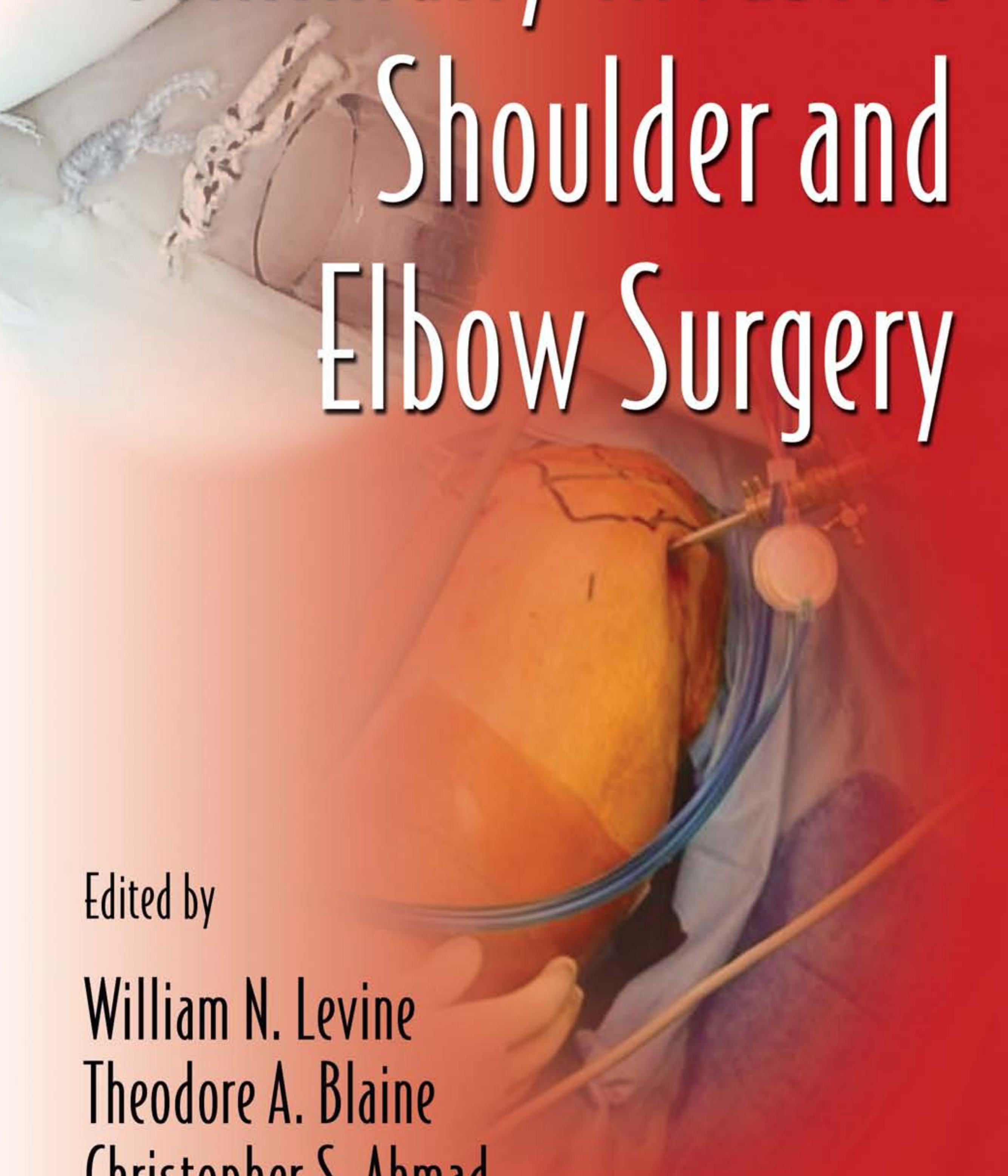
Minimally Invasive Shoulder and Elbow Surgery



Edited by

William N. Levine
Theodore A. Blaine
Christopher S. Ahmad

Minimally Invasive Shoulder and Elbow Surgery

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Series Editors

Alexander R. Vaccaro
Rothman Institute
and
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Boston, Massachusetts, U.S.A.

1. Minimally Invasive Shoulder and Elbow Surgery, *edited by William N. Levine, Theodore A. Blaine, and Christopher S. Ahmad*

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Edited by

William N. Levine
Columbia Presbyterian Medical Center
New York, New York, U.S.A.

Theodore A. Blaine
Columbia Presbyterian Medical Center
New York, New York, U.S.A.

Christopher S. Ahmad
Columbia Presbyterian Medical Center
New York, New York, U.S.A.

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Preface

The management of shoulder and elbow pathology has changed more dramatically over the last decade than many other disciplines in medicine owing to the innovation of minimally invasive surgery. This spectrum of techniques has swept through orthopedic surgery, allowing surgeons to identify, manage, and treat their patients without requiring the large open incisions that could lead to postoperative difficulties. Fewer complications, shorter recovery periods, and the overall ease of treatment have all contributed to the success of these techniques.

This book was designed to provide the reader with the latest approaches in minimally invasive surgery as it applies to the shoulder and elbow. Our contributors are well-respected world leaders at the cutting edge of these procedures and its technology.

Minimally invasive shoulder surgery is covered in detail. This book discusses the basic setup and diagnostic arthroscopy before explaining, step by step, a multitude of procedures, including acromioplasty, distal clavicle resection, instability repair, glenoid debridement, and the treatment of cysts and inflammation, and provides a multi-chapter, in-depth look at rotator cuff repair.

Minimally invasive elbow surgery is also given detailed attention with several chapters devoted to both straightforward procedures, such as diagnostic arthroscopy and tennis elbow debridement, and procedures that only the most experienced arthroscopists should attempt, including managing cubital tunnel syndrome with arthroscopic medial epicondylectomy.

It is our hope that this book is embraced by the orthopedic surgery community as the definitive "how-to" guide on minimally invasive approaches to the shoulder and elbow.

William N. Levine
Theodore A. Blaine
Christopher S. Ahmad

Contents

Contributors

Jeffrey S. Abrams Princeton Orthopaedic & Rehabilitation Associates, Princeton, New Jersey, U.S.A.

Kenneth J. Accousti Department of Orthopedic Surgery, Mount Sinai Medical Center, New York, New York, U.S.A.

Robert Afra Department of Orthopedics, University of California, San Diego, California, U.S.A.

Christopher S. Ahmad Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Hari Ankem Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

April D. Armstrong Department of Orthopedics and Rehabilitation, Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania, U.S.A.

Champ L. Baker, Jr. The Hughston Clinic and The Hughston Foundation, Inc., Columbus, Georgia, U.S.A.

F. Alan Barber Plano Orthopedic and Sports Medicine Center, Plano, Texas, U.S.A.

Shane A. Barwood Department of Orthopedic Surgery, The University of Calgary, Calgary, Alberta, Canada

John-Erik Bell Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Theodore A. Blaine Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Michael H. Boothby Plano Orthopedic and Sports Medicine Center, Plano, Texas, U.S.A.

Gabriel D. Brown Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Taylor D. Brown Mississippi Sports Medicine and Orthopedic Center, Jackson, Mississippi, U.S.A.

Stephen S. Burkhart The San Antonio Orthopedic Group, San Antonio, Texas, U.S.A.

Cordelia Carter Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Ryan Chen Department of Orthopedic Surgery, Washington University School of Medicine, Barnes-Jewish Hospital, St. Louis, Missouri, U.S.A.

A. Martin Clark, Jr. The CORE Institute, Sun City West, Arizona, U.S.A.

Brian J. Cole Departments of Orthopedics and Anatomy and Cell Biology and Division of Shoulder and Elbow Surgery, Department of Orthopedic Surgery, Rush University Medical Center, Rush Medical College, Chicago, Illinois, U.S.A.

Xavier A. Duralde Peachtree Orthopaedic Clinic, Emory University, Atlanta, Georgia, U.S.A.

Sara Edwards Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Neal S. ElAttrache Kerlan-Jobe Orthopedic Clinic and Department of Orthopedic Surgery, University of Southern California School of Medicine, Los Angeles, California, U.S.A.

Mitchell F. Fagelman Department of Orthopedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, U.S.A.

