Title:

Functional evaluation following deltoid muscle resection in patients with soft tissue sarcoma

Running title: Functional evaluation following deltoid muscle resection

Author: Shunsuke Hamada[1], MD, PhD, Yoshihiro Nishida[1,2], MD, PhD, Keisuke Takanari[3], MD, PhD, Takehiro Ota[4], MD, PhD, Hiroshi Urakawa[1,5], MD, PhD, Kunihiro Ikuta[1,6], MD, PhD, Tomohisa Sakai[1], MD, PhD, Satoshi Tsukushi[7], MD, PhD, Yuzuru Kamei[3], MD, PhD, Naoki Ishiguro[1], MD, PhD,

[1] Department of Orthopedic Surgery, Nagoya University Graduate School and School of Medicine, Nagoya, Japan

[2] Department of Rehabilitation, Nagoya University Hospital, Nagoya, Japan

[3] Department of Plastic and Reconstructive Surgery, Nagoya University Graduate School and School of Medicine, Nagoya, Japan

[4] Department of Orthopedic Surgery, Nagoya Memorial Hospital, Nagoya, Japan

[5] Department of Clinical Oncology and Chemotherapy, Nagoya University Hospital, Nagoya, Japan

[6] Department of Genome Medical Center, Nagoya University Hospital, Nagoya, Japan

[7] Department of Orthopedic Surgery, Aichi Cancer Center Hospital, Nagoya, Japan

Present institution

Shunsuke Hamada: Department of Orthopedic Surgery, Aichi Cancer Center Hospital, Nagoya, Japan

Corresponding and reprints request to Y. Nishida, Department of Rehabilitation, Nagoya University Hospital, 65 Tsurumai, Showa, Nagoya, 466-8550, Japan

Phone: 81-52-741-2111, Fax: 81-52-744-2260, E-mail: ynishida@med.nagoya-u.ac.jp

Running Head:

Function after deltoid muscle resection

Abstract

Background: The present study aimed to determine functional outcomes in patients undergoing deltoid muscle resection for soft tissue sarcoma.

Methods: Between 2002 and 2014, 18 patients with soft tissue sarcoma of the shoulder who underwent wide resection including the deltoid muscle and were followed up for more than 12 months, were retrospectively included in the study. Eleven patients were male and 7 were female. The median age was 59 years, median follow-up duration was 37 months. The extent of resection of deltoid muscle, with or without rotator cuff damage, reconstruction methods, adjuvant therapy, oncological outcomes, and the International Society of Limb Salvage (ISOLS) score as functional outcomes were analyzed.

Results: Six patients underwent total resection, and 12 partial resections of deltoid muscle. The rotator cuff was resected in 4 patients. Soft tissue reconstruction was performed in 17 patients using a pedicled latissimus dorsi muscle flap. Two local recurrences and three distant metastases occurred during follow-up. Median overall survival was 72 months. The mean ISOLS score was 25.0 points (±4.6points). Univariate analysis revealed that there was no significant difference in ISOLS score regarding the extent of deltoid muscle resection. Multivariate analysis identified only combined resection of the rotator cuff as a significant

prognostic factor for poor functional outcomes ($p < 0.001$).

Conclusions: The extent of resection of the deltoid muscle might not affect the functional outcomes determined by ISOLS score. If the rotator cuff is resected concurrently, satisfactory functional outcomes might not be obtained.

Mini-abstract:

The functional outcome following deltoid muscle resection in patients with soft tissue sarcoma was evaluated. If the rotator cuff is resected with deltoid muscle, satisfactory functional outcomes might not be obtained.

Key words:

deltoid muscle; rotator cuff; soft tissue sarcoma; functional outcome; wide resection

Introduction

The shoulder is a wide movable joint, in other words, an unstable structure resulting

65 from a specific joint and soft tissue configuration. Because a loose joint capsule and joint
66 structure result in a limited interface of the humerus and scapula, it is the most mobile joint in
67 the human body (1, 2). The shoulder joint is a relatively common location of soft tissue
68 sarcoma, and 14–19% of the cases arise in this region among upper extremity soft tissue
69 sarcomas (3, 4). Surgical intervention with adequate excisional margins is the key to reduce
70 morbidity and mortality (4–6). At the same time, wide resection of the tumor together with
71 surrounding soft tissues often causes various degrees of functional impairment. It is difficult
72 for physicians to achieve both wide resection with adequate safe margin and preservation of
73 post-operative function of the involved extremity (3, 7). When constituents of the structure
74 need to be resected with malignant tumors, shoulder function is variously impaired, dependent
75 on the sacrificed structure. Compared to the lower extremities, particular function of the upper
76 extremity is delicate including precise movements by hands and fingers. Shoulder plays
77 significant roles in mediating the strength, and supporting the movement of hands and fingers
78 through its specific movement and stability.

79 The deltoid muscles widely locate over the shoulder joint, forming a rounded contour.
80 The deltoid is the one of the major muscle groups controlling shoulder abduction (8). In a

normal shoulder with intact musculature, the deltoid provides 50% of the elevation power in the scapular plane (9). Our hypothesis is that deltoid function is lost depending on the amount of deltoid damage, and activities of daily living (ADL) may be impaired to the same extent as with rotator cuff damage. Surgical treatment for soft tissue sarcoma of the shoulder region occasionally requires resection of deltoid muscle. However, only a few previous reports have investigated functional outcomes after deltoid muscle resection in cases of soft tissue sarcoma (1, 2, 8, 10).

