Technical Note

Arthroscopic Biceps Tenotomy Using a Single Portal for Working and Viewing: A Rabbit Model and Technique

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Abstract: Biceps tenotomy (BT) is a common surgery used to address anterior shoulder pain and joint dysfunction in humans. Using animal models to simulate human conditions is an effective and essential research strategy to further understand histologic and biomechanical processes that occur after BT, including the pathology of the detached biceps, secondary tendinopathic conditions of the rotator cuffs, and glenohumeral functional changes. This Technical Note presents a comprehensive step-by-step description of an arthroscopic BT procedure in rabbits. This technique is particularly beneficial, as the mini-invasive arthroscopic technique in a rabbit model is similar to that performed in humans. which resulted in less scarring and injuries to other adjacent structures in comparison with open surgery.

Lesions of the long head of the biceps tendon (LHBT) in humans are a recognized source of anterior shoulder pain and joint dysfunction,[1] which is commonly associated with the presence of rotator cuff tendon pathology.[2-4] Biceps tenotomy (BT) is one of the primary operations suggested or in conjunction with other interventions to address LHBT lesions.[5-7] Notably, some biomechanical studies have determined the LHBT as an anterior stabilizer particularly in the presence of cuff tears that damage the anteroposterior force balance of the shoulder. Researchers have expressed concerns about the histologic changes and biomechanical consequences of its detachment, pertaining to its subsequent effects on joint damage and rotator cuff pathology. Therefore, BT has been performed in many animals to serve as a basic model for studying the pathophysiological and kinematic changes of the shoulder caused by biceps detachment.[5,6,8-13] In this context, the creation of a mini-invasive BT technique in animal models that simulates the arthroscopic procedure in humans as much as possible is essential for better translation and extrapolation of basic sciences to clinical scenarios.

In previous studies, the mini-invasive BT technique, which may be arthroscopic or ultrasound-assisted, was mainly performed in large animals, such as sheep and canines.[10,13,14] However, in some cost-effective small animals, the invasive open approach was the first choice, which may be a barrier to effectively reproduce clinical surgery.[8,9,11,12] Therefore, this Technical Note aims to describe step-by-step an arthroscopic procedure that creates a BT model in a rabbit. This technique is a straightforward, feasible, and reproducible procedure for arthroscopic surgeons.

Surgical Technique (With Video Illustration)

In this Technical Note, Dr. Xu and Dr. Han performed all the procedures (Table 1). The use of animals was approved by the Institutional Animal Care and Use Committee. Dr. Su contributed to the specific design of the detailed procedure.

Step 1: Anesthesia and Positioning

Pentobarbital (3%, 30 mg/kg) was injected intravenously to anesthetize our animal model (skeletally mature male New Zealand White rabbits; age, ~16 weeks; weight, 3.3 kg), and the incision site of the

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Table 1. Step-by-Step Procedure

1. Anesthetize a rabbit place it in a supine position.
2. Palpate the surface bony marks of the surgical limb and create a mini-incision for a single anterolateral portal to be used for visualization and working. Place traction strings near the incision to enlarge the subcutaneous space.
3. Partially split the anterior deltoid and identify the proximal edge of the insertion of the pectoralis major on the humerus to locate the biceps tendon.
4. Open the pectoralis major aponeurosis and the transverse humeral ligament for biceps tendon exposure.
5. Perform ligature and cut the biceps tendon.
6. Confirm the complete the detachment of the biceps tendon using an arthroscope.
7. Close the single mini-incision used for the anterolateral portal.
8. Postoperative care.

shoulder was injected with lidocaine subcutaneously. The rabbit was then positioned on an incandescent lamp heating pad, using bandages to fix the nonsurgical limbs (1 forelimb and 2 hindlimbs) on the surgical bed to prevent any movements during the procedure except for the surgical limb. Two wet gauzes were placed on the eyes of rabbits to prevent corneal trauma and drying. Next, the hair of the surgical forelimb was shaved, and the skin was disinfected with iodophor 3 times. The rabbit was positioned supine and covered with a sterile surgical drape that has a small window for accessing the surgical site. After externally rotating the shoulder, the highest point of the greater tuberosity, clavicle, scapular spine, and humerus shaft were palpated and outlined with surface landmarks (Fig 1A). The SSP insertion site was 10 mm long. A mini-invasive incision (∼8 mm) was then made (Fig 1B).