Larry D. Field Upper Extremity Service, Mississippi Sports Medicine and Orthopedic Center, and Department of Orthopedic Surgery, University of Mississippi School of Medicine, Jackson, Mississippi, U.S.A.

Evan L. Flatow Department of Orthopedic Surgery, Mount Sinai Medical Center, New York, New York, U.S.A.

Michael Q. Freehill Sports and Orthopedic Specialists, Edina, Minnesota, U.S.A.

Leesa M. Galatz Department of Orthopedic Surgery, Washington University School of Medicine, Barnes-Jewish Hospital, St. Louis, Missouri, U.S.A.

Charles L. Getz Department of Orthopedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, U.S.A.

Andreas H. Gomoll Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, U.S.A.

Eric H. Gordon Arkansas Specialty Orthopaedics, Little Rock, Arkansas, U.S.A.

David P. Huberty The San Antonio Orthopedic Group, San Antonio, Texas, U.S.A.

Kent Jackson Hospital for Special Surgery, New York, New York, U.S.A.

Jay D. Keener Department of Orthopedic Surgery, Washington University, St. Louis, Missouri, U.S.A.

Hyun-Min Kim Department of Orthopedic Surgery, Washington University School of Medicine, Barnes-Jewish Hospital, St. Louis, Missouri, U.S.A.

Christian Lattermann Department of Orthopedic Surgery, University of Kentucky, Lexington, Kentucky, and Midwest Orthopaedics at Rush, Rush University Hospital, Chicago, Illinois, U.S.A.

William N. Levine Center for Shoulder, Elbow, and Sports Medicine, Department of Orthopedic Surgery, Columbia Presbyterian Medical Center, New York, New York, U.S.A.

Ian K.Y. Lo Department of Orthopedic Surgery, The University of Calgary, Calgary, Alberta, Canada.

Emilio Lopez-Vidriero Center for Sports Medicine, Department of Orthopedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, U.S.A.

R. Vaughan Massie The Hughston Clinic and The Hughston Foundation, Inc., Columbus, Georgia, U.S.A.

Augustus D. Mazzocca Department of Orthopedic Surgery, University of Connecticut Health Center, Farmington, Connecticut, U.S.A.

Peter J. Millett The Steadman-Hawkins Clinic, Vail, Colorado, U.S.A.

Anand M. Murthi Department of Orthopedics, The Shoulder and Elbow Service, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A.

Gregory P. Nicholson Department of Orthopedic Surgery, Rush University Medical Center, Midwest Orthopaedics at Rush, Rush University Hospital, Chicago, Illinois, U.S.A.

John P. Peden Mississippi Sports Medicine and Orthopedic Center, Jackson, Mississippi, U.S.A.

Matthew L. Ramsey Department of Orthopedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, U.S.A.

Herbert Resch Department of Traumatology and Sports Injuries, University Hospital of Salzburg, Salzburg, Austria

Mark W. Rodosky Department of Orthopedic Surgery, Division of Shoulder Surgery, University of Pittsburgh Sports Medicine, Pittsburgh, Pennsylvania, U.S.A.

Joaquin Sanchez-Sotelo Department of Orthopedic Surgery, Mayo Clinic Rochester, Rochester, Minnesota, U.S.A.

Felix H. Savoie Upper Extremity Service, Mississippi Sports Medicine and Orthopedic Center, and Department of Orthopedic Surgery, University of Mississippi School of Medicine, Jackson, Mississippi, U.S.A.

Jon K. Sekiya Center for Sports Medicine, Department of Orthopedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, U.S.A.

Adam M. Smith Kentucky Sports Medicine Clinic, Lexington, Kentucky, U.S.A.

Stephen J. Snyder Southern California Orthopaedic Institute, Van Nuys, California, U.S.A.

Walter J. Song Department of Orthopedic Surgery, University of Connecticut Health Center, Farmington, Connecticut, U.S.A.

John W. Sperling Department of Orthopedics, Mayo Clinic, Rochester, Minnesota, U.S.A.

Jason A. Stein Department of Orthopedics, The Shoulder and Elbow Service, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A.

Beth E. Shubin Stein Hospital for Special Surgery, New York, New York, U.S.A.

Scott P. Steinmann Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota, U.S.A.

Timothy J. Strigenz Department of Orthopedics and Rehabilitation, Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania, U.S.A.

Douglass E. Stull Department of Orthopedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, U.S.A.

Robert Z. Tashjian Department of Orthopedic Surgery, Washington University School of Medicine, Barnes-Jewish Hospital, St. Louis, Missouri, U.S.A.

Mark Tauber Department of Traumatology and Sports Injuries, University Hospital of Salzburg, Salzburg, Austria

Ilya Voloshin Department of Orthopedics, University of Rochester Medical Center, Rochester, New York, U.S.A.

Gerald R. Williams, Jr. Department of Orthopedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, U.S.A.

Ken Yamaguchi Department of Orthopedic Surgery, Washington University School of Medicine, Barnes-Jewish Hospital, St. Louis, Missouri, U.S.A.

1 Patient Positioning During Arthroscopic Shoulder Surgery

Ilya Voloshin
Department of Orthopedics, University of Rochester Medical Center, Rochester, New York, U.S.A.

Robert Afra
Department of Orthopedics, University of California, San Diego, California, U.S.A.

INTRODUCTION

The last decade has seen an exponential increase in the number of arthroscopic shoulder surgeries performed. The indications for shoulder arthroscopy continue to expand and the procedures are becoming more complex. With the widening indications, more surgical complications have been described (1). Given this robust growth in numbers of arthroscopic shoulder procedures, the surgeons must continue to master their efficiency and quality of surgical procedures. This efficiency, in part, derives from the operating room (OR) set up and proper patient positioning. The two most common positions utilized in shoulder arthroscopy are beach-chair and lateral decubitus positions. The surgeon's preference largely determines which position is used and for which procedures. Both positions have their advantages and disadvantages, requiring surgeon awareness to minimize risk and avoid complications. Regardless of the position chosen, prior to draping, the surgical team must take the time to fine-tune the patient's position. For both positions used for shoulder arthroscopy, this chapter describes setup technique, advantages and disadvantages for each position, complications, and senior author's (IV) rationale for position choice for different surgical procedures.

ANESTHESIA

A brachial plexus block is often utilized in conjunction with general endotracheal anesthesia. The reason for supplemental sedation is poor tolerance for lateral decubitus position by the completely awake patient for a prolonged period of time. This is due to some pressure points (especially, the axillary roll) that may irritate the patient if the procedure lasts beyond two hours. The use of a brachial plexus block should be discussed among the surgeon, anesthesiologist, and the patient, given the risks and potential complications. Although the procedural details are beyond the scope of this chapter, the two most common form of blocks for shoulder arthroscopy are the interscalene and supraclavicular. It is important for a surgeon to firmly appreciate the benefits and risks associated with each block. The block typically provides 8 to 18 hours of pain relief and motor paralysis, depending on the anesthetic cocktail delivered and the block quality.

LATERAL DECUBITUS POSITIONING

The lateral decubitus position with continuous arm traction applied is perhaps the most popular position because of its simple set up and low equipment cost (2).

Preparation of the Operating Room

Prior to the patient transferring from the gurney to the OR bed, it is important for a U-shaped bean bag (3 ft long size; 32 Vacupac, Olympic Medical Seattle, Washington, U.S.A.) and

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Please refer to pages 8–12 for the figures in this chapter.

overlying sheet to be in proper position (Fig. 1). The U end of the bean bag should be cephalad so that the suction end is caudad (out of the way). The flaps should be positioned to avoid blocking adequate shoulder exposure. The base of the U is at the level of the scapula. Also, the suction should be anterior so that it is out of the surgeon's way. Make sure the beans are evenly distributed so that the position of the upper torso and the lower torso are adequately controlled. Deficiency of beans will lead to the body collapsing the bean bag once engaged. An overlying sheet is important because it protects the patient's skin from direct pressure of the bean bag, and it is an aid to position the patient. The authors use a nondisposable sheet to help levitate and reposition the patient to lateral decubitus. It is important not to drag the patient because this will lead to a shift in the bean bag position as it is dragged.

Initial Positioning

While supine on the OR table, general anesthesia is established. The authors prefer to have the endotracheal tube or laryngeal mask airway (LMA) secured to the contralateral side of the mouth, to decrease the risk of inadvertent extubation when removing drapes at the completion of surgery. The appropriate shoulder examination under anesthesia is performed.

