European Journal of Orthopaedic Surgery & Traumatology (2019) 29:373–382
https://doi.org/10.1007/s00590-018-2306-8

GENERAL REVIEW • SHOULDER - ARTHROSCOPY

# Type 2 retear after arthroscopic single-row, double-row and suture bridge rotator cuff repair: a systematic review

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Received: 23 June 2018 / Accepted: 11 September 2018 / Published online: 18 September 2018


## Abstract

**Aim/Purpose** To provide a systematic review of the literature on patterns of retear after single-row (SR), double-row (DR) and suture bridge (SB) techniques.

**Methods** The PubMed and MEDLINE databases were searched for published articles reporting both repair technique and retear pattern. Studies in languages other than English, those reporting open rotator cuff repair as the index procedure, as well as animal and cadaveric studies and those which did not describe patterns of retear, were excluded. MINORS scoring system was used to quantify potential bias in each study. Retears were classified into type 1 (failure at the tendon–bone interface) and type 2 (medial cuff failure). For all studies included, number and type of retears after different repair techniques were reported and analyzed.

**Results** Fourteen studies were included yielding a total of 260 rotator cuff retears. Repair technique had a significant impact on the estimated incidence rate of type 2 retear ($p = .001$). The estimated incidence rate of type 2 retear was 24% with SR (95% CI 14–38%), 43% with DR (95% CI 22–66%), 62% with SB (95% CI 54–70%) and 38% with SB (95% CI 23–57%).

**Conclusion** Despite the lack of high-quality evidence, this study suggests that DR and SB techniques increase the risk of medial cuff failure. Modifications in surgical techniques in both DR and SB repairs can help decrease that risk.

**Level of evidence** Level IV, systematic review of investigations including level IV.

**Keywords** Recurrent cuff tears · Retear patterns · Medial cuff failure · Type 2 retears · Revision rotator cuff repair

## Introduction

Rotator cuff tears are present in about 20% of the general population [1]. Various techniques and approaches have been described to repair a torn rotator cuff. Despite advancements in surgical technique, retear of a previously repaired rotator cuff tendon is relatively common. Retears seen on magnetic resonance images do not always lead to clinical failure [2]. However, patients with intact tendons after repair generally show superior outcomes [3, 4]. Shorter tendons and previous implants at the footprint can be obstacles for a successful revision surgery. Operative techniques affect the rate and pattern of rotator cuff retear. After the introduction of different techniques of arthroscopic repair of the rotator cuff, the effect of suture configuration and construct on retear rates and patterns have been of particular interest.

Previous studies showed superiority of double-row (DR) to single-row (SR) repair with regard to mechanical strength, footprint coverage, gap formation and tendon-to-bone contact that could lead to better healing [5–9]. The suture bridge (SB) technique provides better footprint coverage and larger area of pressurized contact with less gap formation and higher ultimate-to-load failure compared to DR [10, 11]. Despite the biomechanical advantages of DR and SB techniques over SR, excessive contact pressure can reduce blood

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s00590-018-2306-8) contains supplementary material, which is available to authorized users.

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flow to the rotator cuff tendon [12]. Stress concentration and increased risk of retear around the medial anchors have often been noticed and reported during the past decade with DR and SB techniques. Two patterns of retear were subsequently described by Cho et al. [13] in which type 1 is failure at the tendon–bone interface, and type 2 is medial cuff failure with remnant cuff attached to the greater tuberosity.

The effect of suture configuration on retear rates was thoroughly studied by Hein and colleagues [14]. The overall retear rates after SR, DR and SB techniques were 26, 21 and 21%, respectively. Despite the lower incidence of retear after DR and SB, several studies reported an increased risk of medial cuff failure with both techniques [13, 15–18], which potentially has very large consequences in the setting of revision surgery. The purpose of this study was to perform a comprehensive systematic review to determine the different patterns of rotator cuff retear and their influence by the repair technique. We hypothesized that the risk of medial cuff failure would be higher in DR and SB techniques compared to SR.

## Methods

### Literature search

A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [19]. A comprehensive search of the literature was carried out independently by the first two authors in January 2018. The PubMed and MEDLINE databases were searched for published articles describing the effect of repair technique on rotator cuff retear pattern from January 2008 to December 2017. The terms "rotator cuff retear pattern" or "medial cuff failure" were utilized in combination with "single-row," "double-row" or "suture bridge" totaling 6 possible search combinations. The tab "similar articles" and the bibliographies of the included articles were also reviewed to search for additional relevant articles that were not initially identified.

