 hips (330 direct anterior, 57 anterolateral, 89 lateral, 114 posterolateral, 108 posterior), is provided in Table 1. Among included studies, there was uniform distribution of age, sex, and comorbidity [as assessed

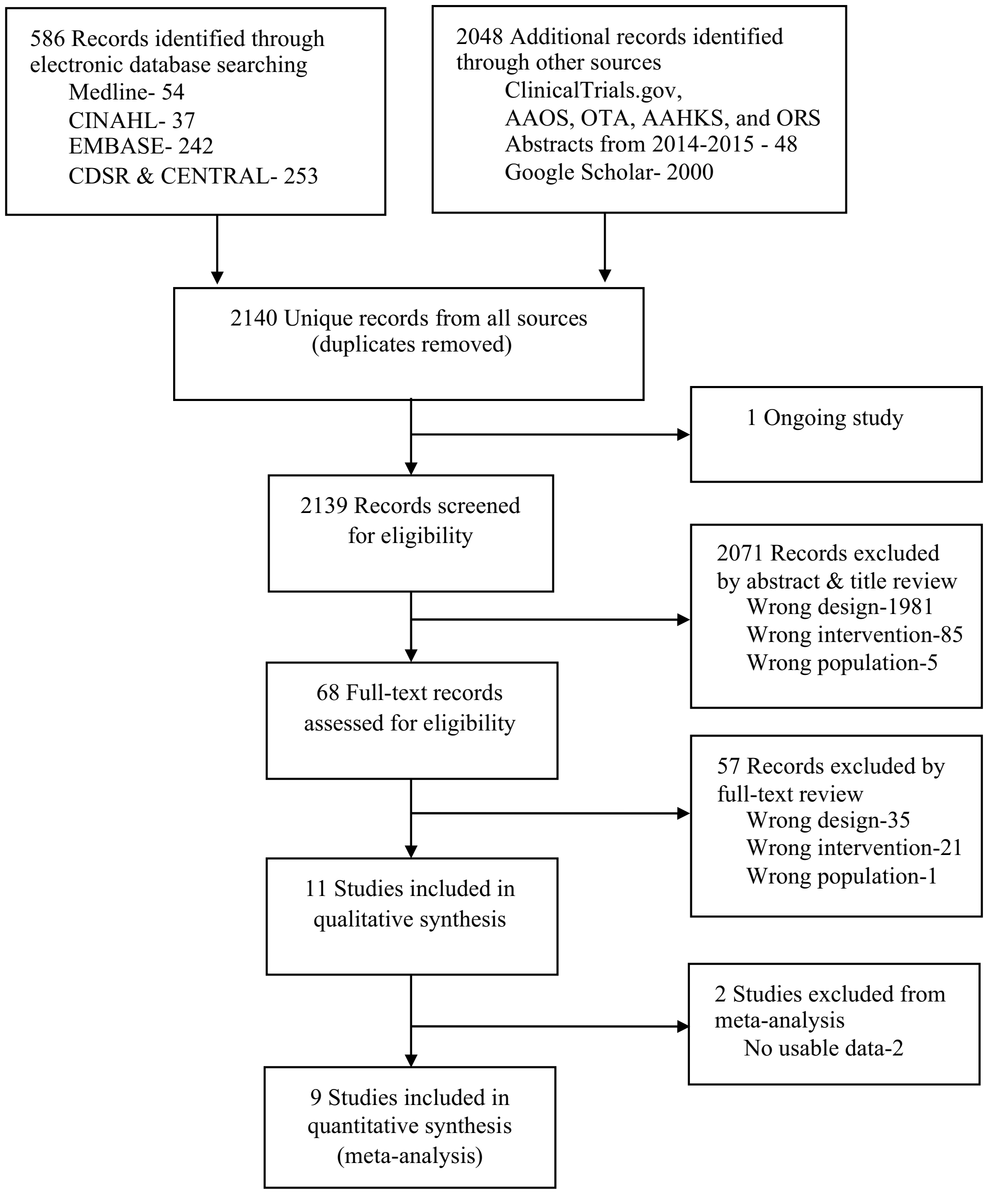


Fig. 1 Study selection flow diagram: *AAHKS* American Association of Hip and Knee Surgeons, *AAOS* American Academy of Orthopaedic Surgeons, *ORS* Orthopaedic Research Society, *OTA* Orthopaedic Trauma Association, *CDSR* Cochrane Database of Systematic Reviews, *CENTRAL* Cochrane Central Register of Controlled Trials, *CINAHL* Cumulative Index to Nursing and Allied Health Literature, *EMBASE* Excerpta Medica dataBASE

by American Society of Anesthesiologists (ASA) score] of patients. Body mass index (BMI) did not vary substantially within studies, with mean BMI reported for DAA and other approaches at 22.6 (range 20.6–26.0) kg/m^2 and 22.4 (range 19.8–26.0) kg/m^2, respectively.

Methodological quality of included studies

Methodological quality assessment is presented in Fig. 2. Randomized studies demonstrated potential for systematic error due to lack of treatment allocation concealment, blinding of personnel/participants, and blinding of outcome assessment. Non-randomized studies demonstrated variable potential for systematic error with regard to comparability of cohorts and outcomes assessment. Publication bias was not assessed due to the limited number of papers included in our study.

Functional mobility

Eight studies reported functional outcomes assessment. The functional outcome measure utilized, as well as timing of

Table 1 Characteristics of included studies

References	Country	Study design	Sample size (direct anterior/control)	Control approach	Age, mean, SD (direct anterior/control)	Gender, % female (direct anterior/control)	Length of follow-up	Number of surgeons/surgeon experience level	Type of implant utilized	Bipolar prosthesis?	Cemented or uncemented
Aiba et al. [19]	Japan	Prospective, randomized	13/16	Posterolateral	81.5 (6.8)/78.6 (7.0)	69.2/68.8	Not specified	1/experienced	Taperloc TM Stem (Biomet)	All	Not specified
Auffarth et al. [6]	Austria	Prospective, randomized	24/24	Direct lateral	82.6 (5.1)/83.7 (6.2)	75/83.3	6 months	8/all had ≥15 years experience	Mueller straight Stem (Zimmer)	Some	Yes
Renken et al. [22]	Germany	Prospective, randomized	30/27	Anterolateral	83 (5.8)/85.5 (7.0)	86.7/88.9	40 days	3/senior surgeons familiar with anterolateral and had performed ≥20 DAA prior to the study	ABG II (Stryker), UHR (Stryker)	All	Yes
Baba et al. [20]	Japan	Prospective, non-randomized	40/39	Posterior	76.7 (7.3)/74.9 (7.7)	82.5/79.5	36 months	6/surgeons had 2–8 years experience and author assisted in all surgeries	Centrax/Accolade TMZF (Stryker)	All	Not specified
Langlois et al. [5]	France	Prospective, non-randomized	38/44	Posterolateral	86 (8.8)/85 (7.7)	84.2/65.9	6 weeks, 12 months by telephone	6/all surgeons undergoing subspecialty training	Meije Duo (Tornier)	All	No
Pala et al. [24]	Italy	Prospective, non-randomized	55/54	Posterolateral	89/87.6†	80/81.5	24 months	6/all surgeons experienced	Hit Medica (Lima), 9 Harmony (Symbios), 5 H-Max (Lima)	Some	Cemented in 98 cases, press-fit in 11 cases (all press-fit were DAA)
Preininger et al. [21]	Germany	Retrospective	55/54	Direct lateral	82 (9)/81 (7)	85.5/81.5	3 weeks	5/not specified	Quadra-C Stem (Medacta), Scan Hip-Optima (Biomet)	All	All

