



# Bubble Sign: An Arthroscopic Technical Trick to Differentiate Between Partial- and Full-Thickness Rotator Cuff Tears

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**Abstract:** Distinguishing between partial-thickness and small focal full-thickness tears of rotator cuff may be important for determining the appropriate surgical treatment options and repair constructs in the care of patients with rotator cuff pathology. This article presents a simple intraoperative technical trick to aid in identification of small full-thickness tears of the superior rotator cuff. The relatively higher-pressured subacromial space and the low-pressured glenohumeral joint are separated by the supraspinatus tendon. When this barrier is compromised due to a full-thickness tear, free fluid flows from high to low pressure down the native pressure gradient. This is seen as the movement of air bubbles into the glenohumeral joint from the subacromial space and can be used to identify the presence of a full-thickness rotator cuff tear on diagnostic arthroscopy.

Arthroscopic shoulder surgery has dramatically impacted the care and treatment of rotator cuff pathology.<sup>1</sup> It has allowed for a multitude of minimally invasive techniques and repair constructs to address rotator cuff pathology. Advanced imaging such as computed tomography arthrography, magnetic resonance imaging, and ultrasonography have become invaluable diagnostic tools in investigating and identifying shoulder pathology.<sup>2-4</sup> However, even with modern advanced imaging modalities, in certain patients it can be challenging to distinguish between partial-thickness rotator cuff tears and focal

full-thickness tears. Often, after a failure of appropriate nonoperative treatment, intraoperative diagnostic arthroscopy is used to confirm the presence and characteristics (type, location, and size) of a rotator cuff tear previously suspected based on advanced imaging modalities.<sup>5,6</sup> This article presents a simple intraoperative technical trick to aid in identification of small full-thickness tears of the superior rotator cuff; the bubble sign can be used arthroscopically to distinguish between partial-thickness (incomplete) tears and full-thickness rotator cuff tears.

## Biomechanics of the Shoulder Joint

The integrity of the native glenohumeral joint relies on a suction cup stabilization mechanism. Similar to how a rubber suction cup is rigid in the center but more flexible in the periphery, the center of the glenoid cavity has a thin layer of articular cartilage that thickens at the periphery. At greater distances from the center of the glenoid cavity, the glenoid labrum and, more peripherally, the capsule both provide additional flexibility.<sup>7,8</sup> Due to this gradual increase in pliancy, the compression of the humeral head into the glenoid cavity removes any interposed fluid in the articulating space and allows the glenoid to form a secure, vacuum-like seal with the humeral head. This vacuum limits the total joint volume, preventing the shoulder joint from easily subluxating.<sup>7,8</sup>

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In addition, the glenohumeral joint has a negative pressure of around  $-4$  mm Hg, which is maintained due to osmotic action by the synovium: for instance, the synovial fluid can have a pressure of 14 mm Hg and the synovial interstitium can have a pressure of 18 mm Hg. This yields a joint fluid pressure of  $-4$  mm Hg.<sup>7,8</sup> In contrast, the subacromial space has a pressure range from 8 to 17.5 mm Hg at rest ( $0^\circ$  of abduction).<sup>9,10</sup> Hence, in the native shoulder joint, there is a natural pressure gradient that is present: there is the lower-pressured glenohumeral joint and the relatively greater-pressured subacromial space, which are separated from each other by the supraspinatus tendon (Fig 1A).

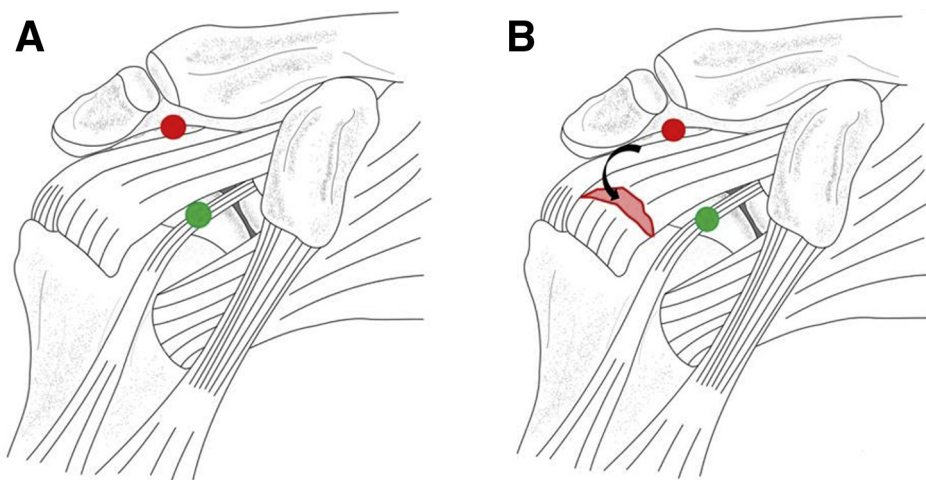
When the integrity of the rotator cuff is compromised due to a full-thickness tear, a connection forms between the high- and low-pressure compartments. Free fluid subsequently flows from the subacromial space (high pressure) and enters the glenohumeral joint (low pressure). As free fluid flows in, the vacuum-like seal once present between the glenoid cavity and the humeral head is now lost along with the limited joint volume (Fig 1B). Hence, the glenohumeral joint loses its native stability. Arthroscopically, this process manifests as air bubbles passing from an area of high pressure (subacromial space) to an area of low pressure (glenohumeral joint) when the supraspinatus tendon is lifted.