### Criteria for eligibility

The inclusion criteria were all clinical studies published in English language that report both the repair technique and the retear pattern. Studies reporting open rotator cuff repair as the index procedure, as well as animal and cadaveric studies and those which did not describe the pattern of retear, were excluded.

### Extraction of data

Relevant information on publication year and journal, type of the study, patient demographics, method and time of diagnosis of retear, repair techniques and retear types were all carefully extracted. Retears were classified into types 1 and 2 according to Cho et al. [13] in which type 1 is failure at the tendon–bone interface, and type 2 is medial cuff failure with remnant cuff remaining attached to the greater tuberosity. Three studies reported SB repair without tying the medial row knots [knotless SB (K-SB)], so we considered this a separate entity.

### Risk of bias

Each study was evaluated for bias using the Methodological Index for Non-randomized Studies (MINORS) scoring system, a valid instrument for assessing the methodological quality of non-randomized comparative and non-comparative studies [20]. Higher scores indicate a lower level of bias, and lower scores indicate a higher level of bias.

### Statistical analysis

Demographic data were presented as they were reported in the original articles. Continuous variable data were reported as means with ranges. For all studies included, number and types of retears after different techniques of repair were reported in a table format. Incidence rate of type 2 retear was considered the main outcome of concern. In comparative studies, patient cohorts were treated separately according to the surgical technique. The pooled event rate was calculated using "meta," an R package for meta-analysis which contains a function "metaprop" designed for calculation of an overall proportion from studies reporting a single proportion. The confidence intervals (CIs) were calculated using an exact binominal approach, so that the estimated confidence interval does not exceed zero or 1 [21].

Between-study heterogeneity was assessed using $I^2$ statistics. Statistical significance of $I^2$ was assessed using chi-squared ($\chi^2$) test. When there was a statistically significant heterogeneity among included studies, random-effect model was used to estimate the pooled incidence. Otherwise, fixed-effect model was used [22].

Meta-regression analysis was used to test whether the incidence of type 2 retear is influenced by the surgical technique, age of patients and/or mean follow-up duration. Sensitivity analysis was conducted to assess the influence of the level of evidence and the risk of bias on the results obtained. To study the effect of the level of evidence, meta-analysis was re-conducted after exclusion of level IV studies. The effect of risk of bias on the results of meta-analysis was assessed using meta-regression. Funnel plots were drawn to check for publication bias. We could not use Egger test [23] to assess the asymmetry of funnel plots as the number of studies was not sufficient.

## Results

The initial search yielded 90 studies. After eliminating duplicate (33) and irrelevant (44) studies, 13 studies met the inclusion criteria (Fig. 1). One study was added during review of additional sources mentioned in the methods section. Overall, 14 studies were included and carefully reviewed reaching a total of 260 rotator cuff retears. There were 8 case series and 6 cohort studies. One study was a level II, 6 were level III and 7 were level IV. The risk of bias assessed by MINORS scoring system ranged from 31% to 88%. A single repair technique was performed in 10 studies, whereas the other 4 were comparative. Of the 10 studies reporting a single technique, 3 studies reported retears after DR, 6 after SB and 1 after K-SB. Descriptive statistics for the patients included are given in Table 1. Diagnosis of retears was achieved by arthroscopy in 2 studies, MRI in 11 and MRA in one. Time to diagnosis of retear from the index procedure ranged between 3 and 28 months.

Number and types of retear after different repair techniques are given in Tables 2, 3, 4 and 5. Two studies reported only type 2 retears, without mentioning the total number of retears. Figure 2 illustrates the percentage of type 2, out of all retears, among the other 12 studies. Rates of type 2, out of all retears, ranged from 16.7 to 26.3% after SR and 0 to 40.1% after K-SB repairs, while it reached up to 53.8% after DR [15] and 80% after SB [24] repairs (Fig. 2).

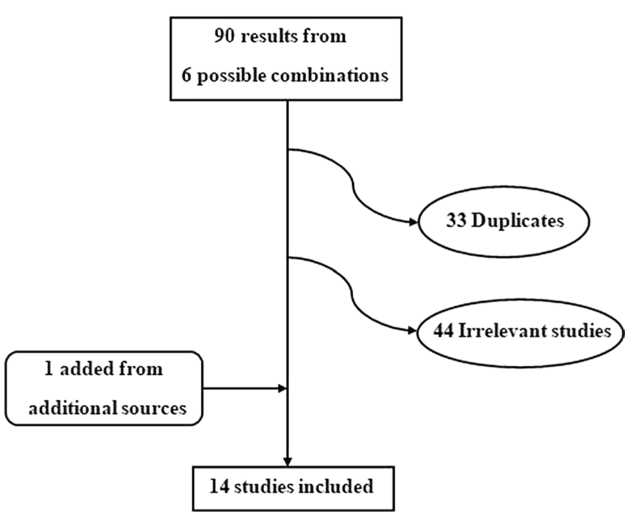


**Fig. 1** Study selection flow diagram

When we pooled all the cohorts (17 cohorts in 11 studies), there was a statistically significant heterogeneity ($I^2 = 56\%$, $p < .01$) [figure A in the supplementary material). Using meta-regression, we found that repair technique had a significant impact on the estimated incidence of retear type 2 ($p = .001$). Repair technique accounted for 80.83% of the heterogeneity. After inclusion of repair technique in the model, the residual heterogeneity decreased to 19.03% ($\chi^2 = .247$).