Table 1 (continued)

References	Country	Study design	Sample size (direct anterior/control)	Control approach	Age, mean, SD (direct anterior/control)	Gender, % female (direct anterior/control)	Length of follow-up	Number of surgeons/surgeon experience level	Type of implant utilized	Bipolar prosthesis?	Cemented or uncemented
Trinh et al. [4]	USA	Retrospective	31/70	Anterolateral, direct lateral, posterior	81.5/80.4†	Not specified	4 months	Not specified/all surgeons doing DAA experienced with approach, variety of experience among other approaches	Not specified	Not specified	None
Tsukada and Wakui [23]	Japan	Retrospective	44/40	Posterior	80.4 (6.9)/81.9 (7.9)	81.8/82.1	12 months	7/all had 1–12 years (one surgeon did posterolateral only, remaining 6 did both)	Not specified	All	Not specified

DAA direct anterior approach, *SD* standard deviation

†No range or standard deviation provided

Fig. 2 Assessment of methodological quality

Risk of Bias Assessment for Included Randomized Studies (Cochrane Risk of Bias Assessment Tool)	Random Sequence Generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Auffarth 2010	Low	High	High	Unclear	Low	Low	Low
Renken 2012	Low	Low	High	Low	Low	Low	Low
Aiba 2015	Low	High	High	Unclear	Low	Low	Low

Risk of Bias Assessment for Included Non-Randomized Studies (Newcastle-Ottawa Scale Assessment Tool)

Author	Study type	Selection (max ✱✱✱✱)	Comparability (max ✱✱)	Exposure/Outcome (max ✱✱✱)	Total Stars
Baba 2013	Cohort	✱✱✱✱	✱✱	✱✱✱	9
Langlois 2015	Cohort	✱✱✱✱	✱✱	✱✱✱	9
Pala 2016	Cohort	✱✱✱✱	✱✱	✱✱	8
Preininger 2011	Cohort	✱✱✱✱	✱	✱✱	7
Trinh 2015	Cohort	✱✱✱✱	✱✱	✱✱	8
Tsukada 2010	Cohort	✱✱✱✱	✱	✱✱✱	8

assessments varied considerably among studies, precluding quantitative comparative analysis [4–6, 19–23]. Results of individual studies are reported in Table 2. Timing of postoperative functional mobility assessment ranged from 1 day to 1 year after surgery, with each study reporting at least one assessment that occurred prior to or around 1 month after surgery.

Four studies reported significant functional mobility differences at various postoperative time points, all favoring the DAA [20–23]. Four studies reported no significant differences in functional mobility for the DAA compared to other approaches [4–6, 19]. Of the four studies that reported no statistically significant differences, two reported non-significant findings favoring the DAA, and two reported non-significant findings favoring other approaches [4–6, 19]. No studies reported statistically significant superior functional results with another surgical approach compared to the DAA.

Overall complication rate

All studies reported overall complication rates. No significant differences were found for overall complication rates in either overall (Fig. 3a) or subgroup analysis (Fig. 3b). The overall complication rate for the DAA was 20.3% and for other approaches was 25.5% [OR 0.92 (95% CI 0.62–1.35); $p = 0.66$].

Table 2 Qualitative Summary of Functional Mobility Assessment

Study	Control approach	Functional outcomes measure	Follow-up period(s)	Mean, median, number of patients, or percent values of functional outcomes metrics: DAA (SD)/control (SD)		Overall summary
Aiba	Posterolateral	Harris Hip Score	Day of discharge (time not specified)	47.3 (15.85)/50.5 (13.14)		No difference
Auffarth	Direct lateral	Harris Hip Score	Pre-injury	73.7 (14.8)/78.1 (11.3)		No difference
			10–14 days post-op	43.6 (7.8)/46 (10.5)		
			6 months post-op	66.1 (10.5)/67.9 (16.5)		
Renken	Anterolateral	Barthel Index	Pre-injury	42.5 (13.9)/40 (7.4)		Patients in DAA group had significantly higher scores at post-op day 5 ($p = 0.009$), day 16 ($p = 0.05$), and day 40 ($p = 0.013$)
			1 day post-op	0 (5.8)/0 (5.4)		
			5 days post-op	20 (13.6)/10 (10.2)*		
			16 days post-op	25 (13.1)/20 (13.9)*		
			40 days post-op	42.5 (14.6)/30 (11.9)*		
Baba	Posterior	Walking Ability (4 categories: unaided walking (including utilization of a T-cane), walking using two crutches or a walker, assisted walking, and use of a wheelchair)	Pre-injury	Not specified		Patients in DAA group had significantly higher rates of walking without assistance (unaided walking, walking with a T-cane, walking with a walker) at 2 weeks ($p < 0.05$)
			2 weeks post-op	65/33.3%*		
			1 month post-op	Not specified		
			6 months post-op	67.5/66.6%		No difference at 6 months
Langlois	Posterolateral	Timed up and go (TUG) test	6 weeks post-op	<10 s	0/6	No difference. Multivariate regression did identify approach as an independent factor related to walking ability [OR 0.14 (95% CI 0.02–0.9); $p = 0.03$]
				10–19	19/10	
				20–29	7/16	
				≥30	12/12	
		Postel Merle d' Aubigne	1 year post-op	Function	3.6 (2.3)/3.4 (2.1)	No difference
				Mobility	4.7 (1.3)/5.3 (0.5)	
Pala	Posterolateral	No functional outcome assessment reported				
Preininger	Direct lateral	Time to first mobilization	Day of first mobilization	2 (2)/4 (4)*		Patients in DAA group had significantly earlier mobilization ($p < 0.01$)
Trinh	Anterolateral, direct lateral, posterior	Number of feet ambulated	1 day post-op	Values not specified		No difference
			2 days post-op	Values not specified		
			3 days post-op	Values not specified		
Tsukada	Posterior	Hospital for special surgery (HSS) hip score (walking function domain)	Pre-injury	33.5 (6.3)/33.7 (5.9)		Patients in DAA group had significantly higher scores at 1 month ($p = 0.019$)
			1 month post-op	24.2 (6.4)/20.2 (7.4)*		
			1 year post-op	29.9 (7.4)/27.2 (7.2)		No difference at 1 year

SD standard deviation

* Statistically significant finding ($p < 0.05$)

