Clinical and biomechanical performance of patients with failed rotator cuff repair

Przemysław Lubiowski · Piotr Kaczmarek · Marcin Dzianach ·
Piotr Ogrodowicz · Maciej Bręborowicz · Jan Długosz ·
Ewa Lisiewicz · Leszek Romanowski

Received: 2 July 2013 / Accepted: 6 July 2013 / Published online: 15 August 2013
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Abstract

Purpose The purpose of the study was clinical and advanced biomechanical evaluation of shoulder function with respect to rotator cuff (RC) integrity following repair.

Methods This was a retrospective study of 111 cases with solid single row rotator cuff repair and a minimal one-year follow-up. The RC repair was performed as an open procedure in 42 patients, arthroscopically assisted in 34 and fully arthroscopic in 48 cases. Evaluation protocol included ultrasound evaluation of the RC integrity, clinical evaluation using shoulder scores and advanced biomechanical evaluation (isometric and the isokinetic strength testing).

Results Ultrasound evaluation revealed complete retear in 16 %, partial retear in 10 % and intact repair in 74 % of the cases.

Isometric testing of flexion and abduction had shown that shoulders with complete retear were weaker by 45 % compared to those with full tendon healing.

Isokinetic testing revealed 29–43 % deficits in peak external rotation torque comparing complete retear vs. normal healing. Patients' ability to generate shoulder power and withstand a load proved to be lower in circumstances of a complete lack of healing (40–43 % and 34–55 %, respectively). Partial retears did not have a negative impact on the biomechanical properties of shoulders. Surprisingly, there

were no significant differences in the shoulder scores related to the quality of healing. In terms of patient satisfaction the results were good and the patients declared themselves better in all cases, no matter what quality of healing had been recorded ultimately.

Conclusions According to the results of this research rotator cuff integrity after open or arthroscopic repair does not seem to affect clinical scores. Recurrent tears may result in lower muscle performance in terms of active motion, strength and endurance. Advanced shoulder testing may be essential in assessing the patients' ability to return to sports or heavy labour.

Introduction

Modern rotator cuff (RC) repair includes minimally invasive arthroscopic procedures providing a stable and solid fixation of the tendons to bone and improved biology with the use of growth factors or scaffolds [1–5]. Despite such efforts the number of retears reported in literature is quite significant. Nevertheless, many patients do quite well even in the presence of lost integrity following RC repair [6, 7]. Most commonly the final results are evaluated according to pain level, clinical status and quality of life. However, to have a more thorough understanding of biomechanical capabilities of the shoulder following the rotator cuff repair, we decided to include advanced strength testing. The aim of the study was clinical and advanced biomechanical evaluation of shoulder function with respect to rotator cuff integrity following repair.

Material and methods

The study included 111 patients who had a single-row cuff repair for a total of 124 shoulder repairs. The patients were a

P. Lubiowski (✉) · P. Ogrodowicz · M. Bręborowicz ·
J. Długosz · E. Lisiewicz · L. Romanowski
Department of Traumatology, Orthopaedics and Hand Surgery,
University of Medical Sciences in Poznań,
ul. 28 Czerwca 1956r 135, 61-545 Poznań, Poland
e-mail: p.lubiowski@rehasport.pl

P. Lubiowski · P. Kaczmarek · M. Dzianach · P. Ogrodowicz ·
J. Długosz
Rehasport Clinic, Poznań, ul. Górecka 30, 61-201 Poznań, Poland

M. Dzianach
Department of General and Interventional Radiology, University of
Medical Sciences in Poznań, ul. Długa 1/2, 61-848 Poznań, Poland

part of a cohort including 243 cases operated upon between 2002 and 2009. The research was approved by the ethical committee of our institution and included patients with rotator cuff repair and no other shoulder pathologies with available documentation at the one-year follow-up. All the participating cases gave written consent.

The follow-up was performed at an average time of 39.5 months (12–98). The average age of patients was 56 years (40–80), with 84 males and 40 females. The rotator cuff repair was performed as an open procedure in 42 patients, arthroscopically assisted in 34 and fully arthroscopic in 48 cases.

Protocol evaluation included ultrasound scans, clinical evaluation and advanced strength testing.

The ultrasound evaluation of rotator cuff integrity had been performed by a ten-year experienced musculoskeletal radiologist, using the 5–12 MHz linear transducer (HD11 XE system, Phillips Ultrasound, Andover, MA, USA). The insertion and the repair sites were graded as complete retear (cRT), partial retear (pRT) and no retear (nRT). Complete retear was assigned if full thickness tear was diagnosed throughout the width of the repaired RC. Partial retear was rated to partially preserved continuity of the repaired cuff. Fully preserved continuity, with full coverage of footprint by cuff tendons, was regarded as no retear (nRT) (Fig. 1).

