




## SURGICAL TECHNIQUE

## The Application of H-Loop in Arthroscopic Knotless Double-Row Rotator Cuff Repairs

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**Objective:** To determine the functional outcomes after a novel method of H-loop knotless double-row technique in patients with rotator cuff tears.

**Method:** From June 2020 to September 2020, a total of six patients (five women, one man) with arthroscopic rotator cuff repair using the H-loop knotless double-row technique were enrolled in our study. The average age is 54 years (range: 50–61 years). The preoperative and final follow-up clinical outcome were evaluated using the American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS), University of California Los Angeles (UCLA) score, and Constant–Murley score. The active shoulder range of motion (ROM) was also collected preoperatively and postoperatively at the final follow-up (forward flexion and abduction). Accordingly, intraoperative and postoperative complications were observed as well.

**Result:** There were six patients that underwent arthroscopic rotator cuff repair using the H-loop knotless double-row technique. The average follow-up period was  $7.52 \pm 0.70$  months. The VAS, UCLA, ASES, and Constant–Murley scores improved from  $5 \pm 2.45$ ,  $15.67 \pm 3.44$ ,  $47.67 \pm 17.41$  and  $49.17 \pm 8.98$  preoperatively, to  $0.83 \pm 0.75$ ,  $36.27 \pm 3.83$ ,  $91.67 \pm 10.76$  and  $85.83 \pm 4.31$  at the final follow-up, with statistical significances of  $P = 0.009$ ,  $P < 0.001$ ,  $P = 0.006$ , and  $P = 0.001$ , respectively. Meanwhile, the active shoulder ROM (forward flexion and abduction) improved from  $135.00 \pm 46.80$  and  $125 \pm 56.48$  preoperatively, to  $173.67 \pm 4.13$  and  $172 \pm 3.27$  at final follow-up, respectively ( $P = 0.082$ ,  $P = 0.088$ ). During the follow-up, there were no postoperative complications such as wound-site infection, nerve or vessel damage, subcutaneous hematoma, and suture anchor problems.

**Conclusion:** With the benefit of reducing the possibility of strangulation and blood supply affection for the rotator cuff, The H-loop knotless double row technique may be an alternative method to significantly improve subjective functional outcomes and increase the healing rate of medium-sized rotator cuff tears with degeneration issues and poor tissue quality.

**Key words:** Double row; H-loop; Knotless; Rotator cuff tear; Suture

### Introduction

Rotator cuff injury is one of the most common injuries that lead to shoulder pain and dysfunction. The prevalence of rotator cuff tears in the general population is about 20%–51%.<sup>1</sup> The treatment of rotator cuff injury includes drug treatment, rehabilitation treatment, and surgical treatment.

With the popularization and development of arthroscopic technology, arthroscopy repair method is mainly used for rotator cuff tear.

In recent years, the healing rate of rotator cuff tears has increased due to the development of various novel repair techniques and instruments.<sup>2</sup> The rotator cuff tear repair method

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has evolved from the single-row to the double-row technique and acquired satisfactory clinical outcomes. To our knowledge, the ideal rotator cuff repair structure should provide both the maximum initial strength and the mechanical stability necessary for tendon-bone healing<sup>3</sup>.

Compared with the double row repair, the suture bridge repair optimizes the biomechanical properties of rotator cuff repair by high initial fixation and maximizes footprint coverage while minimizing gap formation<sup>4</sup>. Due to these favorable biomechanical features, suture bridge repair became a popular option in rotator cuff repair<sup>5</sup>. Nevertheless, several recent studies have indicated the tendency of musculotendinous junction re-tear after suture bridge repair<sup>6,7</sup>. The early results of clinical trials designed by Cho *et al.* have shown that there was a problem of re-tearing after suture bridge repair of rotator cuff tears, mainly medial row tears<sup>8</sup>. In 2010, Hotta *et al.* proposed that the medial row knot of the suture bridge could increase subacromial impact and produce aseptic inflammation, causing persistent shoulder pain in patients after operation<sup>9</sup>. Likewise, Takeuchi *et al.* revealed that the reason may be that the medial row suture and knots will lead to stress concentration and cutting hanging at the tendon-ventral junction, while the medial row knot increases the operation time and operation complexity, especially for novice arthroscopic doctors<sup>5</sup>. Besides, Kim *et al.* recently proposed another reason for the failure of suture bridge may be that the closed cross structure of suture bridge blocks the blood supply of tendons from the medial abdomen to the tear area, resulting in difficulty in tendon-to-bone healing<sup>10</sup>.

