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REVIEW ARTICLE

A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age

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Hypothesis and background: Abnormalities of the rotator cuff are more common with age, but the exact prevalence of abnormalities and the extent to which the presence of an abnormality is associated with symptoms are topics of debate. Our aim was to review the published literature to establish the prevalence of abnormalities of the rotator cuff and to determine if the prevalence of abnormalities increases with older age in 10-year intervals. In addition, we assessed prevalence in 4 separate groups: (1) asymptomatic patients, (2) general population, (3) symptomatic patients, and (4) patients after shoulder dislocation.
Methods: We searched PubMed, EMBASE, and the Cochrane Library up to February 24, 2014, and included studies reporting rotator cuff abnormalities by age. Thirty studies including 6112 shoulders met our criteria. We pooled the individual patient data and calculated proportions of patients with and without abnormalities per decade (range, younger than 20 years to 80 years and older).
Results: Overall prevalence of abnormalities increased with age, from 9.7% (29 of 299) in patients aged 20 years and younger to 62% (166 of 268) in patients aged 80 years and older ($P < .001$) (odds ratio, 15; 95% confidence interval, 9.6-24; $P < .001$). There was a similar increasing prevalence of abnormalities regardless of symptoms or shoulder dislocation.
Discussion and conclusion: The prevalence of rotator cuff abnormalities in asymptomatic people is high enough for degeneration of the rotator cuff to be considered a common aspect of normal human aging and to make it difficult to determine when an abnormality is new (e.g., after a dislocation) or is the cause of symptoms.
Level of evidence: Level III, Systematic Review.

Keywords: Rotator cuff; abnormalities; prevalence; age

The study was performed at the Orthopaedic Hand and Upper Extremity Service, Massachusetts General Hospital–Harvard Medical School, Boston, MA, USA.
Protocol registration: International Prospective Register of Systematic Reviews (PROSPERO) registration number CRD42014008670.
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For many years, rotator cuff abnormalities were ascribed to subacromial abrasion/impingement caused by overhead activities.[20,25] In 1995, Milgrom et al proposed natural aging as the primary reason for cuff changes, as most people participate in limited overhead activity.[21] Additional studies have found rotator cuff abnormalities to be prevalent in both symptomatic and asymptomatic patients.[49] In addition, bilateral cuff abnormalities are commonly found in patients

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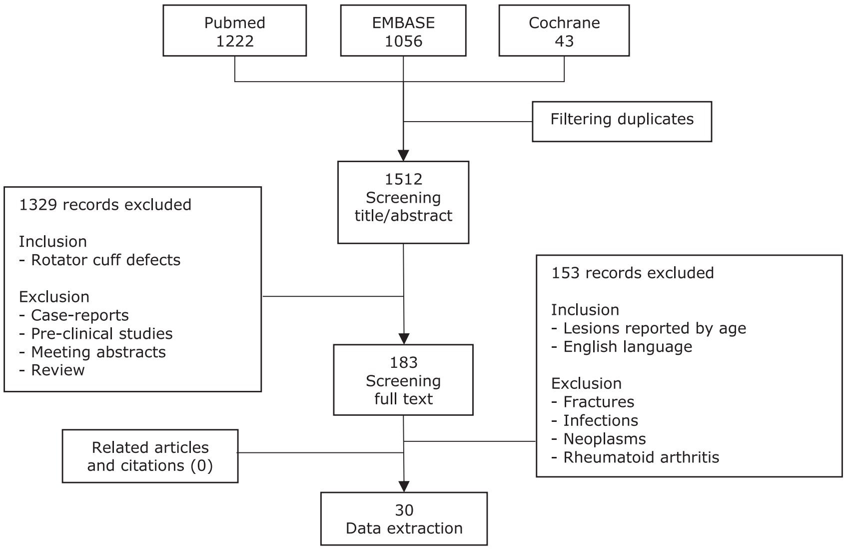

Figure 1 Flow chart of study selection.

with unilateral symptoms.[48] Atraumatic rotator cuff defects are commonly referred to as tears, but if rotator cuff thinning is part of the normal aging process, the word *tear*—which implies damage in need of repair—may be inappropriate. Given that pain—the cognitive and emotional responses to nociception—makes humans feel protective and prepare for the worst, accurate descriptions of the pathophysiologic processes that do not exacerbate maladaptive responses are important.

