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Functional recovery and biomechanical evaluation after tumor resection in the shoulder girdle and reconstruction with a split latissimus dorsi muscle

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Funktionelles Resultat und biomechanische Untersuchungen nach Tumor-Resektion im Bereich des Schultergürtels (Fallbericht)

Zusammenfassung. *Grundlagen:* Es wird ein 20-jähriger Mann vorgestellt, der wegen eines ausgedehnten Desmoidtumors im Schulterbereich marginal reseziert worden ist und intra- und postoperativ nachbestrahlt wurde.

Methodik: Weite Teile des Schultergürtels waren von Tumorgewebe infiltriert weshalb der ventrale Teil des M. deltoideus, zwei Drittel des M. pectoralis major, der M. pectoralis minor, das Schlüsselbein und Teile der Kapsel des Schultergelenks entfernt wurden. Die Rekonstruktion der Muskelfunktion erfolgte durch einen gesplitteten M. latissimus dorsi, welcher mit Meshgraft bedeckt wurde.

Ergebnisse: 3 Jahre postoperativ ist der Mann als Bäcker voll berufstätig, lediglich die Adduktion ist durch das Fehlen des Schlüsselbeins eingeschränkt. Am Institut für Sportwissenschaft wurde die globale Schulterfunktion gemessen und das klinisch gute Ergebnis bestätigt.

Schlussfolgerungen: Ausgedehnte Tumorresektionen im Schulterbereich sind heute bei guter Planung und radikaler Durchführung der Operation mit einzeitiger Rekonstruktion und sehr früh postoperativ eingesetztem Rehabilitationsprogramm möglich. Sportmedizinische Messungen der globalen Schulterfunktion können zur Optimierung des Rehabilitationsprogramms wertvolle Hinweise liefern.

Schlüsselwörter: Tumor, Schultergürtel, Rekonstruktion, gesplitteter M. latissimus dorsi-Lappen, funktionelles Ergebnis, biomechanische Untersuchungen.

Summary. *Background:* A 20-year-old male with a large extra-abdominal fibromatosis of the left shoulder girdle underwent marginal tumor resection, postopoperative radiation therapy and reconstruction with a split latissimus dorsi flap.

Methods: Owing to the tumor involving major parts of the shoulder girdle, the clavicular part of the deltoideus and cranial parts of the pectoralis major and pectoralis minor muscle, parts of the coracobrachial muscle, the clavicle and the coracoid process had to be resected. The reconstruction of the different muscles was performed with a split latissimus dorsi muscle (LD) covered with mesh graft. The LD flap was chosen for its size, ability for compartmentalization, arc of rotation, vascularization and innervation and minimal donor-site morbidity. Owing to the marginal resection of the tumor, intra- and postoperative radiation therapy followed.

Results: The patient has regained excellent function in his left upper extremity and is able to continue his profession as a baker with the exception of adduction being weaker than the contralateral side caused by the missing clavicle.

Conclusions: The transfer of a split latissimus dorsi muscle is an effective procedure to cover defects and restore muscles with different function after extended tumor resection in the region of the shoulder girdle. The functional outcome is excellent and measurements by sport scientists are able to gain valuable results for optimizing the rehabilitation program.

Keywords: Tumor, shoulder girdle, reconstruction, split latissimus dorsi flap, functional result, biomechanical evaluation.

Introduction

Resection of large tumors, especially of the extremities, frequently results in significant functional loss, so that primary reconstruction must be considered mandatory. Extra-abdominal fibromatosis or desmoids are often lo-

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calized in the shoulder region, and radical resection results in loss of function of important muscles and/or nerves [1]. Four quarter resection or amputation, particularly in young patients, must be avoided if possible. The latissimus dorsi muscle transfer is suitable for reconstructing shoulder muscles after tumor resection for the following reasons: first, it is a muscle large enough for this specific kind of reconstruction. Second, on the basis of its anatomical characteristics, this muscle can be split into several compartments [2], while at the same time maintaining vascular supply and innervation. Third, the muscle has a large arc of rotation and finally, harvesting of this muscle is associated with minimal donor-site morbidity.