Henceforth, knotless double-row techniques were recommended as the ideal repair configuration instead<sup>11,12</sup>. Nevertheless, some researchers argue this technique does not provide a strong grasp for the rotator cuff tissue in situations where there is a loss of lateral tendon, poor tendon activity, or more medially basal tear<sup>13</sup>. Thus, a variety of suture techniques have been evolved to ensure knotless repair configuration and improve the fixation strength of the rotator cuff tendon. Burkhart *et al.* demonstrated that the ultimate failure load of the load-sharing rip-stop construct in rotator cuff repair is 1.7 times greater than that of a single-row construct in cadaveric models<sup>14</sup>. Although the rip-stop technique has been shown to increase medial row fixation and provide resistance to tissue cutout, it requires more lateral anchors and poses a risk of strangulation for the suture<sup>12</sup>.

Therefore, a novel method of knotless double-row technique that uses loop suture is introduced to improve fixation strength in the medial row in this study. Interestingly, this loop provides high resistance to tissue cutout and resembles the shape of the letter H; hence, it was named H-loop.

Thus, the aims of this study were: (i) describe the H-loop knotless double-row technique in the rotator cuff tear repair; (ii) to access the functional outcomes using the H-loop double-row technique in patients with rotator cuff tears; and (iii) to summarize the advantages and disadvantages of H-loop knotless double-row technique for rotator cuff tears.

## Methods

### Study Design

From June 2020 to September 2020, patients who received the rotator cuff repair using the H-loop knotless double-row technique were retrospectively identified.

The inclusion criteria were as follows: (i) patients were diagnosed with full or partial thickness supraspinatus and/or infraspinatus tears of small- to medium-size based on the DeOrto and Cofield classification<sup>15</sup>; (ii) the patients received the arthroscopic rotator cuff tear repair surgery using H-loop knotless double-row technique; (iii) the preoperative and final follow-up shoulder function were comprehensively recorded and compared using the American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS), University of California Los Angeles (UCLA) score, and Constant–Murley score.

The exclusion criteria were as follows: (i) an irreparable rotator cuff tear; (ii) an anterior–posterior tear length of greater than 5 cm; (iii) revision surgery; and (iv) shoulder osteoarthritis.

Given the criteria above, a total of six patients (five women, one man) were enrolled in the present study. The average age was 54 years (range: 50–61 years). All patients went through standard radiological rotator cuff tear examination before the operation by magnetic resonance imaging (MRI). All the patients were diagnosed with supraspinatus tear. The degree of tendon mobility and fatty infiltration were evaluated beforehand. According to the Goutallier classification, there are four patients whose fatty infiltration was in grade one and two patients in grade two. Meanwhile, there were three patients who had the type II acromion and the other patients had the type I acromion.

### Surgical Technique

#### Patient Positioning

Patient was placed in the lateral decubitus or the beach chair position after general anesthesia. The operative arm was fixed with 3 kg longitudinal traction, 70° abduction, and 20° flexion by a simple traction frame (Fig. 1), whereas the other arm was placed in the natural position. The coracoid, acromion, and coracoacromial ligaments were marked with a surgical pen. Additionally, four primary viewing portals (anterior, posterior, lateral, and posterolateral) were also marked.

#### Diagnostic Arthroscopy

Firstly, a standard posterior viewing portal was made 2 cm inferior and 1 cm medial to the posterolateral border of the acromion. The 30° arthroscope was inserted into the glenohumeral joint, and the standard anterior portal was subsequently made 1 cm lateral to the tip of the coracoid under the visual location of the spinal needle. Then, the arthroscope was placed in the subacromial space, where the posterolateral (viewing portal) and lateral portal (working portal) were



**Fig. 1** A patient with a left rotator cuff tear was placed in the lateral decubitus position. The operative arm was fixed with 3 kg longitudinal traction, 70° abduction, and 20° flexion by a simple traction frame. Then, the acromion, coracoid, acromioclavicular joint, coracoacromial ligament, and standard portal were marked.