We aimed to perform a systematic review to establish the prevalence of rotator cuff abnormalities and to determine if the prevalence of abnormalities increases with older age. In addition, we assessed prevalence in (1) asymptomatic patients, (2) the general population, (3) symptomatic patients, and (4) patients after a shoulder dislocation.

Materials and methods

Selection criteria

We performed a systematic review adhering to the published guidelines by the Cochrane Collaboration and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[9,22] Our review is registered with PROSPERO,[30] registration number CRD42014008670 (Appendix 1).[40] We included studies that established rotator cuff abnormalities by the individual patient's age or per decade in the English language. Case reports, meeting abstracts, reviews, and preclinical studies were excluded. We also omitted studies addressing rotator cuff tears with associated fractures, infections, neoplasms, or rheumatoid arthritis.

Search strategy

We searched PubMed, EMBASE, and the Cochrane Library up to February 24, 2014, using the search string for title and abstract (rotator cuff [mesh/emtree&regular]) AND (degeneration* OR tear* OR disruption* OR perforation* OR injury* OR "pathologic change*" OR "degenerative change*" OR defect* OR lesion* OR lesion* OR abnormality*) AND (age OR ages OR aged OR aging [mesh/emtree&regular]). See Appendix 2 for each specific search.

This yielded 1222 results from PubMed, 1056 from EMBASE, and 43 from the Cochrane Library. Title and abstract for each result from the databases were independently examined by 2 reviewers (T.T. and B.L.), who subsequently screened the full texts of eligible articles. Both reviewers also scanned the reference lists for additional studies that met the inclusion criteria (Fig. 1). The final list of included studies was agreed to by consensus.

We found 2 overlapping patient cohorts[24,26,32,34] (same authors and patient population) and included only the largest and most detailed studies.[24,26]

Risk of bias assessment

The relevant criteria from the Newcastle-Ottawa Scale for assessing quality of nonrandomized cohort studies were used to assess methodologic quality of the included studies.[37] This scale provides a maximum of 3 stars for method of selection (1) and outcome assessment (2) (Appendix 3).

Data extraction

Two reviewers (T.T. and B.T.R.) independently extracted study data using standardized sheets. Discordance was resolved by both reviewers rechecking their extracted data until data sheets corresponded. For each study, we extracted author, year, institute, retrospective/prospective design, specimen type, rotator cuff visualization, definition of abnormality, number of patients and shoulders, rotator cuff abnormality, and individual age or per decade. We included only tears of the supraspinatus tendon as this was most consistently reported throughout the included studies.

We contacted 70 corresponding authors of studies published after 2006 that did not report individual age but described eligible

Table I Study baseline characteristics

Study	Des	Specimen	NOS	Identification method	Definition of abnormality	Pat	Shoul	Tear	Prop
Petersson[28]	R	Cadaver	NA	Arthrotomy	Thinning, fraying, or fibrous degradation and full-thickness ruptures	76	151	48	32%
Jerosch et al[14]	R	Cadaver	NA	Arthrotomy	McLaughlin criteria[20]	62	122	72	59%
Hijioka et al[10]	R	Cadaver	NA	Arthrotomy	(1) Loss of bursa cuff; (2) tendon surface degeneration; (3) cuff ulcer formation; (4) full-thickness cuff tear	80	160	114	63%
Toolanen et al[42]	P	Dislocation (acute)	1	US	Partial: tendon thinning or irregularity; full: tendon identification impossible and humeral head close to deltoid	65	65	24	37%
Milgrom et al[21]	P	Asymptomatic	2	US	Partial-thickness tears >4 mm	90	180	33	18%
Needell et al[24]	P	Asymptomatic	2	MRI	High-intensity signal on T2-weighted images with discontinuity in the normal signal void not evident on the proton density–weighted scans	100	100	36	36%
Panni et al[26]	R	Cadaver	NA	Arthrotomy	NR	20	40	14	35%
Taylor and Arciero[38]	P	Dislocation (acute)	1	Arthroscopy	NR	63	63	0	0%
Pevny et al[29]	R	Dislocation (acute)	0	Arthroscopy	Patient self-reported rotator cuff tear	52	52	18	35%
Berbig et al[3]	P	Dislocation (acute)	2	US	Partial: <1 cm; full: >1 cm	167	167	53	32%
Tempelhof et al[39]	P	Asymptomatic	2	US	Partial: not included; full: loss of tendon convexity in a longitudinal and transverse plane	411	411	96	23%
Worland et al[47]	P	Asymptomatic	2	US	NR	59	59	40	68%
Schibany et al[33]	P	Asymptomatic	3	US	(1) Tendon identification impossible and humeral head close to deltoid; (2) hypoechoic defect bursal to articular tendon surface; (3) cuff sandglass-like diameter shift, focal thinning, hypoechogenic discontinuity, or nonvisualization	212	212	13	6%
Sorensen et al[36]	P	Symptomatic	2	US	Partial: hypoechoic area at tendon's full-thickness side; full: hypoechoic defect passing from the articular to the tendon's bursal side	104	104	31	30%
Rowan et al*,[31]	R	Symptomatic	2	MRI	Partial: not included; full: intra-articular gadolinium extending from the glenohumeral joint through the disrupted tendon into the subacromial/subdeltoid bursa	332	332	23	7%
Fritz et al*,[7]	R	Symptomatic	2	Athroscopy or arthrotomy	Snyder classification[35]	244	244	104	43%
Kim et al[16]	P	Asymptomatic	2	US	Partial: focal flattening or loss of convexity at cuff's bursal side or hypoechoic (or mixed) in longitudinal and transverse plane; full: cuff not visualized or focal defect when retracting torn tendon ends	237	474	52	11%