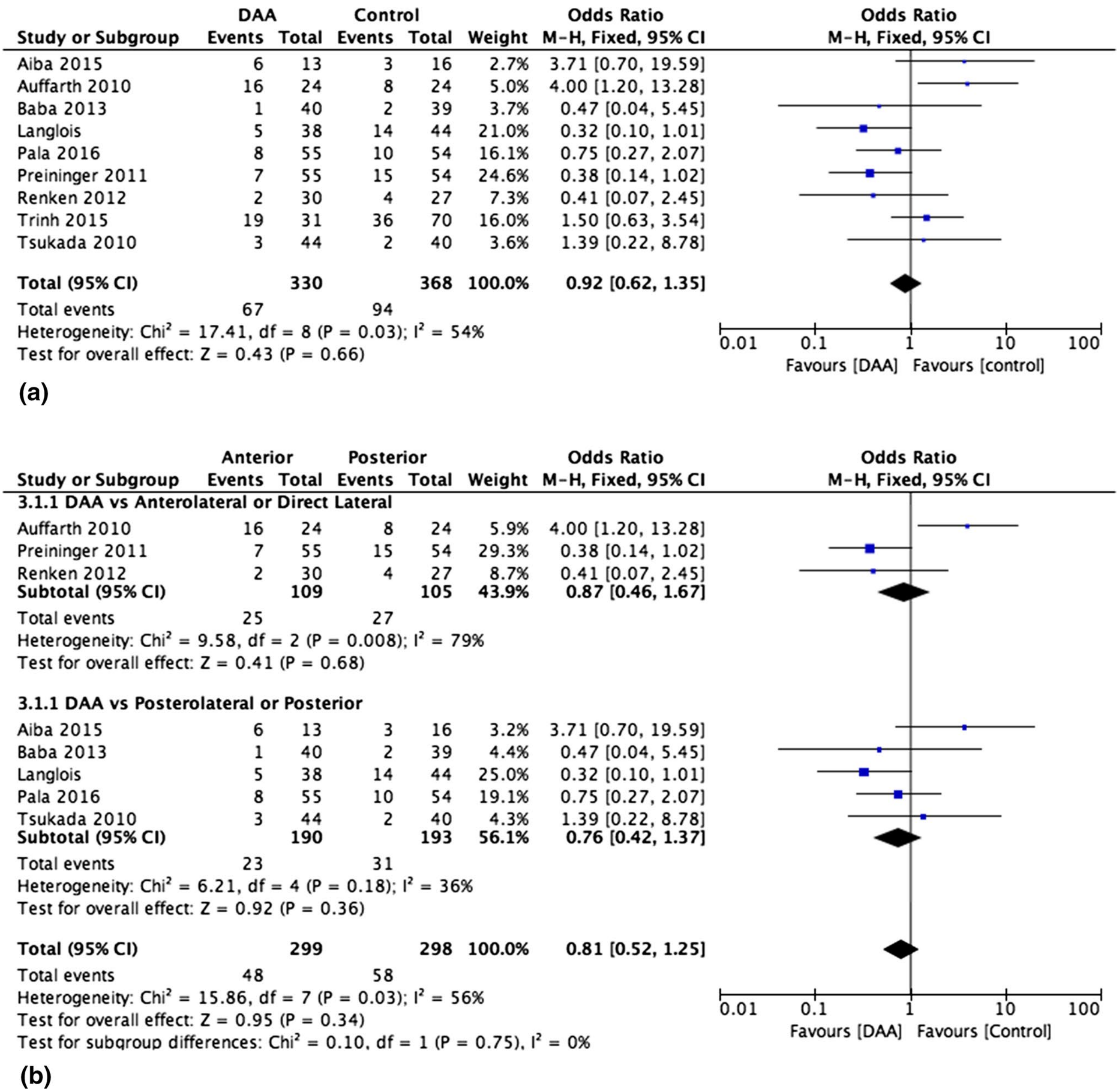


Fig. 3 **a** Overall complication rate for DAA versus control approaches and **b** subgroup analysis of overall complication rate for DAA versus anterolateral and direct lateral approach, and for DAA versus posterolateral and posterior approach [the *solid squares* denote the mean difference, the *horizontal lines* represent the 95% confidence intervals (CI), and the *diamond* denotes the cumulative odds ratio]

Dislocation rate

Dislocation rate was reported in all studies. Meta-analysis demonstrated significantly fewer dislocations with the DAA (0.6%) than with other approaches (5.4%) [OR 0.28 (95% CI 0.06–0.54); $p = 0.003$] (Fig. 4a). Subgroup analysis demonstrated significantly fewer dislocations among DAA (1.1%) versus posterolateral and posterior approaches (7.8%) [OR 0.18 (95% CI 0.05–0.63); $p = 0.007$]; however, no significant difference was shown when DAA (0%) was compared with anterolateral and direct lateral approaches (1.9%) [OR 0.19 (95% CI 0.01–4.03); $p = 0.29$] (Fig. 4b).

Perioperative fracture rate

Fractures that occurred during surgery or the immediate postoperative recovery period were evaluated. Trinh et al. [4] reported a peri-prosthetic fracture in their control group

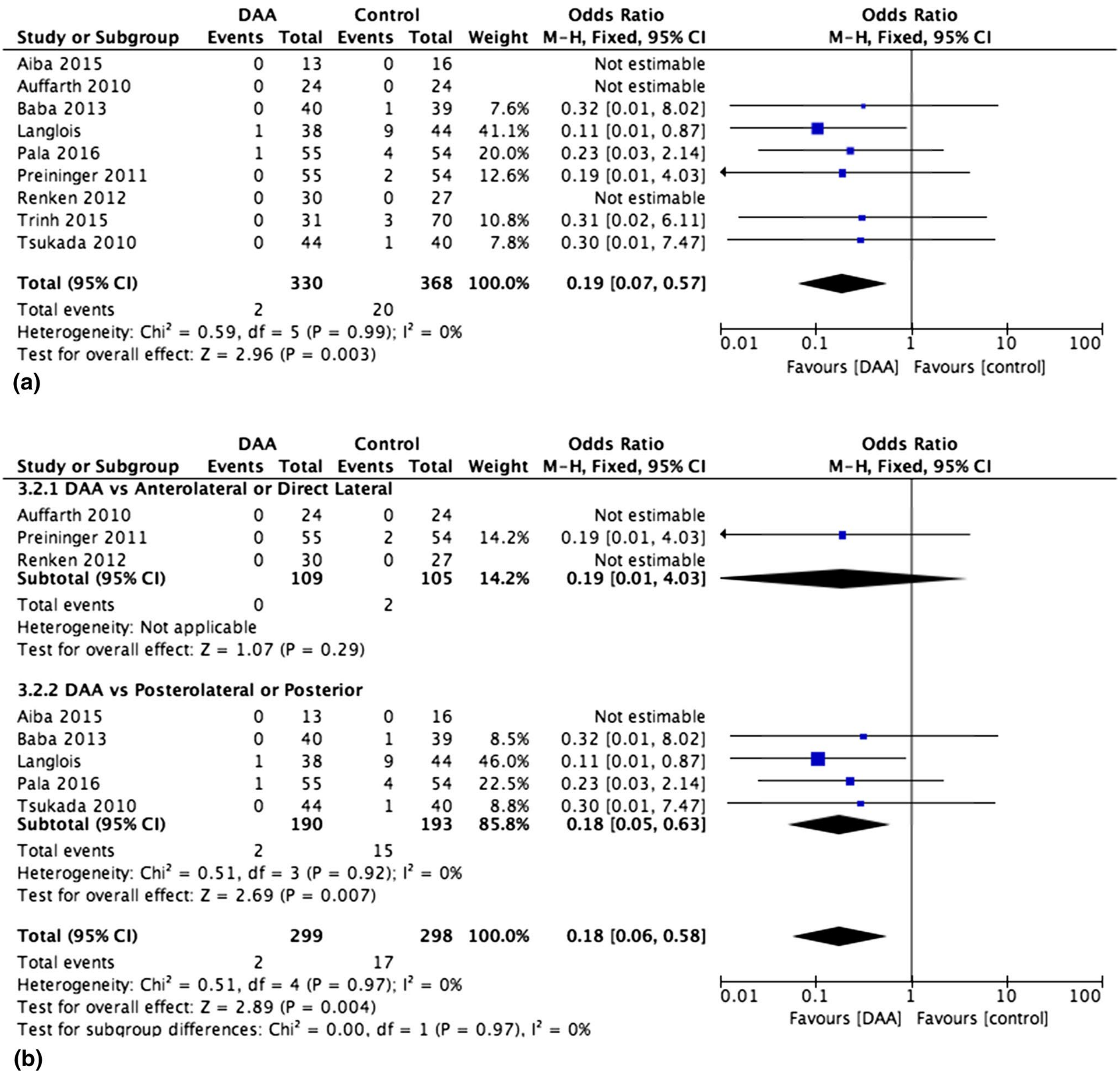


Fig. 4 **a** Overall dislocation rate for DAA versus control approaches and **b** subgroup analysis of dislocation rate for DAA versus anterolateral and direct lateral approach, and for DAA versus posterolateral and posterior approach [the *solid squares* denote the mean difference, the *horizontal lines* represent the 95% confidence intervals (CI), and the *diamond* denotes the cumulative odds ratio]

which occurred several months after the index surgery. This was excluded from our analysis. No significant differences were found for perioperative fracture rate in either overall (Fig. 5a) or subgroup analysis (Fig. 5b). The overall perioperative fracture rate for DAA was 1.8% and for other approaches was 1.1% [OR 1.4 (95% CI 0.48–4.08); $p = 0.67$].