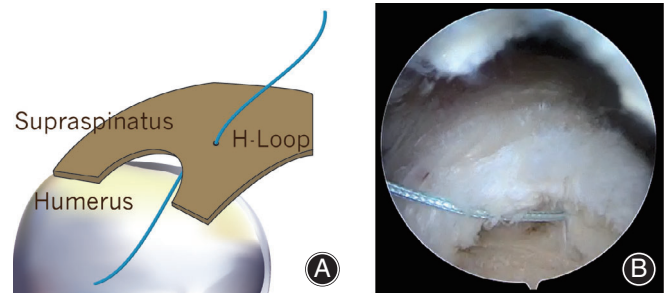
created according to location of the spinal needle. After subacromial decompression and tissue preparation, the quality and elasticity of the rotator cuff tear were evaluated by a tissue grasper. The rotator cuff footprint was prepared by grinding greater tuberosity down the cancellous bone surface that was bleeding with a grinding drill<sup>16</sup>.

#### *The H-Loop Knotless Suture Technique for Rotator Cuff Repair*

The arthroscope was moved to the lateral view portal to assess the pattern of the rotator cuff tear and decide on the medial anchor position (Fig. 2). Subsequently, a #2 FiberWire suture (Arthrex, Naples, FL, USA) was first passed through the torn tissue at 10 mm medial to the lateral edge using a SutureLasso (Arthrex, Naples, FL, USA) shuttling device (Fig. 3). The bursal-free end of the suture was passed through the torn tissue again from the bursal side to the articular side in a horizontal mattress fashion. Then, the middle part of the suture created a loop in the bursal side



**Fig. 2** Intraoperative arthroscopic image in the subacromial space from the lateral view portal shows that the supraspinatus suffers a crescent full-thickness tear.



**Fig. 3** The first tendon passage of the H-loop technique. A #2 FiberWire suture (Arthrex) is first passed through the torn tissue at 10 mm medial to the lateral edge using a SutureLasso (Arthrex) shuttling device.

of the rotator cuff (Fig. 4). The two free ends of the limbs were passed together from the medial to the horizontal loop in an articular-to-bursal direction using SutureLasso. An H-loop was then formed (Fig. 5). When the limbs were given traction from the lateral portal, the H-loop exhibited good performance both in anti-strangulation and anti-tension, acting as a rip-stop (Fig. 6).

After completing the H-loop, the hole was tapped and two double-loaded 4.5 mm TWINFIX PK suture anchors (Smith&Nephew, Andover, USA) were placed at 0.2 mm medial to the humeral head articular cartilage (Fig. 7). The two TigerWire wires of the medial anchor were colored

white and white/blue, respectively. When appropriate traction was given to the blue limbs of the H-loop, the white limbs passed through the torn tissue in an articular-to-bursal direction. The position was 5 mm anterior and posterior to where the free end of H-loop blue limbs passed. The remaining white/blue suture limbs were passed through the torn rotator cuff respectively at approximately equidistant to the position where the white limbs were passed through using the same method. All suture limbs that passed through the torn tissue were not tied and docked through the lateral portal (Fig. 8). After increased tension was given to cover the footprint of the great tuberosity, all six suture limbs were finally fixed into the eyelet of a 4.75 mm SwiveLock anchor (Arthrex, Naples, FL, USA) in the lateral row (Fig. 9). If the rotator cuff tear is massive and large, more H-loops and medial row anchors can be added using the same method.

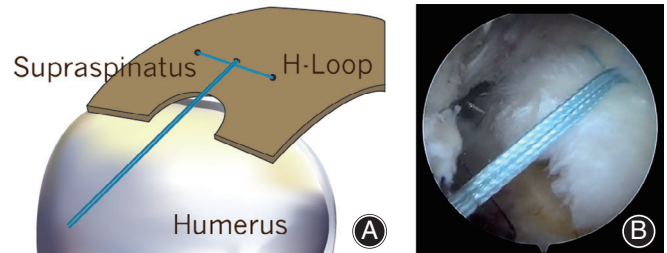
#### Postoperative Rehabilitation

The shoulder was positioned at 30° abduction with an abduction brace for 6 weeks. Some postoperative passive movements were allowed under the guidance of a physiotherapist. At 6 weeks after surgery, active- assisted motions were initiated. From the 10th week to the 12th week after

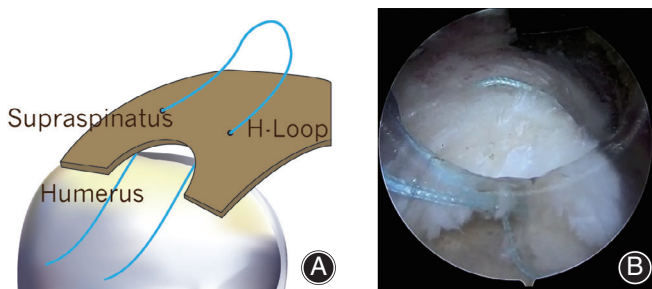
operation, the patient was assigned a strengthening program and some daily movements.

