# Management of Vancouver B2 Periprosthetic Femoral Fractures, Revision Total Hip Arthroplasty Versus Open Reduction and Internal Fixation: A Systematic Review and Meta-Analysis

*Daniel P. Lewis, B Med (Dist),[a] Seth M. Tarrant, B Biomed Sc (Hons), MB BS,[a,b,c] Lachlan Cornford, MB BS (Hons),[a,c] and Zsolt J. Balogh, MD, PhD[a,b,c]*

**Objective:** To identify and analyze the current evidence for the use of open reduction and internal fixation (ORIF) constructs compared with conventional revision total hip arthroplasty (rTHA) for the management of Vancouver B2 periprosthetic femoral fractures (PFFs).

**Data Sources:** A systematic literature search of the MEDLINE, CINAHL, and EMBASE databases was conducted. Prospective and retrospective studies were eligible. No limitation was placed on publication date, with only articles printed in English eligible.

**Study Selection:** Included studies were retrospective studies comparing ORIF and rTHA for the management of Vancouver B2 PFFs.

**Data Extraction:** The primary outcome was the overall complication rate. Other outcomes included as rate of dislocation, revision operation, refracture, infection, nonunion, and subsidence/loosening. Twenty-four studies were included totaling 1621 patients, of which 331 were treated with ORIF and 1280 with rTHA.

**Conclusion:** The 1621 patients included comprised a mixture of different fracture patterns, prostheses, and patient comorbidities. The overall complication rate for ORIF was 24% versus 18% for rTHA ($P = 0.13$). The results demonstrate that rTHA has a similar revision rate to ORIF in PFFs with a loose femoral component and adequate bone stock. ORIF was superior to rTHA in prevention of postoperative dislocation; however, there was no difference between other complications. This review suggests a potential role of both ORIF and rTHA in the management of Vancouver B2 PFFs.

**Key Words:** periprosthetic fracture, open reduction and internal fixation, revision arthroplasty, Vancouver B2 fracture, trauma

**Level of Evidence:** Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

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## INTRODUCTION

Total hip arthroplasty (THA) is an increasingly common procedure.[1] Recent data indicate that Australia and New Zealand have seen an increase in incidence of 2.9%, whereas Sweden and England/Wales have seen a rise of 5.4% and 0.9%, respectively.[1–3] As life expectancies and number of THAs increases, as does the incidence of periprosthetic femoral fractures (PFFs).[4] PFFs are a relatively uncommon complication, with a reported incidence between 0.4% and 4%.[5,6] There is emerging evidence that patients with uncemented femoral fixation and revision THA (rTHA) are at higher risk of periprosthetic fractures compared with primary cemented femoral stems, of both which are becoming increasingly common.[5,7,8]

PPFs are a challenging cohort to manage, especially in the context of multiple medical comorbidities. The Vancouver classification system is frequently used to categorize PFFs and aid in management decisions and has been incorporated into the comprehensive United Classification System.[9,10] The Vancouver classification system considers the location of the fracture relative to the implant, the stability of the implant, and the quality of the surrounding bone.[9] Type A fractures are confined to the greater or lesser trochanters. Type B fractures are diaphyseal at the level of the femoral stem, whereas type C fractures are distal to the prosthetic tip. Type B fractures are further subclassified by the presence of a well-fixed stem (B1), an unstable stem with good bone stock (B2), or an unstable stem with poor bone stock (B3). B2 fractures can be difficult to identify as implant loosening is not always obvious, and the delineation between adequate and inadequate bone stock is somewhat subjective. With that being said, Swedish data suggest that some 47% PFFs are B2.[11]

Conventionally, B2 PFFs have been managed with rTHA with an uncemented stem with or without added internal

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From the [a]Department of Orthopaedic Surgery, John Hunter Hospital, Newcastle, Australia; [b]University of Newcastle, Newcastle, Australia; and [c]Fellow of the Royal Australasian College of Surgeons (FRACS).
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All work was undertaken at John Hunter Hospital, Newcastle, NSW, Australia.
Reprints: Zsolt J. Balogh, MD, PhD, Department of Traumatology, John Hunter Hospital and University of Newcastle, Locked Bag 1, Hunter Region Mail Centre, Newcastle, NSW 2310, Australia (e-mail: zsolt.balogh@health.nsw.gov.au).