Infection rate

Infection rates were reported in all studies. No significant differences were found for infection rate in either overall (Fig. 6a) or subgroup analysis (Fig. 6b). The overall infection rate for DAA was 0.6%, and for other approaches was 1.6% [OR 0.58 (95% CI 0.18–1.88); $p = 0.36$].

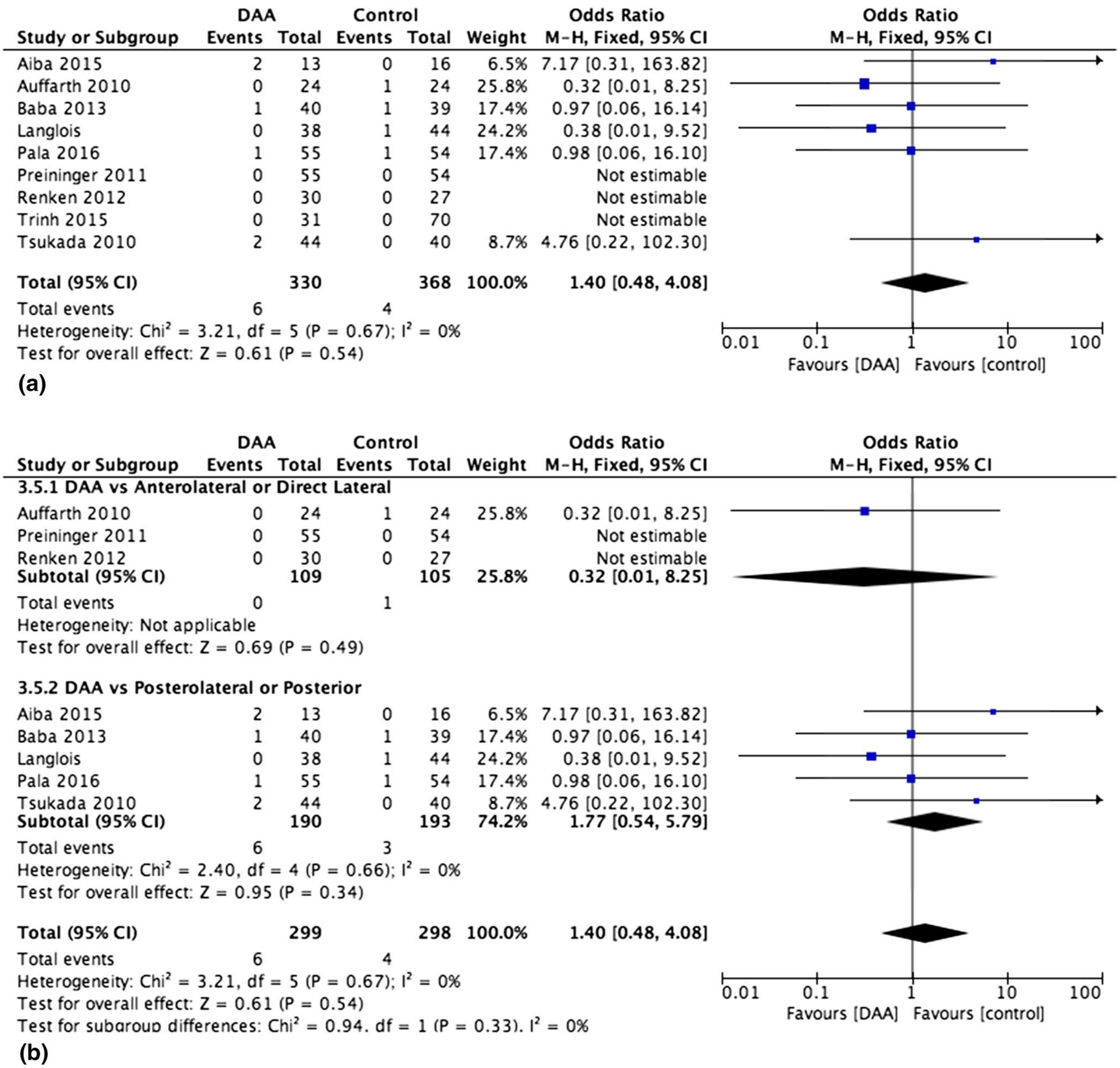


Fig. 5 **a** Overall perioperative fracture rate for DAA versus control approaches and **b** subgroup analysis of perioperative fracture rate for DAA versus anterolateral and direct lateral approach, and for DAA versus posterolateral and posterior approach [the *solid squares* denote the mean difference, the *horizontal lines* represent the 95% confidence intervals (CI), and the *diamond* denotes the cumulative odds ratio]

Re-operation rate

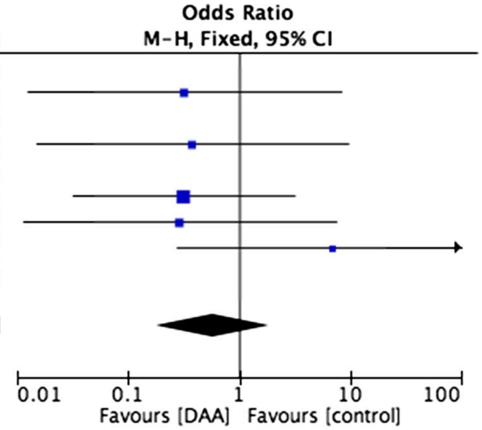
Re-operation rates were reported in all studies. No significant differences in re-operation rate were found in either overall (Fig. 7a) or subgroup analysis (Fig. 7b). The overall re-operation rate for DAA was 1.2%, and for other approaches was 2.2% [OR 0.73 (95% CI 0.24–2.20); $p = 0.58$].