#### Outcome Measures

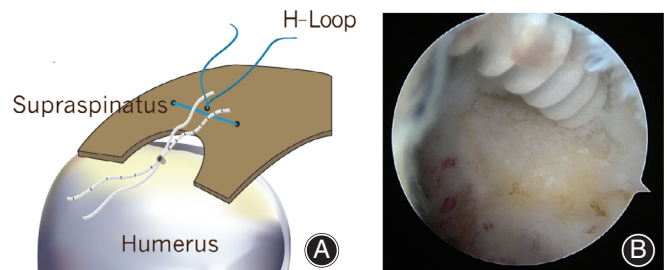
The pre- or final follow-up clinical outcome were evaluated using the following items: American Shoulder and Elbow Surgeons (ASES) score<sup>17</sup>, visual analog scale (VAS), University of California Los Angeles (UCLA) score<sup>18</sup>, Constant–Murley score, and the active shoulder range of motion (ROM).



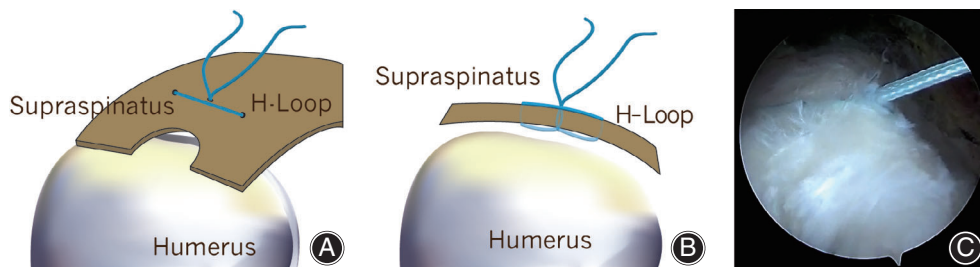
**Fig. 6** When the limbs were given traction from the lateral portal, the H-loop exhibited good performance both in anti-strangulation and anti-tension, acting as a rip-stop.



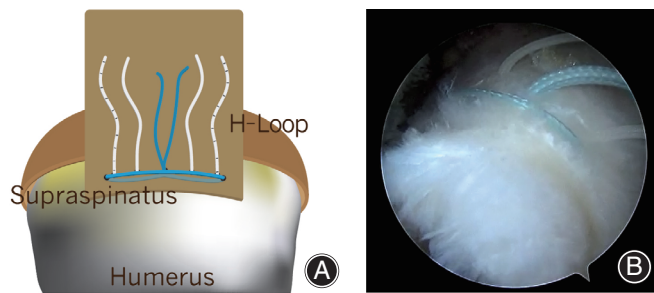
**Fig. 4** The second tendon passage of the H-loop technique. The free end of the suture in the subacromial space was passed through the torn tissue again from the bursal side to the articular side in a horizontal mattress fashion. The horizontal loop was then completed.



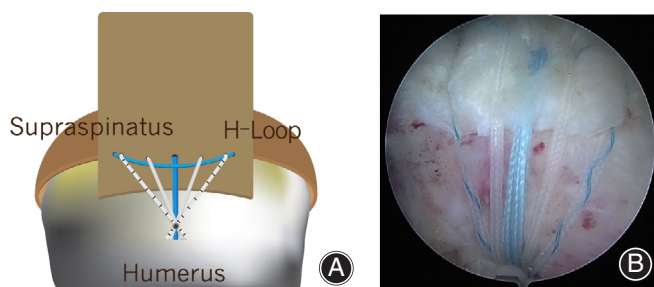
**Fig. 7** After the H-loop was completed, two double-loaded 4.5 mm TWINFIX PK suture anchors (Smith&Nephew) were placed at 0.2 mm medial to the humeral head articular cartilage. The two TigerWire wires were colored white and white/blue, respectively.



**Fig. 5** The third tendon passage of the H-loop technique. The two free ends of the limbs were passed together from the medial to the horizontal loop in an articular-to-bursal direction. A H-loop was formed and acted as a rip-stop. This loop provides high resistance to tissue cutout and resembles the shape of a letter H, hence it was named H-loop.