Step 2: Portal Creation and Skin Traction String Placement

This incision can serve as a standard anterolateral portal. In this rabbit model, we used a 30° otoscope (Jiu Tan, Shenzhen, China) as an "arthroscope" for monitoring, as the routine arthroscope in humans is too large for rabbit model (Fig 2A). Two sutures were stitched in the skin near the incision to enlarge the subcutaneous space as traction strings (Fig 2B), which helps in placing the arthroscope and instruments simultaneously in this single anterolateral portal. Considering the convenience and feasibility of this operation, an arthroscopic irrigation system and trocar instruments were not used in this animal model.

Step 3: Biceps Location and Exposure

The inferior border of the anterior deltoid was partially split along the medial edge of the humerus shaft using a #15-blade scalpel, and the anterior cuffs were exposed (Fig 3A). Next, the back of the scalpel was slid from proximal to distal. The proximal edge of the insertion of the pectoralis major on the humerus was identified when resistance was felt during this sliding maneuver. The proximal extension of the pectoralis major aponeurosis and the transverse humeral ligament was opened using a #15-blade scalpel (Fig 3B and Video 1) under monitoring through the anterolateral portal to expose the biceps in the bicipital groove (Fig 3C and Video 1).

Step 4: Biceps Ligation and Tenotomy

The proximal biceps tendon underwent loop ligation with a 2-0 suture (Ethicon, Piscataway, NJ).[15] A custom curved soft-tissue probe device, a long needle

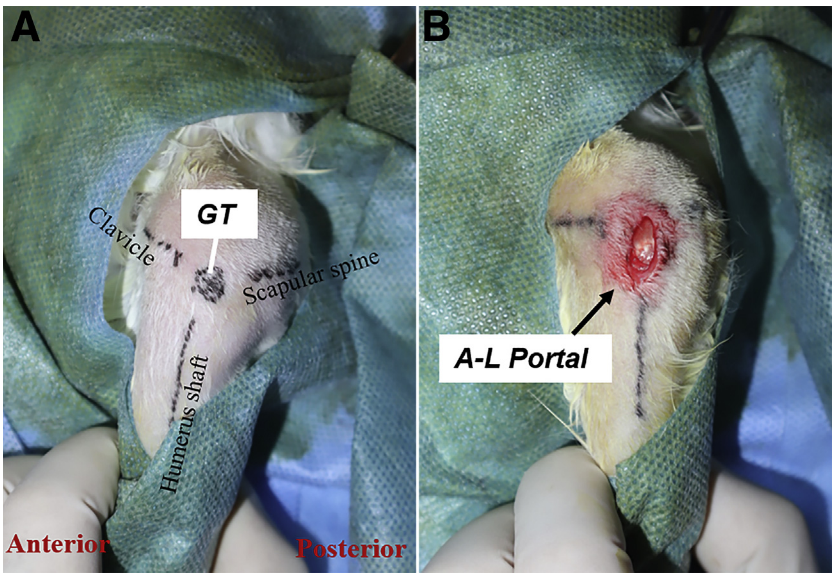

Fig 1. (A) The rabbit is positioned supine with the surface markings (the clavicle, scapular spine, and humeral shaft) done on the left shoulder. (B) Anterolateral mini-incision of the shoulder is created for positioning the arthroscopic anterolateral (A-L) portal. (GT, greater tuberosity.)