Overall mortality

Mortality rates ranged widely among included studies (from 0 to 25%), consistent with substantial variability in the length of time patients were followed for this outcome. No significant differences were found for mortality in either overall (Fig. 8a) or subgroup analysis (Fig. 8b). The

Study or Subgroup	DAA Events	DAA Total	Control Events	Control Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Aiba 2015	0	13	0	16		Not estimable
Auffarth 2010	0	24	1	24	19.2%	0.32 [0.01, 8.25]
Baba 2013	0	40	0	39		Not estimable
Langlois	0	38	1	44	17.9%	0.38 [0.01, 9.52]
Pala 2016	0	55	0	54		Not estimable
Preininger 2011	1	55	3	54	38.8%	0.31 [0.03, 3.13]
Renken 2012	0	30	1	27	20.2%	0.29 [0.01, 7.41]
Trinh 2015	1	31	0	70	3.9%	6.93 [0.27, 175.07]
Tsukada 2010	0	44	0	40		Not estimable
Total (95% CI)		**330**		**368**	**100.0%**	**0.58 [0.18, 1.88]**
Total events	2		6			

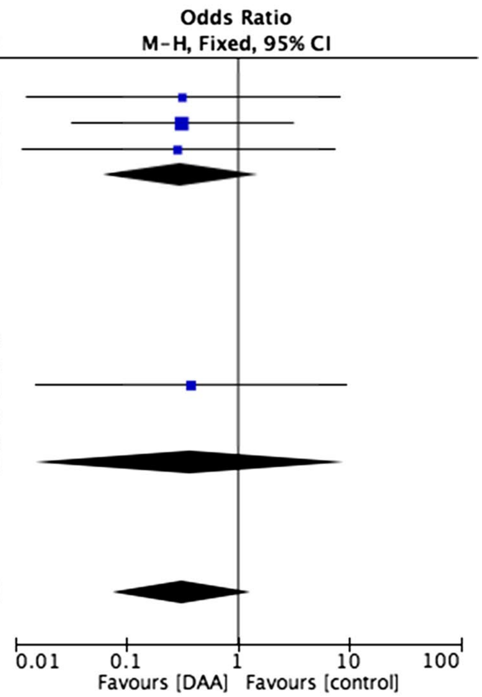
Heterogeneity: $Chi^2 = 2.91$, df = 4 (P = 0.57); $I^2 = 0\%$
Test for overall effect: Z = 0.91 (P = 0.36)



(a)

Study or Subgroup	DAA Events	DAA Total	Control Events	Control Total	Weight	Odds Ratio M-H, Fixed, 95% CI
3.7.1 DAA vs Anterolateral or Direct Lateral						
Auffarth 2010	0	24	1	24	20.0%	0.32 [0.01, 8.25]
Preininger 2011	1	55	3	54	40.3%	0.31 [0.03, 3.13]
Renken 2012	0	30	1	27	21.0%	0.29 [0.01, 7.41]
Subtotal (95% CI)		**109**		**105**	**81.3%**	**0.31 [0.06, 1.57]**
Total events	1		5			
Heterogeneity: $Chi^2 = 0.00$, df = 2 (P = 1.00); $I^2 = 0\%$						
Test for overall effect: Z = 1.42 (P = 0.16)						
3.7.2 DAA vs Posterolateral or Posterior						
Aiba 2015	0	13	0	16		Not estimable
Baba 2013	0	40	0	39		Not estimable
Langlois	0	38	1	44	18.7%	0.38 [0.01, 9.52]
Pala 2016	0	55	0	54		Not estimable
Tsukada 2010	0	44	0	40		Not estimable
Subtotal (95% CI)		**190**		**193**	**18.7%**	**0.38 [0.01, 9.52]**
Total events	0		1			
Heterogeneity: Not applicable						
Test for overall effect: Z = 0.59 (P = 0.55)						
Total (95% CI)		**299**		**298**	**100.0%**	**0.32 [0.08, 1.37]**
Total events	1		6			

Heterogeneity: $Chi^2 = 0.01$, df = 3 (P = 1.00); $I^2 = 0\%$
Test for overall effect: Z = 1.53 (P = 0.13)
Test for subgroup differences: $Chi^2 = 0.01$, df = 1 (P = 0.92), $I^2 = 0\%$



(b)

Fig. 6 **a** Overall infection rate for DAA versus control approaches and **b** subgroup analysis of infection rate for DAA versus anterolateral and direct lateral approach, and for DAA versus posterolateral and posterior approach [the *solid squares* denote the mean difference, the *horizontal lines* represent the 95% confidence intervals (CI), and the *diamond* denotes the cumulative odds ratio]

mortality rate for DAA was 7.6%, and for other approaches was 6.8% [OR 1.17 (95% CI 0.65–2.11); $p = 0.61$].

Operative time

High heterogeneity ($I^2 = 90\%$) precluded quantitative analysis of operative time. Three studies reported significantly longer operative times for the DAA [5, 6, 19]. One study reported significantly shorter operative times for the DAA group [24]. Mean operative duration ranged considerably from 47 to 85.6 min for the DAA, and 54 to 79.3 min for the other approaches. Mean differences within individual studies between DAA and other approaches ranged from 2 to 23.8 min.

Pain

Variability among pain assessment metrics utilized and timing of assessment precluded quantitative analysis. Five studies reported pain outcomes, with 3 favoring DAA

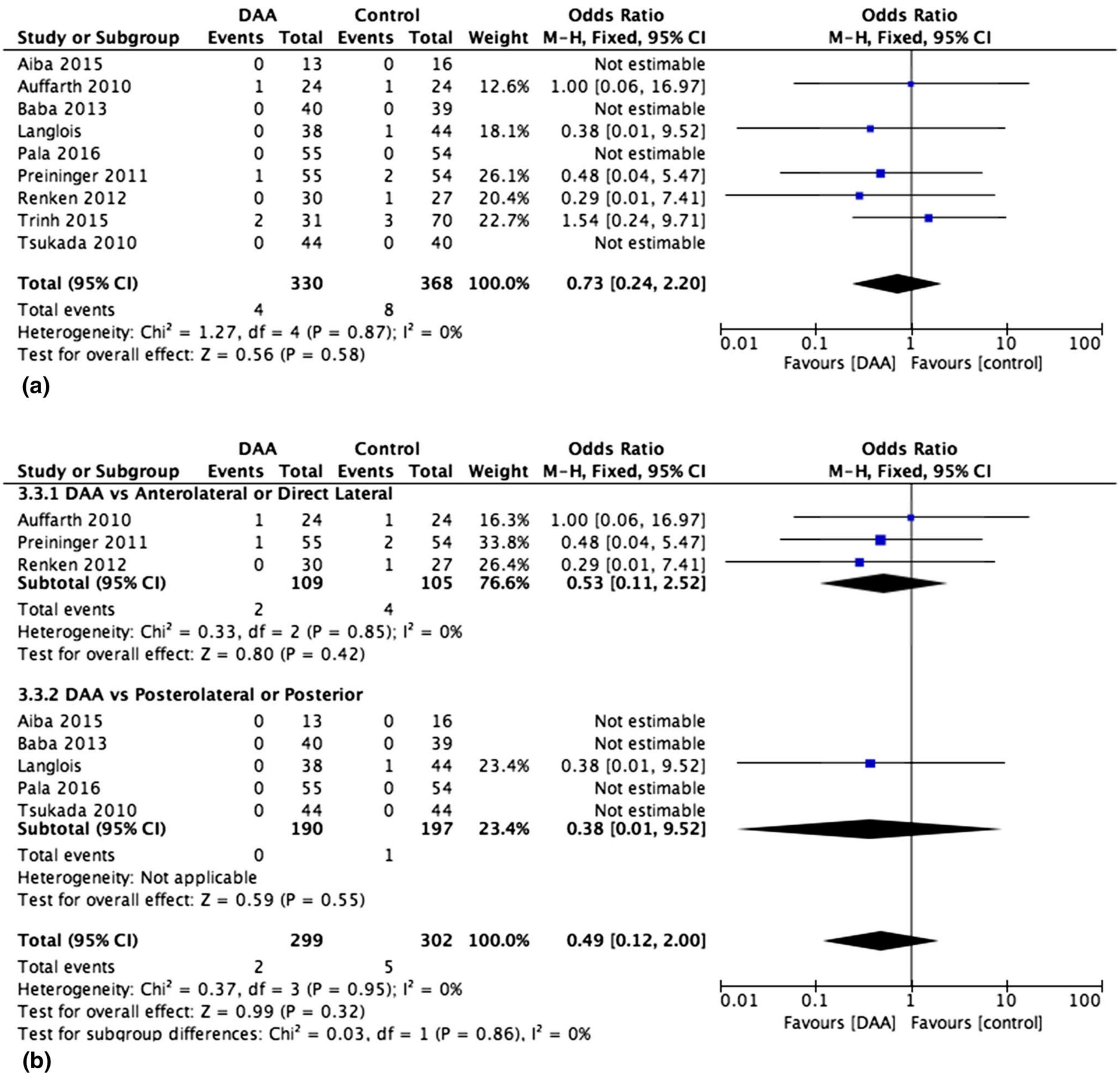


Fig. 7 **a** Overall re-operation rate for DAA versus control approaches and **b** subgroup analysis of re-operation rate for DAA versus anterolateral and direct lateral approach, and for DAA versus posterolateral and posterior approach [the *solid squares* denote the mean difference, the *horizontal lines* represent the 95% confidence intervals (CI), and the *diamond* denotes the cumulative odds ratio]