The estimated incidence rate of type 2 retear was 24% with SR (95% CI 14–38%), 43% with DR (95% CI 22–66%), 62% with SB (95% CI 54–70%) and 38% with SB (95% CI 23–57%) (Fig. 3). Residual heterogeneity per surgical technique was not detected in KLSB and SR groups, was moderate (yet, not statistically significant) in SB group ($I^2 = 32\%$, $p = .16$) and was substantial in DR group ($I^2 = 67\%$, $p = .08$). Neither the duration of follow-up nor the mean age of the patients had an impact on the estimated incidence of type 2 retear ($p = .832$, $p = .9487$) (Figs. 4 and 5).

### Sensitivity analysis

There were five level IV studies (2 in the DR group and 3 in the SB group). The results of meta-analysis after removing those studies are shown in Fig. 6. In the SB group, the number of studies decreased from 9 to 6, the heterogeneity vanished ($I^2$ decreased from 32% to zero%) and the estimated incidence rate of type 2 retear slightly increased (IR = 68%; 95% CI 58% to 76%). In the DR group, no studies were left. Using meta-regression, we found that accounting for the risk of bias has no effect on the observed heterogeneity, i.e., there is no statistical evidence that the estimated incidence rate of type 2 retear was affected by the risk of bias of the studies. ($p = .574$) (Fig. 7).

### Publication bias

To check for publication bias, four funnel plots were drawn (Figs. 8, 9, 10 and 11), one for each surgical technique. In SB group, the studies were more or less symmetrically arranged around the mean estimate. In KLSB, SR and DR groups, as the numbers of the studies were few (< 4 studies), we could not comment on the pattern of arrangement of studies around the mean.

## Discussion

This review demonstrates a higher risk of type 2 retear after DR and SB repairs, as compared to SR and K-SB repairs. Type 2 retears are more challenging to repair compared to