Clinical evaluation included assessment of the active ranges of motion (ROM), pain level (0–10 VAS) and clinical scores: UCLA (University of California in Los-Angeles), the simple shoulder test (SST), and the American Shoulder and Elbow Surgeons (ASES) index (SSI).

Advanced biomechanical evaluation was based on shoulder strength testing performed in isometric and isokinetic mode.

The isometric evaluation of shoulder flexion, abduction, internal and external rotation was performed using electronic dynamometer with dedicated PC software (Forcemeter, Progress, Poland). The patient was always examined in a standing position (Fig. 2). The device was attached either to the floor (flexion, abduction) or the wall (internal and external rotation). The belt was adjusted accordingly and held at the patients' wrist. Flexion strength was evaluated with the arm in a 90° frontal deviation, with abduction at a 90° deviation in the scapular plane. Internal and external rotation strength was examined with the arm along the side and

elbow flexed to 90°. Maximum value [N] was recorded in a six second period of maximum contracture.

Isokinetic shoulder evaluation was performed by means of the Biodex System 3 (Biodex Medical Systems, Inc., Shirley, NY) (Fig. 3) for external and internal rotation; values taken into consideration included peak torque, peak torque to body weight, average power and total work. Measurements were performed at 90, 180, 270 and 360°/s. Isokinetic testing was performed according to the standard protocol used in our institutions. The patient was seated and stabilised in the chair in standard sitting position. Rotation movements were performed successively in four angular velocities 180°/s, 90°/s, 360°/s and 270°/s. Peak torque represents the actual strength of the motion. Peak torque related to body weight is considered to more accurately compare the results between patients with different body sizes. Total work accounts for the ability to maintain peak torque over a period of time and practically describes the resistance to fatigue. Average power represents the dynamics of movement and the ability to generate torque within a short time [8].

Statistical analysis was performed using StatPlus mac 2009 software (AnalystSoft) and included normality tests and the analysis of variance (ANOVA).

Results

The ultrasound evaluation revealed complete retear in 20 cases (16 %), partial retear in 12 cases (10 %) and no retear in 92 (74 %) cases (Fig. 1). The average age in the three groups was 55 years (40–71) in the nRT, 53 years (43–74) in the pRT and 57 years in the retear group (46–80) with a majority of males, respectively, of 64 %, 81 % and 65 %.

The results of the clinical evaluation, isometric and isokinetic testing are displayed in Tables 1, 2, and 3. The level of pain and the follow-up time were significantly higher for the partial retears when compared with the group with intact cuffs. The integrity of the repaired tendons did not make any difference in the clinical scores. Patients with complete retears had significantly lower active flexion, showing no other significant differences in the measured range of active motion.

Fig. 1 Longitudinal ultrasound scans showing complete retear of supraspinatus tendon (a), partial healing (partial retear) (b) and preserved integrity at the repair site (c)

Fig. 2 Isometric testing for abduction (a), flexion (b) and external rotation (c); device (d) and interface (e)

Fig. 3 Isokinetic shoulder testing: setup (a, b); data collection (c)

Table 1 Result of clinical evaluation

Clinical assessment	Averages $\pm$ SD			Statistical significance by ANOVA (p values)		
	Complete retear (cRT)	Partial retear (pRT)	No retear (nRT)	cRT vs. nRT	cRT vs. pRT	pRT vs. nRT
Pain (VAS)	3 $\pm$ 3.4	3.7 $\pm$ 2.3	2.1 $\pm$ 2.4	ns	ns	0.049
SSI-ASES	73 $\pm$ 26.5	70.2 $\pm$ 13.8	79.7 $\pm$ 21.3	ns	ns	ns
SST	8.9 $\pm$ 3.6	9.8 $\pm$ 2.3	9.6 $\pm$ 3.2	ns	ns	ns
UCLA	27.2 $\pm$ 7.6	29.6 $\pm$ 4.5	29.4 $\pm$ 5.9	ns	ns	ns
Flexion (°)	145 $\pm$ 32	169.1 $\pm$ 20.2	163.6 $\pm$ 32.9	0.031	0.05	ns
Abduction (°)	150.3 $\pm$ 32.5	171.8 $\pm$ 15.4	159.6 $\pm$ 36.6	ns	ns	ns
External rotation (°)	47.1 $\pm$ 22.8	55 $\pm$ 20.9	54 $\pm$ 21.8	ns	ns	ns

ns not significant with $p > 0.05$

UCLA University of California in Los Angeles, SST simple shoulder test, SSI-ASES American Shoulder and Elbow Surgeons index

Isometric testing showed the best results in the group with preserved integrity of RC tendons. In comparison, patients with complete retears had significantly weaker flexion, abduction, external and internal rotation. Partial retears did not make the patients weaker than the no-retear group.