and 2 favoring other approaches [5, 6, 21, 22, 24]. Langlois et al. [5] assessed visual analog scale (VAS) scores at postoperative day 5 and found no difference. However, at their final follow-up (mean 22 ± 5.1 months for DAA, 21 ± 5.1 months for controls) patients in the DAA group reported more pain (5.6 ± 1.1 vs. 4.9 ± 1.4, $p = 0.03$) on the Postel Merle d'Aubigné (PMA) metric. Pala et al. [24] reported numeric rating scale scores and found significantly less pain in the DAA group (1.5) versus controls (2.1), $p = 0.001$ (timing of assessment was not specified). Renken et al. [22] reported VAS scores at postoperative days 1, 5, 16, and 40. They reported lower median scores in the DAA group at day 16 (1 ± 1.33 vs. 2 ± 1.53, $p = 0.035$) and day 40 (0 ± 0.31 vs. 1 ± 0.82, $p = 0.0004$). Conversely, Auffarth et al. [6] assessed VAS scores at 12, 24, 48, 72, and 96 h postoperatively and reported higher pain scores at every time point in the DAA group, with a mean difference between the DAA and control groups at each time point of 0.58 ($p = 0.024$). Preininger et al. [21] reported number of days patients required PRN IV analgesics (in addition

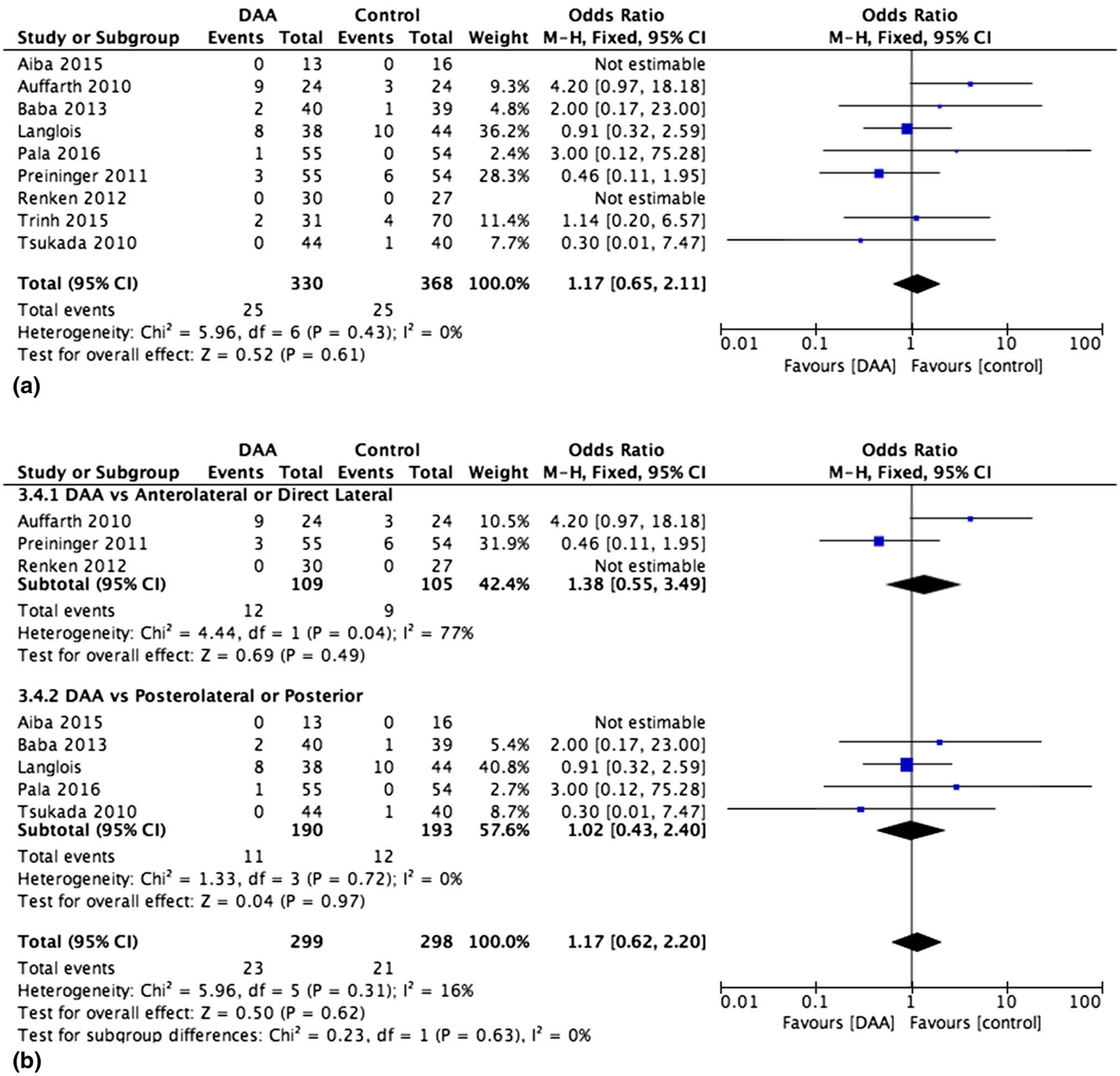


Fig. 8 **a** Overall mortality by final follow-up for DAA versus control approaches and **b** subgroup analysis of mortality by final follow-up for DAA versus anterolateral and direct lateral approach, and for DAA versus posterolateral and posterior approach [the *solid squares* denote the mean difference, the *horizontal lines* represent the 95% confidence intervals (CI), and the *diamond* denotes the cumulative odds ratio]

to baseline 550 mg naproxen BID) and found significantly longer requirements in the DAA group (4.4 ± 4 days) versus controls (3.5 ± 7 days) $p = 0.04$.

Perioperative blood loss

Eight studies reported perioperative blood loss. Variation in method of assessment precluded quantitative analysis. Of the 5 studies that evaluated postoperative hemoglobin drop, 4 showed no significant difference between the DAA and other approaches [4–6, 22]. Pala et al. [24] reported a significantly lower decrease in hemoglobin levels in the DAA group [1.5 (0–5.4) g/dL] versus controls [1.9 (0–4) g/dL], $p = 0.02$. Of the 3 studies that reported volumetric blood loss, 2 found no significant difference [4, 19]. Tsukada and Wakui [23] found significantly higher volumetric intra-operative blood loss in the DAA group (370.1 mL ± 192.1) compared to controls (230 mL ± 114.9) $p = 0.0002$. Three studies reported postoperative transfusion requirement and found no significant difference between approaches [4, 5, 21].

