

Best evidence-based physical therapy treatment following rTSA.

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ABSTRACT

Introduction: The purpose of this study was to examine what the best-evidence based physical therapy treatment following reversed total shoulder arthroplasty is.

Method: A systematic search to relevant scientific articles has been held in Pubmed, Cinahl and PEDro to articles concerning rTSA with the mention of a physio therapeutic post operative protocol and articles concerning physiotherapeutic rehabilitation following TSA or hemiarthroplasty

Results: 9 articles on rTSA were found and the protocol found in these articles shows a build up from passive range of motion typically starting with pendulum exercises in week two to six to active range of motion from week 12. On TSA 4 articles were found which follow a protocol consistent of four phases. Starting with passive range of motion followed by active-assisted range of motion and isometric exercises to active range of motion and strength exercises.

Conclusion: The best evidence-based rehabilitation protocol seems to be a program divided in phases starting with passive range of motion on to active-assisted range of motion to active range of motion and in the last step strength training. Mostly this protocol starts in the first week postoperatively but it might be started as late as week 6.

Search terms: *Arthritis; shoulder; arthroplasty; prosthesis; replacement; inverse; reverse; physical therapy; rehabilitation*

Introduction

Surgery for shoulder pathologies is a common intervention for patients with functional loss and persistent pain in the shoulder notwithstanding conservative therapies. Post-operative care following a conventional total shoulder arthroplasty or a Neer-plastiek has been thoroughly described and documented. Post-operative care following the newer reversed total shoulder arthroplasty (rTSA) has been less researched and documented in spite of the growing number of rTSA placed and the initial and improvingly positive results.

Indicators for surgery are impaired shoulder function and no or little benefit from conservative treatment. Impairment can be due to rheumatoid arthritis, primary osteoarthritis, humeral fractures, rotator cuff tear, cuff tear arthropathy and tumours.

Rheumatoid arthritis is a chronic disease with, in the Netherlands, an annual prevalence of 5 in 1000 and an incidence of 0.3 in 1000 people a year (NHG-arthritis, 2009). Over 2007 the Dutch National Institute of Public Health and the Environment (RIVM) states a higher prevalence of RA in the Netherlands: for men 7.1 in 1000 and for women 11.0 in 1000 (Gommer et al. 2010). Up to the age of 45 the amount of women with RA is three

times higher than men, after which it levels out. The majority of studies on RA carried out in Northern European and North American areas estimate a prevalence of 0.5–1%, and a mean annual incidence of 0.02–0.05% (Alamanos et al. 2004).

After conservative treatment methods to reduce pain and improve shoulder function the next options are surgical interventions in the management of shoulder problems. When the shoulder joint has degenerated, shoulder arthroplasty and post-operative therapy are usually offered. Besides the more common Neer-plastiek and total shoulder arthroplasty there has been a development of the reverse shoulder arthroplasty (Gommer et al. 2010).

The rTSA is most frequently used in situations in which there is a combination of a degenerative glenohumeral joint and a symptomatic deficient or non-functional rotator cuff. Pain after hemiarthroplasty is another indicator to perform rTSA (Wierks et al. 2008, Rockwood 2007, Seebauer et al. 2005).

In the last decade, reverse anatomy shoulder replacements have become increasingly popular, particularly for patients with rotator cuff arthropathy. The semiconstrained reverse shoulder prosthesis, first described by Grammont et al. in 1987 (Grammont et al. 1987), has been used as a treatment for patients with cuff tear arthropathy for which non-operative modalities had failed (Wierks et al. 2008). The rTSA procedure is specifically designed for the treatment of glenohumeral joint arthritis or complex fractures when associated with irreparable rotator cuff damage or in the presence of rotator cuff arthropathy (Boudreau et al. 2007).

The main advantage of rTSA over conventional arthroplasty for patient with rotator cuff deficiencies is that it uses a semi constrained design that provides a mechanical advantage to the deltoid muscle allowing it to participate in forward elevation (Sanchez-Sotelo 2009, Boileau et al. 2005, Boileau et al. 2008). The deltoid is used as a replacement for the rotator cuff providing elevation and abduction of the shoulder (DeFranco et al. 2011). The rTSA is based on two biomechanical concepts: lowering the humerus and medialization of the centre of rotation at the glenoid component (DeFranco et al. 2011).

There is still little known about the different kinds of physical therapy after rTSA and what is the best-evidence based therapy. Boudreau et al. (2007) suggest a protocol following reverse shoulder arthroplasty. They also mention that an optimal postoperative plan of care has, to date, not yet been established (Boudreau et al. 2007), and that the physical therapist should take into consideration that the rehabilitation protocol following rTSA should be different than the protocol following TSA. This because the risk of the altered biomechanical state of the shoulder: for one after rTSA the rotator cuff is usually absent or minimally functional. Rehabilitation is focused on improving deltoid function and functional use of the arm. DeFranco et al. (2011) mention that the prosthesis improves forward elevation and abduction but there may be limitations in activity. The level of activity conducive to long-term survival of the prosthesis is unknown. In fact, there have been no definitive studies outlining the exact amount of activity, including lifting, that the reverse shoulder prosthesis can tolerate (DeFranco et al. 2011).