The present study aimed to determine functional outcomes in patients with soft tissue sarcomas who underwent deltoid muscle resection, and identify prognostic factors for postoperative functional outcomes.

Patients and Methods

Patients

We retrospectively reviewed 26 patients with soft tissue sarcoma in the shoulder treated with wide resection including deltoid muscle, and were followed up for more than 12 months in Nagoya University Hospital and Aichi Cancer Center Hospital from 2002 to 2014.

97 The patients with well-differentiated liposarcoma (n=5) were excluded because the surgical
98 procedure for them has been resection with a marginal margin, differing from that of other
99 soft tissue sarcomas with wide resection. Patients treated with combined resection with the
100 shoulder joint (n=2) were excluded. One patient with missing postoperative data was
101 excluded. Finally, we retrospectively analyzed 18 patients. This retrospective study was
102 approved by our institutional review board (No. 2015-0358). The size of the tumor was
103 determined with preoperative imaging. The maximum diameter of imaged sections was
104 defined as the size. Superficial tumors were defined as those located above the superficial
105 fascia without invasion of the fascia.
106
107 Patient demographics
108 Characteristics and treatment options of the 18 patients are summarized in Table 1.
109 There were 11 males and 7 females, with a median (interquartile range: IQR) age of 59 (52,
110 68) years. The median (IQR) tumor size was 61.0 mm (50.5, 74.5) and this value was used as
111 the cutoff value for the analyses. It was difficult to calculate the deltoid muscle volume due to
112 the effects of tumor compression. Histological subtypes were dermatofibrosarcoma

protuberans (DFSP; 7 cases), undifferentiated pleomorphic sarcoma (UPS; 4 cases), malignant peripheral nerve sheath tumor (MPNST; 3 cases), liposarcoma (2 cases, dedifferentiated liposarcoma and pleomorphic liposarcoma each), synovial sarcoma (1 case) and extra-skeletal osteosarcoma (1 case). Neoadjuvant and/or adjuvant chemotherapy was administered to five patients. Postoperative radiation therapy was given to only one patient due to a microscopic positive surgical margin. The median (IQR) follow-up period was 37.3 (31.6, 62.3) months.

All the patients were followed up every 3-6 months by physical examination and magnetic resonance imaging (MRI) to evaluate any local recurrence. Patients underwent computed tomography of chest every 3 months until 2 years after surgery, and every 6 months thereafter.

Functional evaluation

We determined postoperative function using the International Society of Limb Salvage (ISOLS) scoring system for upper extremities at the last follow-up, which is a modification of the Musculoskeletal Tumor Society (MSTS) score and is a physician derived representative

assessment form for evaluating residual function of the affected limb after the tumor resection (11). In this score, higher overall rating (%) out of 30 points means better limb function. The respective presented data in this study was evaluated at last follow-up, in cases with local recurrence, functional evaluation was performed at the last visit before local recurrence. Clinical data were collected from the patients' clinical records. Clinical factors including gender, age (<60, ≥60 years), primary tumor size (<60, ≥60 mm), histologic type (DFSP, non-DFSP), the extent of resection of the deltoid muscle (complete, partial), resection of the rotator cuff, and radiation therapy were analyzed to evaluate the correlation with postoperative ISOLS scores. Range of motion (ROM) of active flexion and abduction was evaluated for 14 cases, in which ROM data could be extracted from medical record. Cut off point was set up on the basis of each median value. DFSP is now categorized as one of the "intermediate" tumors (12). However, our treatment modality of this tumor has been surgery with a wide surgical margin as with other high-grade sarcomas. However, wide resection often requires deltoid resection, with such cases making up the cohort of the present study. The actual extent of deltoid muscle resection was assessed by the two independent reviewers (S.H., O.T.) with postoperative MRI without patient information.

145

146 Statistical analyses

147 Overall survival rates were estimated by the Kaplan–Meier methods. Clinical
148 variables were investigated as potential prognostic factors for ISOLS score as postoperative
149 functional outcome with univariate and multivariate analyses. All statistical analyses were
150 performed using SPSS version 24 (IBM SPSS, Armonk, NY, USA). Univariate analyses were
151 performed using the Mann–Whitney U test. All variables significant ($p \leq 0.05$) with univariate
152 analyses were entered in the step of the multivariate model selection procedure. Multivariate
153 analyses were performed using multiple regression analysis, and p values of <0.05 were
154 considered to be significant.