Length of stay

Substantial differences in length of stay (5.3–36.1 days), likely reflective of health systems and cultural differences, were present among the studies and precluded meaningful quantitative comparison. No significant differences in length of stay were reported within any of the individual studies.

Discussion

This is the first systematic review and meta-analysis to evaluate the direct anterior approach for hemiarthroplasty in the setting of femoral neck fracture. With regard to early functional mobility, 4 of the 8 included studies that reported functional outcome metrics favored DAA, and no study favored other approaches over the DAA, suggesting superior early functional outcome with the DAA. Conversely, qualitative analysis of operative time, postoperative pain, perioperative blood loss, and length of stay did not clearly favor either the DAA or other approaches. Moreover, with the exception of dislocation rate, there were no significant differences seen for any of the evaluated outcomes in our overall or subgroup quantitative analysis.

The overall risk of dislocation among included studies was 3.2% (0.6% for the DAA, 5.4% for other approaches). Subgroup analysis further demonstrated a significant difference between dislocation rates for the DAA and posterior capsular surgical approaches (posterolateral and posterior). Subgroup analysis of dislocation rates for the DAA versus other anterior capsular approaches (anterolateral and direct lateral), also favored the DAA, but failed to demonstrate statistical significance. These findings support prior literature reporting lower dislocation rates with anterior capsular approaches than posterior capsular approaches for hemiarthroplasty [25–27]. Moreover, the dislocation rate for DAA seen in our meta-analysis (0.6%, ranging from 0 to 2.6% among individual studies) is well below previously published dislocation rates for hemiarthroplasty overall (1.6–16%) and lower than those published for other anterior capsular approaches, anterolateral (0–6%) or direct lateral (0.9–3.3%) [7, 27–33].

Prior literature has demonstrated that dislocation is a serious complication which may be detrimental in terms of quality of life and mortality [29, 34, 35]. Mortality within 6 months of hemiarthroplasty dislocation has been reported to be as high as 65–73% [30, 34]. We believe the low risk of dislocation associated with the DAA merits consideration. Additionally, use of the DAA may allow for avoidance of restrictive postoperative hip precautions. Although postoperative hip precaution protocols were not assessed in this review, for elderly patients with high rates of comorbidities adversely affecting motor skills and cognition, this may also be a salient consideration.

There are several limitations of this systematic review and meta-analysis. The paucity of studies relevant to this topic did not allow for subgroup analysis of each individual surgical approach. Similarly, too few studies met our inclusion criteria for quantitative assessment of potential publication bias to be performed [14]. Furthermore, the limited number of randomized control trials available necessitated inclusion of non-randomized studies. Moreover, rigorous analysis of methodological quality identified some areas of potential bias in the included studies. This was largely related to lack of allocation concealment and participant/personnel blinding. Both of these limitations are common among surgical intervention studies, particularly in the setting of trauma. Also, analysis of functional outcomes was limited by variation among individual studies in type of metrics utilized and timing of assessment. This issue was previously noted by Hutchings et al. [36] in their review of outcomes assessment for proximal femoral fractures and remains a limitation for any literature-based analysis of functional outcomes in this population.

Our analysis was unable to fully account for some technical aspects of the surgical intervention, including use of cemented versus non-cemented prosthetic devices, type of prosthesis (bipolar vs. monopolar), and whether capsular repair was performed. Cement fixation of implants has been shown to confer benefits with regard to functional mobility and implant-related complications [11, 37, 38]. Among the included studies, 2 did not use cemented implants, and 3 failed to specify whether cement was used [4, 5, 19, 20, 23]. However, there did not appear to be substantial differences within individual studies regarding use of cemented implants for the DAA versus other approaches. Variability was found regarding the use of bipolar prostheses (8 studies reported their use in some or all patients, 1 study failed to specify prosthesis type). However, because current literature does not clearly support the superiority of either option, we believe it unlikely that this would substantially impact our measured outcomes [11, 38].

Several of the included studies did not provide information on whether capsular repair was performed, which may be a pertinent factor affecting dislocation rate among posterior capsular approach patients [39]. However, the three studies which compared the DAA to posterior or posterolateral approaches, and specified that capsular repair was performed, demonstrated a higher combined rate of dislocation (10/99 (10.1%)) among posterior capsular approach patients than the two studies of DAA versus posterior or posterolateral approach which did not explicitly specify whether capsular repair had been performed [5/94 (5.3%)] [5, 19, 20, 23, 24].

Of note, the experience level of surgeons in the included studies was varied (Table 1). This may be an important consideration as the DAA has been reported to have a relatively steep learning curve [4, 24, 40, 41]. However, among the 8 studies that specified surgeon experience level, there did not appear to be substantial intra-study variation in surgeon experience between approaches, with the exception of Trinh et al. [4], who compared the DAA to multiple other surgical approaches and whose data were not included in our subgroup analyses. Also, because these injuries are commonly treated by surgeons with a diversity of training and experience, we believe that variation in among surgeon experience level likely adds to the generalizability of our findings.

Conclusion

Despite the stated limitations, our analysis suggests that the DAA provides superior early functional mobility compared to other surgical approaches. Our analysis did not demonstrate a significant difference between the DAA and other approaches with regard to overall complications, perioperative fracture, infection, re-operation rate, mortality, operative time, postoperative pain, perioperative blood loss, or length of stay. The data do, however, demonstrate that the DAA is associated with a significantly lower rate of dislocation when compared with posterior capsular approaches. What proportion of this is attributable to the muscle-sparing aspects unique to the DAA, versus the anterior capsular dissection and direction of intra-operative dislocation shared with other anterior capsular approaches, remains unclear. Further high-quality randomized trials are needed to provide definitive insight into this question and evaluate effect of surgical approach on clinical and functional outcomes after hemiarthroplasty.

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Compliance with ethical standards

Conflict of interest Each author certifies that neither he or she, or a member of his or her immediate family, has any funding or commercial associations (ex. consultancies, equity, stock ownership, patent or licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