Isokinetic testing for external rotation revealed significantly lower values of peak torque, peak torque-to-body-weight, average work and total power when comparing the complete retear group to the remaining two at lower motion velocities (90°/s and 180°/s). Internal rotation testing also showed greater strength for more integrated repair site, however with less significant differences (Table 3).

Discussion

One of the most challenging issues in the rotator cuff repair is to obtain effective and permanent restoration of the tendon-to-bone junction. It is believed that it is not possible to restore the normal tendon-to-bone junction by surgical repair due to very unique structure and function of the junction [9,

10]. The tissue that grows at the tendon repair site has biomechanical properties that are inferior to normal rotator cuff insertion [10]. For that and other reasons lack of proper healing or retear occurs with reported frequency of the problem for 16–94 % of RC repairs [6–8].

Our study has shown incomplete rotator cuff healing after fixation in 26 % of the cases, out of which 16 % did not heal at all and 10 % of the cases healed partially.

It is not quite clear whether the presence of rotator cuff tear or retear have clinical consequences. Asymptomatic rotator cuff tears have been reported by Scarlat and Florescu who showed up to 56 % asymptomatic cuff tears in healthy individuals over 75 years of age [11]. It is debatable whether the shoulder pain and weakness arise from the RC tear alone. Itoi et al. have shown that the intra-articular or intra-bursal injection of local anaesthetic led to increased strength measured by isokinetic testing [12]. Another study by Norlin and Adolfsson showed that patients with small full thickness tear do well following only arthroscopic decompression without repair [13].

Our study has specifically aimed at the impact of the RC tendon healing on subjective and objective measures of shoulder function. The healing was evaluated by ultrasound scan, which has been acknowledged as a reliable method of RC evaluation and has been used in similar studies before [7, 14, 15]. The study does not focus on possible risk factors of RC retear. As already described in other comparative studies the surgical technique had no effect on results in terms of cuff integrity. For the purpose of evaluation of cuff integrity on clinical results data of all patients have been pooled together both in this and other studies [6–8].

Patients' clinical scores (pain, SSI, SST, UCLA, ROM) had improved significantly at follow-up compared to the preoperative status, regardless of the RC integrity at the insertion site. When comparing the results at the final follow-up, patients with a partial retear had slightly more pain compared to those with complete healing. Full-thickness

Table 2 Results of isometric shoulder testing by Forcemeter

Isometric strength	Means $\pm$ SD			Statistical significance by ANOVA (p values)		
	Complete retear (cRT)	Partial retear (pRT)	No retear (nRT)	cRT vs. nRT	cRT vs. pRT	pRT vs. nRT
Flexion	31.1 $\pm$ 22	59.1 $\pm$ 21.2	58.5 $\pm$ 37.2	0.005	0.047	ns
Abduction	33 $\pm$ 19.6	52.8 $\pm$ 27.2	56.9 $\pm$ 35	0.042	ns	ns
External rotation	53.5 $\pm$ 31.6	65.3 $\pm$ 19.2	73.9 $\pm$ 39.8	0.05	ns	ns
Internal rotation	65.2 $\pm$ 29.6	80.4 $\pm$ 15.9	89.3 $\pm$ 43.2	0.040	ns	ns

