



How internal rotation is measured in reverse total shoulder arthroplasty: a systematic review of the literature



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Background: Reverse total shoulder arthroplasty (RTSA) can lead to limited postoperative internal rotation (IR). We assessed how IR is measured and reported in the RTSA literature and examined the relationships between these measures and patient-reported ability to perform activities of daily living.

Methods: We searched MEDLINE, Embase, and the Cochrane Central Register of Controlled Trials for articles published in English from January 2000 through September 2018 that reported clinical outcomes after RTSA (minimum 12-month follow-up). We included studies reporting IR range of motion (ROM) and/or patient-reported functional outcomes related to IR. We identified 255 studies, 35% of which were excluded because they reported no IR outcome measures, leaving 165 studies for analysis.

Results: Studies reported 3 methods of measuring IR ROM: (1) vertebral level (VL) method (ie, the most proximal VL reached by the extended thumb with the arm behind the back), (2) degrees of IR with the arm abducted to 90°, and (3) degrees of IR with the arm in a neutral position. The VL measurement was reported in 89% of studies, but the methods of reporting this measure varied. Only 9% of studies reported functional outcomes related to IR. No study correlated clinical measurements of IR ROM with functional outcomes.

Conclusions: Measures and reporting of shoulder IR after RTSA varied widely. This variability makes it difficult to assess associations between postoperative IR limitation and functional abilities. Standardization of IR measures and reporting is needed to allow meta-analysis of data related to this important outcome.

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Reverse total shoulder arthroplasty (RTSA) is a valuable surgical treatment for patients with shoulder conditions that previously had no satisfactory solutions.^{10,15} However, postoperative limitation in range of motion (ROM) of the shoulder is a major concern. RTSA may diminish patients' ability to perform activities of daily living (ADLs), especially those associated with internal rotation (IR) of the shoulder. Difficulty with toileting is a particular concern for patients undergoing RTSA, and postoperative toileting ability is independently associated with patient satisfaction after shoulder arthroplasty.^{5,26,31}

Evaluation of IR after shoulder arthroplasty is typically accomplished by measuring ROM. Although ROM is considered an "objective" measure, several variables affect its measurement,

including patient sex, age, and arm dominance; presence of pain; and examiner experience.²¹ Furthermore, several methods are used to measure the same plane of motion, which can confound reported results.

Although 3 methods of measuring shoulder IR ROM are described in the literature, only 2 are used consistently in clinical practice. The first is direct measurement of IR using a goniometer with the elbow flexed at 90° and the arm abducted to 90°. This measurement can be performed with the patient sitting, standing, or supine and with or without stabilization of the scapula to prevent scapulothoracic motion. If the scapula is stabilized, then the measurement is typically of glenohumeral motion alone.³² The second method of measuring IR ROM is indirect, by determining the most proximal vertebral level (VL) reached by the extended thumb with the arm behind the back. The VL method is used widely because it is easy to perform and is considered a "functional" measurement.²⁰ However, there are concerns about the VL method, including questions regarding its validity,^{12,13,30} accuracy,^{9,13,14} and reliability.^{9,13} Studies have found that IR ROM as indicated by the VL method typically does not correlate

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with goniometric measurements of IR with the arm abducted to 90°. ^{12,13} The third method involves measuring IR with the arm at the side and the elbow bent 90°. This method is not in widespread use, and its clinical utility is unclear.

Although ROM provides objective information about shoulder mobility, patient goals relate to the patient's ability to perform functional tasks, such as toileting. There is a weak correlation between IR of the shoulder and patient-reported ability to perform ADLs. ²⁹ Therefore, changes in function after RTSA are commonly assessed with a combination of physical measurements and patient questionnaires. ²⁷ Some of the most frequently used patient-reported outcome measures (PROMs) (eg, American Shoulder and Elbow Surgeons [ASES] shoulder score, ²² Constant score, ⁷ Western Ontario Osteoarthritis of the Shoulder score, ¹⁷ and Penn shoulder score ¹⁶) include questions about functional activities involving IR, such as the ability to manage toileting and to wash the back.

Our goals were to determine (1) how IR is measured and reported in clinical studies of RTSA; and (2) how IR ROM measurements correlate with functional abilities after RTSA, especially in ADLs such as toileting.

Materials and methods

This systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. ²³

Eligibility criteria

We included original clinical studies that were published in English during the period of interest, that evaluated the outcomes of RTSA during a minimum of 12 months of follow-up, and that reported any IR outcome data. An IR outcome was defined as any endpoint aimed to assess postoperative IR of the shoulder, including ROM and patient-reported functional outcomes (ie, ability to perform ADLs involving IR, such as reaching the back pocket, tucking in a shirt, washing the back, fastening a bra, or toileting).