In the orthopaedics field there are ongoing developments concerning rTSA while still little is known about the treatment after surgery. It is important to have a rehabilitation programme, but what should the programme consist of: mostly active or mostly passive therapy? This paper is conducted to get insight in the post-operative treatment following the procedure.

The purpose of this study was to examine what the best-evidence based physical therapy treatment following rTSA is and provide a guideline for further research on this topic.

Method

To answer the question a systematic literature research was applied in search of recommended physical therapy or the best-evidence based physical therapy after the reverse total shoulder arthroplasty, rTSA. RTSA was combined with physical therapy and rehabilitation.

Literature search

The search was carried out in the following online databases; Pubmed, Cinahl and PEDro. Access to these databases was acquired through the University of Utrecht and Sharepoint of the University of Applied Science of Utrecht. Search terms used were: 'arthritis', 'shoulder', 'arthroplasty', 'prosthesis', 'physical therapy', 'rehabilitation', 'reverse', 'inverse' and 'replacement'. These terms were first searched as MESH terms. Combining 'rehabilitation' with 'physical therapy', 'arthroplasty' with 'prosthesis'. And 'inverse' with 'reverse'. These combinations were then searched adding 'arthroplasty' and 'shoulder'. General terms were used to prevent missing studies. The references of relevant articles were manually cross-referenced to ensure that all possible articles were considered.

Because of the limited amount of amount of articles initially found on treatment after rTSA another search was conducted on post-operative care after TSA and hemi-arthroplasty. For this the following search terms from the previously named items; 'inverse', 'reverse' were omitted.

Selection of articles

Found articles were first selected on title, abstract, publication date and language. From those initially selected abstracts were read to determine if the articles provided information on rTSA treatment following the operation related to physical therapy and protocol. A number of articles were identified, though most of the articles were more related to orthopaedical topics. The articles were researched on whether they had included a post-operative protocol. Of the articles on TSA and hemi-arthroplasty a physical therapy had to be compared to another kind of post-operative treatment after surgery.

Due to the lack of specific randomized controlled trials and systematic reviews all related articles that mentioned a post-operative protocol were used to provide sufficient data. The articles that didn't mention post-operative protocol were used to get more background information on this kind of operation and the indications to choose this method over others.

The initial search yielded 37 articles. Inclusion criteria were language, Dutch or English, availability of the whole article and a publication date of 2001 or later. Exclusion criteria were any other language and patients younger than 18 years old, bringing the number of articles used to 9 articles on rTSA and 4 articles on physical therapy treatment following TSA or hemi-arthroplasty.

Results

There were 9 articles on rTSA (Zumstein et al. 2011, Wierks et al. 2009, Roy et al. 2010, Cuff et al. 2008, Boileau et al. 2006, Levy (a) et al. 2007, Levy (b) et al. 2007, Golkhe et al. 2007, Boudreau et al. 2007) among them one systematic review (Zumstein et al. 2011) and one clinical commentary (Boudreau et al. 2007). Of the rTSA-related articles, 8 (Zumstein et al. 2011, Wierks et al. 2009, Roy et al. 2010, Cuff et al. 2008, Boileau et al. 2006, Levy (a) et al. 2007, Levy (b) et al. 2007, Golkhe et al. 2007) are orthopaedics related but mention a physiotherapeutic post-operative protocol and 1 (Boudreau et al. 2007) is a recommendation on a physical therapy post-operative protocol. As these articles don't show a physiotherapeutic research question only the data concerning the

post-operative physiotherapeutic protocol is distracted and shown in table 1. The complete data extraction table of these articles can be found under appendix 1.

In 4 studies an immobilizer is used for the first week (Wierks et al. 2009) up to 4 to 6 weeks with revision patients (Boileau et al. 2006) and even 6 weeks in the studies of Levy (b) et al. (2007) and Cuff et al. (2008). This is followed by 6 – 12 weeks of sling use (Wierks et al. 2009, Boileau et al. 2006, Levy (b) et al. 2007). 3 Studies mention sling use from the beginning up to 4, 6 or 12 weeks (Zumstein et al. 2011, Roy et al. 2010, Levy (a) et al. 2007).