**Table 1** Characteristics of included studies ($n = 14$)

| References | Journal | Study design | Level of evid | Sample size (M/F) | Risk of Bias % (MINORS) | Repair technique | Age [mean years (range)] | FU [mean months (range)] | Retears | | | | | | | Method of diagnosis | FU/Time to dx [mean months (range)] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Total (M/F) | Mean age (range) | Type | SR | DR | SB | K-SB | | |
| Trantalis et al. [27] | Arthroscopy | CS | IV | 5 (2/3) | 31 | DR | | 8.6 | | 52 (42–59) | 2 | | 5 | | | Ax | 8.6 (3–16) |
| Yamakado et al. [30] | Arthroscopy | CS | IV | 49 (28/21) | 50 | DR | 64.6 (22–82) | 25 | | 68.3 (65–74) | 2 | | 4 | | | Ax | 8.5 (6–12) |
| Voigt et al. [2] | AJSM | CS | IV | 51 (32/19) | 88 | SB | 62* (37–76) | 24* | 13 | | 1<br>2 | | | 7<br>6 | | MRI | 12 |
| Cho et al. [16] | AJSM | Cohort | III | 180 | 88 | SR 84<br>SB96 | | 7.5 (3–29) | SR 19 (13/6)<br>SB 27 (16/11) | SR 58.1<br>SB 57.6 | 1<br>2 | 14<br>5 | | 7<br>20 | | MRI | 7.5 (3–29) |
| Cho et al. [13] | AJSM | CS | IV | 120 (59/61) | 81 | SB | 55.4 (36–75) | 25.2 (16–34) | 29 | 60.1 (41–75) | 1<br>2 | | | 12<br>17 | | MRI | 25.2 (16–34) |
| Gerhardt et al. [24] | AJSM | Cohort | III | 40 (30/10) | 75 | MMA 20<br>SB 20 | 61.4 | MMA 16.8<br>SB 23.4 | 11 | MMA 61.5<br>SB 61.2 | 1<br>2 | 5 MMA<br>1 MMA | | 1<br>4 | | MRI | 20.1 |
| Hayashida et al. [15] | Arthroscopy | CS | IV | 47 (32/15) | 69 | DR | 65 (42–82) | 26 (24–32) | 13 | 70.2 (42–82) | 1<br>2 | | 6<br>7 | | | MRI | 12 (10–14) |
| Rhee et al. [31] | AJSM | Cohort | II | 110 | 83 | SB 59<br>K-SB 51 | 61 (44–68) | 21.7 (12–34) | 14 | | 1<br>2 | | | 3<br>8 | 3 | MRI | 6.8 (6–12) |
| Lee et al. [17] | Clin Orthop Surg | Cohort | III | 62 26/36 | 56 | SB | 56.1 (29–73) | 27.4 (6–52) | 30 | | 1<br>2 | | | 10<br>20 | | MRA | 6 |
| Neyton et al. [25] | Arthroscopy | CS | IV | 107 (64/41) | 75 | SB | 54.8 (21–74) | 16.1 (12–28) | 11 | 54.7 (44–64) | 1<br>2 | | | 10<br>1 | | MRI | 16.1 (12–28) |
| Kim et al. [18] | AJSM | Cohort | III | | 75 | SR<br>SB<br>K-SB | | | 65 (34/31) | 59.7 (41–78) | 1<br>2<br>Unsp | 15<br>5<br>1 | | 9<br>13 | 12<br>9<br>1 | MRI | 6.21 (3–33) |
| Tanaka et al. [26] | Arthroscopy | CS | IV | 57 (22/35) | 75 | DR absorb. sutures | 63.2 (45–82) | 24.4 (24–33) | 8 | 70.4 (64–75) | 1<br>2<br>Unsp | | 5<br>1<br>2 | | | MRI | 12 |
| Hug et al. [32] | Knee Surg Sports Traumatol Arthrosc | Cohort | III | 22 (14/8) | 63 | K-SB 22 | 63.3 | 24.4 | 5 | | 1<br>2 | | | | 3<br>2 | MRI | 12** |
| Stahnke et al. [33] | Arch Orthop Trauma Surg | CS | III | 13 (7/6) | 50 | SB | 61.1 | 24.9 | 6 | | 2<br>Unsp | | | 4<br>2 | | MRI | 24.9 |

*evid* evidence, *M/F* male/female, *CS* case series, *SR* single-row, *DR* double-row, *SB* suture bridge, *K-SB* knotless suture bridge, *dx* diagnosis, *Ax* arthroscopy, *MRI* magnetic resonance imaging, *MMA* modified Mason-Allen, *MRA* magnetic resonance arthrogram, *unsp* unspecified. *Median ** Same retear rate and pattern at 24 months

**Table 2** Retear patterns after single-row repair

| References | Type 1 | Type 2 | Unspecified | Type 2/Total retears (%) |
|---|---|---|---|---|
| Cho et al. [16] | 14 | 5 | | 26.3 |
| Gerhardt et al. [24][a] | 5 | 1 | | 16.7 |
| Kim et al. [18] | 15 | 5 | 1 | 23.8 |

[a]Modified Mason-Allen single-row

**Table 3** Retear patterns after double-row repair

| References | Type 1 | Type 2 | Unspecified | Type 2/Total retears (%) |
|---|---|---|---|---|
| Trantalis et al. [27] | Not reported | 5 | | |
| Yamakado et al. [30] | Not reported | 4 | | |
| Hayashida et al. [15] | 6 | 7 | | 53.8 |
| Tanaka et al. [26] | 5 | 1 | 2 | 12.5 |

**Table 4** Retear patterns after suture bridge repair

| References | Type 1 | Type 2 | Unspecified | Type 2/Total retears (%) |
|---|---|---|---|---|
| Voigt et al. [2] | 7 | 6 | | 46.2 |
| Cho et al. [16] | 7 | 20 | | 74.1 |
| Cho et al. [13] | 12 | 17 | | 58.6 |
| Gerhardt et al. [24] | 1 | 4 | | 80 |
| Rhee et al. [31] | 3 | 8 | | 72.7 |
| Lee et al. [17] | 10 | 20 | | 66.7 |
| Neyton et al. [25] | 10 | 1 | | 9.1 |
| Kim et al. [18] | 9 | 13 | | 59.1 |
| Stahnke et al. [33] | 0 | 4 | 2 | 66.7 |