Search strategy and study selection process

We searched MEDLINE (PubMed), Embase, and the Cochrane Central Register of Controlled Trials for articles published from January 2000 through September 2018 using the following terms: “shoulder,” “arthroplasty,” “reverse arthroplasty,” and “inverse arthroplasty” (Supplementary Tables S1–S3). Our search returned 1209 potentially relevant titles, from which duplicates were then removed. Two authors independently reviewed all citations. First, they selected studies that were potentially eligible for inclusion on the basis of the title and abstract and excluded any irrelevant studies or cadaveric or biomechanical studies. Second, they determined eligibility on the basis of the full-text article and excluded articles not reporting any IR outcome. In cases of disagreement, a third author determined eligibility. Of the 255 clinical studies of RTSA assessed for eligibility, 90 (35%) were excluded because they did not report any IR outcome data. A total of 165 articles were included in the final analysis (Fig. 1).

Variables and data collection

One reviewer extracted data using a template designed to support standardized extraction, and the other checked the data. We obtained the following data from the studies: authors and year of the study, methodologic design, country where the study was performed, number of participants and/or shoulders, diagnosis,

age, sex, years during which patients were recruited, and follow-up period. The methods used to measure and report IR outcomes were extracted by 2 independent reviewers. In cases of disagreement, a third author decided.

The following data were assessed and collected for each IR outcome: (1) measurement method (eg, VL method, direct measurement of IR with the arm abducted to 90°, validated PROMs, and nonvalidated questionnaires), (2) measurement technique (eg, visual estimation, goniometry, and patient self-report), (3) measurement metric (eg, value at a time point and change from baseline), (4) measurement scale (eg, VL, degrees, and numeric scale), and (5) data summary method (eg, mean, median, number, and percentage). Each study was also evaluated to identify whether the IR ROM results were correlated with patients' ability to perform ADLs.

Study characteristics

The levels of evidence of the included studies were as follows: level IV in 79% (n = 131), level III in 15% (n = 24), level II in 4.2% (n = 7), and level I in 1.8% (n = 3). The studies had a median sample size of 37 patients (range, 5–617 patients) and mean duration of follow-up of 37 months (range, 12–132 months). The studies reported on 9357 patients (67% women) and 9946 RTSAs (589 patients underwent bilateral RTSAs). The mean patient age was 72 years (range, 40–88 years). We did not analyze study quality because our aim was to identify and describe the methods of measuring and reporting IR outcomes rather than to compare treatment results.

Statistical analysis

Results were summarized using frequencies and percentages. Descriptive statistics were used to summarize data, and all analyses were conducted using Stata software (version 14; StataCorp, College Station, TX, USA).

Results

Internal rotation ROM

Reporting prevalence

IR ROM was reported in 164 of the 165 included studies. Of these studies, 117 (71%) measured the preoperative-to-postoperative change in IR ROM whereas 47 (29%) measured IR ROM only postoperatively.

Measurement methods and techniques

Three methods of measuring IR ROM were described. Sixteen studies reported 2 IR measurement methods each, and the remainder reported only 1 method each. These methods included the following: (1) VL method (used in 158 studies [96%]), (2) active IR ROM with the arm abducted to 90° (used in 21 studies [13%]), and (3) active IR ROM with the arm at the side in a neutral position (used in 2 studies [1.2%]) (Fig. 2).

Of the 158 studies that measured the VL, 155 (95%) used visual estimation, 2 (1.3%) used the patient's subjective assessment through pictorial drawings on a questionnaire, and 1 (0.6%) used both methods. Of the 23 studies that measured IR ROM with the arm abducted to 90° or in a neutral position, 8 (35%) reported using a goniometer (handheld in 5 [22%] and digital in 3 [13%]) whereas 2 (8.7%) used 3-dimensional motion analysis; the measurement technique was not reported in the remaining 13 studies (57%) (Fig. 3). Although all studies reported active IR ROM, none reported whether the scapula was stabilized.