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fixation. Traditional teaching has recommended against open reduction and internal fixation (ORIF) because of perceived nonunion rates, long immobilization periods, and higher risk of revision surgery.[6,12] However, as compared with revision, there are features of ORIF that make it an attractive option under certain circumstances. Notably, ORIF is usually less expensive, has shorter operative times, and is considered to be less surgically invasive.[13] This is of particular relevance given the frailty of many who present with PFFs.

Despite emerging observational data on the role of ORIF in B2 management, the overall efficacy and safety are yet to be established in part because of the small sample sizes.[14,15] As such, a systematic review and meta-analysis was designed to establish the current evidence for ORIF in Vancouver B2 patients compared with conventional revision arthroplasty (rTHA). We hypothesized that rTHA as the traditional approach to this problem has more favorable outcomes compared with ORIF in context of a PFF with adequate bone stock and a loose femoral stem.

## METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses was followed, and the methods were registered with PROSPERO, an international prospective register of systematic reviews.[16] PROSPERO ID: CRD42019139505.

## SEARCH STRATEGY

Studies were identified through comprehensive searching of the MEDLINE, CINAHL, and EMBASE databases (1966 to December 6, 2019). The search strategy included a mix of MeSH and free-text terms for the key concepts related to Vancouver B2 PFFs (See MEDLINE search strategy, Supplemental Files). Given the paucity of studies on this topic, the search strategy was broad to maximize the number of included studies identified.

No restrictions were placed on the year of publication; however, only articles in English were eligible. Reference lists of key included articles and latest editions of relevant journals were reviewed for new references. Full articles were read and assessed by 3 reviewers (L.C., D.P.L., and S.M.T.) for relevance and study eligibility. Disagreements on methodology were resolved by discussion, and a fourth reviewer (Z.J.B.) adjudicated over any dispute.

## STUDY SELECTION

Included articles met the following criteria: participants must have undergone a primary or rTHA or hemiarthroplasty and subsequently sustained a Vancouver B2 fracture or equivalent (eg, OTA/AO) that was managed with either ORIF or rTHA. Fractures were classified based on the reported intraoperative findings, as reported by study authors. No restriction was placed on the means of ORIF and could include but was not limited to the use of cable plates, compression plates, locking plates, cerclage wiring, cortical strut allografts, screw fixation, or any combination of the above. rTHA was defined as any form of femoral component revision, with or without cement and with or without additional internal fixation. Only studies with more than 5 (n = 5) included participants with Vancouver B2 fractures were eligible. Studies that comprised a mixture of Vancouver fracture types were eligible if they published outcome data specifically for patients with Vancouver B2. The minimum follow-up time was 12 months. Both single-intervention (ie, ORIF alone) and dual-intervention study designs (ORIF vs. rTHA) were eligible for inclusion.

Only the principal study with the greatest number of subjects was included. In instances where the same patient may have been represented twice in the literature, the authors excluded the smaller of the studies to allow for the largest number of patients to be included in each analysis without duplication of data. After initial screening, duplicate data sets, editorials, and discussion articles were excluded. Studies were excluded from specific analyses if the data set was incomplete. When required, additional data were requested from original authors. Additional data were provided by one author.[11]

## OUTCOME MEASURES

Data relating to study design, country of origin, study period, intervention, patient characteristics, and clinical outcomes were extracted. The primary outcome was the overall complication rate of rTHA and ORIF, defined as a sum of the reported complications. Other outcomes of interest were as follows:

1. Revision operation: any return to theater in the follow-up period to manage a fracture or implant complication. Debridement in the setting of presumed or known infection without implant exchange was not included as a revision operation because it was included under infection,
2. Dislocation,
3. Infection: any documented deep prosthetic joint infection requiring surgical or medical management,
4. Refracture: any new periprosthetic fracture on the same side or refracture through a previously united fracture site,
5. Loosening and subsidence. Subsidence was defined as radiological subsidence of 5 mm of more.[17] Loosening defined using the Harris criteria or other definition used by the study authors,[18] and
6. Nonunion. Defined as a lack of radiological union beyond 6 months postoperatively.[19]

## ASSESSMENT OF STUDY QUALITY

Quality assessment was performed using the validated tool designed by Guo et al,[20] a 20-component checklist specifically designed for quality assessment of case–control and retrospective studies. Guo et al's scoring system does not assign a minimum score in which a certain level of quality is achieved, but instead each of the criterion is intended to be weighed equally.[20]