**Fig. 8** When appropriate traction was given to blue limbs of the H-loop, the four suture limbs from a medial-row anchor were equidistantly passed through the torn rotator cuff near to the position where the blue suture passed through, respectively.



**Fig. 9** Finally, all six suture limbs were fixed into the eyelet of a 4.75 mm SwiveLock anchor (Arthrex) in the lateral row to form the final configuration.

#### Visual Analog Scale (VAS)

The VAS was a 10-cm line with anchor statements. Patients mark points to denote the intensity of their pain. Score of 0 indicates painlessness, 1–3 points indicates mild and bearable pain, 4–6 points indicates the pain affects sleep, but patients can still bear it, 7–10 points indicates increasingly intense, unbearable pain which affects appetite and sleep.

#### American Shoulder and Elbow Surgeons (ASES) Score

The ASES score consists of a total score of 100 points (50 points for daily function and 50 points for pain)<sup>17</sup>. The pain score was calculated by multiplying (10-VAS) by five. As for the functional score, there are 10 individual questions which were answered and scored 0–3, with a maximum original function score of 30. Then, multiply the original score by 5 and divide by 3 to get the final functional score. The final ASES score was calculated by summing the functional score and the pain score. A total score of 0 indicates the worst and 100 indicate the best shoulder function.

#### University of California Los Angeles (UCLA) Score

The UCLA score is widely used to evaluate shoulder function recovery after arthroscopic rotator cuff repair<sup>18</sup>. The UCLA scores were completed by both patients and the doctor. It

was made up of the follow five separate domains: function (10 points), pain (10 points), strength of forward flexion (5 points), active forward flexion (5 points), and overall satisfaction (5 points), with a total score of 35 points. The higher total score indicates the better shoulder function.

#### Constant–Murley Score

Constant–Murley score is a commonly used method for evaluation of rotator cuff tears. It consists of four subscales: pain (15 points), muscle strength (25 points), functional activity (20 points), and shoulder range of motion (40 points). The total score is 100 points, which indicates the best function, and the score of 0 point indicates the worst shoulder function.

#### Range of Motion (ROM)

The active shoulder ROM data was also collected (forward flexion and abduction). The forward elevation and abduction degree with the arm at the side were measured with a goniometer.

#### Statistical Analysis

Statistical analysis was performed by SPSS 20.0 (IBM, Armonk, USA). The continuous data (ASES, UCLA, VAS, Constant–Murley, and ROM) were presented as mean and standard deviation if the data were normally distributed. The paired t-test was conducted to analyze differences between preoperative and final follow-up clinical outcomes. Significance was set at a level of 0.05 with 95% confidence intervals.

## Results

#### General Results

All patients were recently followed-up. The average follow-up time was  $7.52 \pm 0.70$  months. Preoperative tear size was assessed during arthroscopic surgery. Out of all six patients involved, one tear was small (less than 1 cm) and five were medium (1–3 cm in length).

#### Functional Outcomes

##### Visual Analog Scale (VAS)

The VAS scores decreased with statistical significance from preoperative  $5 \pm 2.45$  to  $0.83 \pm 0.75$  at final follow-up ( $P = 0.009$ ). The VAS was reduced by 83.4% at final follow-up compared with the preoperative VAS.

##### American Shoulder and Elbow Surgeons (ASES) Score

The ASES score improved significantly from the preoperative  $47.67 \pm 17.41$  to  $91.67 \pm 10.76$  at final follow-up ( $P = 0.006$ ), the ASES score was improved by 92.30% at final follow-up compared with the preoperative ASES score.

### *University of California Los Angeles (UCLA) Score*

The UCLA scores had shown improvement with statistical significance from preoperative  $15.67 \pm 3.44$  to  $36.27 \pm 3.83$  at final follow-up ( $P < 0.001$ ), the UCLA score was improved by 131.46% at final follow-up compared with the preoperative UCLA score.

### *The Constant–Murley Scores*

The Constant–Murley scores improved from preoperative  $49.17 \pm 8.98$  to  $85.83 \pm 4.31$  at final follow-up ( $P = 0.001$ ), the Constant–Murley score was improved by 74.56% at final follow-up compared with the preoperative Constant–Murley score.