ns not significant with $p > 0.05$

Table 3 Results of isokinetic shoulder testing by Biodex System 3

Isokinetic testing		Means $\pm$ SD			Statistical significance by ANOVA (p values)		
		Complete retear (cRT)	Partial retear (pRT)	No retear (nRT)	cRT vs. nRT	cRT vs. pRT	pRT vs. nRT
ER peak torque	90°/s	13.4 $\pm$ 10	20.9 $\pm$ 6.3	18.1 $\pm$ 8	0.043	0.021	ns
	180°/s	8.6 $\pm$ 9.2	13.2 $\pm$ 6.5	13.1 $\pm$ 7.8	0.046	ns	ns
	270°/s	6.3 $\pm$ 7.5	10.1 $\pm$ 5.7	9.2 $\pm$ 8.1	ns	ns	ns
	360°/s	0.3 $\pm$ 1	3 $\pm$ 5.8	2.5 $\pm$ 5	ns	ns	ns
ER PK/BW	90°/s	15 $\pm$ 10	26.5 $\pm$ 11.8	22.4 $\pm$ 8.4	0.003	0.001	ns
	180°/s	9.1 $\pm$ 11.2	17.8 $\pm$ 6	16.1 $\pm$ 8.9	0.007	0.02	ns
	270°/s	6.2 $\pm$ 7.8	12.3 $\pm$ 7.2	11.7 $\pm$ 9.3	0.036	ns	ns
	360°/s	0.3 $\pm$ 1.1	3.3 $\pm$ 6.6	3 $\pm$ 5.9	ns	ns	ns
ER average power	90°/s	9.9 $\pm$ 8.6	17.4 $\pm$ 5	15.1 $\pm$ 8.5	0.029	0.027	ns
	180°/s	7.6 $\pm$ 8.7	12 $\pm$ 7.2	13.2 $\pm$ 10.3	0.05	ns	ns
	270°/s	4 $\pm$ 4.9	7.1 $\pm$ 7.7	6.5 $\pm$ 8.1	ns	ns	ns
	360°/s	0.1 $\pm$ 0.2	1.6 $\pm$ 3.7	1.4 $\pm$ 3.7	ns	ns	ns
ER total work	90°/s	28.5 $\pm$ 23.7	57.3 $\pm$ 22.8	48 $\pm$ 28	0.012	0.008	ns
	180°/s	14.4 $\pm$ 16	31.9 $\pm$ 15	28 $\pm$ 21.7	0.02	0.038	ns
	270°/s	42.5 $\pm$ 40.1	85.1 $\pm$ 71	61.6 $\pm$ 69	ns	ns	ns
	360°/s	0.1 $\pm$ 0.3	3.2 $\pm$ 7.6	4.2 $\pm$ 13.8	ns	ns	ns
IR peak torque	90°/s	22.7 $\pm$ 16.35	34.2 $\pm$ 15.2	29.5 $\pm$ 12	ns	0.031	0.03
	180°/s	13.9 $\pm$ 12.5	23.6 $\pm$ 14	21.3 $\pm$ 10.6	ns	0.031	ns
	270°/s	17.5 $\pm$ 13.8	24.2 $\pm$ 16.6	20.7 $\pm$ 11.1	ns	ns	ns
	360°/s	11 $\pm$ 9.2	17.9 $\pm$ 15.7	13.8 $\pm$ 9.5	ns	ns	ns
IR PK/BW	90°/s	25 $\pm$ 15.8	41 $\pm$ 13.4	35.9 $\pm$ 13.5	0.005	0.004	ns
	180°/s	13.8 $\pm$ 12.6	28 $\pm$ 13.3	26.4 $\pm$ 12.4	ns	ns	ns
	270°/s	17.5 $\pm$ 14.4	28 $\pm$ 15.2	25.1 $\pm$ 11.6	ns	ns	ns
	360°/s	10.6 $\pm$ 10	20.1 $\pm$ 14.8	17.1 $\pm$ 11.2	ns	ns	ns
IR average Power	90°/s	18.3 $\pm$ 16.5	29.8 $\pm$ 16.3	22.9 $\pm$ 13.7	ns	0.047	ns
	180°/s	10.5 $\pm$ 15	24.3 $\pm$ 17.4	20.5 $\pm$ 15.8	0.029	0.031	ns
	270°/s	14.5 $\pm$ 17.9	26.9 $\pm$ 25.7	17.7 $\pm$ 15.1	ns	ns	ns
	360°/s	8.5 $\pm$ 12.3	18 $\pm$ 23.1	11 $\pm$ 13.3	ns	ns	ns
IR total work	90°/s	59.9 $\pm$ 54	115.6 $\pm$ 61.9	81.6 $\pm$ 44.8	ns	0.005	0.033
	180°/s	26.4 $\pm$ 38	64.7 $\pm$ 40.9	52.3 $\pm$ 34.7	ns	ns	ns
	270°/s	35.4 $\pm$ 39.9	69.7 $\pm$ 72.2	59.8 $\pm$ 68.7	0.013	0.009	ns
	360°/s	15.3 $\pm$ 21.3	34.9 $\pm$ 38.7	22.2 $\pm$ 20.9	ns	0.047	ns

ns not significant with $p > 0.05$

ER external rotation, IR internal rotation, PK/BW peak torque to body weight

retears did not lead to a significant increase in pain. Surprisingly, there were no significant differences in the shoulder scores related to the quality of healing. Complete retears had a negative effect on active elevation compared to the remaining two groups. Again, surprisingly no such effect could be found when active abduction and external rotation were measured. Basically, patients were satisfied no matter what quality of healing had been recorded ultimately.

