BLEEDING FROM THE HUMERAL HEAD INDUCES BONE-MARROW DERIVED CELLS TO REPAIR TENDON AFTER ROTATOR CUFF REPAIR

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In rotator cuff repair, the influx of mesenchymal cells from the blood supply to the tendon-to-bone insertion is essential for tendon healing. However, the kinetics and the role of these cells from the bone marrow have not been clarified. To reveal the spatiotemporal characteristics of the reparative cells from the blood supply, we used green fluorescent protein (GFP) bone marrow chimeric rats expressing GFP only in the circulation and bone marrow cells. Using these chimeric rats, a bilateral supraspinatus repair model was created, and additional drilling to induce bleeding from the bone marrow was performed on the tendon insertion of one side of the shoulders. Then the ratio of GFP-positive cells at the tendon repair site (N = 3) and the healing process (histology [N = 3], biomechanics [N = 7]) of the bilateral shoulder specimens were analyzed at 2, 4, and 8 weeks after surgery. The ratio of bone marrow-derived cells at the repair site was significantly higher in the drilling side at 4 and 8 weeks (P < .05). Histologically, the tendon maturing score was higher in the drilling side at 8 weeks (P < .05). The ultimate failure to form the specimens from the drilling side was significantly greater than the non-drilling side at 4 and 8 weeks (P < .05). These findings suggest that bone marrow-derived cells from humeral bone play an important role in rotator cuff healing after surgical repair.

ANALYSIS OF HUMAN ROTATOR CUFF DERIVED CELLS WITH MULTILINEAGE DIFFERENTIATION POTENTIAL

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To prevent re-tear of the rotator cuff, it is important to regenerate the tendon-to-bone interface after rotator cuff repair. Therefore, we targeted the cells from the torn human rotator cuff and investigated whether they have the potency for multilineage mesenchymal differentiation in vitro. The edges of the rotator cuff were harvested from patients who underwent arthroscopic rotator cuff repair, minced into pieces and cultured in a monolayer. We performed flow cytometric analyses to analyze cell surface markers. To induce multilineage differentiation, the cells were cultured in the osteogenic, adipogenic and chondrogenic differentiation media for 3 weeks. Then they were analyzed by histology, immunohistochemistry, and RT-PCR analyses. In flow cytometric analyses the cells were positive for MSC-related markers; CD29, CD44, CD105 and CD166. On the other hand, the cells were negative for hematopoietic-lineage markers; CD14, CD45 and CD133. After 3 weeks of differentiation culture the cells showed an osteogenic, adipogenic and chondrogenic potential as evidenced by the immunohistochemistry and RT-PCR analyses. This study showed that cells derived from a torn human rotator cuff have the capacity for multilineage mesenchymal differentiation. These results could pave the way for tendon neof ormation and regeneration using progenitor cells. The ability to generate bone-ligament interface is specifically of great importance, as it can be useful in healing torn tendons that require reattachment to bone. Further investigations of the mechanism of tenogenesis are necessary to find out its usefulness.

BEHAVIOR AND PAIN ASSESSMENT IN THE RAT’S ROTATOR CUFF TEAR MODEL

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The purpose of this study was to evaluate the behavior and the inflammatory cytokines (TNF-α) in the rotator cuff tear model. Twenty-five Sprague-Dawley rats were divided into four groups: 1, control (before experiment); 2, sham; 3, rotator cuff tear (RCT); and 4, rotator cuff repair (RCR) groups. Stride Length was examined using cat walk as a behavioral evaluation. Moreover, inflammatory cytokine was measured in the synovia of the sub acromial bursa and the glenohumeral joint at 3 and 8 weeks after the surgery using the ELISA method. Stride length in the RCT group was decreased at 3 days, 1, 2 and 3 weeks after the surgery compared with the control group (P < .05). On the other hand, stride length in the RCR group was increased only 3 days after the surgery with the control group (P < .05). TNF-α in the RCT group was increased compared with the Control and RCR group (P < .05). This data shows that the repair of the rotator cuff was effective in not only the improvement of the shoulder function but also the reduction of the inflammatory cytokines (TNF-α). The data also showed that the inflammatory cytokines (TNF-α) may be one of the pain mechanisms in a rotator cuff tear.