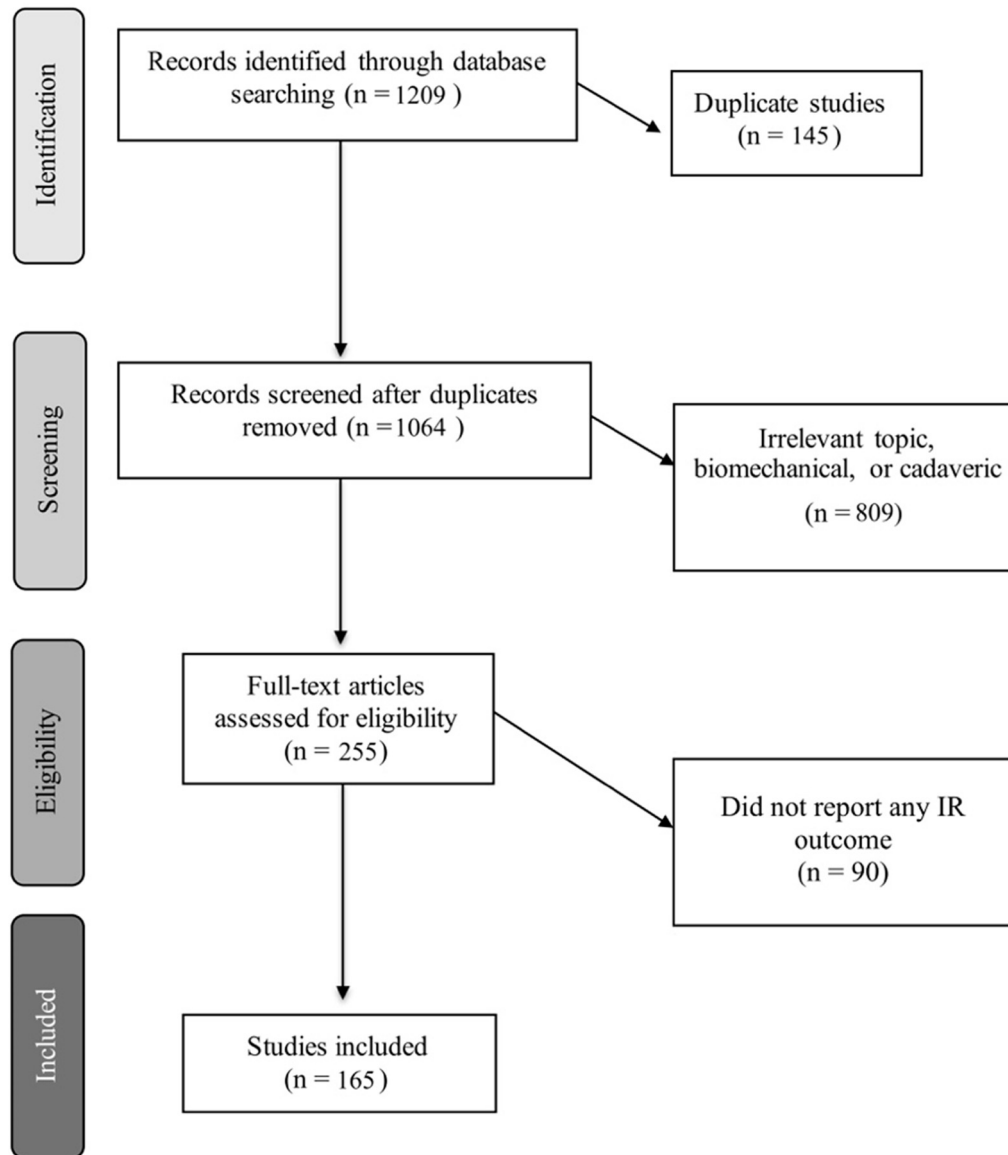


Figure 1 Flowchart of study selection. *IR*, internal rotation.

Measurement scales and data summary methods

There was considerable heterogeneity in the IR measurement scales and data summary methods used. Of the 158 studies that used the VL method, 11 (7%) performed this measurement as part of the Constant score assessment and did not specifically report the VL results but rather reported the overall Constant score. Of the remaining 147 studies that reported the VL method, 82 (56%) reported the specific VL and 65 (44%) converted the VL into 6 numeric scales (Table I). The most commonly reported summary statistic was the mean, which was reported in 112 studies (76%). Other summary statistics included the median, mode, and range (Table II). The number or percentage of patients by VL was reported in 13 studies (8.8%). Some studies further classified postoperative ROM as satisfactory using the VL method and reported the percentage of patients who could reach a certain VL (eg, lumbar spine) or the percentage of patients whose ROM improved by at least 1 VL postoperatively (Table II).

Patient-reported functional outcomes

Reporting prevalence

Patient-reported functional outcomes concerning IR were reported in only 15 of the 165 included studies (9.6%). Although all 165 studies used validated PROMs (eg, ASES shoulder score, Simple Shoulder Test score, and Penn score) that include questions about functional activities involving IR, most studies (n = 150, 91%) reported only the overall PROM score. The overall PROM score is a summary measure that does not allow the assessment of specific domains, such as those related to IR.