(*continued on next page*)

Table I (*continued*)

Study	Des	Specimen	NOS	Identification method	Definition of abnormality	Pat	Shoul	Tear	Prop
Moosmayer et al*,[23]	P	Asymptomatic	2	US	Partial: not included; full: cuff absence, hypoechoic or anechoic discontinuity and contour concavity at tendon's superior border in two planes	270	420	32	8%
Vlychou et al*,[44]	NR	Symptomatic	1	Arthroscopy	Partial: focal hypoechoic or anechoic defect in the tendon, involving either the bursal or the articular surface and manifested in two planes; full: NR	56	56	53	95%
Wissman et al*,[46]	R	Symptomatic	2	MRI	Partial: intermediate or fluid signal on fat-suppressed fast spin-echo T2-weighted image on any imaging plane; full: fluid-filled gap through tendon's entire thickness on fat-suppressed fast spin-echo T2-weighted images on any imaging plane	48	48	42	88%
Yamamoto et al[49]	P	General population	3	US	Partial: regarded as nontears; full: discontinuity and thinning of the rotator	683	1366	283	21%
Zaiton et al*,[50]	P	Symptomatic	2	US	NR	106	106	32	30%
van der Veen et al*,[43]	P	Dislocation (chronic)	2	Arthroscopy	NR	18	18	0	0%
Iagnocco et al[11]	P	Asymptomatic	1	US	NR	97	194	15	8%
Abate et al*,[1]	P	Asymptomatic	2	US	Partial not included; full: tendon defects from the bursal margin to the articular margin	232	464	27	6%
Lesniak et al*,[18]	R	Asymptomatic athletes	2	MRI	NR	21	21	11	53%
Pavic et al*,[27]	R	Dislocation (acute and chronic)	1	Arthroscopy	NR	200	200	99	50%
Zhu et al*,[52]	R	Dislocation (chronic)	0	Arthroscopy	NR	31	31	5	16%
Zbojniewicz et al[51]	R	Symptomatic	3	MRI	Discrete measurable fluid or contrast signal defect on T1- or T2-weighted fat-suppressed sequences within the rotator cuff on at least 2 planes	201	205	25	12%
Clavert et al*,[6]	R	Symptomatic	1	NR	Cuff retraction to zone 2 at most and fatty infiltration ≤ 2	98	98	57	58%

Des, design; *P*, prospective; *R*, retrospective; *NOS*, Newcastle-Ottowa scale; *NA*, not applicable; *Pat*, patients; *Shoul*, shoulders; *Prop*, proportion; *NR*, not reported; *US*, ultrasound; *MRI*, magnetic resonance imaging.

* Full data set by correspondence with authors.

patient cohorts. Seven e-mail addresses were no longer working; 27 were unresponsive, and efforts were abandoned after 3 attempts; 24 replied but were unable to cooperate because of Institutional Review Board restrictions or because data were no longer available; and 12 authors provided us with their data set.