DIFFERENCE IN ELASTICITY OF THE ROTATOR CUFF TENDON BETWEEN HEALTHY YOUNG, AND ELDERLY INDIVIDUALS

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Real-time tissue elastography (RTE), a newly introduced ultrasound technique to evaluate tissue elasticity, has been widely used to make a diagnosis of breast and thyroid cancer. We investigated the difference between the elasticity of the rotator cuff tendons in healthy, young and elderly volunteers with the use of RTE. The rotator cuff tendons of 60 shoulders from 31 healthy volunteers (young group: mean age, 29 years old) and 34 shoulders from 24 healthy volunteers (elderly group: mean age, 70 years old) without any shoulder symptoms were examined using a linear-array transducer (Hitvision Avius, HITACHI). The elasticity of the superficial layer and deep layer of the supraspinatus and infraspinatus tendons was measured with a newly developed coupler with known elasticity. Strain of the tissue was calculated from the color changes on the longitudinal images. The ratio of the tendon strain divided by the coupler strain (strain ratio) was compared between the tendons. The strain ratios of the deep layer were significantly smaller than
those of the superficial layer in both groups (P < .001). Between the groups, there was no difference in the strain ratio of the superficial layers, but the elderly group showed a tendency, though not significant, of a lower strain ratio in the deep layers. The superficial layer of the rotator cuff tendon is more deformable than the deep layer. Rotator cuff tear may be related to the difference in material properties of the superficial and deep layers of the tendon.

5 REGENERATION OF ROTATOR CUFF USING POLY (DL-LACTIDE-CO-GLYCOLIDE) SHEET IN A RABBIT MODEL
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We previously reported the application of novel poly (DL-lactide-co-glycolide) (PLG) scaffolds in osteochondral defect model. In this study, the PLG scaffold was transplanted into rotator cuff defects and evaluated in a rabbit model. General anesthesia was administered to female Japanese white rabbits. The infraspinatus tendon was less than normal infraspinatus tendon at each time point. Thus, and the 8 weeks, and 16 weeks postoperative groups. The stiffness load of the scaffold-humeral head complex was 28.1N at 4 weeks, 28.1N at 4 weeks, and 28.1N at 4 weeks postoperatively using H-E staining and immunostaining of type I, II, and III collagen. The scaffold-humeral head complex was also evaluated mechanically. Microscopically, scaffold fiber remained without dissolution and spindle shaped cells were observed inside the scaffold at 4 weeks postoperatively. At postoperative 8 weeks, PLG scaffold had dissolved. At 16 weeks, linear cell alignment resembling normal enthesis was observed at the scaffold-bone interface. Immunostaining showed type I collagen expression in the tendon area and type II collagen in the enthesis area. The ultimate failure load of the scaffold-humeral head complex was 28.1N at 4 weeks, 71.7N at 8 weeks and 75.3N at 16 weeks postoperatively. There was no statistical difference between normal infraspinatus tendon and the 8 weeks, and 16 weeks postoperative groups. The stiffness was less than normal infraspinatus tendon at each time point. Thus, the novel PLG scaffold has potential for regeneration of rotator cuff defects without using growth factors and cultured cells.

6 REGENERATION OF ROTATOR CUFF TENDON-TO-BONE JUNCTION BY ACELLULAR MATRIX BIOSCAFFOLD COMBINED WITH LOCALLY APPLIED FGF-2
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Management of massive rotator cuff defects is a difficult problem. The purpose of this study was to investigate the histological and molecular biological effect of the local application of fibroblast growth factor (FGF-2) on regeneration and remodeling of rotator cuff tendon defects reconstructed with acellular matrix bioscaffold (AMB) grafts in rats. Adult male Sprague-Dawley rats were assigned to equal groups of FGF-treated and untreated reconstructions. All rats underwent an AMB graft (GraftJacket, Wright med) for a supraspinatus defect (3mm x 5 mm). FGF-2 (100 μg/kg) in a fibrin sealant was applied to both shoulders of the FGF-treated group, while only fibrin sealant was applied to the untreated group. Rats in each group were sacrificed at 2, 6, and 12 weeks after surgery, for histological analysis using tendon-to-bone maturing scores, proliferating cell nuclear antigen (PCNA) assay, and quantitative real-time RT-PCR. In 2 weeks, FGF-treated group had similar tendon-to-bone maturing scores as the untreated group, but many more PCNA positive cells and much higher mRNA levels of col1 and col3 (P < .05). At 6 and 12 weeks, the FGF-treated group had significantly higher tendon-to-bone maturing scores than the untreated group (P < .05) and similar mRNA levels of col1 and col3. The histological remodeling of AMB grafts placed in rat rotator cuff defects was accelerated by the local administration of FGF-2 due to increasing gene expression of col1 and col3. Clinically, the histology and biomechanical strengths in AMB graft constructs may be improved by the local administration of FGF-2 at rotator at the time of cuff reconstruction.