Measurement methods

Of the 15 studies that reported functional outcomes related to IR, 7 used questions extracted from validated PROMs; 6 used customized, nonvalidated questionnaires addressing functional activities involving IR, such as perineal hygiene; and 2 used 3-dimensional motion analysis to evaluate patients' ability to perform functional ADLs.

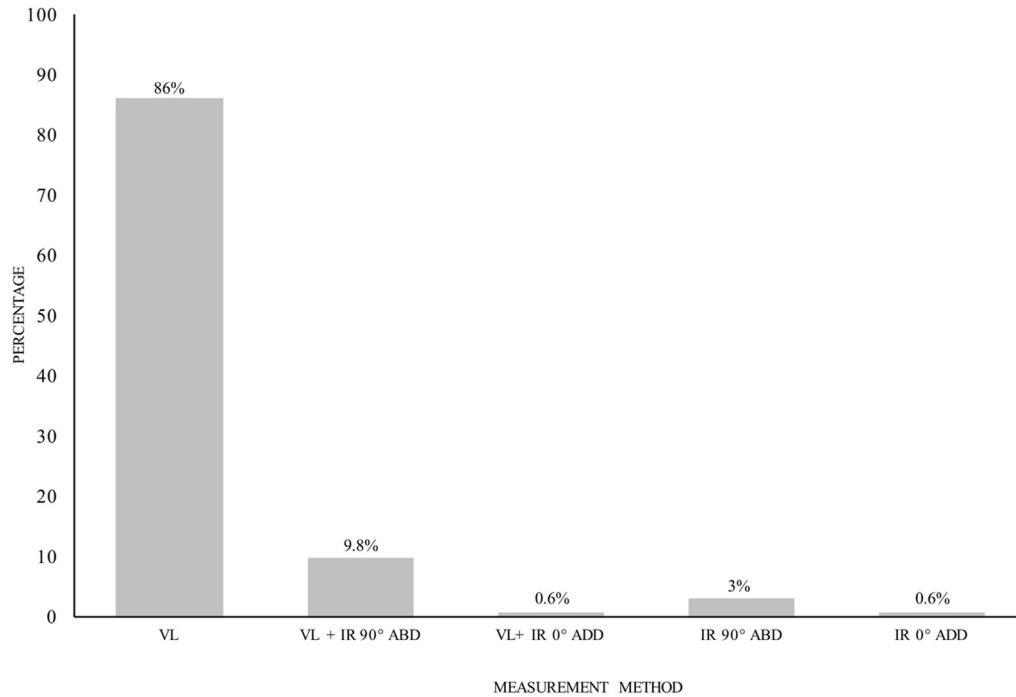


Figure 2 Distribution of methods of measurement of internal rotation (IR) range of motion. VL, vertebral level; ABD, abduction; ADD, adduction.

Correlation of IR ROM with functional outcomes

Only 2 studies correlated IR ROM with functional abilities.^{18,19} In these 2 studies, patients' ROM while performing 4 ADLs was measured with a 3-dimensional motion analysis system preoperatively and postoperatively. IR function was evaluated by asking

patients to tie an apron and to move their hand to their bottom and make a typical motion of wiping. Neither study reported significant changes in IR ROM after RTSA for any of the functional activities evaluated. No study correlated measurements of IR ROM with the ability to perform functional activities that require IR after RTSA.