## DATA SYNTHESIS

RevMan 5.3 (Nordic Cochrane Centre, Denmark) was used to complete the meta-analysis and generate forest plots for all dual-intervention studies. Pooled data are presented using odds ratios. Either a fixed effects or random effects model was used based on the heterogeneity of included studies. A minimum of 2 studies were required for forest plots. Binary outcomes were analyzed using the Mantel–Haenszel method. Single-intervention studies (ie, ORIF or rTHA alone) were analyzed along with corresponding data from dual-intervention studies using OpenMeta (Analyst) (Brown University). Data from single-intervention and dual-intervention studies were then analyzed using the DerSimonian–Laird random effects method to calculate the weighted proportion rate for events in the ORIF and rTHA groups, respectively. Odds ratios were then calculated using the weighted proportions.

## HETEROGENEITY

Heterogeneity was quantified using the I2 test, as it does not inherently depend on the number of studies considered.[21] I2 values range from 0% (homogeneous) to 100% (greater heterogeneity). We used a random effects model for all analyses where the I2 test was greater than 50%. A random effects model was used in all single-arm analyses.[22]

## PUBLICATION BIAS

Funnel plots were examined for evidence of publication bias, and the Egger linear regression test was used to further determine the existence of publication bias.

## RESULTS

Nine hundred and fifty articles were identified, of which 49 full-text articles were assessed for eligibility. Twenty-five full-text articles were excluded for the following reasons: 19 articles had no outcome data, 4 articles had less than the required 5 patients with B2 fractures, and 2 articles included duplicated data (see **Preferred Reporting Items for Systematic Reviews and Meta-Analyses Flowchart**, **Supplemental Digital Content 1**, http://links.lww.com/JOT/B441).

Overall, 24 articles met inclusion criteria, comprising 12 single-intervention studies and 12 dual-intervention studies. The pooled sample size was 1621, of which 338 patients from 14 groups received ORIF, 1280 patients from 22 intervention groups underwent rTHA, and 3 patients were treated either nonoperatively or with a Girdlestone procedure (Table 1).

The mean follow-up time was 37 months, and the mean age of included patients was 75 ± 6 (SD) years. The mean operative time was reported in 8 studies, which showed a significant difference between ORIF and rTHA: 134 ± 14 minutes versus 180 ± 29 minutes ($P = 0.007$). Three studies reported the mean number of Packed Red Blood Cell transfusions which showed that patients with ORIF received an average of 1 unit versus 4 units in the rTHA group ($P = 0.284$). The mean length of stay was reported in 2 studies, with an average length of stay of 16 days in both groups. Meta-analysis results from single-arm analyses are displayed in Table 2.

## INTERVENTION

Seventy-two percent (72%) of the patients with ORIF received the combination of a plate and cerclage wiring/cable fixation (n = 245). Cerclage wiring was used as the only intervention in 15 cases. Cortical strut allografts were used as an adjunct to ORIF in 6 cases.

Of the 1280 patients who underwent femoral revision, 57 percent (57%) received a noncemented stem (n = 735) and 545 received a cemented stem. Nine hundred fifty-five patients underwent femoral revision alone, whereas 274 patients received stem revision plus some form of internal fixation. The most common form of internal fixation in combination with stem revision was cerclage wiring which was used in 86 cases. Cortical strut allografts were used in 65 patients undergoing rTHA.

## COMPLICATIONS

Data were pooled from 1312 patients from 12 dual-arm studies of any reported complication after either ORIF or rTHA for the management of a Vancouver B2 fracture.[10,11,18,22–30] A nonsignificant difference was found between ORIF and rTHA OR 1.31 (95% CI 0.92, 1.87, $P$ = 0.13 i2 = 23%) (Fig. 1 and Table 2).

## DISLOCATIONS

Data were pooled from 1312 patients from 12 dual-arm studies of any reported dislocation after either ORIF or rTHA for the management of a Vancouver B2 fracture.[11,12,19,23–31] A significant difference was found between ORIF and rTHA, favoring ORIF OR 0.43 (95% CI 0.19, 0.95, $P$ = 0.04 i2 = 39%) (Fig. 2 and Table 2).