**Table 5** Retear patterns after knotless suture bridge repair

| References | Type 1 | Type 2 | Unspecified | Type 2/Total retears (%) |
|---|---|---|---|---|
| Rhee et al. [31] | 3 | 0 | | 0 |
| Hug et al. [32] | 3 | 2 | | 40 |
| Kim et al. [18] | 12 | 9 | 1 | 40.1 |

type 1; therefore, technical modifications of both DR and SB techniques were attempted to decrease the stress concentration on medial row anchors, and thereby decrease the risk of medial strangulation and necrosis. In contrast to the mainstream of relatively high rate of type 2 retear after DR and SB repairs, Neyton et al. [25] reported ten type 1 retears and only one type 2 retear after performing a SB repair on 107 patients. In their study, no more than 2 medial row anchors were used, with only one suture on each anchor. Medial row mattress sutures were not over-tensioned. These modifications limited the harmful compression that could form zones of necrosis across the footprint. They also penetrated the tendon at least 5 mm lateral to the MTJ. Similarly, Tanaka et al. [26] demonstrated that using absorbable sutures in the medial row anchors in a DR construct provided less type 2 retears than what was previously reported by the same institution [15]. Excluding these two studies, in which the traditional DR and SB techniques were modified, rate of type 2 retears would be 53.8% after DR repair and would range from 46.2–80% after SB repair (Fig. 2). Knotless SB repair can also be considered a technical modification of SB that shows a relative improvement in the rate of type 2 retears. These results strongly validate our hypothesis that the risk of medial cuff failure is higher with DR and SB repairs.

Medial cuff failure after DR repair was first reported by Trantalis et al. [27] in a case series of 5 patients. Potential causes postulated by Trantalis et al. for this retear pattern were (1) transferring the tension-bearing row more medial, (2) use of braided suture materials that are ultimately stronger than the diseased tendon and (3) oblique passage of instruments through the tendon which puts more tension on the medial cuff, creates larger holes in the tendon which adversely affect the tendon integrity.

The musculotendinous junction (MTJ) is distinctively a vulnerable area. Cho et al. [16] observed type 2 retears mainly at the MTJ. Two recent biomechanical cadaveric studies demonstrated poor holding strength and higher risk of failure when medial sutures were placed through the MTJ, compared to sutures placed through the tendon, 5 mm or 10 mm lateral to the MTJ [28, 29]. This biomechanical factor is chiefly important in chronic degenerative tears with tendon tissue loss and in revision cases. On the other hand, patients with muscle atrophy and/or fatty degeneration more commonly had retears at the footprint because the tendon itself becomes mechanically weaker than the MTJ [13, 16].

In summary, thorough analysis of retear patterns, and their relation with the repair technique, provides new insights about the pathogenesis of rotator cuff retears and

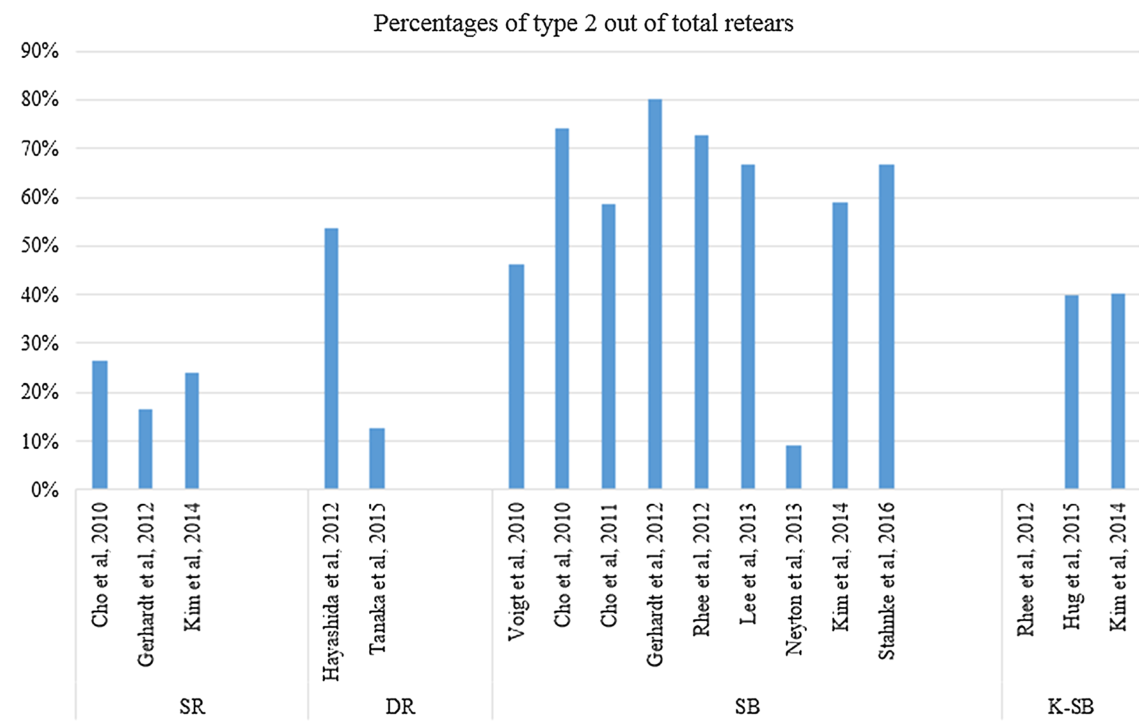


**Fig. 2** Percentages of type 2, out of all, retears in individual studies. *Two studies are not shown, as total numbers of retears were not reported [27, 30]