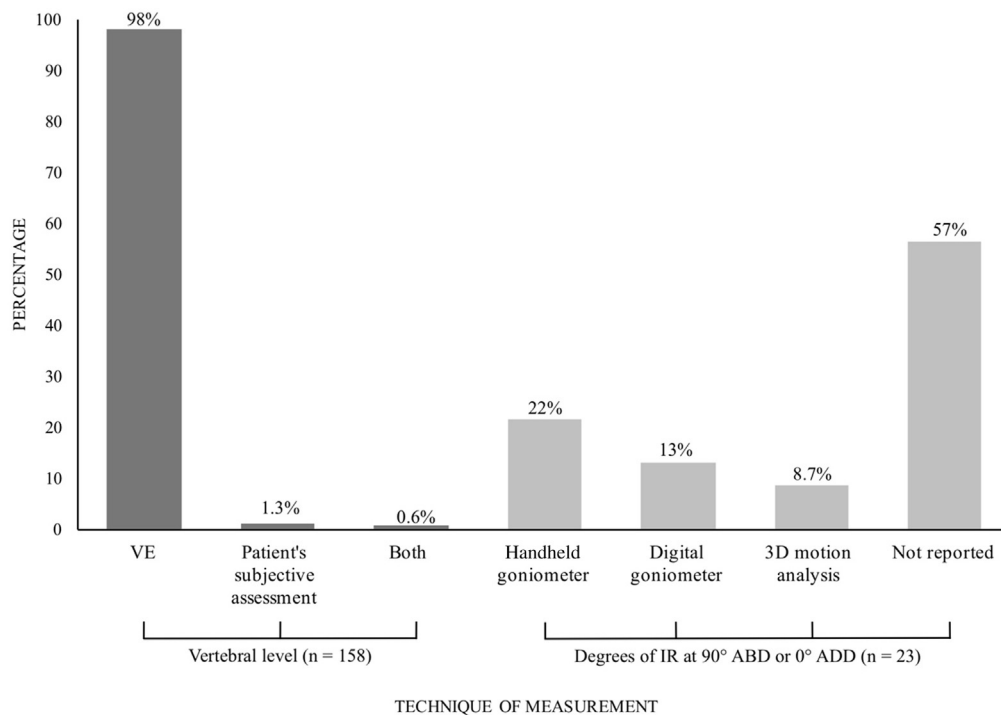


Figure 3 Distribution of techniques of measurement of internal rotation (IR) after reverse total shoulder arthroplasty. VE, visual estimation; 3D, 3-dimensional; ABD, abduction; ADD, adduction.

Table 1
Scales used by clinical studies of reverse total shoulder arthroplasty to convert vertebral levels when measuring IR of shoulder with arm behind back

Scale no.	No. of studies	Scale of measurement	No. of values of scale (range)	Description of values
1 (Constant score)	50	Ordinal	6 (0-10)	0, lateral thigh; 2, buttock; 4, lumbosacral junction; 6, L3 (waist); 8, T12; 10, T7 (interscapular)
2 (IR score)	7	Ordinal	8 (0-7)	0, 0°; 1, hip; 2, buttocks; 3, sacrum; 4, L4-L5; 5, L1-L3; 6, T8-T12; 7, T7 or higher
3	3	Ordinal	6 (1-6)	1, thigh; 2, buttock; 3, sacroiliac joint; 4, waist; 5, thoracic-lumbar junction; 6, scapula
4	2	Ordinal	18 (1-18)	1-12, T1-T12; 13-17, L1-L5; 18, any level below sacral region
5	2	Ordinal	8 (1-8)	1, trochanter; 2-7, not described; 8, T3
6	1	Ordinal	5 (2-10)	2, lateral thigh/buttock; 4, lumbosacral junction; 6, L3 (waist); 8, T12; 10, T7 (interscapular)

IR, internal rotation.

Discussion

Standardizing the tools and methods that health care professionals use to collect clinical outcomes is a critical component of evidence-based medicine. Although IR is one of the main shoulder movements and is essential for performing certain basic ADLs, we found a lack of standardization in the evaluation and reporting of IR after RTSA. Three methods of measuring IR ROM after RTSA were described in the literature. We also found that one-third of the published RTSA clinical studies did not report IR at all. Moreover, there was little reporting of IR-related functional outcomes. Only 9% of the studies included in this review described patient-reported outcomes concerning functional IR, and no study correlated clinical measurements of IR ROM with ADLs. Together, these factors prevent meta-analysis of results to draw valid conclusions about IR ROM after RTSA or the effect of IR ROM on function.

Historically, the measurement of IR ROM of the shoulder has been problematic because of the variety of measurement methods and many factors that can affect results. The measurement of IR ROM with the arm abducted to 90° was first suggested by Cave and Roberts⁴ in 1936. The results of this method can vary depending on whether a goniometer is used,^{11,33} whether the patient is standing or supine,^{6,13} and whether the scapula is stabilized.^{2,6} In our review, only 21 studies (13%) used this method to measure IR ROM. Measurement of passive IR ROM with the patient supine and the arm at 90° of abduction using stabilization of the scapula and a goniometer has been advocated as a reliable and valid method to measure isolated glenohumeral IR motion.^{2,3,13} No studies in our review used this technique. Presumably, all reported results of IR at 90° of abduction in our review reflect a combination of glenohumeral and scapulothoracic motion and not isolated glenohumeral motion.