The patient is placed into the lateral decubitus position with the aid of four people: anesthesiologist at the head, one person on the right, left, and foot of the bed. With the anesthesiologist's count, the patient is turned to the lateral decubitus position in two steps. First, the patient is suspended in the air using the overlying sheet. Then, the operative side is turned up. The person at the foot of the bed repositions to be able to insert an appropriate axillary roll, as the torso is elevated by the other three people. The roll should not be in the axilla per se, but at the U portion of the bean bag to support the thorax and prevent pressure on the dependent shoulder and axilla.

The primary surgeon controls the position of the anterior and posterior sand bag flaps, and the assistant surgeon controls the caudad end of the bean bag. The nurse applies suction to engage the bean bag. Ideally, the patient's torso should be tilted 20° posteriorly (Fig. 2). For a male patient, one must ensure that the genitals are not squeezed between the thighs or faced with excessive pressure against the bean bag. Padding should be placed to unload the fibular head of the bottom leg, to avoid a peroneal nerve palsy. Additional padding should protect the bottom ankle, elbow, and wrist. The anesthesiologist must provide adequate padding under the head to make sure that the neck is in neutral position, to avoid excessive strain on the brachial plexus (Fig. 3). Leg mechanical compression devices are placed to prevent deep venous thrombosis. A pillow is placed between the knees to relieve pressure on the hips (Fig. 4). A sheet is placed over the buttock and a safety strap is applied. The operating table is rotated 45° posteriorly, so the surgeon can approach the head. This allows the surgeon to access the anterior shoulder. The bottom arm is strapped to an arm board at 90° to 120° to the torso. The operative arm is suspended to allow adequate surgical prep, using tape, clamp, or IV pressure bag. A single U drape is placed in the axilla with the open end toward the head. Make sure the adherent flaps stick well to the skin so that the patient does not become wet and hypothermic from the arthroscopy fluid. A lower body bear hugger is applied to keep the torso and lower extremity warm. It is not activated until all sterile drapes are applied, so as not to compromise the sterile field. The double boom shoulder holder (Arthrex Three-Point Traction Tower) is attached at the caudad end of the anterior rail. The head of the boom is extended/rotated to sit 2- to 3-ft above the upper shoulder (Fig. 5).

Final Positioning and Preparation for Surgery

The surgical team should confirm whether perioperative antibiotics have been administered. Skin preparation is accomplished using the solution most preferred by the surgeon. The advantage of betadine is that it stains skin and missed spots are easily located. Some prefer Hibiclens (chlorhexadine), followed by alcohol scrub. Flammability is not an issue, since electrocautery is not used early in the case. In addition, the skin is less irritated than with betadine, and it does not need to be washed off at the end of the case. A drying towel is used along the field edge so that the adhesive on the sterile drapes will stick. A $\frac{3}{4}$ downsheet is placed caudad to the axilla. The gowned surgeon takes control of the forearm with a sterile towel. For surgical cases involving instability and superior labrum anterior-posterior (SLAP) lesions, the extremity is placed into the foam shoulder traction and rotation sleeve (StaR Sleeve, Arthrex Inc.; Naples, Florida, U.S.A.). So that there is adequate length for traction, it is important to place the foam deep into the axilla. The extremity is rotated so that the thumb is at the open side of the sleeve for the rotation to be controlled. Koban is used to wrap the arm and forearm for a snug fit. The distal end of the sleeve is secured to the bottom pulley with an S hook and suspended with 10 pounds for an average size extremity. The weight should be adjusted according to patient size and weight. The strap is opened and applied to the most proximal portion of the foam sleeve, near the axilla. Six to eight pounds are applied for traction to the second hook. Ideally, the arm is abducted 70° and forward flexed 15°. The strap is overwrapped with a second Koban (Fig. 6). The authors like to apply an impervious U drape below the axilla and the tails taken toward the head. A paper U drape is applied in a similar fashion. A paper U drape with fluid bag is based over the neck, and tails are taken toward the torso.

BEACH-CHAIR POSITION

For many surgeons, the beach chair is chosen because the shoulder is in position similar to open surgery and conversion to open surgery is easier (3). The beach-chair position is increasing in popularity since the advent of special arm and shoulder positioners, which facilitate the control of the arm and exposure to the posterior aspect of the shoulder.

Preparation of the Operating Room

The senior author (IV) has been using the T-max Shoulder Positioner and Spider Limb Positioner (Tenet Medical Engineering, Calgary, Alberta, Canada) for shoulder arthroscopy in the beach-chair position (Fig. 7). The Spider Limb Positioner allows excellent control, positional freedom, and ability to apply traction to the operative extremity.

The shoulder positioner needs to be safely secured to the OR table. Gel padding is used to avoid pressure points on patient's back. The arm positioner is attached to the shoulder positioner. A nitrogen hose from the arm positioner is connected to the nitrogen wall outlet set at 100psi.

Initial Positioning

The patient is initially in a supine position. Because patients tolerate the sitting position better than the lateral decubitus, beach-chair position allows the option of performing shoulder arthroscopy solely under the interscalene block without any supplemental sedation. This may be beneficial when a patient has a serious cardiopulmonary ailment. If additional sedation is desired, the patient is intubated in the supine position.

The shoulder positioner is raised, and the patient is flexed 80° at the waist. This brings the acromion parallel to the floor to facilitate access to the posterior portal (Fig. 8). The patient's head is secured on a padded head positioner. It is important to make sure that the neck is in neutral position (Fig. 9). The torso is secured by special side supports, to prevent shifting the patient during surgery when traction is applied (Fig. 10). The lower extremities are placed on a pillow with knees flexed, to protect the peroneal nerve and soft tissue. The contralateral arm is placed on an arm board with special attention paid to the padding for the ulnar nerve at the level of the cubital tunnel.

The operating table is rotated 45° posteriorly, so the surgeon has enough access to the posterior shoulder and does not feel cramped by the anesthesia equipment. The operative arm is suspended to allow adequate surgical prep, using tape, clamp, or IV pressure bag. A single U drape is placed in the axilla with the open end toward the head. Make sure the adherent flaps stick well to the skin so that the patient does not become wet and hypothermic from the arthroscopy fluid. A lower body bear hugger is applied to keep the torso and lower extremity warm. It is not activated until all sterile drapes are applied, so as not to compromise the sterile field.

Final Positioning and Preparation for Surgery

The operative extremity is prepped and a drying towel is used along the field edge, so that the adhesive on the sterile drapes sticks. Two sterile impervious U drapes are applied from below and above the shoulder creating a good seal to the skin. Two paper U drape are applied in a similar fashion. A paper U drape with fluid bag is based inferior to the axilla with tails taken toward the head. The gowned surgeon takes control of the forearm with a sterile towel. The extremity is placed into the special foam forearm cuff with metal bar (part of Spider Limb Positioner and shoulder stabilization kit) (Fig. 11). Koban is used to wrap the forearm for a snug fit. The Spider Limb Positioner is dressed with the special sterile limb positioner drape (part of the shoulder stabilization kit). The forearm sleeve is secured to the limb positioner, which allows motion and all three planes. At this point, the patient is positioned for the arthroscopic procedure with adequate access to all areas of the shoulder. If the decision is made to convert to an open procedure, it can be easily performed without the need to reposition the patient. Patient's flexion at the waist level can be easily adjusted without the need for redraping. Special attention must be paid to the neck and head position if patient is flexed or if extended at the waist level or intermittent traction is applied to the operative extremity during surgery.

DISCUSSION

Lateral Decubitus

Lateral decubitus position has several advantages. Access to the anterior, posterior, superior, and inferior labrum is easier in the lateral decubitus position compared to the beach-chair position (4). When performing shoulder arthroscopy for multidirectional instability, SLAP, or Bankart injury, visibility is improved with the lateral decubitus position.

Jerosch et al. (5), in a cadaveric study, determined that when performing an arthroscopic shoulder capsular release for adhesive capsulitis, the optimum position for the operative extremity is in the abducted, externally rotated position. This positioning mimics the lateral decubitus position. With the arm thus situated, the axillary nerve stays in its native position, while the glenohumeral capsule tightens. This increases the distance between the two structures, allowing the surgeon to release the inferior capsule more safely.