155

156 **Results**

157 Surgical resection and reconstruction

158 Total resection of the deltoid muscle was performed in 5 patients (28%, Figure 1) and
159 partial resection in 13 (72%, Figure 2); 5 patients underwent resection of less than half the
160 deltoid muscle. Nine patients underwent resection of the anterior component mainly, and 4 of

161 the posterior component. Resection of the rotator cuff, including supraspinous muscle,
162 infraspinatus muscle and teres minor muscle, was performed in 4 patients. Soft tissue
163 reconstruction was performed in 17 patients (94%) using the pedicled latissimus dorsi muscle
164 flap. In those patients, eight patients underwent skin grafting additionally. Postoperative
165 radiotherapy was performed in one patient because of a positive surgical margin, and was not
166 performed in any of the other patients. Adjuvant chemotherapy was performed in 5 patients
167 (28%) based on considerations such as high-grade malignancy, large size, and being not elder.
168
169 Oncological outcomes
170 The median follow-up duration was 72 months (range, 12–124 months). Two local
171 recurrences and three distant metastases occurred during follow-up. Regarding two cases of
172 local recurrence, local recurrence occurred 7 months after surgery in one case, the case
173 received radiation therapy. Another case of local recurrence occurred 13 months after surgery
174 with distant metastasis, the case received chemotherapy.
175 At the final follow-up, 12 patients were continuously disease free (CDF), one was alive with
176 disease (AWD), three were dead of disease (DOD), and two were dead of other disease

177 (DOOD). The overall survival rate at 5 years was 73% (Figure 3).

178

179 Postoperative functional outcomes

180 As for the functional evaluation, the mean ISOLS score was 25.0 (±4.6) points.
181 Mean scores of each item were as follows; “pain” was 4.5 (±0.8), “function” was 3.9 (±1.1),
182 “emotional acceptance” was 3.9 (±1.1), “hand positioning” was 4.0 (±1.1), “dexterity” was
183 4.8 (±0.5), and “lifting ability” was 3.9 (±0.8) at the last follow-up. Taken together, function
184 and satisfactory and elevation scores were relatively low, whereas pain and dexterity, which
185 was considered to reflect the usefulness of the hand joints, exhibited satisfactory scores. In
186 general, the results of the functional evaluation were a plateau one year after the operation,
187 and were equivalent to the evaluation at the last follow-up.

188 Univariate analysis revealed that gender ($p = 0.050$), histological type other than
189 DFSP ($p = 0.007$), tumor size ($p = 0.016$), tumor depth (($p = 0.011$), and rotator cuff resection
190 ($p = 0.003$) were significant prognostic factors for functional outcomes (Table 2). There was
191 no significant difference in the extent of deltoid muscle resection or the presence of skin
192 grafting. Because the collinearity was clinically suggested for tumor depth and rotator cuff

resection, we performed multivariate analysis excluding tumor depth in this study. Multivariate analysis identified resection of the rotator cuff alone as a significant poor prognostic factor ($p < 0.001$) (Table 3). No significant differences in functional scores were observed in gender, histological subtype, tumor size or tumor depth.

In the 14 cases, the mean ROM of active flexion and abduction was 151 (±36) degree and 160 degree (±48), respectively. Interestingly, there was no statistical difference in ROM between total and partial deltoid resection (flexion; $p=0.744$, abduction; $p=0.746$). Whereas the mean ROM of abduction in 3 patients who undergo the rotator cuff resection (77 degree) was significantly lower than that in 11 patients who preserve rotator cuff (149 degree, $p < 0.029$) (Suppl. Table 1).

Discussion

Based on the tumor location and invasion, the extent of resected muscle varies during surgeries for soft tissue sarcoma to obtain a safe margin from the tumor. The deltoid muscle is a widespread muscle and plays multiple roles in functions such as flexion, abduction, and extension of the shoulder joint (8, 13, 14). Therefore, the deltoid muscles are occasionally

209 included within the surgical margin of soft tissue sarcoma arising in the shoulder, and these
210 resections tend to adversely affect joint function. The present study is the first to evaluate the
211 correlation between functional outcomes and various clinical factors in cases with soft tissue
212 sarcoma undergoing deltoid muscle resection. We first hypothesized that functional outcomes
213 would be influenced by the extent of the deltoid muscle resection. However, this parameter
214 did not affect the functional outcomes significantly, while, in addition to deltoid muscle
215 resection, rotator cuff resection was the only independent prognostic factor for poor functional
216 outcomes with inferior ROM in this study.

217 In the oncological field of soft tissue sarcomas around shoulder, deltoid muscles
218 occasionally need to be resected combined with tumors. Considering that combined
219 dysfunction of the deltoid muscle and rotator cuff may worsen its biomechanical function and
220 stability, preservation of rotator cuff is crucial to maintain the biomechanical function and
221 stability in surgeries of soft tissue sarcomas, particularly in surgeries of deltoid muscle
222 resection required. A few reports have highlighted the relationship of the deltoid muscle and
223 rotator cuff for shoulder function. Highet et al. evaluated the effect of either deltoid or
224 supraspinatus paralysis on the abductor strength under each isolated nerve block (15). He

225 reported that full active abduction was preserved in case of compete paralysis of deltoid
226 muscle, although the paralysis of supraspinatus caused the severely damage of active
227 abduction. This result is consistent with our results that the extent of resection of the deltoid
228 muscle did not affect the functional outcomes significantly unless rotator cuff is resected
229 concurrently.