Measuring IR with the arm behind the back (the VL method) gained popularity after 1994, when the examination committee of ASES recommended it as part of the standards for physical examination of the shoulder.²⁵ The VL method was considered an

indirect functional measure of IR and was based on the recognition that the inability to reach a determined VL limits some functional activities, such as reaching the back pocket, toileting, or dressing.²⁰ Several studies have questioned the validity, accuracy, and reliability of the VL method as a measure of glenohumeral IR ROM. Using radiography and computed tomography scans of shoulders of healthy volunteers, Mallon et al²⁰ found that maximal IR with the arm behind the back is an invalid measure of IR at the glenohumeral joint because this motion occurs by a combination of movements between the glenohumeral joint, the scapulothoracic articulation, and the elbow. Similarly, in 137 patients with unilateral shoulder pain, Ginn et al¹² showed that IR measured using the VL method has a low to moderate correlation with active IR with the arm abducted to 45° or 90°. They concluded that the VL method does not accurately reflect the IR ROM of the glenohumeral joint.

Studies have also shown that the VL method does not accurately reflect the true VL reached by the patient when assessed using conventional radiographs.^{9,13,14} Edwards et al⁹ found poor inter-observer reliability of the VL method among 13 expert evaluators. The VL as visually estimated by these evaluators deviated, on average, by 1 VL from the actual VL reached by the patient as shown on radiographs. Similarly, Hall et al¹³ found that the VL visually estimated by 6 expert evaluators deviated, on average, by 1.8 VLs from the actual VL reached by the patient as shown on radiographs. Han et al¹⁴ showed that the accuracy of the conventional method to estimate the VL was lower than the accuracy of a measuring-tape method. In addition, the results of the conventional method of estimating the VL were found to be significantly associated with patients' body mass index values, with correlation coefficients as low as 0.105 for the lumbar level in patients with a body mass index of 25 or greater (ie, overweight or obese).

Despite its limitations, the VL method was used in 89% of the studies included in this review and is the most commonly used measure of IR ROM in RTSA clinical research. One reason for its popularity is that the VL method is a component of 2 of the most widely used outcome scores, the Constant score⁷ and the physician-assessment section of the ASES score.²² Moreover, the VL method is easy to perform and requires no measurement device.

A major drawback of using ROM as the only IR outcome measure is that it may not reflect a patient's ability to perform functional tasks.²⁹ None of the studies included in our review correlated clinical measures of IR ROM with functional outcomes. Two studies used 3-dimensional motion analysis of ROM during performance of ADLs and found no change in IR ROM during ADLs after RTSA, despite a greater proportion of patients being able to perform those ADLs postoperatively.^{18,19} Namdari et al,²⁴ who used 3-dimensional motion analysis in healthy volunteers, reported that the mean IR ROM required to perform functional tasks was 102° with the arm at the side. However, functional ROM may be different in patients who

Table 2
Methods for summarizing data used by 147 studies reporting IR using VL method

Method of reporting	n (%) ^a
Mean	112 (76)
Median	17 (12)
No. and % of patients by VL	13 (8.8)
% of patients who reached certain VL	8 (5.4)
No. and % of patients for whom IR improved by ≥1 VL	2 (1.4)
Range	2 (1.4)
Mode	1 (0.7)

IR, internal rotation; VL, vertebral level.

^a Percentages sum to greater than 100% because some studies used more than 1 method to summarize the data.

have undergone RTSA than in healthy volunteers. In addition, clinical measurement of IR with the arm at the side in a neutral position is not frequently used because IR is blocked by the torso when the arm is at the side. In our review, only 2 studies measured IR ROM with the arm at the side.

The lack of clinically relevant measures limits an assessment of the effect of IR ROM on clinical results and functional activities after RTSA. It may be that measures of shoulder IR ROM are unnecessary when assessing the results of RTSA. The ability to perform ADLs after RTSA is the most important outcome to patients and surgeons. Only 1 study in our review did not report measurements of IR ROM, instead reporting only functional outcomes related to IR.¹

Another metric proposed to assess the clinical importance of a change in ROM after RTSA is the minimal clinically important difference (MCID). This metric is an estimate of the smallest change in ROM that a patient would perceive as important. Only 1 study reported that the MCID for the VL according to the scale used in the Constant score (Table I) was 2 points.²⁸ However, this result should be evaluated cautiously because the statistical methods for estimation of the MCID have been widely criticized.⁸ Furthermore, a change of 2 points in the VL scale of the Constant score can reflect a change of just 1 VL (eg, a patient reaching L2 scores 4 points whereas a patient reaching L3 scores 6 points). One VL is within the error range reported for the VL method^{9,13}; therefore, a change of 2 points in the scale used in the Constant score may simply reflect measurement error of the VL method.