TABLE 1: Physiotherapeutic protocol following rTSA

	Specific mention physical therapy	Population (m/f) Kind of research	Sling/brace/Immobilizer	Week 0 - 6	Week 6 - 12	Week 12 +
Zumstein et al. 2011		21 articles 782 rTSA (761 pt)	- Sling in IR (10 studies) - Brace in abd and neutral rotation (4 studies) - 3-6 weeks	1-3 weeks Unrestricted PROM 2-6 weeks start AROM		
Wierks et al. 2009	No physical therapy for first 3 months	N=20 (4/16) Age 71 (45-88) all operations performed by one surgeon.	Day 0 – 7 Shoulder immobilizer 1 – 12 weeks Sling	- P ROM of elbow - A ROM of wrist, hand - Pendulum exercises - ROM elbow	- Pendulum exercises - ROM elbow	Start physiotherapy
Roy et al. 2010		N=44 (14/30) Age 73 (---)	4-6 weeks Routine sling	Standard rehabilitation protocol		
Cuff et al. 2008		94 (31/63) Age 72(52-88)	0 – 6 weeks Immobilizer	Daily pendulum exercises.	Start PROM exercises Use in ADL.	Start strength-training shoulder.
Boileau et al. 2006		N=45 (9/36) CTA → 21 pt Age 77 (67-86) FS → 5 pt Age 72 (66-79) Revision → 19 pt Age 67 (50-87)	Simple sling. Revision pt; immobilization 4 weeks w abduction splint in 60*.	Pendulum exerc. 5 min, 5 times a day 3 weeks start physio Mobilize arm in scapular plane above horizontal level. DON'T mobilize above 90* abd. w. ext rotation. (risk of dislocation)		
Levy (a) et al. 2007	All under supervision of a physiotherapist.	N=18 (7/11) Age 72 (56-83) 19 shoulders, 18 patients	0-6 weeks Brace 6 weeks Sling	Passive Pendulum exercises	Gentle active and active-assisted activities	Start resistive exercises.

	Specific mention physical therapy	Population (m/f) Kind of research	Sling/brace/ Immobilizer	Week 0 - 6	Week 6 - 12	Week 12 +
Golkhe et al. 2007		N=34 (5/29) Age 86 (---)	6 weeks Abduction brace	PROM and AAROM exerc. incl concentric PROM. Elevation, abd, IR AAROM exercises with limit in ROM. Isometric exercises for m. deltoid.	Active exercising and strength of deltoid. With max 2 kg in hand for first 12 weeks.	
Levy (b) et al. 2007	All under supervision of a physiother- apist.	N=29 (4/25) Age 69 (42 – 80) Hemiarthro- plasty prosthesis removal	0-6 weeks Shoulder immobilizer 6 weeks Sling	Passive ROM exercises (pendulum exercises only)	Gentle active and active- assisted activities	Start resistive exercises.
Boudreau et al. 2007	Proposed rehabilitati- on protocol, divided in 4 stages ALL: -NO combined IR/ADD/EX T - NO gleno- humeral EXT beyond neutral.	7 articles (1987 to 2006) with published outcomes for patients who have undergone reverse total shoulder arthroplasty secondary to rotator cuff arthroplasty/ deficiency. Follow up between 16 – 44 months		Immediate postsurgical phase, joint - Hand, wrist, elbow exercises - PROM forward flex, elevation; slowly increase, pain- free, up to 120* in week 6. In supine. - PROM ER in scapular plane, pain-free. - submax pain- free deltoid isometrics in scapular plane - cryotherapy	AROM, Early strengthening phase - Hand, wrist, elbow strengthening exercises - PROM IR pain-free, up to 50* - Continue PROM - Start Assisted ROM/AROM from supine to sit/stand - Start light ADL use of hand (drinking/ eating)	Moderate Strengthening - enhance functional use - enhance shoulder mechanics (strength, power, endurance) - No lifting over 2.7 kg - No sudden movements 4+ months Continued Home Program - continue strength gains - Continue functional and recreational activities

* IR: internal rotation, ER: external rotation, abd: abduction, flex: flexion, ext: extension, ROM: range of motion, PROM: passive range of motion, AROM: active range of motion, AAROM: active assisted range of motion, pt: patient, ADL: activities of daily living, CTA: cuff tear arthrosis, FS: fracture sequelae.

Wierks et al. (2009) and Boudreau et al. (2007) recommend ROM exercises for elbow, wrist and hand starting in the first week. Passive ROM exercises for the shoulder are started in week 0 – 6 with pendulum exercises (Wierks et al. 2011, Cuff et al. 2008, Boileau et al 2006, Levy (a) et al. 2007, Levy (b) et al. 2007) or other PROM exercises (Zumstein et al. 2011, Golkhe et al. 2007). Cuff et al. (2008) starts other PROM exercises in week 6. Zumstein et al. (2011) starts with AROM in week 2- 6, 4 other studies (Levy (a) et al. 2007, Golkhe et al. 2007, Levy (b) et al. 2007, Boudreau et al. 2007) do AROM exercises between the 6th and 12th week. Light strengthening exercises start as early as 6 weeks (Golke et al. 2007, Boudreau et al. 2007) but most studies start at 12 weeks (Cuff et al. 2008, Levy (a) et al 2007, Levy (b) et al. 2007, Boudreau et al. 2007).

Of the TSA related articles 1 is a RCT (Agorastides et al. 2007), 2 are controlled trials (Mulieri et al. 2010, Boardman et al. 2001) and 1 is a clinical commentary (Wilcox et al.

2005). Agorastides et al. (2007) and Mulieri et al. (2010) compare protocols while Boardman et al. (2001) describes a non-comparative clinical trial and Wilcox et al. (2005) shows an authority-based protocol. All articles are rated following the guideline of the CBO [scoring A1 – D] and are described below with the highest rating above and the lowest rating below. An overview of these articles can be found in table 2.