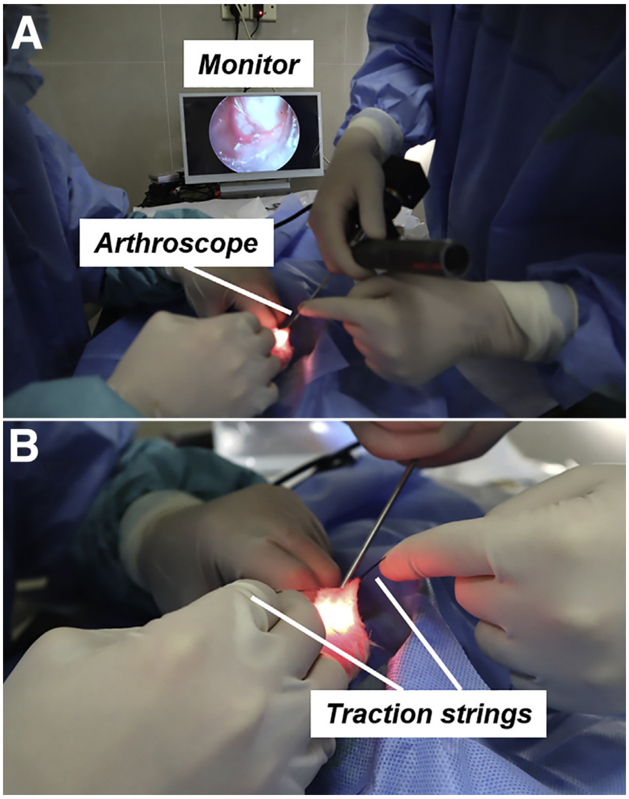

Fig 2. (A) A 30° otoscope (2.7-mm; Jiu Tan, Shenzhen, China) is used as an "arthroscope" for monitoring after inserting it into portal. (B) Traction strings stitched to the skin near anterolateral portal for subcutaneous space enlargement and better visualization.

(0.9 mm × 80 mm, KDL Co. Ltd., Zhejiang, China) with a crooked end (Fig 4), was used to grasp the biceps for suture loop ligation. The midportion of the biceps tendon was both viewed and grasped through the anterolateral portal from beneath the bicipital groove (Fig 5A and Video 1). Next, the ophthalmic micro-tweezer shuttled 2 suture limbs onto the curved end of the probe, which pulls the suture through the bottom of the biceps tendon. Subsequently, the suture was retrieved from the anterolateral portal using tweezers (Fig 5 B and C; Video 1). The self-cinching suture loop was then manually created outside (Fig 5D). It was shuttled through the anterolateral portal and onto the biceps tendon to tighten the loop, using the tweezer as a knot pusher (Fig 5E). After manually tensioning the suture loop for tendon traction, a #15-blade scalpel was used to perform the BT proximal to the previously placed suture loop with monitoring done via the anterolateral portal (Fig 5F and Video 1).

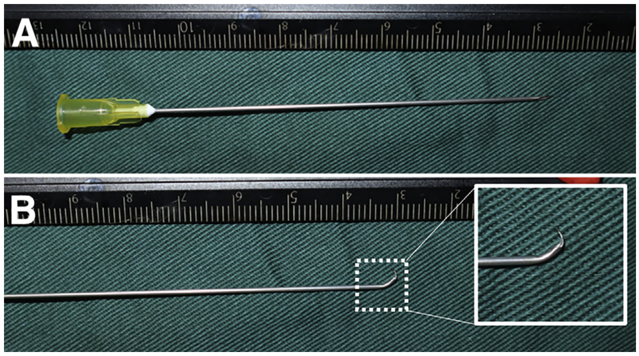

Fig 4. (A) A long needle (0.9 mm × 80 mm; KDL Co. Ltd., Zhejiang, China) with (B) a crooked end (white box) is used as a curved soft-tissue probe device to grasp the biceps.

Step 5: Arthroscopic Biceps Detachment Confirmation

After tenotomy, the biceps tendon was freed from the groove. The elbow was moved to confirm the complete detachment of the biceps tendon via an arthroscope inserted through the anterolateral portal, ensuring no connecting tendon tissues remained (Fig 6 and Video 1).

Step 6: Mini-Incision Closure

The mini-incision for the anterolateral portal was closed using a 3-0 ETHILON suture (Johnson & Johnson) (Fig 7). The total procedure time was approximately 10 minutes. The specialized instruments used for animal model creation are presented in Figure 8. All tips and tricks used in this technique are listed in Table 2.