Case report

Surgical procedure

In the following, we present the case of a 20-year-old man with a huge tumor mass in the left shoulder girdle. After a biopsy was taken, histological investigation revealed the tumor to be a desmoid tumor. After given informed consent by the patient we tried to resect the tumor as radical as possible. During the operation, an $18 \times 12 \times 6$ cm tumor on the left anterior thoracic wall was excised together with the overlying skin, the excisional biopsy scar, cranial two-thirds of the pectoralis major and the pectoralis minor muscle, the lateral two-thirds of the clavicle, the proximal third of the coracobrachial muscle, the ventral half of the deltoid muscle, the coracoid process and a 4×3 cm piece of the shoulder joint capsule. Because the tumor nearly had infiltrated the joint capsule of the shoulder, we decided to run intra- and postoperative radiation therapy comprising a total dose of 60 Gy.

Primary reconstruction appeared to be meaningful in this context for preventing major loss of function. This was carried out with a split latissimus dorsi muscle (Fig. 1a–d), separated from its origin and insertion and attached only to the thoracodorsal vessels and nerve pedicle [3, 4]. It replaced the pectoralis major muscle in the cranial two-thirds and the deltoid muscle in its ventral part. The muscle itself was sutured ventrally to the ribs and caudally to the rest of the original but denervated muscle, cranially only to the fascia of the neck and the medial part of the clavicle and laterally to the humerus. The second part of the split muscle was aligned from cranial to caudal position and sutured to the rest of the deltoid muscle. The insertion-tendon of the latissimus dorsi flap was fixed onto the humerus. The muscle itself, which was revealed to have good vascular supply, was covered with a mesh skin graft harvested from the right thigh.

The postoperative course was without complications, the left upper arm was positioned into 90° of abduction with the help of a splint for a period of six weeks. Intensive physical therapy was started three weeks postoperative, and after six weeks, the abduction splint was removed. Recovery was excellent and Fig. 2a–c shows range of motion 3 years postoperative. Currently the patient shows no signs of local recurrence and is able to continue his profession as a baker.