Agorastides et al. (2007) have compared an early with a late mobilization regime after a hemi-arthroplasty after a humeral fracture and its effect on tuberosity healing, range of motion and function.

The early mobilization group started therapy with arm in a sling in combination with two weeks of pendulum and elbow exercises then progressed from the third to the sixth week exercises progressed to active-assisted exercises and from week seven moved to active exercises.

The late mobilization group had their arm in a sling for the first six weeks and only had elbow exercises. Pendulum and active-assisted therapy were done between the seventh and the twelfth week. And active exercises started at the thirteenth week.

Outcomes were tested with the constant shoulder assessment (CSA) and oxford score using a goniometer for range of motion and a digital spring balance for power. At final follow-up at 12 months Agorastides et al. (2007) have found no significant difference in the CSA and Oxford scores between the two groups though the improvement on both the CSA and Oxford score is more evident in the late mobilization group.

Mulieri et al. (2010) compare a formal physiotherapeutic therapy program (group A) with a home-based, physician directed therapy (group B) after total shoulder arthroplasty in two consecutive years.

Therapy for group A consists of 4 phases, showing a build up in activity. Phase I (0-3 weeks) has the arm in a sling except during ROM exercises of the elbow, wrist and hand, and supine passive ROM to a maximum of 20° of external rotation (ER) and 120° of elevation in the scapular plane. During phase II (4 to 6 weeks) patients progressed to resisted elbow, wrist and hand exercises. Supine active-assisted ROM (AAROM) of the shoulder with a wand, isometric shoulder exercises and closed chain kinetic shoulder exercises. In phase III the sling was discontinued. AAROM, isometrics and closed chain kinetics of the shoulders were continued, while starting supine and prone AROM in standing. Phase IV consisted of a continuation of AROM in standing and start with resistive strength and activities of daily living (ADL).

Group B had an immobilizer except during pendulum exercises bathing for the first 6-8 weeks. Then the immobilizer was discontinued and there was a start with supine and AAROM forward flex exercises, as well as encouragement in ADL use. After 14 weeks the patients were allowed to participate in any activities that comfort and confidence allowed.

Results are tested with the ASES (American Shoulder and Elbow Surgeons) score, the SST (simple shoulder test), ROM and SF-36. Results between both groups are comparable. Group B scored slightly higher in all parameters except internal rotation and abduction at final follow up.

Boardman et al. (2001) apply and evaluate a standard home-based rehabilitation protocol to assess the efficacy of the program by determining outcomes for ranges of motion in a patient population with osteoarthritis, rheumatoid arthritis, traumatic arthritis, osteonecrosis, cuff tear arthropathy and other diagnoses. Patients underwent a standardized home-based therapy program beginning on the first postoperative day, using the principles of Hughes and Neer (1975). Patients got instructions by a

TABLE 2: Physiotherapeutic protocol following TSA

TSA Auteur	Kind of research	Research Question	Population (m/f) Age	Post-operative protocol	Follow up and Results
Agorastides et al. (2007)	RCT Pedro: 6/10 CBO : A2 (or B)	Compare early vs. late mobilization regime after a hemiarthroplasty after 3 or 4 part humeral fracture and its effect on tuberosity healing, ROM and function.	N=49 (10/39) Early 26 Late 23 Age 70 (34-85)	Both with physiotherapy Early: 2 weeks: arm in sling with pendulum and elbow exercises. Wk 3-6; progress to active-assisted exercise Wk 7 onwards: active exercises. Late: 6 weeks: arm in sling in neutral rotation with elbow exercises. Wk 7 – 12; pendulum exercises to active-assisted exercises Wk 13 onwards; active exercises.	12 months No statistical difference between the groups at 6 and 12 months. Improvement slightly more evident in late mobilization group. ROM/Strength/Pain/ADL → No statistically significant differences. → ROM > 0.19 Follow up 3, 6, 12, most recent months
Mulieri et al. (2010)	CT CBO : B	Comparison of formal PT therapy vs. home-based, physician-directed therapy after TSA.	N=81 (35/46) PT: 43 Physician: 38 Age – (38 -82)	PT: - Phase I (0-3 weeks) immobilizer/sling exc during ROM of elbow, wrist and hand. Supine PROM max 20° ER, 120° elevation in scapular plane - Phase II (4-6 weeks) sling exc bathing and exercise. ROM elbow, wrist and hand. AAROM of shoulder. Isometric shoulder exercises and closed chain kinetic shoulder exercises. -Phase III (7-9 weeks) stop sling AAROM of shoulder, isometrics and closed chain kinetics continue. Supine and prone AROM of shoulder starts - Phase IV Shoulder AROM in standing, resistive strength and ADL Physician-directed - Immobilizer 6-8 weeks excl. bathing and pendulum exercises. - After 6-8 weeks, stop immobilizer, start sling for outside act. Supine and AAROM forward flex exercises. And ADL use - After 14 weeks pt. can do any activities if comfort and confidence allow.	Results between both groups are comparable. Group B scored slightly higher in all parameters except IR and abd at 3 months. Significant difference in favour of physician-directed program ROM elevation p=0.0237 ROM abduction p= 0.0298
Wilcox et al. (2005)	Clinical commentary CBO : D	Rehabilitation following total shoulder arthroplasty Provide a guideline for a post-op protocol after TSA	Nothing mentioned	REHAB in 4 phases Phase I: Immediate postsurgical phase (0-4 weeks) Phase II: Early strengthening phase (start at 4-6 weeks) Phase III: Moderate Strengthening (start at 6 weeks) Phase IV: Advanced Strengthening Phase (start at 12 weeks)	
Boardman et al. (2001)	CT CBO: C	Apply and evaluate a standard home-based rehab protocol to asses the efficacy of the program by determining outcomes for ranges of motion.	81 shoulders, N=77 (26/51) Age 65 (31-85)	Post op: shoulder immobilizer 1 week. At nights 1 month. Wk 2-4: sling in daytime. Wk 1: PROM shoulder Wk 3: start pulley exercises WK 5: start with wand and isometric strength exercises. Program based on principles of rehabilitation of Hughes and Neer (1975)	Minimum 2 year follow up Elevation ER IR Preop 84 21 sacrum Intreop 144 41 98 Post op 136 48 T12