Hypotensive anesthesia improves visualization, allowing lower pump pressures to avoid excessive tissue distension. A potential advantage of the lateral decubitus position over the beach-chair position is a decreased risk of stroke. The cerebrum is in a dependent position, which decreases the risk of a cerebrovascular ischemic event during intraoperative hypotension. However, Palermo et al. (6) determined that patients with congestive heart failure were both subjectively and physiologically less tolerant of the lateral decubitus position, in comparison to the sitting position. When operating on patients with a history of heart failure, the surgeon must be cognizant of the fact that airway obstruction and lung diffusion impairment may become a clinical issue.

Several downsides to the lateral decubitus position exist. The risk of some of the complications can be minimized by surgical prudence. Other risks are inherent to the surgical position and must be dealt with as they arise.

According to Hoenecke et al. (4), conversion of the lateral decubitus position to an open approach could be more difficult than for the beach-chair position, especially for an anterior approach.

Various types of neurologic injuries have been described with the lateral decubitus position. Neurologic complications have included compression of the dorsal digital nerve of the thumb, peroneal nerve, ulnar nerve, and traction-induced trauma to the brachial plexus (7). According to Bigliani et al. (2), brachial plexus strain was the most common complication associated with the lateral decubitus position in the 1980s. The nerve injury usually resolved over a 6- to 12-week period.

Overstretching was the mechanism most commonly involved in neuropraxias that developed with shoulder arthroscopy in the lateral decubitus position. This was due to traction on the operative shoulder or lateral flexion of the neck. Klein et al. (8), in a cadaveric study, determined that, at a given flexion angle, increasing abduction of the operative shoulder leads to a decrease in the strain on the brachial plexus. At a given abduction angle, increasing flexion results in a decrease in the strain on the brachial plexus. At the extremes, however, visibility is thoroughly limited. As such, the authors proposed a balance between strain minimization and visibility maximization. They suggested such combinations of positions as 45° of forward flexion with 90° of abduction and 45° of forward flexion with 0° of abduction. The authors believed that repositioning during the case between these two positions would achieve a balance between adequate visibility and the least amount of strain on the brachial plexus. Pitman et al. (9) demonstrated, with somatosensory evoked potentials, that the incidence of subclinical neuropraxia is high in the shoulder operated on in the lateral decubitus position. The musculocutaneous nerve was the most vulnerable nerve; the injury usually occurred when the nerve enters the conjoint muscles. Others have proposed the head position to be the culprit. The angle between the head and shoulder is widened, as the head is placed into extension with lateral flexion to the contralateral side. Shaffer et al. (10) advocated use of no more than 10 pounds (4.5 kg) for arm traction, to decrease the risk of injury to the brachial plexus. However, no scientific evidence was offered to substantiate this weight. Berjano et al. (11) described three cases of ulnar nerve neuropraxia on the operative extremity, while the patients were in the lateral decubitus position. Symptoms resolved over a 12-week period. They attributed the neuropraxia to the way that the adhesive traction system was wrapped around the elbow. Traction on the extremities never exceeded 3 kg.

Pavlik et al. (12) described a shoulder arthroscopy case in the lateral decubitus position in which the patient developed a contralateral brachial plexus palsy. Ten pounds of traction were applied in the 45 min surgical case. The patient was found to have a C7-T1 palsy postoperatively. There was no mention of a brachial plexus block or placement of an axillary role. An x-ray of the neck revealed bilateral cervical ribs. In order to avoid a traction injury to the operative shoulder, the anesthesiologist, in this case, elevated the head slightly passed neutral to prevent stretch of the plexus; however, in effect, the contralateral brachial plexus was placed on stretch. They believed the head position, lack of an axillary role, in conjunction with the abnormal anatomy, resulted in stretching of the lower roots, leading to a palsy.

Gonzalez Della Valle et al. (13) measured the pressure under the inferior shoulder and chest wall, while using various devices as an "axillary role": 1 L lactated Ringer's bag in conjunction with a pillow under the head, a gel pad in conjunction with a pillow under the head, and a double inflatable pillow system, under the chest wall and head (Shoulder-Float, Trimline Medial Products; Branchburg, New Jersey, U.S.A.). They found the average pressure beneath the shoulder without any supporting device to be 64 mmHg, using the 1 L bag was 34 mmHg, using the gel pad was 27 mmHg, and using the inflatable pillow was 10 mmHg ($P < 0.001$). Additionally, a significantly positive correlation was found between body weight and pressure beneath the shoulder. The limiting factor in making clinical use of this data is that there is no threshold value of what pressure becomes clinically relevant. Of note, the inflatable pillows are easier to position, in that the patient's torso does not need to be elevated for the device to be placed.

Beach-Chair Position

According to Hoenecke et al. (4), using the beach-chair position during shoulder arthroscopy presents the anatomy in an "upright, anatomic" position. It minimizes spatial disorientation. More importantly, however, it is easier to convert to an open anterior procedure from the beach-chair position than from the lateral decubitus position. Yet, the most commonly mentioned reason surgeons choose to use the beach-chair position over the lateral decubitus position is most likely due to the lower incidence of nerve palsy.

According to Hoenecke (4), if traction is needed to facilitate visualization or space needed to perform surgery while shoulder arthroscopy is performed in the beach-chair position, one of two things is necessary. Either the assistant will be occupied applying traction, instead of helping the primary surgeon with the surgery; or a relatively expensive spatial positioning device is needed to provide traction for exposure of the subacromial or intra-articular space. As well, access to the axillary pouch and the posterior recess is difficult. Baechler et al. (14) acknowledged the difficulty of performing an arthroscopic SLAP repair, utilizing the beach-chair position. Depending on the lateral acromial morphology, the assistant surgeon may need to displace the humeral head inferiorly with longitudinal traction if the patient is in the beach-chair position. They concluded that if the surgeon determines preoperatively by the method they describe that the humeral head must be inferiorly displaced by greater than 25% of the humeral head diameter to achieve adequate arthroscopic access to the superior glenoid, they recommended the lateral decubitus position for that patient. However, modern limb positioners can apply intermittent traction without occupying the assistant surgeon and allow adequate access to the superior glenoid.

Several drawbacks to the beach-chair position have been described. When an open camera lens system is used during beach chair positioned shoulder arthroscopy, there is the potential for fogging of the arthroscopic lens as a result of the flow of irrigation down the scope when the camera is held in an "uphill" position from a posterior viewing portal (3).

Although many authors have discussed brachial plexus palsies after shoulder surgery in the lateral decubitus position, a few have described a neuropraxia in the beach-chair position. Mullins et al. (15) describe a hypoglossal nerve neuropraxia that developed after shoulder arthroscopy and open cuff repair with the patient in the beach-chair position. The nerve palsy was completely resolved by postoperative week eight. The complete vascular and neurologic work-up was negative. The authors offer two possible causes. Either the hypoglossal nerve was compressed by the endotracheal tube, or a change in the patient's head position during the case led to the nerve being compressed beneath the mandibular angle. A change in the head position is prone to occur during patient position changes, such as reclining the operative table or tilting it to one side or the other during the operative case. They suggest frequent checks to confirm proper head alignment and position. Interestingly, Cooper et al. (16) reported a case of a contralateral brachial plexus palsy while in the beach-chair position. This patient had an open shoulder procedure, while the contralateral arm was abducted to 90° and placed on an arm board. The patient developed a C5 and C6 root palsy. The authors believed it was due to prolonged stretching of the plexus.

Bhatti et al. (17) described a case in which the patient underwent a shoulder arthroscopy in the beach-chair position with postoperative loss of vision in one eye and significantly limited gaze in all directions. The neurologic and cardiovascular work-up was negative. The patient's vision returned to near normal over the ensuing two weeks. The authors reported intraoperative hypotension used to aid in visualization as a potential risk factor. The intraoperative blood pressure reading may have been falsely higher than the true pressure in this case, because the blood pressure cuff was placed around the ankle, which was in a dependent position. They believed the etiology of the visual loss and opthalmoplegia was an orbital or extraocular muscle ischemic process, suggesting the scattering of emboli and multiple vascular occlusions. Theoretically, because of the beach-chair position, the cerebral blood flow "fights" gravity. This "upright" position may become a risk factor of an ischemic insult during hypotensive surgery, especially in a patient with other known risk factors (i.e., obesity, high cholesterol level, hypertension, diabetes, hypercalcemia, and history of stroke or cardiovascular disease).