230 In musculoskeletal oncology, several reports regarding the function after deltoid
231 muscle resection have been published (1, 2, 8, 10). Mimata et al. reported on the limb
232 function of 8 patients after surgery for deltoid muscle sarcoma (10). The mean ISOLS score of
233 their population was 81% in the total / subtotal resection group and 100% in the partial
234 resection group. They suggested that shoulder function depended on the residual deltoid
235 muscle volume of the affected shoulder, which is inconsistent with the results of our study in
236 which the amount of residual deltoid muscle was not significantly related to functional
237 outcome. To evaluate the volume in detail may have made the results of the previous report
238 and this study not conflictable. Other reports based on small numbers of cases demonstrated
239 similar results to those in the present study that showed that resection of deltoid muscle does
240 not affect functional outcomes of the shoulder. Markhede et al. stated that muscle strength

241 reduction did not exceed 40% in any direction after deltoid resection based on 5 cases
242 analyzed (8). They speculated that the remaining muscle, such as the rotator cuff, may have
243 hypertrophied during follow-up. Muramatsu et al. also stated that resecting the entire deltoid
244 muscle resulted in slight impairment of function in 4 cases (2). The present study analyzed 18
245 cases, the largest number of cases ever, and exhibited a slight difference in the mean ISOLS
246 score between a complete resection group (76.7%) and partial resection group (87.5%). A
247 larger cohort might demonstrate greater differences in functional outcomes. In addition to
248 deltoid muscle resection, rotator cuff resection was the only independent prognostic factor for
249 poor postoperative function in the present study. Previous reports did not investigate the
250 relationship between the shoulder function and rotator cuff damage in addition to that of
251 deltoid muscle (2, 7, 8). Khruekarnchana et al reported two cases of desmoid tumor of
252 shoulder, and concluded that shoulder function may be preserved if only one of the force
253 couple is disrupted; in other words, if both deltoid and rotator cuff are damaged, the involved
254 shoulder function will be impaired (1). The loss of compensative muscle force for the deltoid
255 muscle, induces functional instability and instability pain (16).

256 We did not take axillary nerve status into account for functional evaluation, which is

257 critical for deltoid muscle function (17, 18). The axially nerve enters quadrangular space to
258 posterior section, and commonly branches on the posterior border of deltoid muscle (17).
259 Although we did not evaluate axially nerve resection in this study because of the insufficiency
260 data, there is a possibility that functional outcome of the four cases who underwent resection
261 of posterior component might have equivalent function to that of the case with total resection
262 of deltoid, due to the possible resection of axillary nerve.

263 Soft tissue reconstruction is necessary for extensive defects after wide resection.
264 Particularly, highly mobile joints such as the shoulder should be covered by stable and durable
265 soft tissue to avoid motion limitation (19). Several methods of reconstruction after excision of
266 the deltoid muscle have been reported, such as a pedicled latissimus dorsi musculcutaneous
267 (LD) flap, a pedicled trapezius musculocutaneous flap, and a pedicled pectoral major
268 musculocutaneous flap (10). In this cohort, most cases underwent reconstruction using the LD
269 flap, which is generally used after resection of shoulder sarcoma surgery because of its
270 technical reliability and good functional outcome (2, 10, 19). Functional reconstruction using
271 LD flap has been reported (2, 20). Muramatsu et al. reported functional neuro-pedicled
272 reconstruction of LD after complete resection of the deltoid muscle following complete

resection (2). However, any additional contribution of neuro-pedicled LD flap reconstruction for post-operative shoulder is not determined because of the favorable functional outcomes with non-functional LD flap reconstruction after total deltoid resection (1, 8). In cases with combined resection of the rotator cuff with deltoid muscle, functional LD flap reconstruction might be more beneficial. Other clinical variables were not found to be significant prognostic factors. DFSP, which was the major histological subtype in this study, is a superficial sarcoma characterized by an infiltrative pattern along connective tissue planes, often arising in the shoulder region (21, 22). In cases of DFSP, although the superficial deltoid muscle is resected with tumors, muscles of deep layer, rotator cuff, are preserved, with favorable shoulder function obtained post-operatively.

Adjuvant radiation therapy was performed in only one patient, and so its impact on functional outcomes including the risk of joint contracture, could not be evaluated in the present study. In our treatment modality adjuvant radiotherapy is not administered provided that a microscopic negative surgical margin is obtained. Recent studies have shown that preoperative radiation therapy allowed a close surgical margin for soft tissue sarcoma, because the quantitative width of the negative margin did not significantly influence the

289 oncological outcome (23, 24). Resection with close margins with radiotherapy may minimize
290 muscle excision and improve functional outcomes.

291 There were several limitations in our study. First, our cohort size was small and the
292 statistical power may have been insufficient for a detailed analysis of prognostic factors
293 related to functional outcomes. However, compared with previous reports (1, 2, 8, 10), the
294 cohort of 18 cases in the present study represents the largest study of cases with soft tissue
295 sarcoma requiring deltoid muscle resection. Second, we did not analyze the association of
296 deltoid muscle resection area with the precise range of motion in each direction. The deltoid
297 muscle is composed of three parts: the anterior deltoid, lateral deltoid, and posterior deltoid,
298 and is responsible for 57% of the shoulder abduction torque, 49% of the flexion, and 15% of
299 the extension (8, 25). Resection of a different part may yield different functional outcomes,
300 despite equivalent resection volume of deltoid muscle. However, the functional evaluation
301 method of the present study could not detect the difference in shoulder function due to
302 differences in deltoid muscle resection and its strength. Third, we evaluated postoperative
303 function using only ISOLS score. The ISOLS scoring system for the upper arm is widely used
304 as a disease-specific evaluation tool for assessing physical function in patients with

musculoskeletal tumors, however, may not strictly reflect the precise function of cases with deltoid muscle resection. It has been used for functional evaluation in musculoskeletal oncology, although other shoulder specific functional scores may need to be applied such as Simple Shoulder Test (SST), University of California at Los Angeles (UCLA) Shoulder, Constant, and Shoulder Pain and Disability Index (SPADI) scores (26–28).