ROM: range of motion, PROM: passive range of motion, ER: external rotation, AAROM: active-assisted range of motion, ADL: activities of daily living, flex: flexion, IR: internal rotation

physiotherapist while in the hospital. At 5 weeks they received a new set of instructions on newer exercises. A sling was worn for the first week and at night for 1 month. Starting from week one AROM of hand, wrist, forearm and elbow and PROM of the shoulder within the limits of stability. At week 3 assisted pulley exercises were added for elevation. At 5 weeks active assisted motion and stretching with a wand for flexion-extension, elevation-adduction, ER and IR at 90° abduction were started. Isometric light strengthening exercises also started at 5 weeks with slow progression to the use of elastic strap strengthening at 9 weeks.

With a minimum of 2-year follow-up all patients showed improvement in range of motion. This rehabilitation protocol can maintain shoulder motion safely after TSA, with the anticipation of better motion and tendon healing in patients with primary osteoarthritis than in other patients.

Wilcox et al. (2005) provide a guideline for a post-operative protocol following TSA based on the rehabilitation protocols of Hughes and Neer (1975), Brems (1994) and Brown et al. (1998).

The rehabilitation protocol is built up in four phases and has an added algorithm for progression in the rehabilitation program. In Phase 1, from 0 to 4 weeks, the main goals are the healing of soft tissue, maintaining the integrity of the replaced joint, gradually increasing the PROM of the shoulder and restoring the AROM of the hand, wrist and elbow, reducing pain and inflammation and gain independence in ADL with modifications. In Phase 2, week 4 to 6, the importance is laid on restoring full PROM, gradually restoring active motion, continuation of healing of soft tissue, control of pain and inflammation and re-establishing dynamic shoulder stability. Phase 3, starting at week 6, consists of gradually restoring of shoulder strength, power and endurance while optimizing neuromuscular control and gradual return to functional activities with involved upper extremity. In this phase no lifting heavier than 3 kg and no sudden lifting, jerking or pushing movements are allowed. Phase 4, starts at 12 weeks, and continues with the goals of phase 3 adding a gradual improvement of muscular strengthening, power and endurance as well as return to more advanced functional activities and progress to weight-bearing exercises.

Discussion

Even though the first rTSA was first performed in the late 80's by Grammont et al. (1987) and has since increased in popularity there is, besides the authority-based article by Boudreau et al. (2007) no published data available on the postoperative care following rTSA. As the technique is still developing there are articles on the orthopaedic related side of the intervention. In some of which there is a mention of a post-operative protocol involving physical therapy. At this time no randomized controlled trial, controlled trials or even case studies can be found on the post-operative protocol following rTSA. Therefore, literature search was broadened to other articles concerning shoulder replacement surgery as well as orthopaedic articles. Unfortunately the amount of data on orthopaedics articles on this subject was also limited. Only literature published in or after 2001 was included and then only if there was mention of a post-operative protocol.

The articles on rTSA were all of limited use concerning the postoperative protocol quoted given that they were all orthopaedics related and have little to say on the physiotherapeutic program that they prescribed. Despite their reliability for the research carried out (on the scale used by CBO) for their physiotherapy program they are all in scale D of the CBO scale (authority based) as none of them compare or explain where this protocol comes from. In the article of Roy et al. (2010) a standard

rehabilitation protocol was mentioned, but it was not mentioned if this included physical therapy or not and what the protocol consisted of. The researchers of the article by Cuff et al. (2008) were partly paid by the manufactures of the prosthesis, as were both articles by Levy (a)(b) et al. (2007). In the article by Wierks et al. (2009) they specifically mention that for the first three months there is no physical therapy. The patients do start with exercises for elbow, wrist and hand and pendulum exercises. When physical therapy starts at 3 months it is not specified which exercises this therapy includes. The article by Boudreau et al. (2007) scores a D on the CBO scale as it is authority based.