Step 7: Postoperative Care

Postoperatively, this animal was allowed to recover from anesthesia in a recovery cage with a heating incandescent lamp. A prophylactic antibiotic—ampicillin

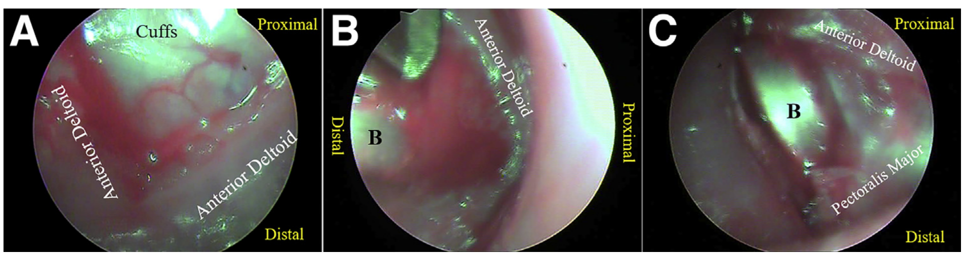

Fig 3. (A) The anterior deltoid is split to expose the anterior subdeltoid space using a #15-blade scalpel under monitoring in the anterolateral portal. (B) The proximal extension of the pectoralis major aponeurosis and the transverse humeral ligament are opened to (C) expose the biceps. (B, biceps.)

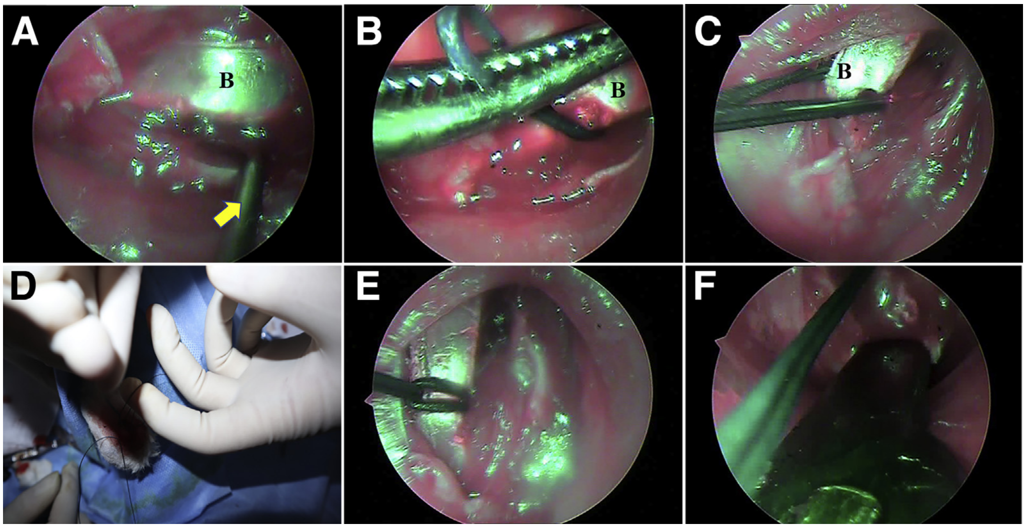

Fig 5. (A) The crooked end of the long needle (yellow arrow) slides into the bottom of the bicipital groove to shuttle the suture under the biceps tendon. (B) The ophthalmic micro-tweezer grasps 2 suture limbs of the suture that were passed under the biceps tendon and (C) pulls them outside the anterolateral portal. (D) The self-cinching lasso-loop is manually created outside, and (E) the knot loop was shuttled onto the biceps tendon through the portal, using the micro-tweezer as a knot pusher. (F) When enough traction is maintained on the tendon using the lasso-loop, the proximal biceps tendon is cut using a #15-blade scalpel through the portal with monitoring.

50 mg/kg body weight—was administered for 3 days after surgery. Postoperatively, the animal was returned to the housing cage, cared for by a veterinarian, and monitored daily for signs of pain and infection.

Discussion

As BT is a common surgery performed to address anterior shoulder pain and joint dysfunction, this model has been widely used to investigate its effects on the biceps, the secondary pathophysiological changes of the rotator cuff tendons, and the kinematics of the shoulder joint caused by biceps detachment.[5,6,8-13] Beach et al.[9] found that BT altered the adjacent intact tendons and glenoid cartilage in the presence of a supraspinatus tear. However, Chen et al.[8] reported that the procedure partially preserved shoulder function and restored tendon health without causing detrimental effects to the joint cartilage in the presence of chronic massive rotator cuff tears. Similarly, Hong et al.[12] also found that no shoulder functional changes occur after BT. These findings in animal models, although not completely consistent, help in further understanding BT and rotator cuff tendon pathology in humans. Invasive open surgery for model creation in these animal studies may likely cause interference as excessive acute inflammatory responses and postoperative tissue adhesions are inevitable postoperatively.[16,17] Based on anatomy, these posttraumatic complications in this model creation procedure may directly influence adjacent cuff tendons, which may possibly cover up the tendinopathic conditions induced by overuse or the imbalance of the force couples of the shoulder joint. Moreover, joint functional and kinematic assessments and glenohumeral cartilage analysis in these animals

Fig 6. (A) The elbow is moved to separate the proximal biceps tendon (white asterisk) from the distal (yellow asterisk). (B) Complete detachment of the biceps tendon is confirmed via an arthroscope, ensuring that no connecting tendon tissues remained at the stump of the distal biceps tendon.