Conclusions

In conclusion, we evaluated the functional outcomes of patients with soft tissue sarcoma who underwent deltoid muscle resection. Total resection of the deltoid muscle may allow satisfactory functional outcomes, although further evaluation in larger population is required. Combination resection of rotator cuff was the prognostic factor for poor functional outcomes.

Acknowledgements

We thank Ms Eri Ishihara for her valuable secretarial assistance with this study.

321

322 ***Funding***

323 There are no potential conflicts of interest with regard to this work.

324

325 **References**

326 1. Khruekarnchana P, Suzuki K, Fukuda H. Shoulder function after subtotal excision of the
327 deltoid muscle and of the deltoid and infraspinatus muscles in extra-abdominal desmoid
328 tumor: A long-term follow-up in two cases. J Shoulder Elb Surg. 2004;13:119–22.

329 2. Muramatsu K, Ihara K, Tominaga Y, Hashimoto T, Taguchi T. Functional reconstruction
330 of the deltoid muscle following complete resection of musculoskeletal sarcoma. J Plast
331 Reconstr Aesthet Surg. 2014;67:916–20.

332 3. Collin C, Hajdu SI, Godbold J, Friedrich C, Brennan MF. Localized operable soft tissue
333 sarcoma of the upper extremity. Presentation, management, and factors affecting local
334 recurrence in 108 patients. Ann Surg. 1987;205:331–9.

335 4. Forsberg JA, Healey JH, Brennan MF. A probabilistic analysis of completely excised
336 high-grade soft tissue sarcomas of the extremity: an application of a Bayesian belief network.

337 Ann Surg Oncol. 2012;19:2992–3001.

338 5. Gronchi A, Colombo C, Raut CP. Surgical management of localized soft tissue tumors.

339 Cancer. 2014;120:2638–48.

340 6. Maretty-Nielsen K, Aggerholm-Pedersen N, Safwat A, et al. Prognostic factors for local

341 recurrence and mortality in adult soft tissue sarcoma of the extremities and trunk wall. Acta

342 Orthop. 2014;85:323–32.

343 7. Lohman RF, Nabawi AS, Reece GP, Pollock RE, Evans GRD. Soft tissue sarcoma of the

344 upper extremity: A 5-year experience at two institutions emphasizing the role of soft tissue

345 flap reconstruction. Cancer. 2002;94:2256–64.

346 8. Markhede G, Monastyrski J, Stener B. Shoulder function after deltoid muscle removal.

347 Acta Orthop Scand. 1985;56:242–4.

348 9. Allen AA, Drakos MC. Partial detachment of the deltoid muscle. A case report. Am J

349 Sports Med. 2002;30:133–4.

350 10. Mimata Y, Nishida J, Gotoh M, Akasaka T, Shimamura T. Limb function after excision of

351 a deltoid muscle sarcoma. J Shoulder Elbow Surg. 2013;22:e1-5.

352 11. Enneking WF, Dunham W, Gebhardt MC, Malawar M, Pritchard DJ. A system for the

353 functional evaluation of reconstructive procedures after surgical treatment of tumors of the
354 musculoskeletal system. Clin Orthop Relat Res. 1993;:241–6.
355 12. Fletcher CDM, Bridge JA, Hogendoorn PCW MF. WHOClassification of Tumours of
356 Soft Tissue and Bone. Pathology and Genetics of Tumours of Soft Tissue and Bone. 4th ed.
357 Lyon; 2013.
358 13. Arteau A, Seeli F, Fuchs B. Complete deltoid resection in early childhood without muscle
359 transfer results in normal shoulder function at long-term follow-up: a case report. J Med Case
360 Rep. 2017;11:13.
361 14. Yoon JP, Seo A, Kim JJ, et al. Deltoid muscle volume affects clinical outcome of reverse
362 total shoulder arthroplasty in patients with cuff tear arthropathy or irreparable cuff tears. PLoS
363 One. 2017;12:1–14.
364 15. Highet, W. B. Procaine Nerve Block in the Investigation of Peripheral Nerve Injuries. J.
365 Neurol. Neurosurg. Psychiatry 1942; 5:101–116.
366 16. Hsu HC, Luo ZP, Cofield RH, An KN. Influence of rotator cuff tearing on glenohumeral
367 stability. J Shoulder Elbow Surg. 1997;6:413–22.
368 17. Zhao X, Hung LK, Zhang GM, Lao J. Applied anatomy of the axillary nerve for selective

neurotization of the deltoid muscle. Clin Orthop Relat Res. 2001;:244–51.

18. Loukas M, Grabska J, Tubbs RS, Apaydin N, Jordan R. Mapping the axillary nerve within the deltoid muscle. Surg Radiol Anat. 2009;31:43–7.

19. Kim JS, Lee JS, Yoon JO, Park JB. Reconstruction of the shoulder region using a pedicled latissimus dorsi flap after resection of soft tissue due to sarcoma. J Plast Reconstr Aesthetic Surg. 2009;62:1215–8.