### Surgical Technique (With Video Illustration)

The patient is carefully placed in a beach chair position (Fig 2A). The operative extremity is prepped and draped in the normal sterile fashion, and the portal sites

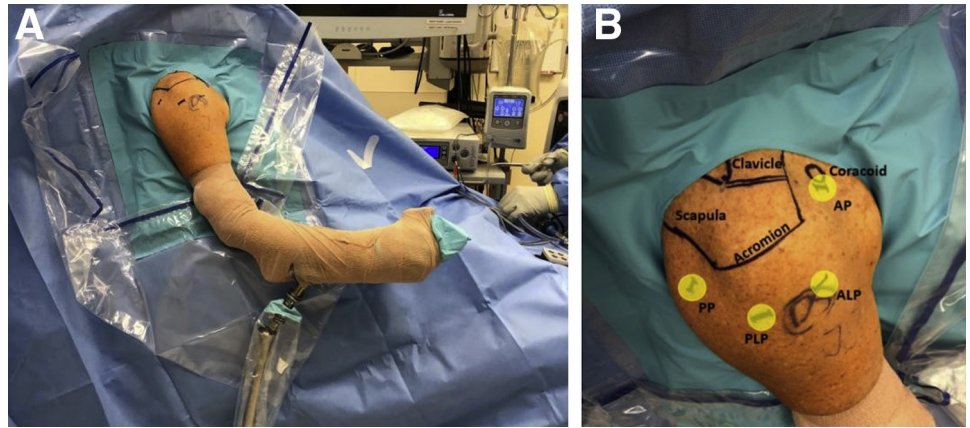
are marked using a surgical marker referenced off the bony landmarks of the acromion, acromioclavicular joint, lateral clavicle, and coracoid (Fig 2B). The operative shoulder is placed in neutral rotation and slight flexion, and this position is held by a commercially available arm positioning device (Spider 2 Limb Positioner; Smith & Nephew, Andover, MA). A portal incision is made for the posterolateral soft spot portal. The scope is introduced into the joint. We localized the anterior portal through the rotator interval using an 18-gauge spinal needle. Diagnostic arthroscopy is performed with an arthroscopic probe in the anterior portal and the camera in the posterior viewing portal.

The arthroscopy video shows the view of the right glenohumeral joint from the posterior aspect, with the supraspinatus tendon at the top of the field, the humeral head at the bottom, and the long head of the biceps tendon traversing from the middle of the field to the top left side (Fig 3A). The preoperative magnetic resonance imaging scan had demonstrated pathology of the tendinous insertion of the supraspinatus on the greater tuberosity. We perform a standardized and complete diagnostic arthroscopy of the glenohumeral joint as is well described. However, to fully investigate the crescent tissue of the supraspinatus tendon, it has been our practice to move the forearm from neutral rotation to about  $30$  to  $35^\circ$  of adducted external rotation. An arthroscopic probe or nerve hook is placed over the intra-articular portion of the biceps tendon (if present) and used to lift the crescent tissue of the rotator cuff off the greater tuberosity. As the probe lifts the supraspinatus tendon, air bubbles can be seen rushing into the field of view as they are moving down



**Fig 1.** (A) This diagram demonstrates the native shoulder joint. The high-pressured subacromial space (red mark) has a pressure range around 8-17.5 mm Hg at  $0^\circ$  of abduction. The glenohumeral joint (green mark) has a much lower pressure of around  $-4$  mm Hg. As seen in the diagram, an intact rotator cuff separates these 2 areas of high and low pressure, hence creating a native pressure gradient. (B) When a full-thickness tear occurs in the superior rotator cuff, there is now a conduit that connects the high- and low-pressure areas, causing a loss of the native pressure gradient. This results in movement of air from the subacromial space (the high-pressure area; red) to the glenohumeral joint (the low-pressure area; green), which we call the "bubble sign."