## INFECTION

Data were pooled from 1312 patients from 12 dual-arm studies of any reported deep infection after either ORIF or rTHA for the management of a Vancouver B2 fracture.[10,11,18,22–30] A nonsignificant difference was found between ORIF and rTHA OR 0.74 (95% CI 0.34, 1.60, $P$ = 0.45 i2 = 0%) (see **Figure**, **Supplemental Digital Content 2**, http://links.lww.com/JOT/B442 and Table 2).

## REFRACTURE

Data were pooled from 323 patients from 11 dual-arm studies of any reported refracture after either ORIF or rTHA for the management of a Vancouver B2 fracture.[12,19,23–31] A nonsignificant difference was found between ORIF and rTHA OR 2.51 (95% CI 0.68, 9.29, $P$ = 0.17 i2 = 0%) (see **Figure**, **Supplemental Digital Content 3**, http://links.lww.com/JOT/B443 and Table 2).

## REVISION

Data were pooled from 1312 patients from 12 dual-arm studies of any reported revision or reoperation procedure after either ORIF or rTHA for the management of a Vancouver B2 fracture.[11,12,19,23–31] A significant difference was found

**TABLE 1.** Table of Included Studies

| | Country | Study Period | Fracture Types Included in the Article | No. of B2 Patients | ORIF | rTHA | Other Interventions | Mean Follow-Up, mo | Mean Age |
|---|---|---|---|---|---|---|---|---|---|
| Baum et al[23] | Switzerland | January 2007 to March 2017 | B2 | 59 | LCP (n = 24) ± cerclage wiring (n = 21) ± locking attachment plate (n = 11) | Noncemented (n = 21) and cemented (n = 14) | | 53 | 84† |
| Bulatovic et al[24] | Montenegro, Serbia, and Croatia | January 2004 to December 2015 | B | 10 | LCP (n = 5), DCP (n = 2), and cerclage wire (n = 2) | Cemented long stem + cerclage wires (2) (n = 1) | | 15 | 60* |
| Corten et al[35] | Canada | August 1996 to August 2007 | Only B2 | 31 | | Cemented long stem (endurance DePuy or Ind/Echleon S&N) + cerclage wiring (n = 31) ± CSA (n = 22) + lateral plate (n = 1) | | 33 | 82 |
| Chatziagorou et al[11] | Sweden | | B2 | 989 | Conventional plate (n = 66), locking plate (n = 38), cerclage alone (n = 12), and others (n = 19) | Stem revision alone (n = 710) and stem revision plus ORIF (n = 144). Noncemented (n = 565) and cemented (n = 289) | | 34 | 79 |
| Fuchtmeier et al[36] | Germany | January 2007 to December 2012 | A, B, and C | 52 | | Noncemented Wagner SL revision stem (n = 52) | | 57* | 76* |
| Holley et al[25] | USA | 1984 to 2001 | A, B, and C | 20 | Unknown plate + morselized bone graft (n = 2) | Cemented alone (n = 6) revision + CSA (n = 5), revision + CSA + plate (n = 2). Noncemented alone (n = 2), revision + CSA (n = 2), and revision + CSA + plate (n = 1) | | 54 | 64 |
| Inngul et al[26] | Sweden | January 1998 to December 2012 | B and C | 25 | Single lateral plate ± cerclage wiring (n = 9) | Cemented and noncemented prostheses (n = 16) | | 39* | 82* |
| Joestl et al[19] | Austria | 2000 to 2014 | B2 alone | 36 | LCP (4.5 mm) (n = 8) | Noncemented Helios revision stem (n = 14) and Hyperion revision stem (n = 14) | | 15 | 81 |
| Ko et al[37] | Hong Kong | January 1996 to December 2000 | B2 alone | 14 | | Noncemented Wagner revision stem (n = 14) | | 56 | 75 |