7 ATTACHMENT OF THE INFERIOR GLENOHUMERAL LIGAMENT-LABRUM COMPLEX TO THE GLENOID: AN ANATOMICAL STUDY—PART II
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The exact attachment of the inferior glenohumeral ligament-labrum complex (IGHL-LC) has not been studied yet. The purpose of this study was to assess it histologically. Fifty five cadaveric shoulders (mean age, 81 years old) were investigated histologically. Cross-sections were made in a radial fashion at 2 and 4 o’clock and the width of the IGHLLC attachment was measured. The attachment of the IGHL-LC had an origin from both the articular cartilage of the glenoid and the scapular neck in all shoulders. There were three types of attachment: bone type which mainly had its origin from the bone, cartilage type which mainly had its origin from the articular cartilage, and the middle type which originated from bone and cartilage equally. At 2 o’clock, 19 shoulders (39%) were bone type, 21 shoulders (43%) were cartilage type, and 9 shoulders (18%) were middle type. At 4 o’clock, 37 shoulders (68%) were bone type, 9 shoulders (16%) were cartilage type, and 9 shoulders (16%) were middle type. The width of the attachment at 4 o’clock was significantly longer than that at 2 o’clock. The width of bone type attachment was significantly longer than that of cartilage type attachment at 4 o’clock. The attachment of the IGHLLC was classified into three types histologically. This study gives us the fundamental information of the IGHL-LC attachment for repairing a Bankart lesion.

8 AN ADDITIONAL HALF HITCH IS NECESSARY FOR ARTHROSCOPIC KNOT TYING
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The biomechanical properties of arthroscopic knot tying with No. 2 Fiberwire (Sliding knots: Tennessee slider, Duncan loop, and SMC knot, Non-sliding knots: Revo knot, Rotator Cuff knot, Surgeon’s knot) were investigated. Tensile testing for failure was performed using a materials testing machine, 10 times in each knot, and then ultimate load and failure load were recorded. When a suture slipping in the knot was seen at least once in ten tests, a half hitch was added followed by tensile testing again until suture breakage occurred in all 10 tests. Average ultimate load without an additional half hitch was 20N in Tennessee slider, 20N in Duncan loop, 60N in SMC knot, 21N in Revo knot, 24N in Rotator Cuff knot, 29N in Surgeon’s knot. For all 3 sliding knots, suture slipping occurred in all 10 tests. The ultimate load of sliding knots was significantly less than that of nonsliding knots (P < .01). Additional 4 half hitches for all sliding knots and an additional half hitch for Revo knot and Rotator Cuff knot were necessary to avoid suture slipping in the knot. The final
failure load with additional half hitches was not significantly different among all six knot tying styles. For arthroscopic surgery, an additional half hitch is necessary to improve the initial strength of the knot tying, specifically for sliding knots.

9 COMPARISON OF LONG-TERM RESULTS BETWEEN CONSERVATIVE AND OPERATIVE TREATMENTS OF ROTATOR CUFF TEARS

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The purpose of this study is to clarify the difference in long-term results between conservative and operative treatments of rotator cuff tears. Participants were 147 shoulders diagnosed as having rotator cuff tears from 1992 to 1999. We could follow-up 112 shoulders by telephone survey, and we could evaluate 73 shoulders (51 treated conservatively and 22 treated operatively), because we excluded 22 shoulders which were dead, 16 shoulders which were impossible to evaluate due to dementia and 1 shoulder which received shoulder trauma. The average age of the 73 shoulders was 61 years old, and their average follow-up period was 14 years. We used the pain score (30 points) and the activities of daily life score (10 points) of the Japan Orthopaedic Association shoulder scoring system. The average of the pain score of patients treated conservatively and operatively was 25.7 and 27.7, respectively, and the patients with no pain were 57% and 77%, respectively, and the patients with only slight pain were 33% and 14%, respectively. The average scores of activities of daily life were both 9.5, and patients with no disturbance in daily life were both 73%. When we limit the subjects to 60 years old or younger, the pain score of patients treated conservatively was lower than that of patients treated operatively (P=.0443). In conclusion, in both conservative and operative treatment cases, about 90% had zero or only slight pain and about 70% had no disturbance in daily life. However, the younger patients treated conservatively tended to have more significant pain than those treated operatively.