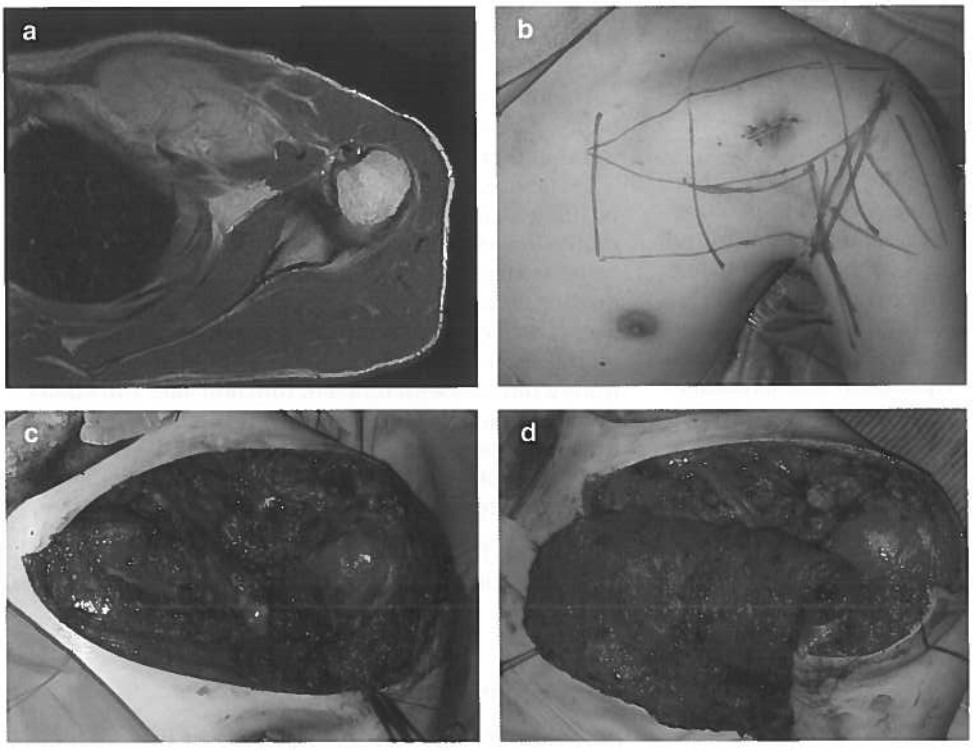

Fig. 1: (a) MRI of the huge tumor mass involving the muscles. (b) Preoperative drawing of the area to be resected, centrally located are the sutures after biopsy. (c) After resection of the tumor and 2/3 of the pectoralis and deltoid muscles. (d) Latissimus dorsi muscle after transfer and before being split in position

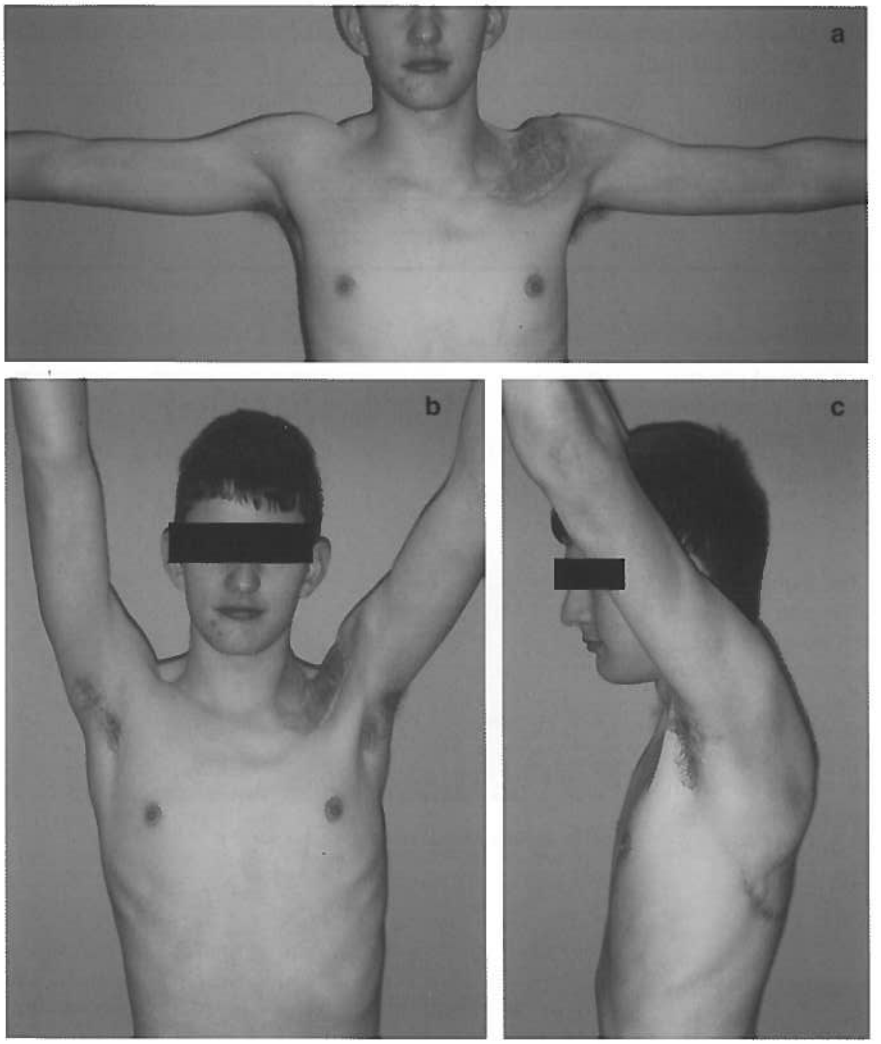

Fig. 2: Functional results postoperative

Evaluation

To quantify motor function of the shoulder [5] the patient was evaluated at the Department of Sport Science and compared to an age- and sex-matched control subject with comparable anthropometric characteristics.