References

1. Zuckerman JD (1996) Hip fracture. N Engl J Med 334(23):1519–1525. doi:10.1056/nejm199606063342307
2. Richmond J, Aharonoff GB, Zuckerman JD, Koval KJ (2003) Mortality risk after hip fracture. J Orthop Trauma 17(8 Suppl):S2–S5
3. Schneider K, Audige L, Kuehnel SP, Helmy N (2012) The direct anterior approach in hemiarthroplasty for displaced femoral neck fractures. Int Orthop 36(9):1773–1781. doi:10.1007/s00264-012-1535-4
4. Trinh TQ, Ferrel JR, Pulley BR, Fowler TT (2015) Short-term outcomes of femoral neck fractures treated with hemiarthroplasty using the anterior approach. Orthopedics 38(12):e1091–e1097. doi:10.3928/01477447-20151120-05
5. Langlois J, Delambre J, Klouche S, Faivre B, Hardy P (2015) Direct anterior Hueter approach is a safe and effective approach to perform a bipolar hemiarthroplasty for femoral neck fracture: outcome in 82 patients. Acta Orthop 86(3):358–362. doi:10.3109/17453674.2014.1002987
6. Auffarth A, Resch H, Lederer S, Karpik S, Hitzl W, Bogner R, Mayer M, Matis N (2011) Does the choice of approach for hip hemiarthroplasty in geriatric patients significantly influence early postoperative outcomes? A randomized-controlled trial comparing the modified Smith-Petersen and Hardinge approaches. J Trauma 70(5):1257–1262. doi:10.1097/TA.0b013e3181eded53
7. Leonardsson O, Rolfson O, Rogmark C (2016) The surgical approach for hemiarthroplasty does not influence patient-reported outcome. Bone Joint J 98(4):542–547
8. Yue C, Kang P, Pei F (2015) Comparison of direct anterior and lateral approaches in total hip arthroplasty: a systematic review and meta-analysis (PRISMA). Medicine 94(50):e2126. doi:10.1097/md.0000000000002126
9. Zawadsky MW, Paulus MC, Murray PJ, Johansen MA (2014) Early outcome comparison between the direct anterior approach and the mini-incision posterior approach for primary total hip arthroplasty: 150 consecutive cases. J Arthroplasty 29(6):1256–1260. doi:10.1016/j.arth.2013.11.013
10. Parvizi J, Restrepo C, Maltenfort MG (2016) Total hip arthroplasty performed through direct anterior approach provides superior early outcome: results of a randomized, prospective study. Orthop Clin N Am 47(3):497–504. doi:10.1016/j.ocl.2016.03.003
11. Miyamoto RG, Kaplan KM, Levine BR, Egol KA, Zuckerman JD (2008) Surgical management of hip fractures: an evidence-based review of the literature. I: femoral neck fractures. J Am Acad Orthop Surg 16(10):596–607
12. Parker MJ (2015) Lateral versus posterior approach for insertion of hemiarthroplasties for hip fractures: a randomised trial of 216 patients. Injury 46(6):1023–1027
13. Kunkel S (2016) Systematic review and meta-analysis of the direct anterior approach for hemiarthroplasty in the treatment of traumatic femoral neck fractures. University of York. http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016051618
14. Higgins P, Green S (2011) Cochrane handbook for systematic reviews of interventions Version 5.1.0 [updated March 2011]. The Cochrane Collaboration
15. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151(4):264–269
16. Higgins JP, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JA (2011) The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 343:d5928
17. Wells G, Shea B, O'Connell D, Peterson J, Welch V, Losos M, Tugwell P (2007) Newcastle–Ottawa Scale.

Hospital Research Institute Ottawa. http://www.ohrica/programs/clinical_epidemiology/nosgenpdf
18. Hozo SP, Djulbegovic B, Hozo I (2005) Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 5(1):13. doi:10.1186/1471-2288-5-13
19. Aiba H, Watanabe N, Nishimori Y, Onogi H, Oguri Y, Yamagami T, Okamato H, Sakurai H, Otsuka T (2015) Randomized study of direct anterior approach versus posterior approach for bipolar hemiarthroplasty of the hip. J J Ortho Rheum 1(2):010
20. Baba T, Shitoto K, Kaneko K (2013) Bipolar hemiarthroplasty for femoral neck fracture using the direct anterior approach. World J Orthop 4(2):85–89. doi:10.5312/wjo.v4.i2.85
21. Preininger B, Jesacher M, Fabsits E, Winkler T (2011) Earlier postoperative mobilization with minimally invasive hip hemiarthroplasty. Unfallchirurg 114(4):333–339
22. Renken F, Renken S, Paech A, Wenzl M, Unger A, Schulz AP (2012) Early functional results after hemiarthroplasty for femoral neck fracture: a randomized comparison between a minimal invasive and a conventional approach. BMC Musculoskelet Disord 13:141. doi:10.1186/1471-2474-13-141
23. Tsukada S, Wakui M (2010) Minimally invasive intermuscular approach does not improve outcomes in bipolar hemiarthroplasty for femoral neck fracture. J Orthop Sci 15(6):753–757. doi:10.1007/s00776-010-1541-6
24. Pala E, Trono M, Bitonti A, Lucidi G (2016) Hip hemiarthroplasty for femur neck fractures: minimally invasive direct anterior approach versus postero-lateral approach. Eur J Orthop Surg Traumatol 26(4):423–427. doi:10.1007/s00590-016-1767-x
25. Enocson A, Tidermark J, Tornkvist H, Lapidus LJ (2008) Dislocation of hemiarthroplasty after femoral neck fracture: better outcome after the anterolateral approach in a prospective cohort study on 739 consecutive hips. Acta Orthop 79(2):211–217. doi:10.1080/17453670710014996
26. Abram SG, Murray JB (2015) Outcomes of 807 Thompson hip hemiarthroplasty procedures and the effect of surgical approach on dislocation rates. Injury 46(6):1013–1017. doi:10.1016/j.injury.2014.12.016
27. Skoldenberg O, Ekman A, Salemyr M, Boden H (2010) Reduced dislocation rate after hip arthroplasty for femoral neck fractures when changing from posterolateral to anterolateral approach. Acta Orthop 81(5):583–587. doi:10.3109/17453674.2010.519170
28. Li L, Ren J, Liu J, Wang H, Sang Q, Liu Z, Sun T (2016) What are the risk factors for dislocation of hip bipolar hemiarthroplasty through the anterolateral approach? A nested case-control study. Clin Orthop Relat Res 474(12):2622–2629. doi:10.1007/s11999-016-5053-3
29. Unwin AJ, Thomas M (1994) Dislocation after hemiarthroplasty of the hip: a comparison of the dislocation rate after posterior and lateral approaches to the hip. Ann R Coll Surg Engl 76(5):327–329
30. Keene GS, Parker MJ (1993) Hemiarthroplasty of the hip—the anterior or posterior approach? A comparison of surgical approaches. Injury 24(9):611–613
31. Bush JB, Wilson MR (2007) Dislocation after hip hemiarthroplasty: anterior versus posterior capsular approach. Orthopedics 30(2):138–144
32. Paton RW, Hirst P (1989) Hemiarthroplasty of the hip and dislocation. Injury 20(3):167–169
33. Barnes CL, Berry DJ, Sledge CB (1995) Dislocation after bipolar hemiarthroplasty of the hip. J Arthroplasty 10(5):667–669. doi:10.1016/S0883-5403(05)80213-X
34. Blewitt N, Mortimore S (1992) Outcome of dislocation after hemiarthroplasty for fractured neck of the femur. Injury 23(5):320–322
35. Enocson A, Pettersson H, Ponzer S, Törnkvist H, Dalén N, Tidermark J (2009) Quality of life after dislocation of hip arthroplasty: a prospective cohort study on 319 patients with femoral neck fractures with a one-year follow-up. Qual Life Res 18(9):1177–1184. doi:10.1007/s11136-009-9531-x
36. Hutchings L, Fox R, Chesser T (2011) Proximal femoral fractures in the elderly: how are we measuring outcome? Injury 42(11):1205–1213. doi:10.1016/j.injury.2010.12.016
37. Taylor F, Wright M, Zhu M (2012) Hemiarthroplasty of the hip with and without cement: a randomized clinical trial. JBJS 94(7):577–583. doi:10.2106/jbjs.k.00006
38. Parker MJ, Gurusamy KS, Azegami S (2010) Arthroplasties (with and without bone cement) for proximal femoral fractures in adults. Cochrane Database Syst Rev 6:Cd001706. doi:10.1002/14651858.CD001706.pub4
39. Hughes AW, Clark D, Carlino W, Gosling O, Spencer RF (2015) Capsule repair may reduce dislocation following hip hemiarthroplasty through a direct lateral approach: a cadaver study. Bone Joint J 97-b(1):141–144. doi:10.1302/0301-620x.97b1.34038
40. Goytia RN, Jones LC, Hungerford MW (2012) Learning curve for the anterior approach total hip arthroplasty. J Surg Orthop Adv 21(2):78–83
41. Seng BE, Berend KR, Ajluni AF, Lombardi AV Jr (2009) Anterior-supine minimally invasive total hip arthroplasty: defining the learning curve. Orthop Clin North Am 40(3):343–350. doi:10.1016/j.ocl.2009.01.002