**TABLE 1.** (*Continued*) Table of Included Studies

| | Country | Study Period | Fracture Types Included in the Article | No. of B2 Patients | ORIF | rTHA | Other Interventions | Mean Follow-Up, mo | Mean Age |
|---|---|---|---|---|---|---|---|---|---|
| Lunebourg et al[27] | Switzerland | 2002 to 2007 | B | 23 | Stainless steel curved plate with 3 screws proximal and distal to the fracture (n = 16) | Cemented revision stem + cerclage wiring (n = 7) | | 42* | 79* |
| Marx et al[38] | Germany | January 2002 to December 2003 | B2 and B3 | 15 | | Noncemented Wagner revision stem (n = 15) | | 60–96 | 68 |
| Moreta et al[32] | Spain | 1995 to 2011 | A, B, and C | 14 | | Noncemented revision stem (14) ± CSA (n = 4) | | 34* | 76 |
| Mukundan et al[39] | UK | 1995 to 2005 | A, B, and C | 42 | | Long stem revision (n = 19), long stem revision + DCP (n = 8), and distal locking long stem (n = 15) | | >24* | 74* |
| Niilkura et al[28] | Japan | 2005 to 2012 | A, B, and C | 6 | Narrow LCP (n = 2) and reversed LCP-DF (n = 1) | Noncemented long stem + cerclage wiring (n = 1) and cemented stem + cerclage wiring (n = 1) | Conservative (n = 1) | 18* | 80 |
| O'Shea et al[40] | Ireland | July 1999 to 2003 | B2 and B3 | 10 | | Noncemented extensively porous revision ± CSA ± cerclage wiring ± trochanteric fixation (n = 10) | | 34* | 75* |
| Park et al[14] | South Korea | | B2 alone | 27 | Large fragment LCP + cerclage wiring (n = 27) | | | 12 | 71 |
| Pavlou et al[29] | UK | 1995 to 2007 | B | 66 | Unknown plate (n = 10) and unknown plate plus + graft (n = 4) | Stem revision (n = 52) ± CSA (n = 27) | | 12 | 75* |
| Phillips et al[41] | UK | May 2099 to May 2010 | A, B, and C | 32 | | Cemented and noncemented—typically long noncemented stem with bipolar head (n = 32) | | 24* | 80* |
| Sledge et al[42] | USA | January 1996 to July 1998 | B2 alone | 7 | | Stem revision + cerclage wiring + CSA (2) (n = 7) | | 33 | 64 |
| Smitham et al[15] | Australia | May 2002 to May 2014 | B2 alone | 52 | Large plate + cerclage wiring (n = 52) | | | 48 | 82 |

(*continued on next page*)

 

**TABLE 1.** (*Continued*) Table of Included Studies

| | Country | Study Period | Fracture Types Included in the Article | No. of B2 Patients | ORIF | rTHA | Other Interventions | Mean Follow-Up, mo | Mean Age |
|---|---|---|---|---|---|---|---|---|---|
| Solomon et al[12] | Australia | January 2000 to February 2010 | B2 alone | 21 | Cable plating + nonlocking screws (n = 12). | Long revision stem + cerclage wiring; cemented (n = 4) and noncemented (n = 5) | | 59 | 75 |
| Spina et al[30] | Italy | June 1998 to May 2017 | B2 alone | 34 | Cable plate + bicortical screws + cerclage wiring (n = 20) and cerclage wiring alone (n = 1) | Long noncemented stem + cerclage wiring (n = 9) and cement-on-cement long stem revision + cable-ready tro-chanteric plate (n = 2) | Conservative (n = 1) and Girdlestone (n = 1) | 30 | 78 |
| Young et al[43] | New Zealand | January 1999 to October 2004 | A, B, and C | 10 | | Long extensively coated noncemented stem + cerclage wires (n = 9) and long cemented stem + cerclage wires (n = 1) | +cup revision n = 2 | 40* | 79* |
| Zuurmond et al[31] | Netherlands | March 1992 to February 2006 | A, B, and C | 26 | Unknown fixation n = 6 | Stem alone (n = 11), stem plus ORIF (n = 9) | | 65 | 73 |

*Demographic data may include fracture types other than B2.
†Median data.
CSA, cortical strut allograft; DCP, dynamic compression plate; LCP, locking compression plate; LCP-DF, locking compression plate–distal femur.

between ORIF and rTHA, favoring rTHA OR 1.65 (95% CI 1.12, 2.43, $P = 0.001$ i2 = 0%) (Fig. 3 and Table 2).

## SUBSIDENCE

Data were pooled from 1164 patients from 7 dual-arm studies of any reported stem subsidence greater than 5 mm after either ORIF or rTHA for the management of a Vancouver B2 fracture.[11,19,23,24,26,27,30] A nonsignificant difference was found between ORIF and rTHA OR 1.95 (95% CI 0.95, 4.02, $P = 0.07$, i2 = 0%) (see **Figure, Supplemental Digital Content 4**, http://links.lww.com/JOT/B444 and Table 2).