Modified "Hybrid" Position

Hoenecke et al. (4) introduced the La Jolla beach-chair position, which is a hybrid of the lateral decubitus and the traditional beach chair positions. The patient is placed on the OR table in the supine position and is propped up into a "lazy" lateral decubitus position at 45°, using a triangular foam pillow. The hips are flexed, the head elevated, and the foot dropped as with the traditional beach-chair position. A traction device is then used, as with a lateral decubitus position. They report on a case series of 50 patients with procedures varying from subacromial decompressions and rotator cuff repairs to SLAP and anterior instability repairs. Three cases were converted from an arthroscopic to an open procedure, and visualization was reportedly "excellent." They reported no complications with the surgical positioning. They felt they were able to benefit from the advantages of both traditional beach chair as well as lateral decubitus positioning. However, the predominant risk factor of the lateral decubitus position is due to the traction on the operative arm, that is, brachial plexus neuropraxia, it seems to us that this risk factor is not circumvented. As such, although Hoenecke et al. (4) believe that they have the advantage of both positions while using the La Jolla beach chair, the authors believe they also have the disadvantage of both positions while using the La Jolla beach-chair position.

SENIOR AUTHOR'S (IV) PREFERRED METHOD FOR POSITIONING

Beach-Chair Position

Senior author (IV) utilizes the beach-chair position for arthroscopic procedures involving rotator cuff repair and arthroscopic work in the subacromial space. The T-max Shoulder Positioner and Spider Limb Positioner are used. Even though this equipment is expensive, the advantages include the freedom to position and secure the limb in almost any location in space. This facilitates arthroscopic work during rotator cuff repair, especially with massive tears and subscapularis tears, where the shoulder may have to be fully internally rotated for visualization of the lesser tuberosity or fully externally rotated for visualization of the posterior aspect of the greater tuberosity. This can be done in the lateral decubitus position, but would certainly require an extra surgical assistant for holding the upper limb in desired position. Also, the beach-chair position can be easily converted to an open procedure. This is beneficial for chronic retracted subscapularis tears that may require extensive mobilization or when a pectoralis major transfer is contemplated. The hydraulic arm positioner also applies longitudinal traction when more space is needed in the subacromial space. The traction can subsequently be released once the necessary work is done. This intermittent application of traction allows the surgeon to apply considerable traction for a short period of time to perform necessary work without the risk of continuous traction that may result in brachial plexus injury.

Lateral Decubitus Position

The lateral decubitus position is used for arthroscopic SLAP repairs and arthroscopic procedures for shoulder instability, where access is needed to both the anterior, posterior, and inferior capsule (Fig. 12). In a beach-chair position, the humeral head hangs down and posterior secondary to gravity, making access to posterior capsule and axillary pouch more challenging. Whether the instability is anterior or posterior, it is important to mobilize the capsule in a south to north direction, reducing the volume of the inferior pouch and creating a shift similar to an open procedure. Having improved access to these areas in lateral decubitus position facilitates the ability to accomplish these tasks. Also, if a HAGL (humeral avulsion of the inferior glenohumeral ligament) lesion is identified, arthroscopic management would require adequate access to the axillary pouch for proper visualization.

In the arthroscopic SLAP repair, the lateral decubitus position is preferred because it allows the superior capsule and synovium to fall away form the superior labrum (Fig. 13). This provides for easier passage of sutures around the labrum and suture management. In a beach-chair position, the superior synovium and capsule tend to lie immediately on top of the superior labrum, secondary to gravitational forces. This makes arthroscopic suture passage more challenging. Also, access to posterior labrum, which is often required, is easier in lateral decubitus position. As described earlier, better visualization of posterior capsule and labrum leads to easier suture passage and management.

FIGURE 1 A U-shaped bean bag with U portion positioned cephalad.

FIGURE 2 Torso should be tilted 20° posteriorly to keep glenoid parallel to the floor.

FIGURE 3 Adequate padding under the head keeps the head in neutral to avoid excessive strain on the brachial plexus.

FIGURE 4 Pillows provide adequate padding for peroneal nerve on the bottom leg and take the tension off the hips. Sequential compression devices are placed on both calves.

FIGURE 5 The double boom shoulder holder (Arthrex Three-Point Traction Tower) is positioned.

FIGURE 6 Final set up for lateral decubitus position.

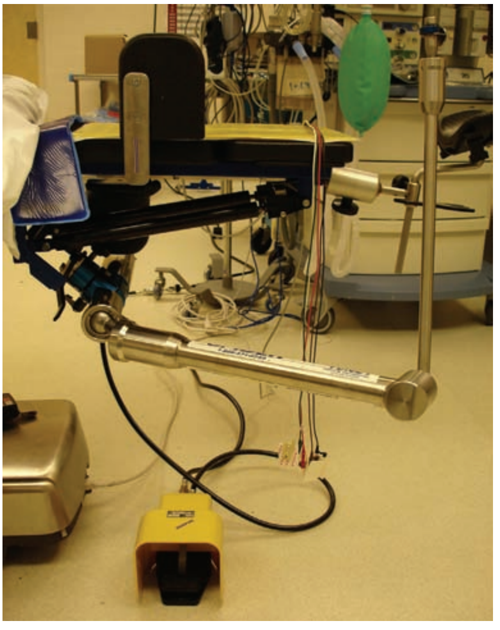

FIGURE 7 The T-max shoulder positioner and spider limb positioner.

FIGURE 8 The patient is placed at 80° of flexion at the waist level.

FIGURE 9 Head and neck are placed in neutral position.

FIGURE 10 Side supports prevent shifting the patient during surgery.

FIGURE 11 Final set up in beach-chair position.

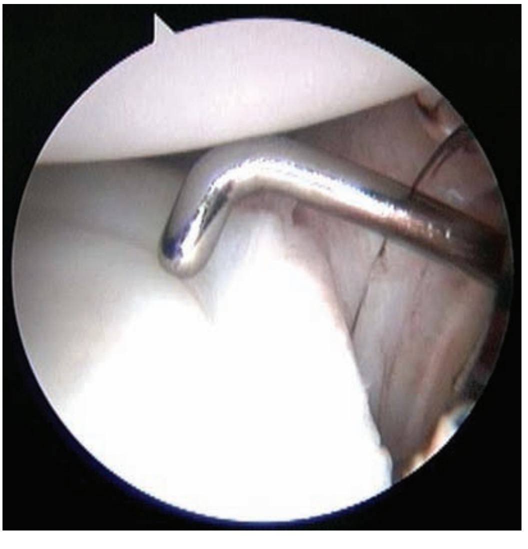

FIGURE 12 View of posterior-inferior labrum in lateral decubitus position.

FIGURE 13 View of Type II superior labrum anterior-posterior lesion in the lateral decubitus position.

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2 Diagnostic Shoulder Arthroscopy

Jason A. Stein and Anand M. Murthi
Department of Orthopedics, The Shoulder and Elbow Service, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A.

INTRODUCTION

Diagnostic shoulder arthroscopy can be a simple and quick procedure. Each surgeon can develop his or her own order and method for performing the procedure, but it is paramount that a fast, efficient, and thorough examination be performed. Because of time limitations, surgeons must be able to quickly and accurately identify reparable pathologic abnormalities to ensure enough time to perform repairs. We find that a circular examination, starting with the articular surfaces and ending with the rotator cuff, is effective. This can be accomplished within minutes. A similar methodical approach is then used in the subacromial space.

ARTICULAR SURFACES

The articular surface of the glenoid and humeral head should be inspected at the beginning of the procedure. The articular surface of the humeral head is smooth and ovoid. The posterior lateral aspect of the humeral head is devoid of cartilage and is referred to as the *bare area*. This will be visualized later in the procedure. The glenoid is shaped like an inverted comma and has a normal indent in its anterior edge. A small circular area with very thin cartilage is present at the center of the glenoid and should not be mistaken for arthritis (Fig. 1).