Outcome measures

We pooled the results of individual patients from each study. Subsequently, we calculated the prevalence of tears of the supraspinatus (odds ratios and 95% confidence intervals [CI]) per decade, ranging from younger than 20 years to older than 80 years of age. We included both partial and complete tears if both were reported. In addition, we assessed prevalence in (1) asymptomatic patients, (2) patients with abnormalities when symptoms were unknown (ie, the general population, including cadavers), (3) symptomatic patients, and (4) patients with previous shoulder dislocations. We assessed differences by Pearson χ^2 test and regarded a P value $< .05$ as significant.

The specific cohorts in our study are drafted from different populations. Asymptomatic patients and patients with abnormalities when symptoms are unknown come from the general population; symptomatic patients and patients with shoulder dislocation come from mainly surgically treated cohorts. This difference in cohort selection introduces too much selection bias to appropriately compare subgroups directly.

Study characteristics

Thirty full-text articles met our inclusion criteria and were included in this review. Sixteen studies (53%) were conducted prospectively; one study did not mention time of enrollment. Ten studies reported abnormalities in asymptomatic volunteers[1,11,16,18,21,23,24,33,39,47]; 5 studies (4 of which were cadaver studies) reported prevalence in the general population[10,14,26,28,49]; 8 included symptomatic patients[6,7,31,36,44,46,50,51]; and 7 described patients with acute or chronic shoulder dislocations.[3,27,29,38,42,43,52] The majority of the studies used ultrasound to image the rotator cuff (43%; 13 of 30). Twelve studies did not define rotator cuff abnormality; the remaining studies used various definitions (Table I).

Median quality score was 2 stars, ranging from 0 to 3 (Table I). We could not grade anatomic studies as no good grading tools exist.

Study population

We included 6112 shoulders in 4331 patients with 1452 cuff abnormalities. A total of 2444 shoulders were asymptomatic; 1881, of which 473 were cadaveric, were sampled from the general population; 1193 were symptomatic; and 594 had experienced a dislocated shoulder.

Results

Overall prevalence of abnormalities ranged from 9.7% (29 of 299) in patients aged 20 years and younger and increased to 62% (166 of 268) in patients of 80 years and older ($P < .001$; Fig. 2); odds ratio, 15; 95% CI, 9.6-24; $P < .001$ (Table II).

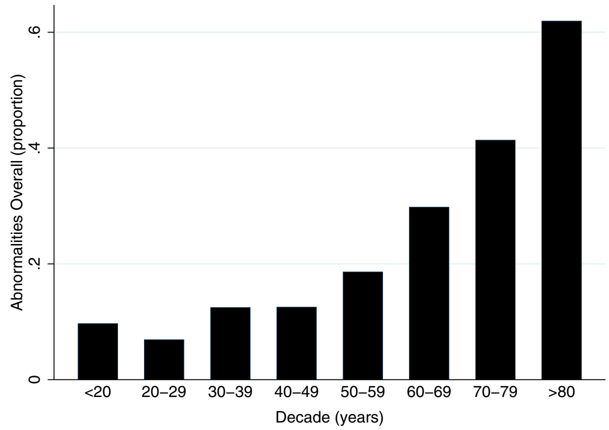

Figure 2 Histogram of rotator cuff abnormalities by age group across all studies.

Increasing prevalence persisted, regardless of symptoms, in the general population and in patients with a dislocated shoulder. Abnormalities ranged from 6.7% (5 of 75) in asymptomatic patients older than 20 years to 56% (33 of 59) in patients 80 years and older ($P < .001$) (odds ratio, 18; 95% CI, 6.3-50; $P < .001$); from 0% to 65% (106 of 164) in the general population ($P < .001$) (odds ratio, 62; 95% CI, 22-177; $P < .001$); from 9.9% (26 of 264) to 50% (4 of 8) symptomatic patients ($P < .001$) (odds ratio, 9.2; 95% CI; 2.2-39; $P = .003$); and from 9% (3 of 33) to 62% (23 of 37) in patients with shoulder dislocation ($P < .001$) (odds ratio, 16; 95% CI, 4.2-64; $P < .001$).

Because one study[49] made up 22% of our cohort, we conducted a sensitivity analysis by excluding this study from analysis. Increased prevalence over time remained significant at $P < .001$, both overall and in the general population (Appendix 4).