Testing equipment and procedures

Two tests were accomplished, one of which was an isokinetic shoulder test on a Contrex Multi Joint (CMV, Switzerland) [6]. This device allows combined measurements of force/torque and muscular activity (EMG). The subjects lay backwards on a seat, fixed with three padded safety belts, as described by Wilk et al. [7], one of them a pelvic strap and the two others crossing diagonally at the level of the sternum. Their arms were fixed in prone position by straps at a mechanical lever in order to assure that the lever's pivot and the shoulder joint conform [8]. The subjects repeated unilateral concentric ante- and retroversion in their shoulder joint four times in rapid succession at a given speed of movement of 60°/s, with a rest period of five minutes between left and right arm movements. Maximum force should be reached as fast as possible.

The second test was on a swim pull bench – ballistic diagnosis [9]. The subjects lay face down on a board on which they moved forward by imitating a bilateral swim stroke on a rail. They were instructed to perform bilateral retroversion starting at a shoulder angle of 100° until the neutral zero position. Throughout the movement the subjects maintained a constant elbow angle of 10°. Unilateral force [N] and muscle activity were measured.

Additionally, during isokinetic and ballistic testing, muscle activation was measured using surface electromyography (MyoSystem2000, Noraxon U.S.A. Inc., AZ, USA). To ensure a minimum of impedance, skin was prepared with abrasive gel and alcohol. After the testing procedure was explained to the subjects, the origin and insertion of the observed muscles were determined [10]. Surface electrodes were placed over the deltoid and pectoralis major muscle, the upper part of the trapezoid and latissimus dorsi muscle in a belly-tendon configuration (Blue sensor short-time EMG-surface electrodes, AMBU, Germany).

Tab. 1: Comparison of isokinetic and ballistic tests

Testing procedure	Control subject			Patient		
	Left	Right	Ratio [left/right]	Left	Right	Ratio [left/right]
CON-TREX anteversion [Nm]	68.18	79.23	0.86	43.40	68.60	0.63
CON-TREX retroversion [Nm]	39.30	35.00	1.12	30.90	42.40	0.73
Swim stroke [N]	175.67	181.33	0.97	76.67	112.67	0.68

The distance between the centers of each pair of electrodes was 20 mm and electrode impedance was kept below 10 kΩ as recommended by SENIAM [11]. A ground electrode was placed over the sternum for the first and over the clavicle for the second test. EMG data were recorded and processed with MyoResearch 2000 (Noraxon U.S.A. Inc., AZ, USA).

Prior to the testing procedure, the subjects performed ten-minute gymnastics including arm rotations and swinging as well as some strengthening exercises.

The EMG data were rectified. Furthermore, data were smoothed with a root mean square of 50 ms, by accepting only data over 20% of the peak value [9, 12]. To achieve peak and mean of the sampled data, a comparison mode for isokinetic testing was used. To analyze data of the swim pull bench, the best and the worst attempts were deleted. Out of the three attempts which were left, mean force data and mean muscle activity were calculated.

Fig. 3: Isokinetic shoulder test of the patient

Results

Torque and force production by the left and the right arm as well as their ratio are shown in Table 1 for both the control and the patient.

Figures 3 and 4 show the on and offset times (intermuscular coordination) for both subjects in the isokinetic shoulder test. Intermuscular coordination during swim stroke shows that on average the patient activated the right side first. The control person did not show this kind of laterality. During this ballistic movement, the control person activated the latissimus and deltoid after the trapezoid muscle. However, the patient activated all muscles approximately at the same time.