SUPERIOR LABRUM

The superior labrum has received much attention in recent years. It usually is triangular in shape and blends with the insertion of the long head of the biceps tendon at the supraglenoid tubercle (Fig. 2). Anatomic studies describe two main types of superior labra. Sixty percent of the time, the labrum has a "central detachment": the labrum attaches at the periphery and is free centrally. In this case, normal hyaline cartilage covers the superior edge of the glenoid and it is normal to be able to insert a probe between the two. The labrum may appear mobile, but this is not abnormal. Forty percent of the time, the labrum is attached centrally and is therefore not mobile (1).

The superior labrum can become torn, causing pain and instability. These superior labral anterior to posterior (SLAP) tears occur in many varieties that can be categorized into four main types (some argue seven types) (2). Type I (Fig. 3) is simply fraying of the labrum, with an intact attachment. Type II (Fig. 4) is a detachment of the labrum from the glenoid. Type III is a bucket handle tear. Type IV is a bucket handle tear that extends into the biceps tendon (3).

ANTERIOR STRUCTURES

Simply move the camera up and over the humeral head, and the camera will present a view of the anterior structures (Fig. 5). The anterior superior labrum has a great deal of variation. In approximately 12% of shoulders, the labrum above the glenoid notch is absent. This is referred to as a *sublabral hole* and is a normal variant. In 1.5% of shoulders, the middle glenohumeral ligament (MGHL) is cordlike and inserts directly into the superior labrum. This leaves a hole, referred to as a *Buford complex* (4).

Please refer to pages 17–23 for the figures in this chapter.

The rotator interval is easily visualized. It is composed of the superior glenohumeral ligament (SGHL) (Fig. 6), the coracohumeral ligament (CHL) (Fig. 7), the joint capsule, the biceps tendon, and the superior portion of the MGHL. The SGHL is the primary restraint to inferior translation of the humeral head in adduction and medial translation of the biceps tendon. It originates from the supraglenoid tubercle and inserts just superior to the lesser tuberosity. It can be difficult to visualize and often is obscured by the synovium or the biceps tendon. It is present in approximately 94% to 100% of shoulders and can be visualized with the arm adducted and externally rotated.

The MGHL originates from the glenoid labrum below the SGHL and inserts just medial to the lesser tuberosity. It often crosses and blends into the subscapularis tendon. It is somewhat more variable and is present in only 85% of shoulders. The subscapularis tendon, which is anterior to the MGHL, is easily visualized, with its superior border making up the inferior aspect of the rotator interval. The entire tendon should be inspected, especially for partial superior tears, which often are discovered at its insertion into the lesser tuberosity (Fig. 8) (5).

INFERIOR STRUCTURES

Looking further down the anterior portion of the shoulder, the inferior glenohumeral ligament (IGHL) becomes visible (Fig. 9). This ligament really is a complex, composed of anterior (2 to 4 o'clock position) and posterior (7 to 9 o'clock position) bands, with an axillary pouch interposed. A great deal of variation exists: a distinct ligament is present in 72%, a capsular thickening is present in 21%, and nothing is present in 7% of shoulders. The ligament is best visualized by abducting the arm. The posterior band is more prominent with the arm internally rotated, and the anterior band is most visible with the arm externally rotated. The axillary pouch should be inspected (Fig. 10).

Bankart lesions can be visualized at this time (Fig. 11). They can represent avulsions of the labrum and/or the IGHL from the anterior inferior glenoid and can include a bony defect. The IGHL and/or labrum also can avulse from its glenoid attachment and heal along the medial glenoid neck. This is referred to as an *anterior ligamentous periosteal sleeve avulsion*. The axillary pouch can be lax and compose a larger than normal volume in patients with multidirectional instability, or it can be inflamed in adhesive capsulitis (Fig. 12). Occasionally, the IGHL can avulse from the humerus, and this is referred to as a *humeral avulsion of glenohumeral ligament* lesion. Posteriorly, the same pathologic abnormality can occur and often is referred to as a *posterior Bankart tear* (Fig. 13).

While examining the pouch, attention should be focused on the humeral head. Posteriorly, a "bare area" devoid of cartilage will be observed. This indicates the insertion area of the infraspinatus tendon and should not be mistaken for a Hill-Sachs lesion, which occurs more medially and is surrounded by cartilage.

POSTERIOR STRUCTURES

The posterior labrum can next be quickly inspected by bringing the arthroscope from the inferior pouch posteriorly (from inferior to superior) along the posterior margin of the glenohumeral joint (Fig. 14). The posterior labrum is variable in appearance, and sublabral holes often are present. The posterior labrum can be frayed and mobile.

LONG HEAD OF THE BICEPS

The long head of the biceps should be thoroughly inspected. First, its origin can be variable, as categorized by four different types: Type I (22%), posterior attachment; Type II (33%), small amount of anterior attachment; Type III (37%), equal posterior and anterior attachment; and Type IV (8%), mostly anterior attachment (6). The entire tendon should be examined for fraying and for inflammation. The portion of the tendon that lies inside the bicipital groove can be pulled into the joint and examined for pathologic abnormality (Figs. 15 and 16). Often, fraying (Fig. 17) or inflammation (Fig. 18) of the tendon is observed.

ROTATOR CUFF

Next, the intra-articular portion of the rotator cuff should be examined. This can be facilitated by abducting and externally rotating the arm to view the most anterior portions of the cuff. It often is necessary to lift the rotator cuff with the probe to fully visualize the insertion of the cuff into the greater tuberosity. The rotator cable also can be visualized. It is a thickening of the capsule that extends from the biceps to the insertion of the infraspinatus. This delineates the rotator crescent, the attachment of the infraspinatus and supraspinatus to the greater tuberosity. This is easily delineated because the vasculature of the cuff ends at the cable. The crescent appears avascular (Fig. 19). During this examination, attention must be paid to articular sided partial thickness rotator cuff tears, which may not be easily identified from the subacromial space (Fig. 20).

SUBACROMIAL SPACE

After the intra-articular portion of the diagnostic arthroscopy, attention turns to the subacromial space. The first structure that is apparent is the coracoacromial (CA) ligament (Fig. 21). This can be frayed (Fig. 22) or inflamed. It can be quadrangular (48%), Y-shaped (42%), or composed of a single band (8%) (7). Anteriorly, the ligament is separated from the deltoid, but posteriorly, the ligament can merge with the deltoid fascia. Subacromial impingement is tested by bringing the arm into forward elevation and internal rotation. In this position, the rotator cuff will abut the CA ligament (Fig. 23). After the bursal tissue is cleared, the extra-articular portion of the rotator cuff can be visualized along with its insertion into the greater tuberosity. Full-thickness and bursal sided partial thickness tears can be seen (Fig. 24).

The shape of the undersurface of the acromion is visualized and is categorized into three types: Type I, flat; Type II, curved; and Type III, hooked (8). Spurs can occur and usually are anterolateral, at the CA ligament insertion site (Fig. 25).

SUMMARY

Diagnostic arthroscopy can be a simple, quick, and efficient procedure. If performed systematically and methodically, in conjunction with a physical examination in the office and with the patient under anesthesia, all pertinent shoulder pathologic abnormalities can be identified and appropriately treated.

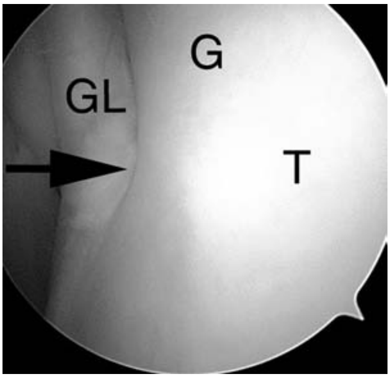

FIGURE 1 The glenoid (*G*) is shaped like an inverted comma. The *arrow* points to the indentation, which represents the fusion of its two ossific nuclei. The articular cartilage in the center of the glenoid (*T*) is very thin and should not be mistaken for arthritis. The glenoid labrum (*GL*) also is seen.

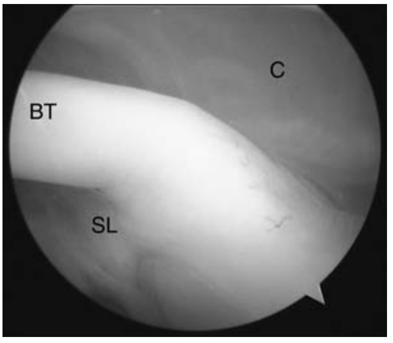

FIGURE 2 The superior labrum (*SL*) is peripherally attached in this patient. It blends with the insertion of the biceps tendon (*BT*). In this view, the capsular extension (*C*) can be seen over the glenoid.