20. Pruzansky M, Kelly M, Weinberg H. Latissimus dorsi musculocutaneous flap for elbow extension. J Surg Oncol. 1991;47:62–6.

21. Farma JM, Ammori JB, Zager JS, et al. Dermatofibrosarcoma protuberans: how wide should we resect? Ann Surg Oncol. 2010;17:2112–8.

22. Fields RC, Hameed M, Qin L-X, et al. Dermatofibrosarcoma protuberans (DFSP): predictors of recurrence and the use of systemic therapy. Ann Surg Oncol. 2011;18:328–36.

23. Ahmad R, Jacobson A, Hornicek F, et al. The Width of the Surgical Margin Does Not Influence Outcomes in Extremity and Truncal Soft Tissue Sarcoma Treated With Radiotherapy. Oncologist. 2016;21:1269–76.

24. Gronchi A, Verderio P, De Paoli A, et al. Quality of surgery and neoadjuvant combined

therapy in the ISG-GEIS trial on soft tissue sarcomas of limbs and trunk wall. Ann Oncol. 2013;24:817–23.

25. Ackland DC, Pak P, Richardson M, Pandy MG. Moment arms of the muscles crossing the anatomical shoulder. J Anat. 2008;213:383–90.

26. Marchese C, Cristalli G, Pichi B, et al. Italian cross-cultural adaptation and validation of three different scales for the evaluation of shoulder pain and dysfunction after neck dissection. Acta Otorhinolaryngol Ital. 2012;32:12–7.

27. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. Arthritis Care Res. 1991;4:143–9.

28. Simovitch RW, Friedman RJ, Cheung E V, et al. Rate of Improvement in Clinical Outcomes with Anatomic and Reverse Total Shoulder Arthroplasty. J Bone Joint Surg Am.

Figure legends

401 Figure 1. Twenty-nine year-old woman with MPNST arising in the left shoulder. Complete
402 resection of deltoid muscle including rotator cuff and reconstruction using a latissimus dorsi
403 muscle flap was performed. (A) A T2-weighted axial MRI before surgery. (B) A T2-weighted
404 axial MRI after surgery.
405
406 Figure 2. Fifty-five year-old woman with DFSP arising in the left anterior shoulder. Partial
407 resection of the anterior component of deltoid muscle and reconstruction using a latissimus
408 dorsi muscle flap was performed. (A) A T2-weighted axial MRI before surgery. (B) A
409 T2-weighted axial MRI after surgery.
410
411 Figure 3. Post-operative overall survival in patients with soft tissue sarcoma arising in
412 shoulder region (n=18). The graph shows the cumulative post-operative overall survival using
413 the Kaplan-Meier estimated methods.

Table 1. Patient characteristics

Characteristics	Value
Gender, n (%)	
Male	11 (61)
Female	7 (39)
Median age, years (range)	59 (22-83)
Median size, mm (range)	61.0 (13-157)
Histological subtype, n (%)	
DFSP	7 (39)
UPS	4 (22)
MPNST	3 (16)
Liposarcoma	2 (11)
Others	2 (11)
Radiation therapy, n (%)	
Postoperative	1 (6)
None	17 (94)
Adjuvant chemotherapy, n (%)	
Yes	5 (28%)
No	13 (72%)
Median follow up, months (range)	37 (12-124)

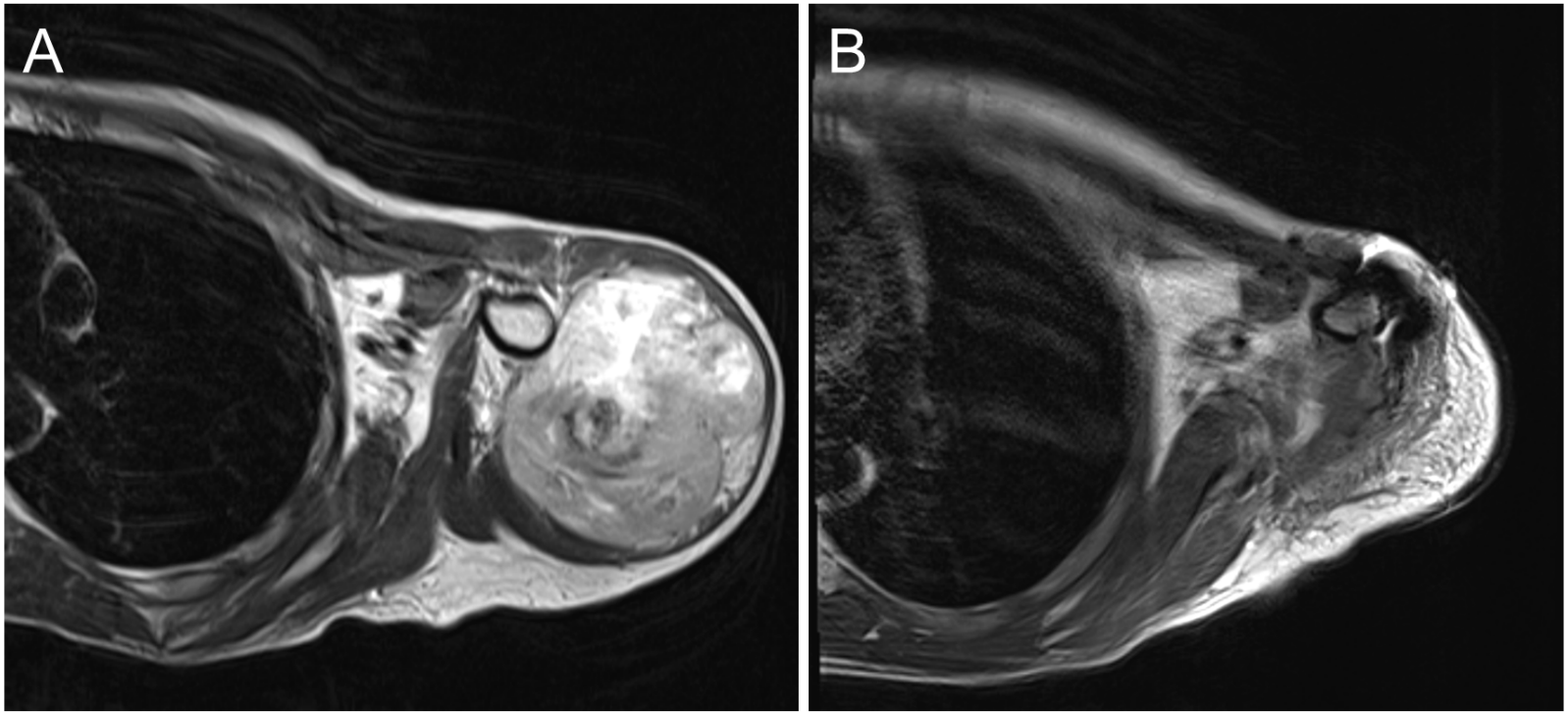
DFSP, Dermatofibrosarcoma protuberans; UPS, undifferentiated pleomorphic sarcoma; MPNST, Malignant Peripheral Nerve Sheath Tumor