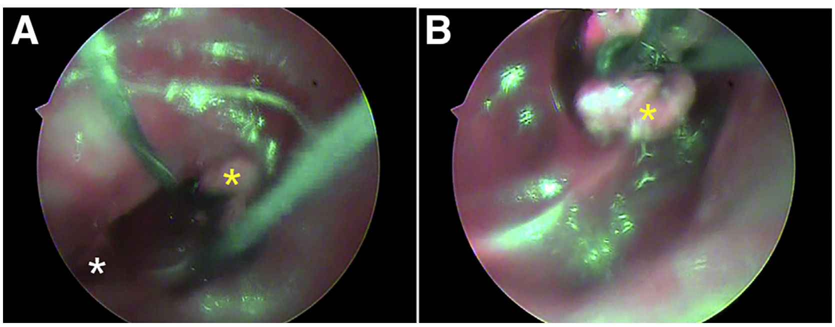

Fig 7. The mini-incision for the anterolateral portal is closed using a 3-0 ETHILON suture.

may be limited as post-traumatic tissue responses may result in joint stiffness, especially in combination with the creation of a rotator cuff tear model.[6,8]

Therefore, in this Technical Note, we described step-by-step a detailed arthroscopic procedure to create a BT model in rabbits. All advantages and disadvantages are displayed in Table 3. With only a single mini-incision created for positioning a portal that facilitates working and viewing, this technique minimizes the problems caused by open surgery for model creation as seen in previous studies, resulting in less risks of scarring and tissue adhesion, decreased postoperative analgesia requirements, and an early return to activities for animals. These postoperative conditions are more consistent with those in humans who undergo arthroscopic BT. Despite the requirement of some additional instruments for animal models or some technical difficulties using arthroscopy, this technique is reproducible and robust using off-the-shelf materials for most arthroscopic surgeons who intend to perform BT model creation in a rabbit. The rabbit model is cost-effective, with a relatively shorter study period compared with some large animals. Meanwhile, as the rat or mouse model is relatively small with less maneuverability, the rabbit model may be more appropriate to investigate the effectiveness of surgical techniques in sports medicine. Hopefully, this technique can assist other researchers in performing related animal studies more effectively and reasonably.

Fig 8. The specialized instruments for the arthroscopic biceps tenotomy technique in the rabbit model, which includes an otoscopic system that comprises a 2.7-mm otoscope, camera and illuminant, #15-blade, and bending or straight micro-tweezer.

Table 2. Tips and Tricks

1. Effective blunt separation using micro-tweezer and sufficient elevation of subcutaneous space using traction strings are critical for adequate biceps exposure in the arthroscopic view and manipulation through a single anterolateral portal.
2. Feeling the resistance of the proximal edge of the insertion of the pectoralis major on the humerus when sliding the back of a blade from the proximal to distal helps to quickly identify the location of the biceps.
3. Maintaining tension on the biceps using a self-cinching lasso-loop and moving the elbow appropriately help in easily performing biceps tenotomy using a blade.
4. Carefully splitting the inferior border of the anterior deltoid must be carefully done, as the cephalic vein runs along the anterior and middle portion of the deltoid.
5. Feeling the tension on the biceps tendon insertion at the radial tuberosity when moving the elbow helps to check the complete detachment of the biceps tendon.

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Table 3. Advantages and Disadvantages

Advantages
1. Mini-invasive model creation using arthroscopy
2. Decreasing undue tissue adhesion that inevitably occur in open surgery
3. Decreasing early acute inflammatory tissue reactions caused by excessive incision and tissue separation

Disadvantages
1. Requirement of an "arthroscopic system" and more specialized instruments for animal models
2. Higher surgical skills and technical difficulties
3. Relatively more time to create models

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