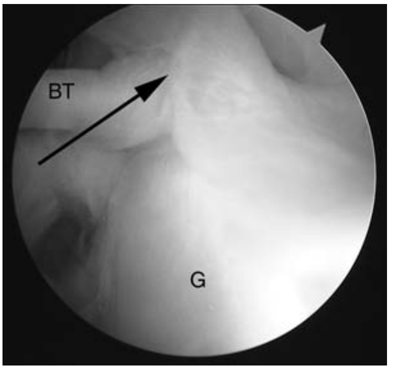

FIGURE 3 The *arrow* points to the superior labrum, which is frayed. This represents a Type I superior labral anterior to posterior lesion. The biceps tendon (*BT*) and glenoid (*G*) also can be seen in this view.

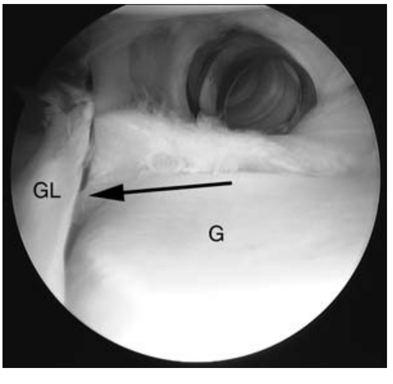

FIGURE 4 The *arrow* points to the area where the superior glenoid labrum (*GL*) has detached from the glenoid (*G*). This is a Type II superior labral anterior to posterior lesion.

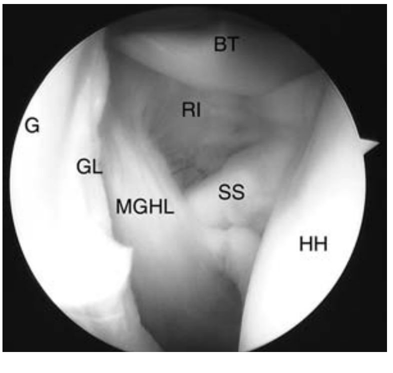

FIGURE 5 Viewed from posterior to anterior, the biceps tendon (*BT*), rotator interval (*RI*), middle glenohumeral ligament, subscapularis tendon (*SS*), and humeral head (*HH*) are clearly visualized. *Abbreviations*: G, glenoid; GL, glenoid labrum; MGHL, middle glenohumeral ligament.

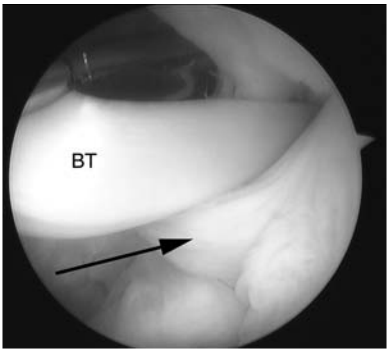

FIGURE 6 The *arrow* points to the superior glenohumeral ligament as it passes around the biceps tendon (*BT*).

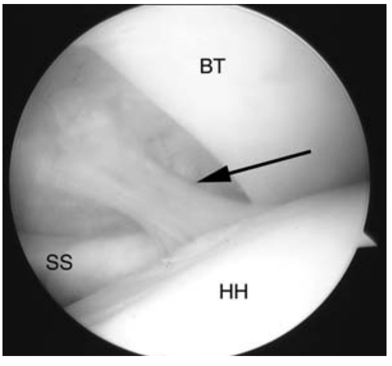

FIGURE 7 The *arrow* points to the deep band of the coracohumeral ligament. *Abbreviations*: BT, biceps tendon; HH, humeral head; SS, subscapularis tendon.

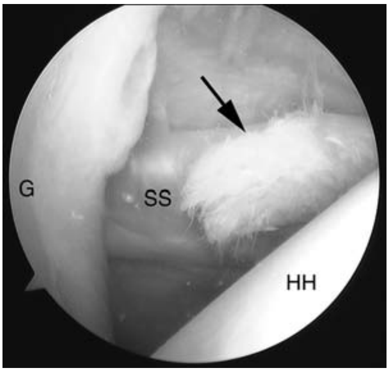

FIGURE 8 The *arrow* points to a partial thickness tear of the subscapularis tendon (*SS*). *Abbreviations*: G, glenoid; HH, humeral head.

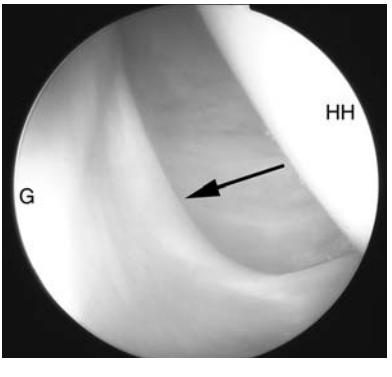

FIGURE 9 The *arrow* points to the inferior glenohumeral ligament. *Abbreviations*: G, glenoid; HH, humeral head.

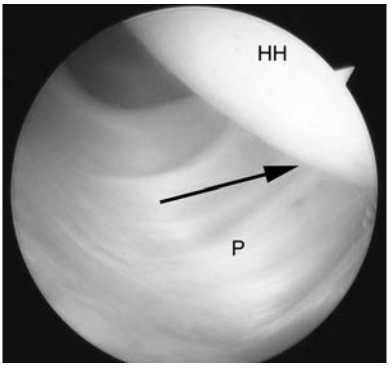

FIGURE 10 The axillary pouch (*P*) is shown. The *arrow* points to the insertion of the inferior glenohumeral ligament into the humeral head (*HH*).

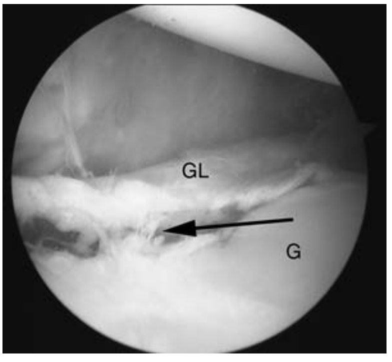

FIGURE 11 The *arrow* points to a Bankart lesion, which is the separation of the anterior inferior glenohumeral ligament and labrum from the glenoid rim. *Abbreviations*: G, glenoid; GL, glenoid labrum.

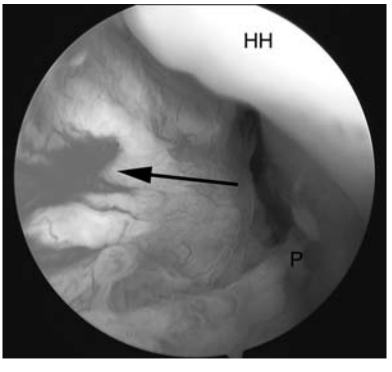

FIGURE 12 Axillary pouch (*P*) with adhesive capsulitis. The *arrow* points to inflamed synovium. *Abbreviation*: HH, humeral head.

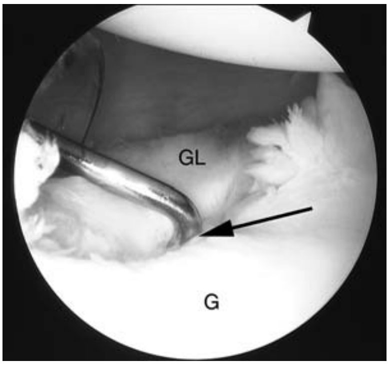

FIGURE 13 Posterior Bankart tear. This view is from anterior to posterior. The *arrow* is pointing to the area where the posterior labrum has torn off of the glenoid rim. *Abbreviations*: G, glenoid; GL, glenoid labrum.

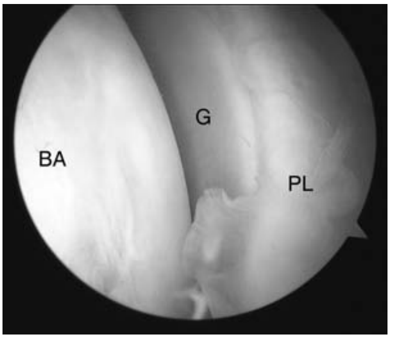

FIGURE 14 A posterior to anterior view shows the posterior labrum (*PL*) and the bare area of the humeral head (*BA*). *Abbreviation*: *G*, glenoid.