**Fig 2.** (A) The patient is placed in the beach-chair position, and the right upper extremity is prepped and draped in the normal sterile fashion. The operative shoulder is placed in neutral rotation and slight flexion, and this position is held by a commercially available arm positioning device (Spyder; Smith & Nephew). (B) The coracoid, anterior portal (AP), anterolateral portal (ALP), posterolateral portal (PLP), and posterior portal (PP) are carefully marked.



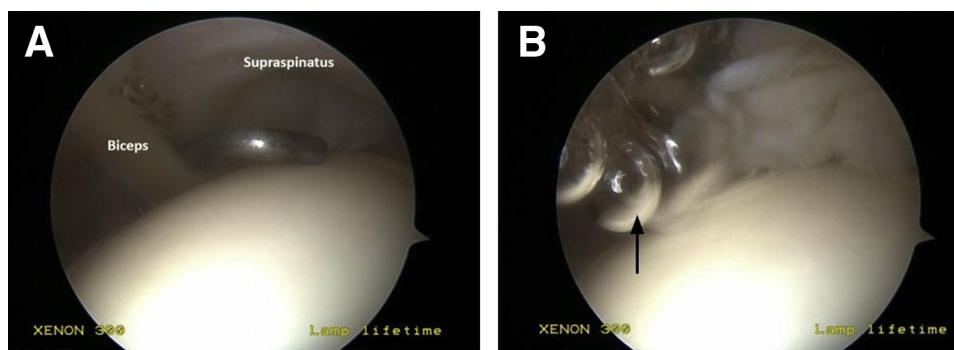
the pressure gradient from the subacromial space to the glenohumeral joint (Fig 3B). The presence of these bubbles, which we have called the “bubble sign,” helps confirm a focal full-thickness tear. If no “bubble sign” is demonstrated, we will often mark the tissue from outside-in via an 18-gauge spinal needle and a size 0 monofilament suture that can be identified on the bursal side of the rotator cuff once in the subacromial space. After completion of the diagnostic arthroscopy and completion of all intra-articular treatment, we turn our attention to the subacromial space. A blunt trocar is used to introduce the camera sleeve. A gentle sweep of the lateral gutter is performed. The subacromial space is cannulated to establish a lateral subacromial portal. Bursal tissue is cleared, and the rotator cuff tear is identified from the bursal side.

### Discussion

This article presents a simple and quick intraoperative technical trick to aid in identification of small full-thickness tears of the superior rotator cuff. We suggest that the observation of air bubbles moving from high pressure (subacromial space) to low pressure

(glenohumeral joint) compartments can indicate a full-thickness compromise in the rotator cuff tendon. The included video from a portion of a diagnostic shoulder arthroscopy in the beach chair position nicely demonstrates this phenomenon (Video 1).

Distinguishing between partial-thickness tears, sometimes called incomplete tears, and full-thickness tears (complete) on advanced imaging and even intraoperatively can be less than straight forward. Discerning the difference may have important implications on intraoperative disease management and repair techniques. For partial-thickness tears, debridement alone, in-situ repair, and take down/completion and repair have all been advocated. Current literature on the arthroscopic diagnosis of rotator cuff tears involves many methods by which a fluid is introduced into the shoulder joint to observe for various signs that would indicate a partial or full-thickness rotator cuff tear. For instance, Martin et al.<sup>11</sup> explored a method in which a 22-gauge needle was used to inject a solution of saline containing air bubbles. The study found that air bubbles can be seen leaving the glenohumeral joint and attaching to the tear edge in instances where a



**Fig 3.** (A) An intra-articular diagnostic arthroscopy of a patient in the beach-chair position showing the right glenohumeral joint from the posterior viewing portal. The humeral head, supraspinatus tendon (labeled), and long head of the biceps tendon (labeled) are in view. (B) As the supraspinatus tendon is raised by the blunt trocar, air bubbles (the “bubble sign”; black arrow) can be seen entering from the subacromial space (not visualized) into the field of the glenohumeral joint.