10 SEQUENTIAL SUPRASPINATUS FAT INFLTRATION IN THE SURGERY CASE OF ROTATOR CUFF TEAR

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We evaluated the change in fatty infiltration at multiple time points after surgery, and looked for possible associations with several pre- and post-operative factors. We evaluated 495 shoulders that underwent surgical repair of a rotator cuff tear, and were followed up for 1 year or longer after surgery. We evaluated fatty infiltration of the supraspinatus muscle before surgery and at 6 months and 1 year after surgery; magnetic resonance (MR) images were used to classify infiltration according to Nakagaki’s classification system. A correlation was found between the grade of fatty infiltration and the following factors: medical history; tear size; arthrosis-related change; sequential UCLA score; and brightness change in the insertion of the supraspinatus tendon at 6 months after surgery. Among shoulders classified preoperatively as Grade 1 (n=105) or Grade 2 (n=172), 90% or more of shoulders were unchanged in classification at 1 year after surgery. Among shoulders classified preoperatively as Grade 2 (n=218), 87 shoulders (40%) were improved and 126 shoulders (58%) were unchanged at 1 year after surgery. There was a statistically significant correlation between the grade of fatty infiltration and tear size. Fatty infiltration also showed a weak, but statistically significant, correlation with arthrosis-related change and the preoperative UCLA score, but showed no correlations with medical history or postoperative UCLA score at 6 months or 1 year after surgery. Finally, there was a statistically significant correlation between the grade of fatty infiltration and the brightness change at the insertion of the supraspinatus tendon at 6 months and 1 year after surgery.

11 BONE SCINTIGRAPHY FINDINGS IN SHOULDERS WITH ROTATOR CUFF TEARS: A COMPARISON OF PAINFUL AND ASYMPTOMATIC TEARS

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Nocturnal pain is a characteristic pain accompanying rotator cuff tears (RCTs), but the fact that RCTs can be asymptomatic suggests that the RCT itself is not necessarily the cause of pain. It is possible that joint inflammation accompanying RCTs is associated with this pain. Joint inflammation is assessed clinically by an increased uptake of radioisotopes ([18F] FDG, Tc HMDP) in bone scintigraphy. Our objective was to study bone scintigraphy findings in cases of asymptomatic RCTs. Volunteers without shoulder complaints were recruited from patients who had already undergone bone scintigraphy, and ultrasound-identified asymptomatic RCTs. These were compared with 28 cases diagnosed with RCTs and who had undergone surgery (the painful RCT group). Tc HMDP was used for bone scintigraphy. Ninety volunteers were registered. Of them, 34 shoulders in 26 patients had asymptomatic RCTs. Thirty-two shoulders in 20 patients did not have RCTs. RI uptake in the asymptomatic RCT group was the same as that measured for the non-tear group (1.7±0.3 vs 1.7±0.4, n.s.). Increased RI uptake was only observed in the painful RCT group (2.2±0.4, p<.05). Asymptomatic RCT is not associated with joint inflammation. Our results support the theory that shoulder arthritis is a cause of pain accompanying RCTs. We believe that the treatment of RCTs should focus on controlling the shoulder arthritis.

12 DEVELOPMENT OF THE LESION PREDICTION SYSTEM FOR THROWING SHOULDER INJURY USING PITCHING MOTION

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We reported that humeral head abnormality in the asymptomatic phase was the lesions which were closely related to the consecutive onset of throwing shoulder injury. We also developed the lesion prediction system using dynamic analysis of pitching motion. However, in this system, there were some problems in making the pitching motion efficiently. The purpose of this study is to develop a new system that can predict the humeral head abnormality easily and can simulate a pitching motion which efficiently prevents the lesion. The subjects were 18 asymptomatic collegiate baseball players who took part in both MRI and pitching motion analysis. We analyzed the data of some joint angles during pitching motion with principal component analysis and classified the motion patterns into the principal component scores. We did logistic regression analysis with the humeral head abnormality on MRI and the principal component scores and found the principal components which significantly affected the lesion. We also calculated a regression formula which predicts the probability of lesion existence and evaluated the validity of the regression model. Eight players had humeral head abnormality on MRI. We could predict the lesion existence with 89% accuracy.
We can make a new pitching motion easily while we operate the parameters of the principal component scores referring to the probability of lesion existence. We can express the new motion with 3D animations. We developed a system that can predict humeral head abnormality and could simulate new pitching motions which effectively prevent the lesion from being formed and progressing.