Our study has several limitations. First, we analyzed measures of IR after RTSA, which may not be extrapolated to other shoulder operations or arthroplasties. Measurements of IR may be more relevant after other procedures than they are after RTSA. Second, the ordinal nature of VL data presents a challenge when summarizing and reporting results; in the studies we reviewed, 6 different numeric scales were used to convert VL data for analysis (Table I). Similarly, 7 summary statistics were used to describe VL data (Table II). The most common statistic used to summarize VL data was the mean, despite the known limitations of averaging ordinal variables. This heterogeneity in the methods used to summarize and report the data prevents pooling IR results across RTSA studies or comparing IR results between studies.

Conclusion

IR is under-reported in the RTSA literature, with one-third of studies not reporting IR outcomes. Although the VL method was reported in 89% of studies, there was substantial heterogeneity in the methods of summarizing and reporting data among studies. The current measurement techniques reported in the clinical RTSA literature prevent accurate assessment of the effects of RTSA on IR and meaningful comparisons between studies. Few studies report functional outcomes after RTSA as they relate to IR ROM. Our findings suggest a need for greater standardization in the measurement and reporting of clinical outcomes used to assess IR after RTSA.

Disclaimer

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Supplementary data

Supplementary data to this article can be found online at [10.1016/j.jses.2019.10.109](https://doi.org/10.1016/j.jses.2019.10.109).

References

1. Aleem AW, Feeley BT, Austin LS, Ma CB, Krupp RJ, Ramsey ML, et al. Effect of humeral component version on outcomes in reverse shoulder arthroplasty. *Orthopedics* 2017;40:179–86. <https://doi.org/10.3928/01477447-20170117-04>.
2. Awan R, Smith J, Boon AJ. Measuring shoulder internal rotation range of motion: a comparison of 3 techniques. *Arch Phys Med Rehabil* 2002;83:1229–34.
3. Boon AJ, Smith J. Manual scapular stabilization: its effect on shoulder rotational range of motion. *Arch Phys Med Rehabil* 2000;81:978–83.
4. Cave EF, Roberts SM. A method for measuring and recording joint function. *J Bone Joint Surg Am* 1936;18:455–65.
5. Chen AL, Bain EB, Horan MP, Hawkins RJ. Determinants of patient satisfaction with outcome after shoulder arthroplasty. *J Shoulder Elbow Surg* 2007;16:25–30. <https://doi.org/10.1016/j.jse.2006.04.013>.
6. Cieminski CJ, Kelly SM, Nawrocki TJ, Indrelie AJ, Klaers H, Stelzmler MR. Comparison of shoulder internal rotation passive range of motion in various positions in nonathletic persons and the establishment of normative values for the sidelying position. *J Shoulder Elbow Surg* 2016;25:1523–31. <https://doi.org/10.1016/j.jse.2016.01.007>.
7. Constant CR, Murley AHG. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987;214:160–4.
8. Copay AG, Chung AS, Eyberg B, Olmscheid N, Chutkan N, Spangehl MJ. Minimum clinically important difference: current trends in the orthopaedic literature, part I: upper extremity: a systematic review. *JBSJ Rev* 2018;6:e1. <https://doi.org/10.2106/jbjs.Rvw.17.00159>.
9. Edwards TB, Bostick RD, Greene CC, Baratta RV, Drez D. Interobserver and intraobserver reliability of the measurement of shoulder internal rotation by vertebral level. *J Shoulder Elbow Surg* 2002;11:40–2. <https://doi.org/10.1067/mse.2002.119853>.
10. Familiari F, Rojas J, Doral MN, Huri G, McFarland EG. Reverse total shoulder arthroplasty. *EFORT Open Rev* 2018;3:58–69. <https://doi.org/10.1302/2058-5241.3.170044>.
11. Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Phys Ther* 1987;67:1867–72.
12. Ginn KA, Cohen ML, Herbert RD. Does hand-behind-back range of motion accurately reflect shoulder internal rotation? *J Shoulder Elbow Surg* 2006;15:311–4. <https://doi.org/10.1016/j.jse.2005.08.005>.
13. Hall JM, Azar FM, Miller RH III, Smith R, Throckmorton TW. Accuracy and reliability testing of two methods to measure internal rotation of the glenohumeral joint. *J Shoulder Elbow Surg* 2014;23:1296–300. <https://doi.org/10.1016/j.jse.2013.12.015>.
14. Han SH, Oh KS, Han KJ, Jo J, Lee DH. Accuracy of measuring tape and vertebral-level methods to determine shoulder internal rotation. *Clin Orthop Relat Res* 2012;470:562–6. <https://doi.org/10.1007/s11999-011-2112-7>.
15. Hyun YS, Huri G, Garbis NG, McFarland EG. Uncommon indications for reverse total shoulder arthroplasty. *Clin Orthop Surg* 2013;5:243–55. <https://doi.org/10.4055/cios.2013.5.4.243>.
16. Leggin BG, Michener LA, Shaffer MA, Brenneman SK, Iannotti JP, Williams GR Jr. The Penn shoulder score: reliability and validity. *J Orthop Sports Phys Ther* 2006;36:138–51. <https://doi.org/10.2519/jospt.2006.36.3.138>.
17. Lo IK, Griffin S, Kirkley A. The development of a disease-specific quality of life measurement tool for osteoarthritis of the shoulder: the Western Ontario Osteoarthritis of the Shoulder (WOOS) index. *Osteoarthritis Cartilage* 2001;9:771–8.
18. Maier MW, Caspers M, Zeifang F, Dreher T, Klotz MC, Wolf SI, et al. How does reverse shoulder replacement change the range of motion in activities of daily living in patients with cuff tear arthropathy? A prospective optical 3D motion analysis study. *Arch Orthop Trauma Surg* 2014;134:1065–71. <https://doi.org/10.1007/s00402-014-2015-7>.
19. Maier MW, Zeifang F, Caspers M, Dreher T, Klotz MC, Rettig O, et al. Can reverse shoulder arthroplasty in post-traumatic revision surgery restore the ability to perform activities of daily living? *Orthop Traumatol Surg Res* 2015;101:191–6. <https://doi.org/10.1016/j.otsr.2014.12.007>.
20. Mallon WJ, Herring CL, Sallay PI, Moorman CT, Crim JR. Use of vertebral levels to measure presumed internal rotation at the shoulder: a radiographic analysis. *J Shoulder Elbow Surg* 1996;5:299–306.
21. McFarland EG. Shoulder range of motion. In: Kim TK, Park HB, El Rassi G, Gill H, Keyurapan E, editors. *Examination of the shoulder: the complete guide*. New York: Thieme; 2006. p. 15–87.
22. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. *J Shoulder Elbow Surg* 2002;11:587–94. <https://doi.org/10.1067/mse.2002.127096>.
23. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015;4:1. <https://doi.org/10.1186/2046-4053-4-1>.
24. Namdari S, Yagnik G, Ebaugh DD, Nagda S, Ramsey ML, Williams GR Jr, et al. Defining functional shoulder range of motion for activities of daily living. *J Shoulder Elbow Surg* 2012;21:1177–83. <https://doi.org/10.1016/j.jse.2011.07.032>.
25. Richards RR, An KN, Bigliani LU, Friedman RJ, Gartsman GM, Cristina AG, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg* 1994;3:347–52.