possibly their future prevention. The risk of medial cuff failure seems to be higher after DR and SB techniques; however, a few technical modifications and tricks can help reduce this risk.

## Limitations

There are a few limitations to this review: First, most studies included were retrospective studies presenting low levels of evidence and bias heterogeneity. Second, the details of repair techniques with SR, DR and SB were not standardized in all studies; Gerhardt et al. [24] performed a modified Mason-Allen repair as opposed to a classic SR repair reported in other two studies included [16, 18]. Similarly, Tanaka et al. [26] used absorbable sutures in the medial row anchors, which was not done in other studies describing DR repair. Neyton et al. [25] modified the SB technique to decrease the tension on the medial row sutures. Third, we did not present the management nor the outcomes of the retorn tendons as they were mostly not reported in the original articles.

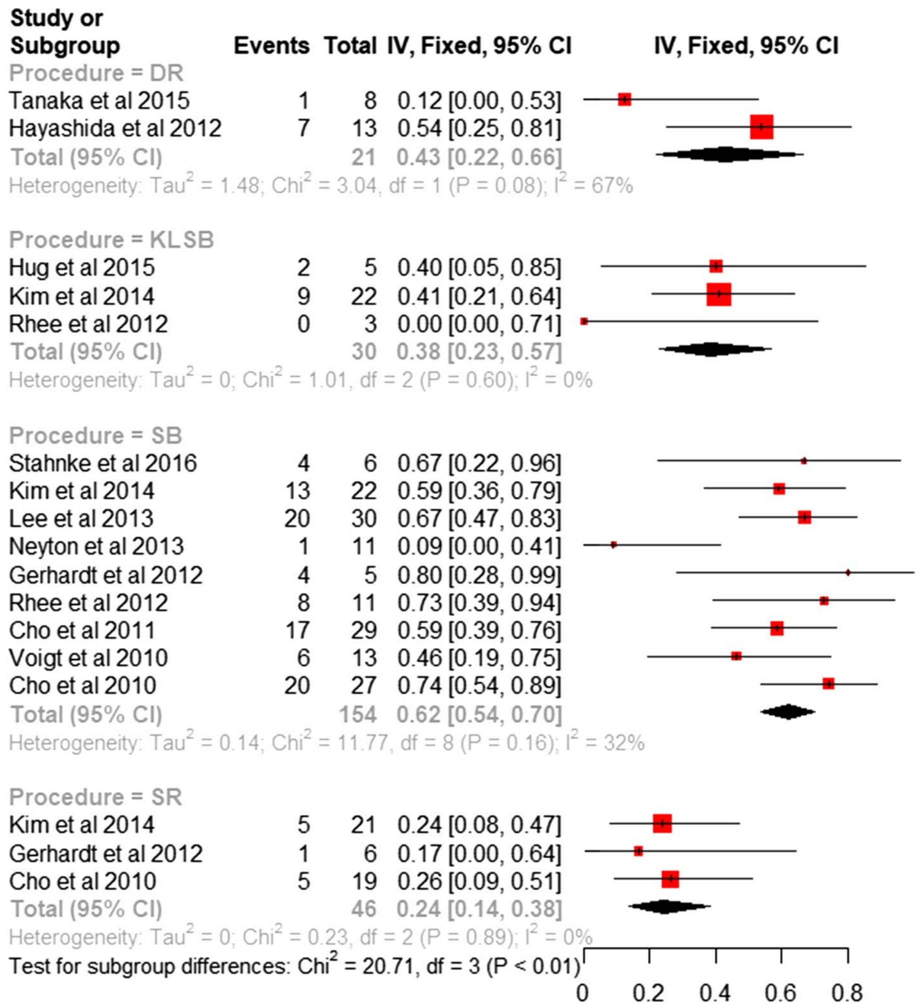


**Fig. 3** Forest plot of the incidence of type 2 retear according to surgical technique

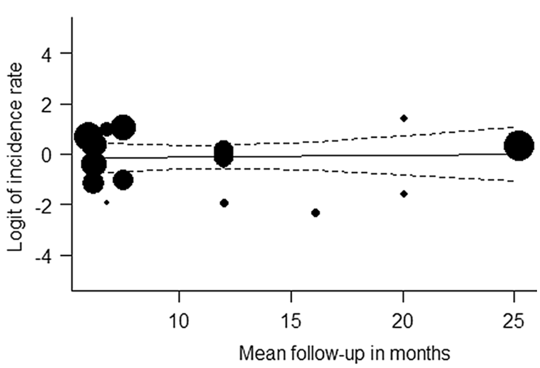


**Fig. 4** Effect of the mean follow-up duration in months on the estimated incidence rate of type 2 retear

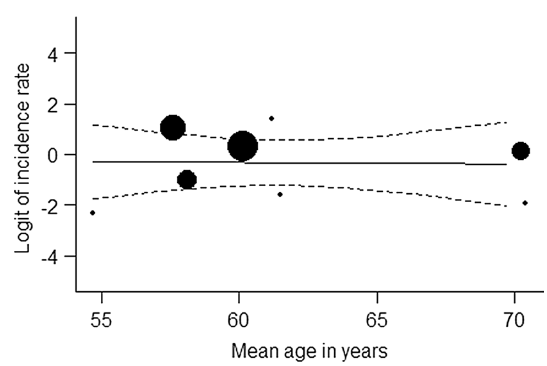


**Fig. 5** Effect of the mean age in years on the estimated incidence rate of type 2 retear

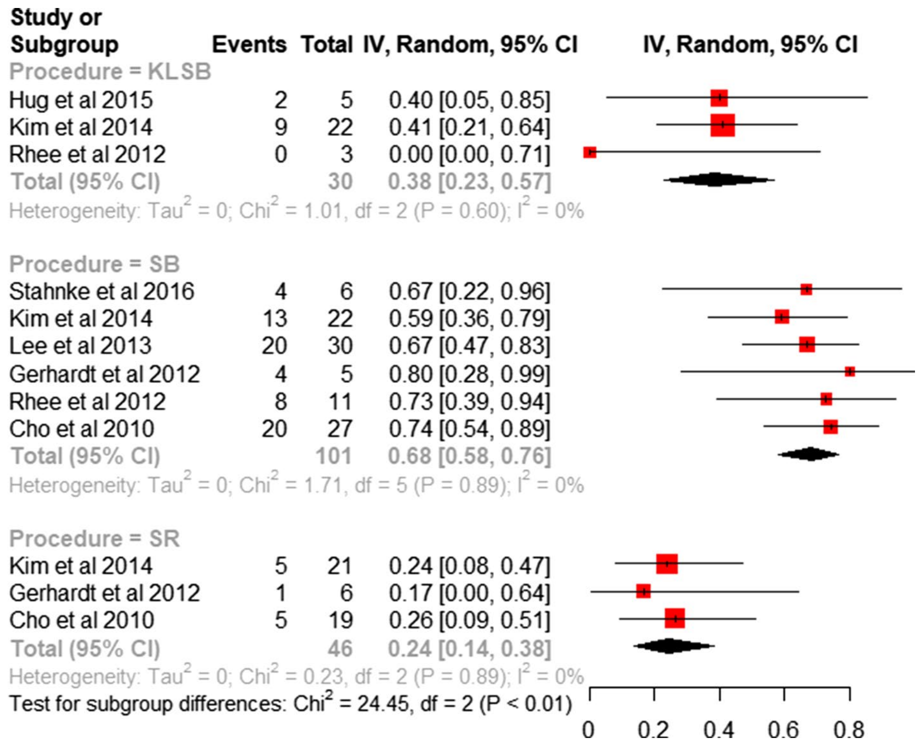


**Fig. 6** Forest plot of the incidence of type 2 retear according to surgical technique after excluding level IV studies