However, the most striking differences among the patients was revealed by objective measures. Static isometric testing of flexion and abduction had shown that shoulders with complete RC retear were weaker by 45 % compared to those

with full tendon healing. More dynamic testing in the isokinetic mode had revealed 29–43 % deficits in peak external rotation torque comparing complete retear vs. normal healing. Patients' ability to generate shoulder power and withstand a load proved to be lower in circumstances of a complete lack of healing (40–43 % and 34–55 %, respectively). Partial retears did not have a negative impact on the biomechanical properties of shoulders. Moreover, those patients also did better on testing than complete retears.

As in our study, Yoo et al. and Liem had found a negative influence of retear on clinical results [16, 17]. In Liem's study, shoulder abduction was decreased for cuffs with retear

among open and arthroscopically repaired patients, yet significant differences were found only among the latter group. Zumstein et al. and Verma et al. found no difference in the outcome scores and pain level among patients with or without RC retear [7, 18]. In Verma's study, patients with failed RC repair had significantly lower strength of forward flexion but not external rotation; and that was found regardless of the repair technique (arthroscopic vs. mini-open). Bishop et al., in a prospective study, examined RC integrity by also comparing arthroscopic versus open repair [6]. The authors found superior isometric testing results for flexion and external rotation as well as ASES and Constant score in the group with intact cuffs. Pain values remained improved following repair with no difference between preserved and return RC at the follow-up. They had also found that there was no significant difference in outcomes between open versus arthroscopic repair for any of the scores when the intact and retear groups were compared. Work by Millar et al. showed that regardless of the cuff integrity following repair parameters of pain, range of active motion, external and internal rotation strength improved with no significant differences [5]. However, patients with intact cuffs had better abduction strength and less pain on overhead activity. Demirors et al. found that the failed rotator cuff repair group showed lower levels of isokinetic extension and internal rotation. Despite high failure rate in their group functional results were satisfactory [19].

We have used more advanced and extensive biomechanical and objective measurements in this study including isometric and isokinetic evaluation. Isometric testing is a simple, quick and relatively inexpensive method of objective shoulder strength evaluation [20]. It allows for the detection of static strength deficits not being able to evaluate more advanced functionality. Isokinetic testing is more sophisticated, allowing a more functional evaluation [8]. It is possible to detect deficits in a moving shoulder and also reflects shoulder ability to generate power and performance of a working shoulder over time. Our study demonstrates that patients with complete retears are not only weaker in shoulder motion, but also are not able to perform work with different loads over a period of time. This may have an impact on the ability to return to heavy labour or sports. For those reasons, it seems that more objective measures should be introduced in populations that return to full activity. Possibly, for such patients, limitation of shoulder loading should be suggested.

We have also looked at patients with partial retears (or partial healing). Those patients performed as well as those with normal healing in both subjective and objective evaluation. The only exception was a slightly higher pain level. A similar phenomenon had also been found among patients with partial RC tears that seem to experience more pain than those with full thickness tears, and in theory, cause abnormal

tension to the remaining tendon fibres [21]. In our study this group showed otherwise good function and had comparable biomechanical abilities as patients with complete healing.

Many studies and conference presentations have attempted to improve cuff integrity results by applying the double row or double row suture-bridge technique. The techniques seem to have superior biomechanical and biological properties [1–3]. Although the techniques do not prove to be clinically superior to single row fixation, they may have advantages in improving cuff integrity when the double row technique is used [1–3, 22–25]. Based on that and results of our study we should tend to obtain the best possible healing in patients with high biomechanical demands. Having good integrity leads to superior strength and endurance results. This issue might be important for heavy physical workers or athletes (not necessarily fully professional) wishing to get back to previous activity on a similar level. The physical performance of workers might be important information for employers bearing in mind both job safety, safe return to former duties and costs of work-related injuries. Proper testing and its results would help to determine time of returning to sports or heavy labour or establishing permanent limitations for future activity.

Conclusions

According to the results of this research rotator cuff integrity after open or arthroscopic repair does not seem to affect clinical scores. Recurrent tears may result in lower muscle performance in terms of active motion, strength and endurance. Advanced shoulder testing may be essential in assessing the patients' ability to return to sports or heavy labour.

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