## NONUNION

Data were pooled from 205 patients from 6 dual-arm studies of any reported radiological nonunion after either

**TABLE 2.** Single-Arm Meta-analysis

| | rTHA | | ORIF | | | |
|---|---|---|---|---|---|---|
| | n/N | WPR (95% CI) | n/N | WPR (95% CI) | OR (95% CI) | *P* |
| Overall complications | 227/1280 | 19.6% (15–24) | 66/326 | 19.9% (12–28) | 1.02 (0.75–1.38) | 0.89 |
| Revision | 169/1193 | 10.5% (6–15) | 52/326 | 11.4% (6–17) | 1.09 (0.7–1.61) | 0.65 |
| Dislocation | 68/1191 | 4.8% (4–6) | 6/299 | 1.3% (0–3) | 0.31 (0.11–0.85) | 0.02* |
| Infection | 46/1182 | 3.4% (2–4) | 7/305 | 2.4% (1–4) | 0.67 (0.30–1.51) | 0.34 |
| Refracture | 9/328 | 2.3% (1–4) | 11/190 | 4.4% (2–7) | 1.76 (0.65–4.76) | 0.27 |
| ASL + sub | 40/1140 | 3% (2–4) | 15/249 | 5.6% (3–8) | 1.95 (1.03–3.69) | 0.04* |
| Nonunion | 12/268 | 2.7% (1–5) | 8/89 | 7.1% (1–13) | 2.70 (0.88–8.25) | 0.08 |

OR<1 favors ORIF. OR>1 favors rTHA.
n, number of cases; N, sample size; WPR, weighted proportion rate.
*$P < 0.05$.

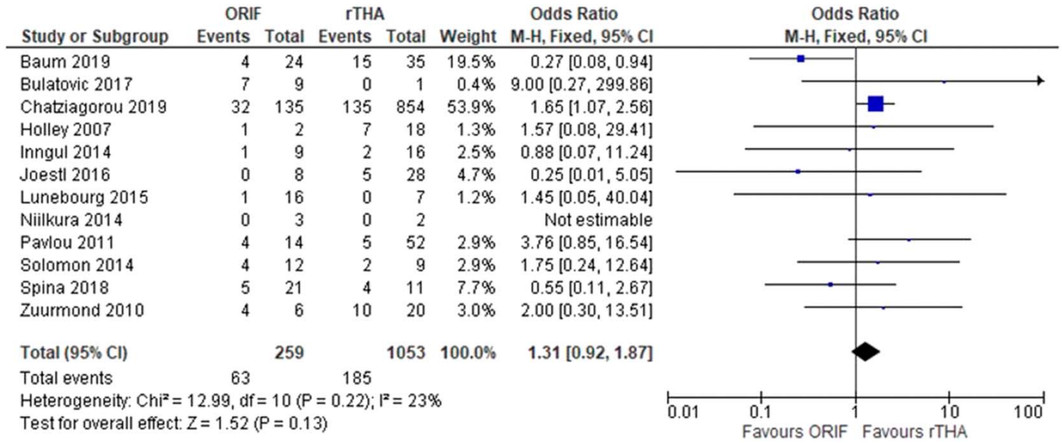


**FIGURE 1.** Complications. **Editor's Note:** A color image accompanies the online version of this article.

ORIF or rTHA for the management of a Vancouver B2 fracture.[19,23–26,29] A nonsignificant difference was found between ORIF and rTHA OR 2.29 (95% CI 0.88, 5.96, $P$ = 0.09, i2 = 50%) (see **Figure**, **Supplemental Digital Content 5**, http://links.lww.com/JOT/B445 and Table 2).

## STUDY QUALITY

Overall, the mean study quality score was 13 ± 1 out of a possible 20 points. Six studies published case-by-case data in the form of a table.[14,25,28,29,31,32] All of the included studies were retrospective and all but 2 reported data from a single institution.[10,30] Analysis of the funnel plot calculated using the complication data indicated no evidence of publication bias (see **Figure**, **Supplemental Digital Content 6**, http://links.lww.com/JOT/B446).