Discussion

Abnormalities of the rotator cuff are more common with age, but the exact prevalence of abnormalities and the extent to which abnormalities cause symptoms are topics of debate. Our aim was to perform a systematic review to determine the general prevalence of rotator cuff abnormalities and to determine the prevalence according to symptoms and after dislocation. We identified a high rate of rotator cuff abnormalities in both symptomatic and asymptomatic patients, in the general population, and after shoulder dislocations, increasing with age—a prevalence high enough for degeneration of the rotator cuff to be considered a common aspect of normal human aging. Whereas many surgeons favor a "wear and tear" theory, it is also possible, and in our opinion more likely, that the rotator cuff is subject to an inherent degenerative process similar to thinning and graying of the hair.

Our study has several limitations. First, abnormalities are established by various methods, of which direct

Table II Overall prevalence of rotator cuff abnormalities and in asymptomatic patients, in the general population, in symptomatic patients, and after shoulder dislocation

	Decades							
	<20	20-29	30-39	40-49	50-59	60-69	70-79	>80
Overall								
Number of shoulders	299	434	481	933	1531	1134	1032	268
Prevalence cuff abnormality (n)	9.7% (29)	6.9% (30)	13% (60)	13% (117)	19% (285)	30% (338)	41% (427)	62% (166)
P value				*<.001*				
Odds ratio (95% CI)	*Reference value*	0.69 (0.41-1.2)	1.3 (0.83-2.1)	1.3 (0.87-2.1)	2.1 (1.4-3.2)	4.0 (2.6-5.9)	6.6 (4.4-9.8)	15 (9.6-24)
P value		.18	.24	.19	*<.001*	*<.001*	*<.001*	*<.001*
Asymptomatic								
Number of shoulders	0	75	70	470	807	495	468	59
Prevalence cuff abnormality (n)		6.7% (5)	21% (15)	%4 (18)	9.5% (77)	16% (77)	28% (130)	56% (33)
P value				*<.001*				
Odds ratio (95% CI)	—	*Reference value*	3.8 (1.3-11)	0.56 (0.20-1.5)	1.5 (0.58-3.8)	2.6 (1.0-6.6)	5.4 (2.1-14)	18 (6.3-50)
P value			.014	.26	.42	*.048*	*<.001*	*<.001*
General population								
Number of shoulders	2	12	140	254	473	442	394	164
Prevalence cuff abnormality (n)	0%	0%	2.9% (4)	7.9% (20)	14 (67%)	31% (138)	50% (196)	65% (106)
P value				*<.001*				
Odds ratio (95% CI)	—	—	*Reference value*	2.9 (0.97-8.7)	5.6 (2.0-16)	15 (5.6-43)	34 (12-93)	62 (22-177)
P value				.056	*.001*	*<.001*	*<.001*	*<.001*
Symptomatic								
Number of shoulders	264	193	212	123	163	120	109	8
Prevalence cuff abnormality (n)	9.9% (26)	4% (8)	14% (29)	40% (50)	61% (163)	68% (81)	63% (69)	50% (4)
P value				*<.001*				
Odds ratio (95% CI)	*Reference value*	0.40 (0.18-0.89)	1.5 (0.83-2.55)	6.2 (3.6-11)	15 (8.7-24)	19 (11-33)	16 (9.0-28)	9.2 (2.2-39)
P value		.026	.20	*<.001*	*<.001*	*<.001*	*<.001*	*.003*
Dislocations								
Number of shoulders	33	154	59	85	88	77	61	37
Prevalence cuff abnormality (n)	9% (3)	11% (17)	20% (12)	34% (29)	47% (41)	55% (42)	53% (32)	62% (23)
P value				*<.001*				
Odds ratio (95% CI)	*Reference value*	1.2 (0.34-4.5)	2.6 (0.66-9.8)	5.2 (1.5-18)	8.7 (2.5-31)	12 (3.4-43)	11 (3.0-40)	16 (4.2-64)
P value		.74	.17	.011	*.001*	*<.001*	*<.001*	*<.001*

CI, confidence interval; *n*, number; overall sums asymptomatic, general population, symptomatic, and dislocations; general population includes cadavers.
Italic text indicates statistically significant difference.

visualization by arthroscopy or arthrotomy is considered the reference standard. This might lead to both underreporting and overreporting when other modalities are used. Second, there was wide variety of definitions and criteria for diagnosis of cuff abnormalities. Recording of abnormalities may have varied by study, which could hinder determination of a definitive rate. Also, the large variation in the definition of an abnormality—along with the differences in mean age between studies—might explain the variation in the proportion of cuff abnormalities between individual studies. A common interpretation would benefit future studies and clinical practice. Third, after contacting the corresponding author, we were able to include previously unreported individual patient data from 12 studies. These data were not verified by peer review. Fourth, cadaver studies could not be assessed for methodologic quality. Finally, there was no accounting for the severity of the abnormality, so we do not know if symptomatic or postdislocation abnormalities were larger defects on average.