The variables of the exercises are not described in an exact way. It is not specified exactly what the exercises consist of and what the parameters are. Pendulum exercises are best specified by Boileau et al. (2006) who recommend 5 minutes each time, 5 times a day. The PROM exercises typically start between the second and sixth week, while the AROM ones typically start at the sixth week. Following the natural healing course of tissue previously mentioned build-up in program seems normal. But as the rTSA alters the normal function of the joint by lowering the humerus and medialization of the centre of rotation at the glenoid component it cannot be naturally assumed that the protocol used following hemi- or total arthroplasty is the same as for rTSA. In the rTSA design the deltoid muscle plays a vital role in the control and function of the shoulder.

Comparing the functional outcome of rTSA has been difficult due to different case histories. Boileau et al. (2006) compares the outcomes of 3 groups with different preliminary complaints. While Roy et al. (2010), Wierks et al. (2009) and Levy (a) et al. (2007) have several case histories in the same research group; Cuff et al. (2008) only has patients with rotator cuff deficiency; Golkhe et al. (2007) and Levy (b) et al. (2007) on the other hand have revision patients with failed hemiarthroplasties. There are many ways of measuring progress that makes it difficult to compare scores. Some articles noted down the ROM scores, others the ASES score or the Oxford score. There seems to be a tendency that salvation operations yield the least improvement in ROM and pain management. While an operation for arthrosis and cuff tear yields the best results, closely followed by rTSA for fracture of the humerus (Boileau et al. 2006). Boileau et al. (2006) is the only one to differentiate the results in these three groups.

Among the articles on TSA and hemiarthroplasty the article by Agorastides et al. (2007) has a score of 6 out of 10 on the PEDro score. Making it the most reliable article used for this research. Of the clinical trials the article by Mulieri et al. (2010) scores a B in the CBO scale and Boardman et al. (2001) scores a C on the same scale. The article by Wilcox et al. (2005) is a D on this scale as its authority based.

The TSA articles (Wilcox et al. 2005, Boardman et al. 2001, Mulieri et al. 2010) show a protocol set up in 4 phases and it is mentioned in 2 (Wilcox et al. 2005, Boardman et al. 2001) that this protocol is based on the protocol of Hughes and Neer (1975). The program in the early mobilisation group as described by Agorastides et al. (2007) has 3 steps that in time and load correspond with the phases described by Mulieri et al. (2010), Wilcox et al. (2005) and Boardman et al. (2001). The late mobilisation group of Agorastides et al. (2007) and the physician directed program by Mulieri et al. (2010) both start later with their protocol, starting AAROM only between week 6 to 12 instead of between week 3 to 6 as described by Boardman et al (2001), Wilcox et al. (2005) and in the early protocol of Agorastides et al. (2007). Active ROM exercises are started at 6 to 9 weeks in the protocols of Boardman et al. (2001), Wilcox et al. (2005), the early mobilisation group of Agorastides et al. (2007) and the standard protocol of Mulieri et al. (2010) compared to the late mobilisation group of Agorastides et al. (2007) and the

physician directed program of Mulieri et al. (2010) where AROM is started at 13 or 14 weeks respectively. The results, in range of motion reached, between the articles is, again, difficult to compare as the case histories are diverse and as a result a different outcome in range of motion is to be expected.

The protocols mentioned in the rTSA articles are not divided in phases; nevertheless they show a similar build-up in increase of load over time as in the TSA articles. Starting with passive range of motion exercises, like pendulum exercises, progressing to active range of motion exercises via active-assisted range of motion exercises. Strength training usually starts with isometric exercises progressing to resistive strength training.

The article by Agorastides et al. (2007) shows slightly more improvement for the late mobilization group, though the results aren't significant. Both groups in the article by Mulieri et al. (2010) have a similar outcome with slightly higher scores for the physician directed program, this program only starts with exercises from week 6 or 8 onwards and progresses in exercises only if comfort and confidence allow. It seems indicated to start with a period of rest to allow the soft tissue to heal and then slowly adding and progressing in exercises. Firstly by starting passive range of motion at the 5th to 7th day post-operatively with pendulum exercises, forward elevation, external and internal rotation starting in supine to allow the shoulder to be in an optimal relaxed position progressing to gentle pulley exercises. Shoulder exercises can possibly be done in combination with exercises for the elbow, wrist and hand. At 17 to 20 days post-operatively one can gently start strength training with isometric exercises. At 4 to 6 weeks one can start with active range of motion exercises. 6 to 8 week post-operatively early strengthening can be introduced with increased attention to the deltoid muscle. Over the entire course of the rehabilitation a close look should be kept on pain free motion.