## DISCUSSION

This review is the largest review of B2 fracture management in the published literature. The overall pooled sample included some 1621 patients. Although conventional consensus recommends that B2 fractures are managed with noncemented rTHA, the pooled sample in this study indicates that a 55% of B2 fractures are being treated with alternate means of fixation. Three hundred thirty-eight (21%) of included participants underwent ORIF, of which a combination of a plate and cerclage wiring/cable fixation was used in most patients. For patients treated with rTHA, 735 patients (57%) underwent noncemented revision and 545 (43%) received a cemented revision. The presence of ORIF and cemented rTHA may be due to a changing mantra of B2 fixation, especially in the context of elderly and frail patients. Historically, the distinction between B1 and B2 was important, because well-fixed stems in B1 fractures were treated with ORIF and loose stems in B2 fractures were treated with rTHA. However, the results indicate an emergence of nonconventional options in B2 PFF management. It is important to note that although this review is novel, the included studies reflect clinical practice in many centers around the world where ORIF and rTHA are used as treatment options for Vancouver B2s.

The results of this review call into question both the existence of and rationale for a dogmatic approach to B2 management. We found no significant difference in overall complication rates between ORIF and rTHA in both dual-

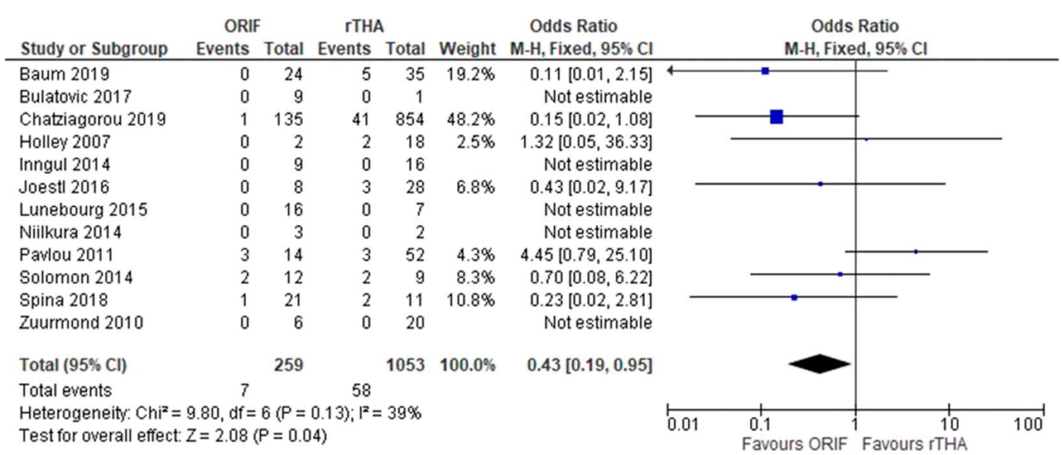


**FIGURE 2.** Dislocations. **Editor's Note:** A color image accompanies the online version of this article.

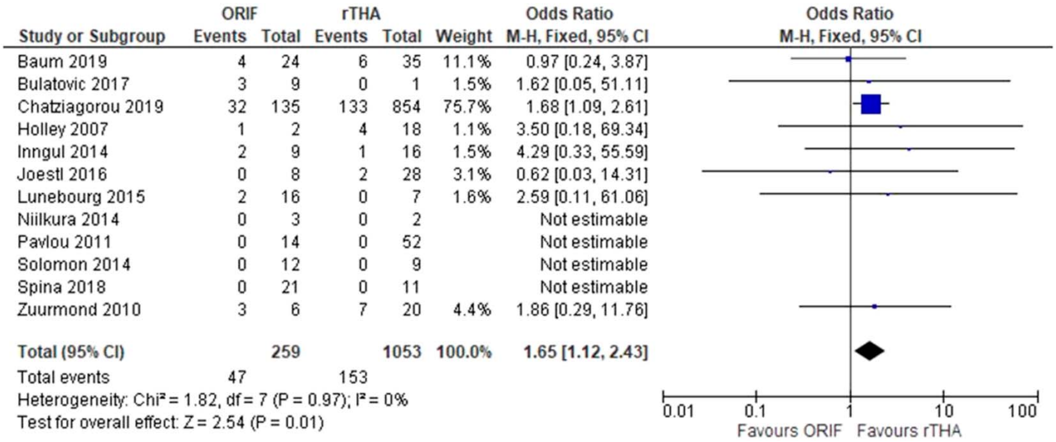


**FIGURE 3.** Revision. **Editor's Note:** A color image accompanies the online version of this article.

arm and single-arm analyses, with similar results for infection, refracture, and nonunion rates. It must be noted that nonunion is much more likely to be a concern in ORIF constructs, as a distal fitting/loading revision does not necessarily rely on bony union. Rather expectedly, ORIF was found to have a significantly lower dislocation rate than rTHA, which stands to reason given the physiological and biomechanical changes involved in rTHA. As in previous studies, ORIF was found to have a statistically higher revision rate; however, this difference was only significant in the dual-arm analysis, and when single-arm data were added to the mix, there was no longer a significant difference. The lack of significance after the addition of single-arm studies likely implies that centers who use ORIF constructs in B2 management more often, to the point they can assemble a cohort, reported lower revision rates. The absolute revision rate from dual-arm studies was 18.1% in the ORIF group and 14.5% in the rTHA group ($P = 0.01$), whereas in the combined single-arm and dual-arm analyses, ORIF had a 11.4% revision rate compared with 10.5% in the rTHA group ($P = 0.65$). The lack of statistical significance in the larger analysis undermines one of the largest barriers to ORIF for B2 fractures, being that ORIF is fraught with higher revision rates, an assumption that is questioned by the results presented here. It is important to note that the types of revisions required are vastly different after failed ORIF and rTHA. Given the inherent nature of rTHA for PFF management, if a patient requires a rerevision, it is likely to be a major revision, whereas ORIF constructs may be amenable to relatively minor revisions. Further research is needed to identify the rate of major and minor revisions after rTHA and ORIF for B2 fractures; however, the overall revision rate seems to be similar between groups.