### *The Active Shoulder Range of Motion (ROM)*

The active shoulder ROM (forward flexion and abduction) improved from preoperative  $135.00 \pm 46.80$  and  $125 \pm 56.48$ , to  $173.67 \pm 4.13$  and  $172 \pm 3.27$  at final follow-up, respectively ( $P = 0.082$ ,  $P = 0.088$ ). There were no significant differences between preoperative and final follow-up active shoulder ROM.

### **Complications**

During the follow-up, there were no postoperative complications such as wound-site infection, nerve or vessel damage, subcutaneous hematoma, and suture anchor problems.

### **Discussion**

The prevalence of rotator cuff tears increases with age, acting as one of the main contributors of shoulder pain and dysfunction<sup>19</sup>. Suture bridge repair is a popular option due to its satisfactory clinical outcomes<sup>20,21</sup>. However, the occurrence of re-tear in the repaired tendon remains a significant problem that must be looked into. Re-tears are associated with various factors, such as the age, tear pattern, the choice of surgical technique for repair, and the degree of tendon mobility and fatty infiltration. It is widely known that the standard suture bridge technique involves sutures being tied as a horizontal mattress knot and the free suture limbs are then used to create crossed suture bridges over the tendon<sup>22</sup>. Even though the medial knots could enhance fixation strength and increase ultimate failure loads, the complexity and time taken for surgery increases, too. In addition, studies have demonstrated that these knots may loosen through repetitive load, leading to knot impingement or irritation on the acromion that inhibits tendon-bone healing<sup>9,23,24</sup>. Besides, it was pointed out through several animal studies that the crisscross configuration of suture bridge repair causes tendon compression that ultimately leads to a 50% reduction in blood flow<sup>25</sup>. Therefore, the knotless double-row technique is recommended. However, some studies have indicated the risk of early suture loosening after cycling, which could affect gap formation at the bone-tendon interface of the greater tuberosity<sup>21</sup>. Additionally, the knotless technique results in biomechanics in the medial row that is inferior to the knot-tying technique<sup>20</sup>.

This article details the H-loop knotless double row technique, which consists of a knotless H-loop and double row configuration. All passed sutures are parallel to the distal rotator cuff tendon. The passed limbs were knotless, maintaining blood supply to the medial tendon<sup>26</sup>. Furthermore, the knotless technique has a lot of advantages including reduced surgery time and eliminating medial knot impingement and irritation within the sub-acromial space<sup>27</sup>.

In an effort to preserve the advantages of knotless repair method, the H-loop suture technique is introduced in the medial row for this study. The H-loop is created with three passages through the rotator cuff using a separated #2 FiberWire suture. In contrast to conventional suture method, the H-loop suture technique is more efficient and reproducible, thus reducing surgical time and learning curve. Moreover, this technique has several other advantages. First of all, H-loop reduces the tension of retreated torn tendon due to the traction of the free limbs. Secondly, additional H-loops reduce the need for medial anchors according to the tear pattern, lifting a certain level of medical economic burden off patients. Thirdly, the H-loop technique is knotless, which means impingement and irritation that are caused by knots can be reduced. Fourth, The H-loop acts as a rip-stop construct that resists tendon cutout. Lastly, the traction of H-loop allows the inner row rivets to be distributed more evenly in a tension-free manner. Nevertheless, the H-loop double row technique has its own disadvantages too. Although the H-loop double row technique can save one anchor in the medial and lateral row, it also leads to increased stress concentration in the anchor. This may increase the risks of anchor removal, especially in patients with osteoporosis. Other than that, the H-loop double row technique may suit patients with crescent and U-shaped rotator cuff tear better. It is not as applicable for those with an L-shaped or reversed L-shaped tear. Furthermore, the technical difficulty level for the H-LOOP double row technique is higher since the passage through the rotator cuff may be more complex than other techniques.

There were several limitations to this study. First, further studies are needed to make comprehensive comparisons between the biomechanical and clinical outcomes of this technique with other suture methods, such as the standard suture bridge. Second, the sample size was not large enough to and the follow-up time was not long enough to accurately investigate the long-term results.

In summary, this article introduces a novel method of knotless double-row technique that integrates H-loop in medial row fixation. Although research was not performed on the biomechanical properties of this repair method, strong fixation in the medial row and excellent interconnectivity footprint coverage were observed when knotless double-row technique was combined with H-loop in repairing rotator cuff tears. Owing to its ease of conduction and satisfactory preliminary clinical outcome, this technique may be an alternative approach in repairing medium-sized rotator cuff tears with issues of degeneration and poor tissue quality, to increase tissue holding strength and healing rate.

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