26. Rojas J, Joseph J, Liu B, Srikumaran U, McFarland EG. Can patients manage toileting after reverse total shoulder arthroplasty? A systematic review. *International orthopaedics* 2018;42:2423–8. <https://doi.org/10.1007/s00264-018-3900-4>.
27. Sims MT, Detweiler BN, Scott JT, Howard BM, Detten GR, Vassar M. Inconsistent selection of outcomes and measurement devices found in shoulder arthroplasty research: an analysis of studies on ClinicalTrials.gov. *PLoS One* 2017;12:e0187865. <https://doi.org/10.1371/journal.pone.0187865>.
28. Torrens C, Guirro P, Santana F. The minimal clinically important difference for function and strength in patients undergoing reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2016;25:262–8. <https://doi.org/10.1016/j.jse.2015.07.020>.
29. Triffitt PD. The relationship between motion of the shoulder and the stated ability to perform activities of daily living. *J Bone Joint Surg Am* 1998;80:41–6.
30. Wakabayashi I, Itoi E, Minagawa H, Kobayashi M, Seki N, Shimada Y, et al. Does reaching the back reflect the actual internal rotation of the shoulder? *J Shoulder Elbow Surg* 2006;15:306–10. <https://doi.org/10.1016/j.jse.2005.08.022>.
31. Wiater BP, Boone CR, Koueiter DM, Wiater JM. Early outcomes of staged bilateral reverse total shoulder arthroplasty: a case-control study. *Bone Joint J* 2013;95-B:1232–8. <https://doi.org/10.1302/0301-620x.95b9.31445>.
32. Wilk KE, Reinold MM, Macrina LC, Porterfield R, Devine KM, Suarez K, et al. Glenohumeral internal rotation measurements differ depending on stabilization techniques. *Sports Health* 2009;1:131–6. <https://doi.org/10.1177/1941738108331201>.
33. Williams JG, Callaghan M. Comparison of visual estimation and goniometry in determination of a shoulder joint angle. *Physiotherapy* 1990;76:655–7.