A key limitation of this article is the relatively subjective nature of the Vancouver system. The radiological interobserver reliability has previously been shown to be higher in patients with cemented femoral stems than noncemented stems.[33,34] Although the classification system is underpinned by the intraoperative findings, there is limited evidence on the intraoperative interobserver reliability of the system. As such, what is classified as loose for one surgeon may not be by another. The same is true for bone quality. In the context of this review, there is no way of validating or correlating the assessment of bone quality nor stem looseness, and the reported classification must be relied on. Although every attempt was made to only include B2 fractures, it is likely that not all patients may be categorized as B2 by all surgeons, reflecting an error in the Vancouver system more so than this review.

Another key limitation is the lack of any prospective studies in this area. Although the quality of the included studies is reasonable, the pooled sample reflects a retrospective cohort with a mixture of operative interventions and surgical techniques. In particular, the disparity in size between the numbers included in ORIF and rTHA groups and the fact that most patients with rTHA were from a single article, likely skews the results in favor of rTHA. Statistical heterogeneity was not of concern in this project, but because many studies used expertise-based trial designs, whereby the surgeon could decide the treatment given, subanalyses for specific intervention types were inhibited because of small numbers in each treatment category. It is also important to note that the inclusion of patients with hemiarthroplasty introduces another level of heterogeneity, with potential greater surgical times and blood loss from preparation and insertion of an acetabular component, if it were to be revised along with the femoral stem. Furthermore, time to reoperation and survival analyses were not able to be completed, whereas analysis of operative time and transfusion requirements were impacted by poor reporting among included studies. Given that the included studies were retrospective, selection bias is an important potential explanation for the differences between ORIF and rTHA. It is likely that ORIF was chosen both for more unwell, frailer patients and those with amenable fracture characteristics. Frailer patients may be selected for ORIF so as to avoid the rigors of rTHA, and those that retained a portion of intact bone-prosthesis interface or were believed to be “not loose enough” may have also been treated with ORIF. The effect of this bias is unknown, as it is likely the ORIF group contained both the more complex patients as well as the simpler PFFs in the pooled cohort. The true effect of this bias could only be answered fully with an appropriately sized randomized controlled trial.

## CONCLUSION

Overall, the results indicate that rTHA has a similar revision rate than ORIF in PFFs with a loose femoral component and adequate bone stock. Fewer dislocations were seen in ORIF constructs; however, there was no difference between other complications. The results challenge the dogma that all B2s must be revised and open the door for reasoned thought and decision-making. Although rTHA is likely to remain the mainstay of treatment, ORIF should be considered in patient populations where rTHA is not ideal. Furthermore, the results show that if ORIF is selected, the outcomes are not disastrous as convention would have us believe and may offer a benefit over rTHA in select populations. In conclusion, there is likely a place for clinical judgment in the determination of Vancouver B2 PFF management, one whereby the surgeon considers patient and fracture characteristics in deciding between ORIF and rTHA constructs. Further research will help identify patients who may benefit from ORIF over rTHA.

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