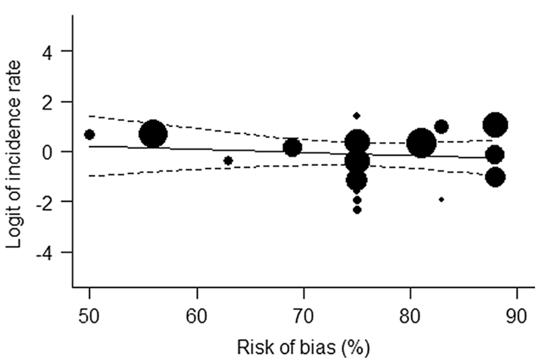


**Fig. 7** Effect of the risk of bias on the estimated incidence rate of type 2 retear

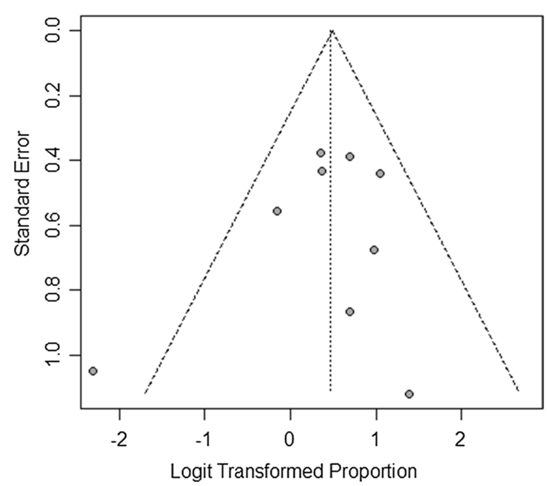


**Fig. 8** Funnel plot to examine publication bias in studies estimating the incidence rate of type 2 retear using SB technique

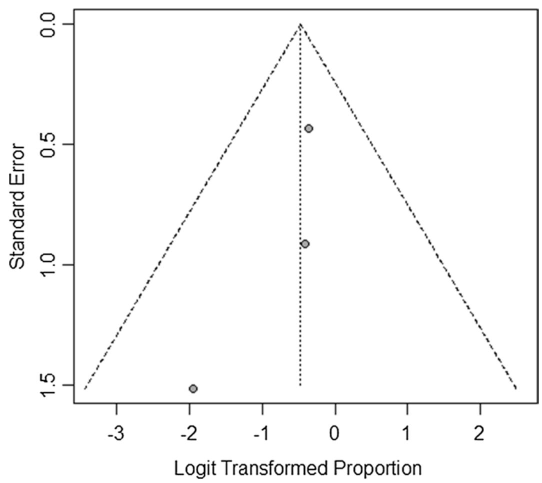


**Fig. 9** Funnel plot examining publication bias in studies estimating the incidence rate of type 2 retear using KLSB technique

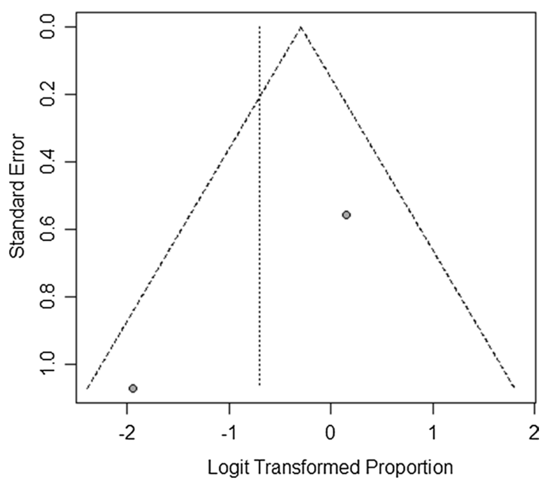


**Fig. 10** Funnel plot examining publication bias in studies estimating the incidence rate of type 2 retear using DR technique

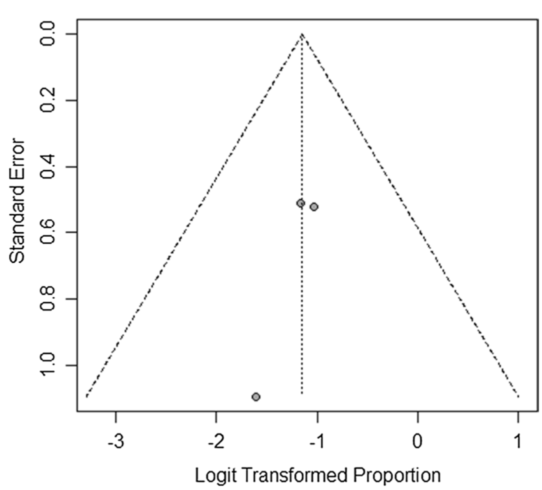


**Fig. 11** Funnel plot examining publication bias in studies estimating the incidence rate of type 2 retear using SR technique

## Future directions

Further studies evaluating the prognosis of both types of retears are needed. In case the long-term outcomes of type 2 retears are significantly worse, having a few more type 1 retears might be better than having less type 2 retears.

# Conclusion

Despite the lack of high-quality evidence, the studies subjectively analyzed in this review suggest that double-row and suture bridge techniques increase the risk of medial cuff failure. Modifications in surgical techniques in both DR and SB repairs can help decrease that risk.

## Compliance with ethical standards

**Conflict of interest** All authors declare that they have no conflict of interest.

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