Discussion

Successful functional muscle transfer after major tumor resection presupposes careful selection of the donor muscle [13]. On the one hand the muscle must be large

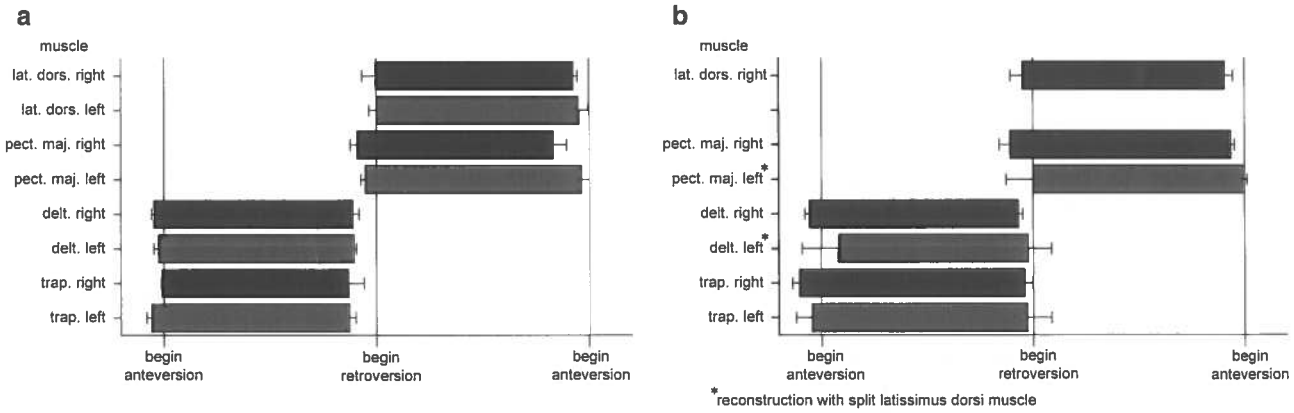

Fig. 4: (a) Control subject – intermuscular coordination during isokinetic testing. (b) Patient – intermuscular coordination during isokinetic testing

enough to do the job, and on the other hand the donor site morbidity must be kept to the minimum.

Derderian et al. [14] reported from a 25-year experience that microvascular free-tissue transfer represents a major advance in the treatment of complex traumatic defects of the upper extremity. However, only 1% of the cases they studied involved defects in the shoulder region [12]. The latissimus dorsi as donor site muscle was used in this time period only in 11% of all cases. Mordick et al. [15] showed that latissimus dorsi transfer after extensive soft tissue loss was successful in restoring active elbow flexion in a patient who returned to competitive high school volleyball thereafter. The reported strength differences in the injured versus uninjured extremity was 8–25 lb.

Using the latissimus dorsi muscle flap in the upper extremity resulted in satisfactory functional recovery [16]. But there is still a lack of scientific knowledge about strength values, imbalances and intermuscular coordination after surgery in the shoulder girdle using latissimus dorsi muscle.

In general, strength differences in normal populations or athletes can reach up to 10%, for example, in leg strength due to leg dominance or earlier leg injuries [17, 18]. It is not yet known if this is also true for shoulder or shoulder girdle strength. Our experience with athletes indicates that strength imbalances in the upper extremities are even more pronounced.

As shown in Table 1, the ratio data of the patient deviate stronger than the reference data. However, isokinetic absolute torque is comparable between the two subjects. Compared to the 20-month follow-up study of Mordick et al. [15], our patient showed less strength differences between the injured and the healthy side. A comparison is only partly possible because of the different injury area and other muscles involved in the test situation.

It was conspicuous that the patient had remarkable muscle activation in the deltoid muscle during anteversion. Also the activation of trapezoid and deltoid muscles on the right side during retroversion was noteworthy. Higher standard deviations of the patient indicate altered intermuscular coordination. Especially the reconstructed deltoid muscle showed later and inconsistent on- and offset compared to the unaffected side. EMG measurements on the swim pull bench, which are not presented in detail, showed similar activation patterns. The reason might be a different mechanical situation in the shoulder joint due to the missing clavicle.

New approaches in movement science underline individual muscle activation patterns. Comparing the healthy side in both subjects in isokinetic testing, earlier onset of muscle activation (pre-activation) is obvious. Pre-activation could be the patients' strategy to produce maximal torque.