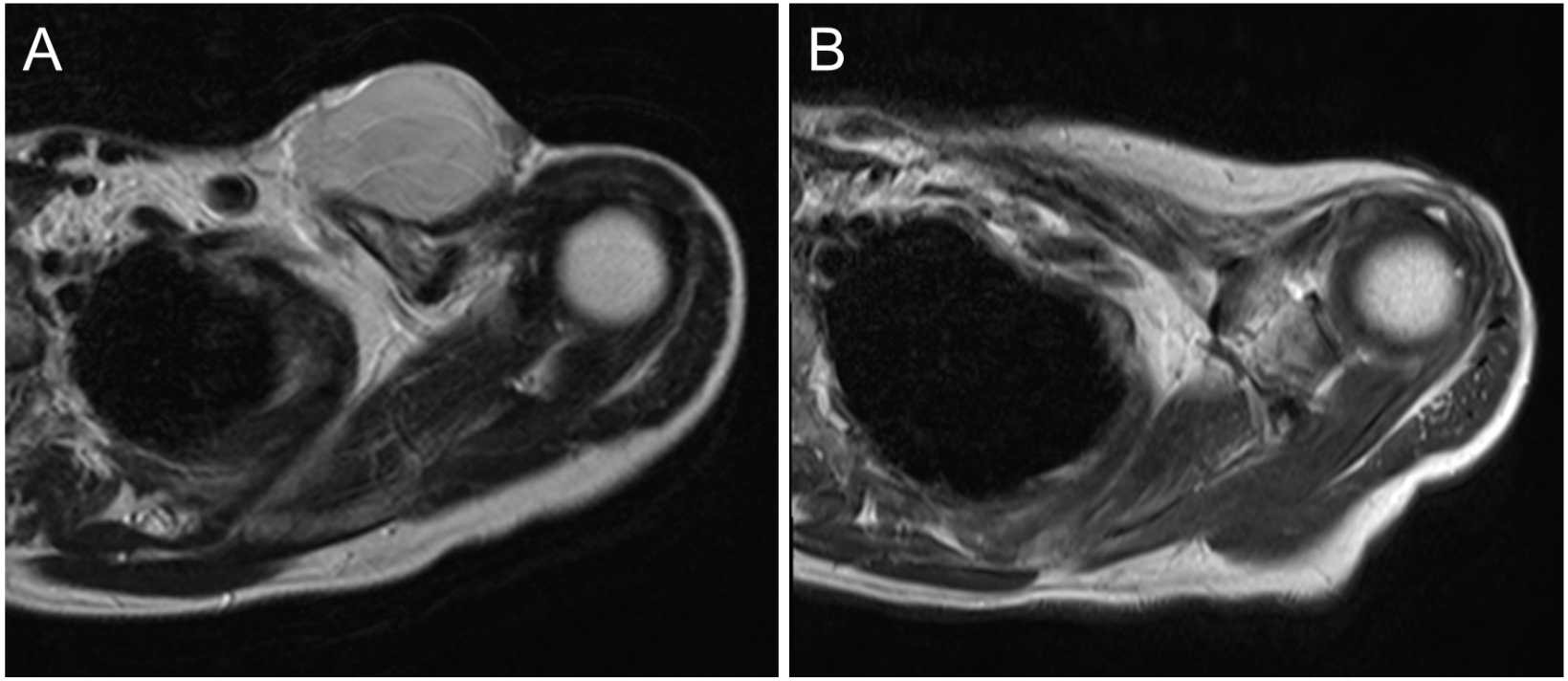
Table 2. Univariate analysis for ISOLS score