As shoulder problematics are increasing due to an aging population, the incidence of this operation will most likely increase with it as well. More research is needed in a postoperative protocol following rTSA as it is plausible that the prevalence will increase. The function of the shoulder joint is altered and the rehabilitation should be altered accordingly. Maybe mobilisation should start sooner or later as investigated by Agorastides et al. (2007). And as the deltoid is the main mover in the rTSA shoulder with the cuff muscles being less functional or deficient it is recommended to have more specific exercises for the deltoid. Maybe a pre-operative program would be indicated, as is now often the case before total knee or hip arthroplasty.

Conclusion

As the literature on the physiotherapeutic treatment following rTSA is limited the conclusion is based on literature concerning the physiotherapeutic treatment following TSA. Wilcox et al. (2005) and Boardman et al. (2001) show an effective post-operative protocol based on the protocol of Hughes and Neer (1975). The protocols prescribed for the control groups by Agorastides et al. (2007) and Mulieri et al. (2010) also show a similar build up. Though the late mobilisation group of Agorastides et al (2007) and the physician directed group of Mulieri et al. (2010) start with therapy only at week 6 and then follow through a similar program. The best evidence-based rehabilitation protocol seems to be a program divided in phases starting with passive range of motion on to active-assisted range of motion, to active range of motion and in the last step strength training. Mostly this protocol starts in the first week postoperatively but it might be started as late as week 6 as the research by Agorastides et al. (2007) and Mulieri et al. (2010) show.

As a specific program for treatment following rTSA hasn't been researched, more research is indicated.

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Appendix 1: Data extraction table for rTSA articles.

rTSA Auteur	Kind of research	Number of patients / shoulders	Research Question	Post-operative (Physio-therapeutic) protocol	Follow up and Results
Zumstein et al. – 2011	Systematic Review CBO: A1	21 articles 782 RtSA (761 pt)	1) To determine the overall rates of problems, complications, reoperations and revisions after rTSA 2) To compare influence on the final functional outcome 3) To analyse the different problems, complications, reoperations and revisions based on the etiology of rTSA	<i>Rehabilitation protocol (as part of results, but not researched or compared)</i> - Sling in internal rotation (10 studies) - Brace in abduction and neutral rotation (4 studies) - Sling discontinued between 3 – 6 weeks - Unrestricted PROM 1-3 weeks - AROM started between 2 – 6 weeks - Strength 3 – 12 weeks	24 months <i>Results not applicable for this paper</i> <i>Results not relevant for this paper</i>
Wierks et al. – 2009	Clinical trial CBO: B Prognostic study	20 (4/16) Age 73 (45 – 88) All operations performed by one surgeon.	rTSA comparison to determine the learning curve for the procedure. Pre ok requirements: -Functional deltoid -Adequate glenoid -Proximal humeral bone quality	<i>Rehabilitation protocol (as part of results, but not researched or compared)</i> Post operative protocol, NO physical therapy for first 3 months: DAY 1 - Shoulder immobilizer - P ROM of the elbow - A ROM of wrist and hand Week 1 – 12 - Sling - Pendulum exercises - ROM elbow exercises	Minimal follow-up of 3 months <i>Results not relevant for this paper</i>
Roy et al. – 2010	Prospective study CBO: C	44 patients Mean age 73	Determine the relationship between different outcome indicators in 44 patients	<i>Rehabilitation protocol (as part of results, but not researched or compared)</i> Post-operatively, a routine sling was employed for 4-6 weeks followed by standard rehabilitation protocol.	24 months <i>Results not applicable for this paper</i>
Cuff et al. - 2008	Prospective study CBO: B/C	52-88 years Mean age 72 96 shoulders	To examine the use of reverse shoulder arthroplasty with use of a 5.0 mm peripheral locking screws for baseplate fixation and a lateralized center of rotation for the treatment of shoulders with rotator cuff deficiency	<i>Rehabilitation protocol (as part of results, but not researched or compared)</i> Physiotherapy not mentioned Week 1-6: shoulder immobilizer + daily pendulum exercises. Week 6: stop immobilizer, start passive ROM exercises + use in ADL Month 3: start strength-training shoulder.	24 months ASES score from 30 – 77.6 ASES (pain) 15 – 41.6 SST 1.8 – 6.8 Abd: 61* - 109.5* flex: 63.5* – 118* ext rot: 13.4 – 28.2
Boileau et al. - 2006	Clinical study CBO: B	45 (9/36) - CTA → 21 pt Mean age 77 (67-86) - FS → 5 pt Mean age 72 (66-79) - Revision → 19 pt Mean age 67 (50-87)	To analyse the midterm results and potential complications of the Delta prosthesis in 3 groups of patients. → CTA: massive and irreparable cuff tear arthrosis → FS: proximal humeral fracture sequelae → Revision surgery after failure of previous arthroplasty.	Simple sling. Pendulum exercises 5 min a day, 5 times a day At 3 weeks. Physio start. Mobilize arm in scapular plane above horizontal level. NOT allowed to mobilize arm above 90* abd. with ext rotation. (in risk of dislocation) Revision pt; immobilization 4 weeks w abduction splint in 60*.	3, 6, 12 months and then yearly Ant elevation CTA: 53 – 123 * FS: 56 – 122 Rev: 56 – 113 All: 55 – 121 Ext rotation CTA: 9 - 14* FS: -2 - 9