**Table 1.** Pearls and Pitfalls of the Bubble Sign

Pearls	Pitfalls
The “bubble sign” helps confirm a full-thickness tear of the superior rotator cuff tendon	The “bubble sign” is not present once a full-thickness tear reaches a critical size, after which the native pressure gradient will be lost
This “bubble sign” can be viewed in either beach-chair or lateral decubitus position, as it takes advantage of the natural pressure gradient	Surgeons should not substitute this technical pearl for a thorough diagnostic arthroscopy
This technique can be performed during any diagnostic arthroscopy	

rotator cuff tear was present. The authors suggest that this technique may be a simpler and safer method of identifying rotator cuff pathology while still maintaining its sensitivity. A similar study performed by Moon et al.<sup>12</sup> discussed an air-infusion technique in which the glenohumeral joint was inflated with air and then observed bursoscopically for leakage of air bubbles, indicating a full-thickness rotator cuff tear. The study concluded that this technique was an effective way of differentiating between partial and full-thickness rotator cuff tears. Lo et al.<sup>13</sup> took a similar approach by injecting saline into the suspected tear and observing the swelling of the rotator cuff tendon. However, this method is used to identify an intratendinous tear of the rotator cuff rather than a full-thickness tear.<sup>13</sup> The method demonstrated by Simon et al.<sup>14</sup> uses the presence of an air bubble to signify an intact rotator cuff. In contrast, our technique uses the presence of an air bubble to indicate the presence of a rotator cuff tear. While the technique proposed by Simon et al.<sup>14</sup> uses the native intra-articular pressures to assess rotator cuff integrity, its sensitivity relies on the proper flushing of air bubbles from the fluid inflow to avoid false positive results.

It has been our practice that if a partial-thickness articular sided tear is identified, we will often mark the tissue from outside-in via an 18-gauge spinal needle and a size 0 monofilament suture that can be identified on the bursal side of the rotator cuff once in the subacromial space for further investigation. This allows us to accurately assess the depth of the tear to distinguish whether it is shallow, moderate, or high grade. Previous authors have defined and used different classification systems for partial-thickness tears. The most widely used system for partial-thickness tears is the Ellman classification in which Grade 1: partial tear <3 mm deep, Grade 2: partial tear 3-6 mm deep (depth not exceeding one-half of the tendon thickness) and Grade

3: partial tear >6 mm deep.<sup>15</sup> There is currently no consensus on current management of full-thickness or partial-thickness tears.<sup>16-20</sup> However, several longitudinal studies have demonstrated that the natural history of partial-thickness tears may be different than that of full-thickness tears.<sup>21,22</sup> Thus, we feel that differentiation between partial-thickness and full-thickness tears is important in the treatment for rotator cuff disease. We have found that the “bubble sign” helps confirm a full-thickness tear of the superior rotator cuff (Table 1). When this is observed, we no longer find the utility in performing an outside-in tagging/marking suture, which saves both time and resources (Table 2). It is a quick and simple technical pearl to aid in the accurate diagnosis and appropriate treatment of rotator cuff disease.

This observational technique has many advantages. The “bubble sign” as described in our article differs from other published techniques in that it does not require the introduction of saline, air, or other fluid to visualize a full-thickness supraspinatus tendon tear. Instead, our method takes advantage of the natural pressure gradient already present in the native shoulder joint to simply observe for movement of air bubbles from subacromial space to glenohumeral joint during diagnostic arthroscopy. Because of the natural pressure gradient, the bubble sign can be observed in patients positioned in either the beach chair or lateral decubitus position. However, once a full-thickness tear reaches a critical size, the pressure gradient between the subacromial space and the glenohumeral joint is lost and the “bubble sign” will not be present. We believe that this bubble sign can be a useful diagnostic tool, especially when used in conjunction with advanced imaging and a thorough diagnostic arthroscopy, to accurately differentiate small full-thickness rotator cuff tendon tears from partial-thickness rotator cuff tears prior to moving into the subacromial space during a diagnostic arthroscopy. This technical maneuver should not replace any part of a thorough and exhaustive diagnostic arthroscopy but is rather meant to augment it.

**Table 2.** Advantages and Disadvantages of the Bubble Sign

Advantages	Disadvantages
The observation of the “bubble sign” saves time and resources (no need for injection of air, saline, or other fluid or outside-in marking suture)	This technical pearl is not useful for identifying intratendinous tears
No additional skills or special equipment required	
The technique is easily reproducible by any surgeon	

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