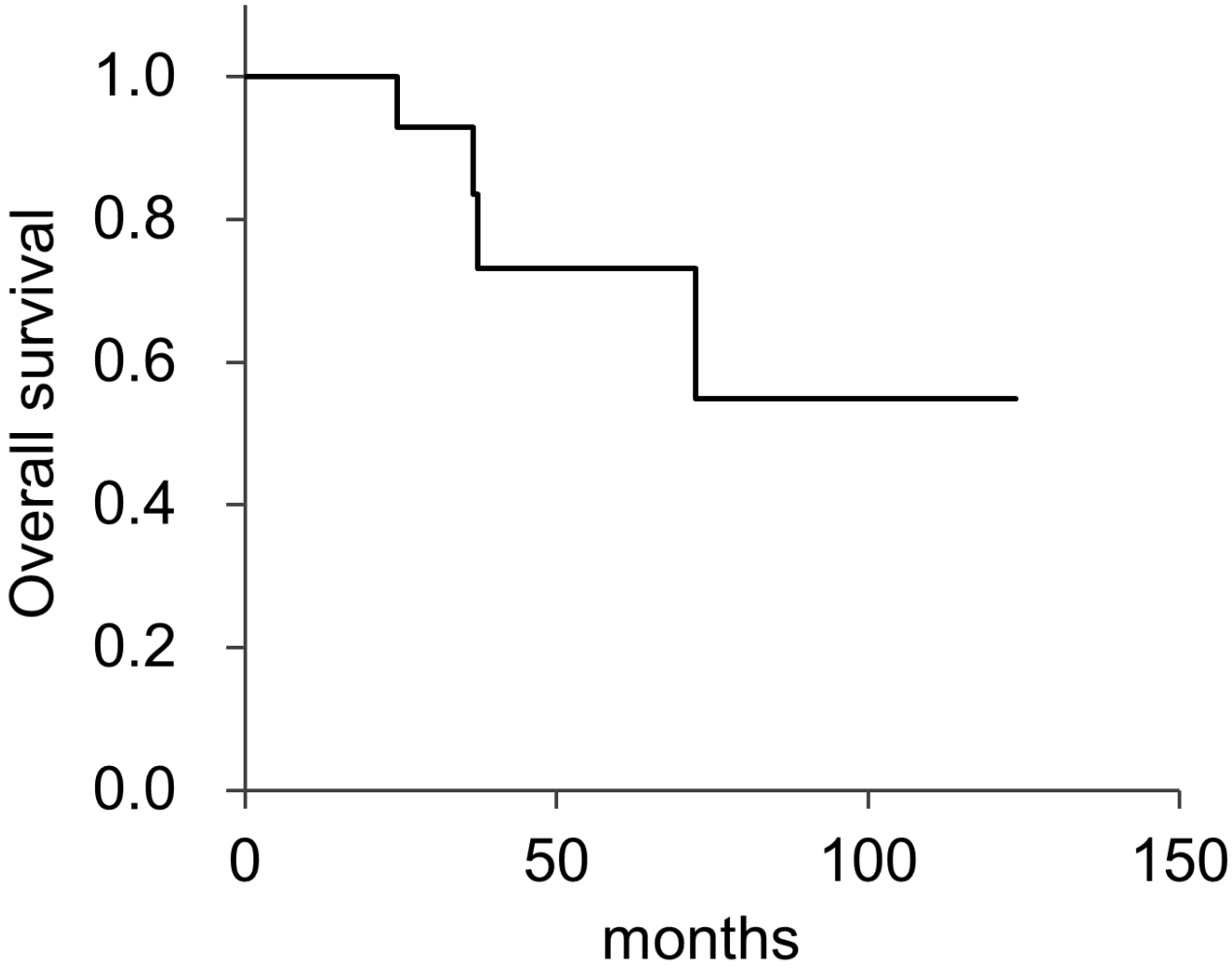
Variables		N	Average score	P value
Gender	Male	11	23.8	0.050
	Female	7	27.3	
Age, years	<60	10	25.5	0.929
	>60	8	24.8	
Histological subtype	DFSP	7	28.4	0.007
	Others	11	23.1	
Tumor size, mm	<60	10	28.0	0.016
	>60	8	21.6	
Tumor depth	Superficial	9	27.9	0.011
	Deep	9	22.4	
Resection of deltoid muscle	Complete	5	22.8	0.214
	Partial	13	26.1	
rotor cuff resection	Yes	4	17.8	0.003
	No	14	27.3	
Skin grafting	Yes	8	23.9	0.263
	No	10	26.2	

Table 3. Multivariate analysis for ISOLS score

Variables		N	95%CI	P value
Gender	Male	11	(-1.891, 4.153)	0.431
	Female	7		
Histological subtype	DFSP	7	(-3.136, 4.709)	0.669
	Others	11		
Tumor size, mm	<60	10	(-5.646, 2.761)	0.469
	>60	8		
Tumor depth	Superficial	9	(-4.410, 2.776)	0.629
	Deep	9		
rotor cuff resection	Yes	4	(-12.059, -4.163)	<0.001
	No	14		


A
B


A
B


Overall survival
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
months