When a pathophysiologic process such as rotator cuff tendinopathy is common in patients with and without symptoms, it becomes more difficult to confidently associate symptoms with pathophysiologic changes and more difficult to prove that interventions that address this pathophysiologic process are better than the natural history of the untreated condition. Rotator cuff defects can lead to weak external rotation[16] and rotator cuff arthropathy because of a lack of centralization in the glenoid during activity.[13] Given this, it could be argued that even asymptomatic defects merit treatment; but that remains to be proved because it is not clear that surgery can prolong the durability and function of the rotator cuff[17] or avoid rotator cuff arthropathy.[13] In fact, relief of subjective symptoms (which are subject to regression to the mean,[2,4,5] the self-limiting course of symptoms,[17] and the placebo effect[45]) is more predictable than integrity of the cuff[12,19]; although there is a high rate of recurrent defects, people feel better after surgery.[15,41] Without well-designed placebo-controlled surgical trials, we cannot be certain about the effectiveness of surgery on subjective outcomes such as pain. A recent systematic review of sham surgery–controlled trials emphasizes the strong placebo effect associated with surgery; in half of the included studies, placebo performed as well as the investigated procedure.[45] It is important to be sure that operative interventions for the rotator cuff are a wise investment of hope, an effective use of resources, and worth the small but real risk of iatrogenic harm, the risk of medicalizing common symptoms, and the risk of interfering with the development of effective coping strategies.

Interestingly, our study suggests that abnormalities found after shoulder dislocations increase with age, similar to other groups in our study, complicating accurate distinction of acute tears from more typical defects on imaging tests. A high prevalence of asymptomatic abnormalities makes interpretation of diagnostic test results more difficult and the likelihood that a given abnormality is new or even the direct cause of symptoms much lower. More work is needed on techniques for distinguishing acute tears from attritional defects and for determining whether a radiologic finding is the cause of the symptoms. One approach might be to perform bilateral imaging with ultrasound; if an abnormality is present in the contralateral shoulder with no history of trauma, it might be reasonable to conclude that the abnormality present in the traumatic shoulder is unlikely to be truly new. Other methods, such as ratings of fatty infiltration and atrophy of the associated muscles, might also be important. Those approaches merit additional research.[8] For future prospective studies to determine the positive and negative predictive value of various diagnostic tests, we need consensus on the reference standard for a symptomatic abnormality.

To gain confidence in the diagnosis and treatment of rotator cuff disease, several lines of investigation are necessary. First, we must establish the prevalence of normal variations and age-related changes and quantify the chance that a given abnormality causes symptoms. Second, we must reliably and accurately identify tears that progress to rotator cuff arthropathy. Third, we must prove that our interventions are better than placebo interventions or better than the natural history of the disease. This systematic review begins to address the first of these aims by reviewing all the studies of age-related prevalence of rotator cuff abnormalities. Our study confirms that abnormalities are more common with age (1) in asymptomatic patients, (2) in the general population, (3) in symptomatic patients, and (4) after shoulder dislocation. Abnormalities can therefore be difficult to isolate as the primary symptom generator. Surgeons and patients should be aware of the current limitations in the management of shoulder pain that may or may not be attributed to a rotator cuff abnormality.

Conclusions

Our aim was to review the published literature to establish the prevalence of abnormalities of the rotator cuff and to determine if the prevalence of abnormalities increases with older age in 10-year age intervals. In addition, we assessed 4 separate groups: (1) asymptomatic patients, (2) general population, (3) symptomatic patients, and (4) patients after shoulder dislocation.

The prevalence of rotator cuff abnormalities in asymptomatic people is high enough for degeneration of the rotator cuff to be considered a common aspect of normal human aging and to make it difficult to determine when an abnormality is new (e.g., after a dislocation) or is the cause of symptoms. In addition, we need evidence that treatment of these abnormalities improves symptoms better than placebo does.

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Disclaimer

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jse.2014.08.001.

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