In conclusion, the split latissimus dorsi muscle transfer used in this case proved to be an effective method of reconstructing shoulder muscles with different function after tumor resection. This difficult surgical procedure requires the patient to be highly motivated and compliant with rehabilitative effort. It is generally accepted in sport science that an effective training program should be guided by physiological assessment [5]. This principle should be included in the rehabilitation and training process of future patients.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Case Report

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Successful management of osteosynthesis infection caused by *Enterococcus faecium* after severe leg trauma*

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Erfolgreiche Behandlung einer Osteosynthese-Infektion durch *Enterococcus faecium* nach multiplen offenen Beinfrakturen

Zusammenfassung. *Grundlagen:* Infektionen von alloplastischem Material werden meist durch Staphylokokken verursacht. Enterokokken sind selten Auslöser von Infektionen nach osteosynthetischen Verfahren. *Enterococcus faecium* ist gegen viele Antibiotika resistent; Glycopeptide sind Mittel der Wahl.

Methodik: Wir berichten über einen 41-jährigen Mann, welcher im Rahmen eines Arbeitsunfalls eine drittgradig offene Quetschverletzung mit Kettenfrakturen des rechten Femurschaftes, medialen Femurkondylen, der distalen Tibia, des Mittelfußes und der Zehen erlitt.

Ergebnisse: Die Erstversorgung umfasste das Stabilisieren der Brüche mittels Fixateur externe, Fasziotomie und Debridement der Wunden und Applikation eines VAC-Systems. Am dritten posttraumatischen Tag wurde der Oberschenkelbruch osteosynthetisch durch eine LISS-Platte versorgt. Erneut wurden Gewebsnekrosen debridiert und das VAC-System gewechselt. Nach vier Wochen wurde die Haut mit einem Meshgraft-Autotransplantat gedeckt. Während der siebenten Woche kam es zu einem Ausriss der LISS-Platte, und ein neues System musste implantiert werden. Aus nekrotischem Gewebe im Bereich der Ausrissstelle wurde *Enterococcus faecium* isoliert. Eine Behandlung mit intravenösem Vancomycin wurde begonnen. Der Patient musste sich zwei weiteren chirurgischen Eingriffen mit Debridement von Nekrosen und Implantation von autologer Spongiosa und BMP 7 unterziehen. Die antibiotische Therapie wurde mit Linezolid p.o. für weitere sechs Wochen fortgeführt. Der Fixateur externe konnte entfernt werden und der Patient tolerierte moderate mechanische Belastung gut. Nach neun Wochen zeigten Röntgen und CT einen weitgehend regenerierten Oberschenkelknochen und ein gutes Ergebnis im Bereich des Sprunggelenkes. Sechs Monate im Anschluss an das komplizierte Trauma war der Patient wieder im Stande, ohne Hilfe zu gehen, und es gab keinen Hinweis für eine Neuinfektion.

Schlussfolgerungen: Die multimodale Vorgehensweise mit schrittweiser Rekonstruktion der schweren Weichteilschädigung als auch der knöchernen Verletzungen erlaubte eine Wiederherstellung mit einem guten funktionellen und kosmetischem Ergebnis. Linezolid erwies sich als effektives Antibiotikum in der oralen Therapie dieser schweren Enterokokkeninfektion.

Schlüsselwörter: Osteosynthese, Osteomyelitis, *Enterococcus fecium*, Linezolid.

Summary. *Background:* Infection of alloplastic material is usually caused by staphylococci. Enterococci rarely have been implicated in infections after osteosynthesis. *Enterococcus faecium* is resistant to most antibiotics with glycopeptides being considered the treatment of choice.

Methods: We describe the case of a 41-year-old male, who sustained a trauma during a working accident with multiple open fractures of the right femur, tibia, food and toes.

Results: Initial treatment included stabilizing the fractures using external fixation and debridement of wounds with the application of a vacuum assisted device. On the third day post trauma, the fracture was stabilized by osteosynthesis with LISS lateral and of the median

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