13 HOW OFTEN SHOULD WE SURGICALLY TREAT THE HILL-SACHS LESION?
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A large Hill-Sachs lesion has been considered as a risk factor for postoperative recurrence. We previously introduced a new concept of the ‘glenoid track’ and a way to evaluate the risk of engagement with the glenoid rim. The purpose of this study was to clarify the incidence of Hill-Sachs lesions that engage with the anterior rim of the glenoid. We retrospectively reviewed CT images of 50 shoulders with recurrent anterior dislocation (average age, 27 years old). Using the software, ‘zioTerm2009’, which allows us to make multi-planar reconstruction, the DICOM data were reconstructed to 1-mm-thick slices in the oblique-coronal plane perpendicular to the line connecting the medial margin of the cuff attachment site. In these slices, we measured the maximum distance along the humeral head surface from the medial margin of the Hill-Sachs lesion to the medial margin of the footprint of the rotator cuff. The most medial margin of the Hill-Sachs lesion was located 14.9 mm plus or minus 3.5 mm (8.6 mm to 22.0 mm) medial from the footprint, which was equivalent to 72% plus or minus 21% (42%-127%) of the glenoid track width. In two cases (4%), the most medial margin of the Hill-Sachs lesion extended medially over the glenoid track. Burkhart et al. analyzed the results of 194 arthroscopic Bankart repairs and reported that the incidence of engaging Hill-Sachs lesion was 1.5%. In our 50 cases, the incidence was 4%. The Hill-Sachs lesion that needs to be treated surgically is proved to be a rare pathological condition.

14 THE RELATIONSHIP BETWEEN THE LOCATION AND SYMPTOMS OF ROTATOR CUFF TEARS
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The purpose of this study was to elucidate the relationship between the location and symptoms of rotator cuff tears. A medical checkup was conducted for 402 residents of a mountain village. The subjects included 147 individuals with 203 shoulders in which rotator cuff tears were observed through ultrasonography (males, 80 shoulders; females, 123 shoulders; mean age, 71.5 years old). The presence or absence of symptoms in shoulders at the time of the checkup was confirmed through interviews, and the location of the rotator cuff tear as well as complications in the long head of the biceps (LHB) were diagnosed using ultrasonography. The location of the tear was recorded under three categories, the superior facet (SF), the middle facet (MF) of the greater tubercle, and the lesser tubercle (LT). Subjects were divided into two groups based on the presence or absence of current symptoms in the shoulder. The two groups were compared using the ultrasonographic observations described above. Symptomatic tear accounted for 54 shoulders and asymptomatic tear accounted for 149 shoulders, and significantly more numerous cases showed symptoms with a complete tear in SF, when the tear reaches MF, and when the tear reaches LT, respectively. The presence or absence of LHB lesion was unrelated to symptoms. The results of this study showed that rotator cuff tears started at the superior facet of the greater tubercle and more cases showed symptoms along with the widening of tears to the middle facet of the greater tubercle and lesser tubercle.

15 ROTATOR CUFF RECONSTRUCTION AND HUMERAL HEAD REPLACEMENT FOR RCDA CAN IMPROVE SHOULDER ROM IN PATIENTS WITH PSEUDOPARALYSIS
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Recently, reverse shoulder arthroplasty in patients with Rotator Cuff Deficient Arthropathy (RCDA) is widely performed all over the world. However, it is not able to be used in Japan yet. We performed a novel strategy for RCDA from 2001. Smallest size of humeral head was used for closing the cuff defect. Also, if the cuff defect was not able to be closed by decreasing the head size, we added muscle tendon transfer such as latissimus dorsi transfer for a postero-superior defect and pectoralis major transfer for an anterosuperior defect. The aim of this study was to investigate shoulder ROM after this strategy for RCDA with pseudoparalysis of the shoulder at more than a year post surgery follow-up. Twenty-three shoulders in 22 patients were studied. The mean age at the time of surgery was 73 (range, 58 to 83 years old). Six shoulders required a latissimus dorsi transfer, 1 shoulder had pectoralis major transfer performed. We investigated the postoperative range of motion of the shoulder using the scores of the Japanese Orthopaedic Association. The average follow-up period was 2.3 years. All cases except 3 were able to elevate to more than 100 degrees. The average flexion was improved from preoperative 40 degrees to postoperative 129 degrees. Average postoperative external rotation of the shoulder improved from 9 degrees preoperatively to 31 degrees postoperatively. The JOA score improved from 33.2 points preoperatively to 77.2 points postoperatively. In conclusion rotator cuff repair and a humeral head replacement with smallest head in patients with RCDA could get a good functional recovery even in cases with pseudoparalysis of the shoulder.