					Rev: 8 - 1 All: 7 - 11 Pain (VAS 0 - 10) CTA: 1.7 FS: 2.6 Rev: 4.5 All: 3.2 Constant score: CTA: 18 - 66 FS: 15 - 61 Rev: 15 - 46 All: 17 - 58
Levy (a) et al. - 2007	Therapeutic level	18 (7/11) Age 72 (56 - 83)	Report results of the reverse shoulder prosthesis in revision surgery for patients with an unsatisfactory outcome from a hemiarthroplasty undertaken for a rotator cuff dysfunction in the presence of glenohumeral arthritis.	Shoulder brace for 6 weeks. Passive pendular exercises start 1 day after surgery. After 6 weeks; sling Begin gentle active and active-assisted activities. 12 weeks; start resistive exercises.	Mean follow up 44 months - ASES 29.1 - 61.2 - Pain 7.3 - 2.5 - Function forward (VAS) 2. - Flex 49.7 - 76.1 - abd 42.2 - 77.2
Golkhe et al. - 2007	Opinion	34 (5/29) Age 86 (---)	Guideline to Restoration of shoulder function, if possible, pain-free by revision to an implant that provides the deltoid muscle a new fulcrum, a medialized centre of rotation with adequate pretension so that rotator cuff loss is compensated.	All under physio supervision 6 weeks post op: abd brace PROM or AAROM exercises incl. continuous passive motion. Elevation, abduction, IR active-assisted exercises with limitation in ROM. Isometric exercises for m. deltoid. From 6 th week; active exercising and strength of deltoid. With max 2 kg in hand for first 12 weeks.	31.5 months Constant score 17.5 - 63 ROM elevation 48 - 125 *
Levy (b) et al. - 2007	Level of evidence: IV, therapeutic level	29 (4/25) Age 69 (42 - 80) Hemiarthroplasty prosthesis removal	Report results of the reverse shoulder prosthesis in revision surgery for patients with an unsatisfactory outcome from a hemiarthroplasty for proximal humeral fractures associated with glenoid arthritis and rotator cuff deficiency.	First 6 weeks; Shoulder immobilizer + passive ROM exercises (pendulum exercises only) After 6 weeks; arm in sling + gentle active and active-assisted activities At 12 weeks: start resistive exercises. All under supervision of a physiotherapist.	35 months ASES: 22.3 - 52.1 ROM Forward flex: 38.1 - 72.7 Abd: 34.1 - 70.4 Ext rot; 11.2 - 17.6
Boudreau et al. - (2007)	Clinical commentary	7 articles (1987 to 2006) with published outcomes for patients who have undergone reverse total shoulder arthroplasty secondary to rotator cuff arthroplasty /	Provide a guideline for rehabilitation following rTSA	The optimal protocol for rehabilitation following rTSA has not been established yet. And more research needs to be done. rTSA as treatment for RC arthropathy seems viable. Proposed rehabilitation protocol, divided in 4 stages ALL: -NO combined IR/ADD/EXT - NO glenohumeral EXT beyond neutral. * Phase I; immediate postsurgical phase, joint protection (day 1 -	The active forward elevation and/or the constant murley measured pre- and postoperatively. Active forward elevation: 42-73 / 100 - 137 → at least 105 degrees of active forward elevation should be

Best evidence-based physical therapy treatment following rTSA.

Dieuwke Hettinga

deficiency.	week 6)	expected.
Follow up between 16 – 44 months	<ul style="list-style-type: none"> - Hand, wrist, elbow exercises - PROM forward flex,elevation; slowly increase, pain-free, upto 120* in week 6. In supine. - PROM ER in scapular plane, pain-free. - submax pain-free deloid isometrics in scapular plane - cryotherapy 	Constant score 14 – 29 / 56.7 – 69
	<p>* Phase II: AROM, Early strengthening phase (week 6 – 12)</p> <ul style="list-style-type: none"> - Hand, wrist, elbow strengthening exercises - PROM IR pain-free, upto 50* - Continue PROM - Start Assisted ROM/AROM from supine to sit/stand - Start light ADL use of hand (drinking/eating) 	The main fields to focus on rehab after RTSA are <ul style="list-style-type: none"> - Joint protection - Deltoid function - Functional and RO expectations
	<p>* Phase III: Moderate Strengthening (week 12+)</p> <ul style="list-style-type: none"> - enhance functional use - enhance shoulder mechanics (strength, power, endurance) - no lifting over 2.7 kg - no sudden movements 	risk of dislocation: IR + ADEL EXT
	<p>* Phase IV: Continued Home Program (typically 4+ months post operative)</p> <ul style="list-style-type: none"> - Continue strength gains - Continue functional and recreational activities 	

* IR: internal rotation, ER: external rotation, abd: abduction, flex: flexion, ext: extension, ROM: range of motion, PROM: passive range of motion, AROM: active range of motion, AAROM: active assisted range of motion, pt: patient, ADL: activities of daily living, CTA: cuff tear arthrosis, FS: fracture sequelae.

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