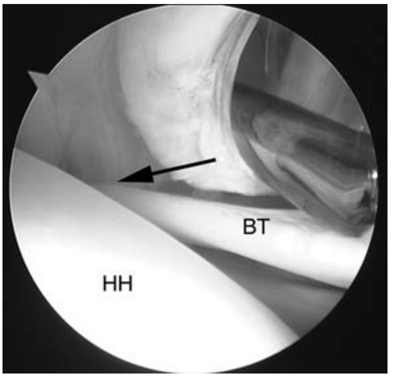

FIGURE 15 The *arrow* points to the extra-articular portion of the biceps tendon (*BT*) "pulled" into the joint. *Abbreviation*: HH, humeral head.

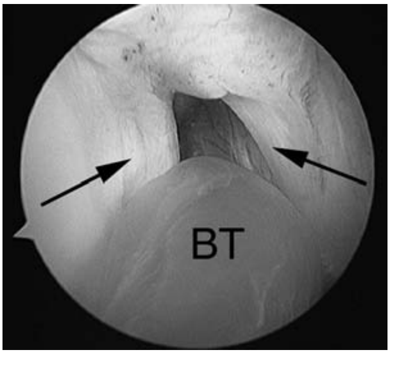

FIGURE 16 The exit of the biceps tendon (*BT*) through the rotator interval is shown. The superior bands of the coracohumeral (*arrows*) ligament are seen flanking the tendon.

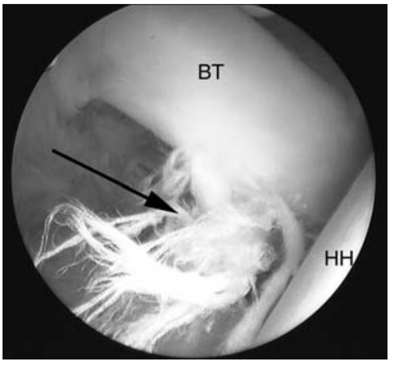

FIGURE 17 The *arrow* points to fraying of the biceps tendon (*BT*). *Abbreviation*: HH, humeral head.

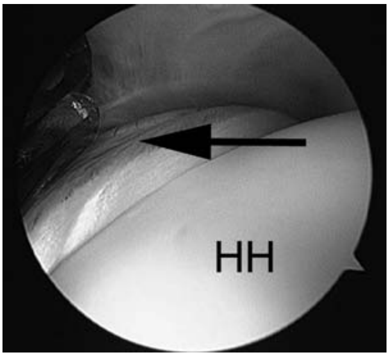

FIGURE 18 The *arrow* points to inflammation of the biceps tendon. *Abbreviation*: HH, humeral head.

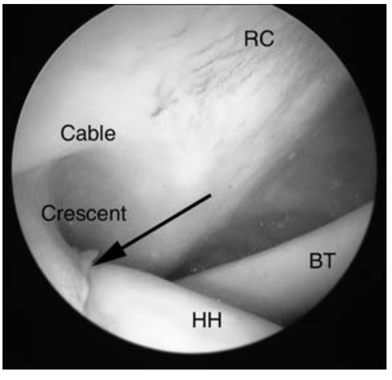

FIGURE 19 The articular side of the rotator cuff (*RC*) insertion is composed of two components. The vascular portions of the supraspinatus and infraspinatus end at the rotator cable and form a band. The cable then inserts into the greater tuberosity (*arrow*) through the rotator crescent. *Abbreviations*: BT, biceps tendon; HH, humeral head.

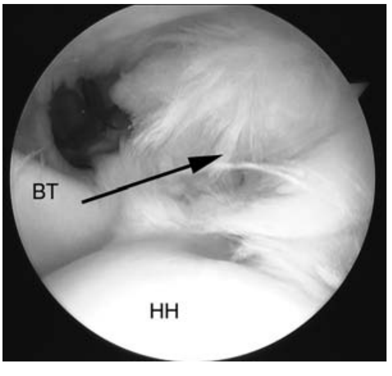

FIGURE 20 The *arrow* points to an articular sided partial thickness tear of the supraspinatus tendon. *Abbreviations*: BT, biceps tendon; HH, humeral head.

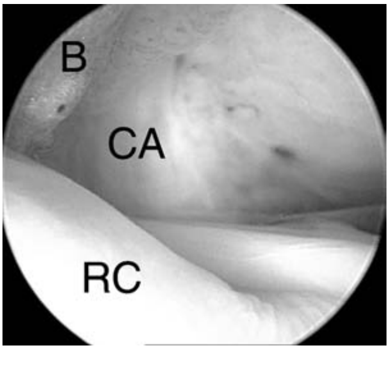

FIGURE 21 The coracoacromial (*CA*) ligament is the most anterior structure seen in the subacromial space. The rotator cuff (*RC*) and bursal tissue (*B*) also are seen in this picture.

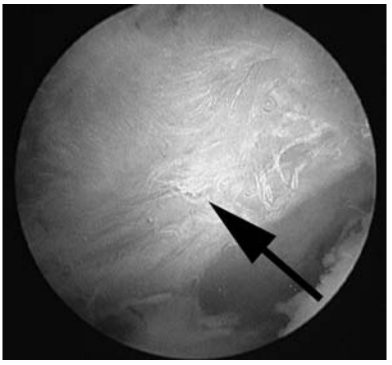

FIGURE 22 The *arrow* points to a thickened and frayed coracoacromial ligament.

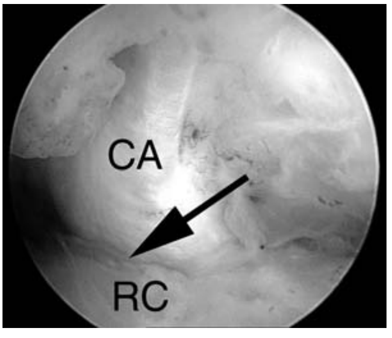

FIGURE 23 Subacromial impingement is tested by ranging the arm to determine whether the rotator cuff (*RC*) impacts the coracoacromial (*CA*) ligament. The *arrow* indicates the point of impact.

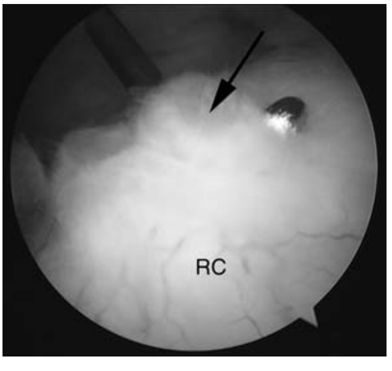

FIGURE 24 The *arrow* and probe indicate a bursal sided partial thickness rotator cuff tear. The remaining rotator cuff (*RC*) appears intact and well vascularized.

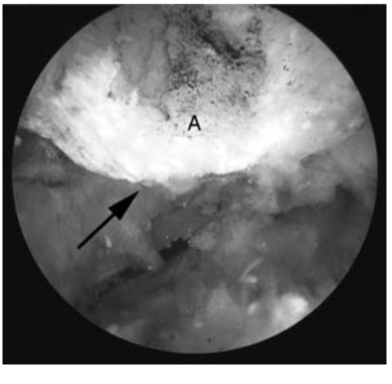

FIGURE 25 The *arrow* points to an acromial spur after the bursa and coracoacromial ligament have been removed during a subacromial decompression. *Abbreviation*: *A*, acromion.

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3 Knot Tying

Christian Lattermann
Department of Orthopedic Surgery, University of Kentucky, Lexington, Kentucky, and Midwest Orthopaedics at Rush, Rush University Hospital, Chicago, Illinois, U.S.A.

Gregory P. Nicholson
Department of Orthopedic Surgery, Rush University Medical Center, Midwest Orthopaedics at Rush, Rush University Hospital, Chicago, Illinois, U.S.A.

INTRODUCTION

Surgical knot tying has been a basic surgical skill for centuries. Over 1400 different knots have been described, most of which have their roots in fishing and sailing. Orthopedic knot tying used to be less of a technical difficulty then in other general surgery subspecialties; however, with the advent of minimally invasive techniques, arthroscopic surgery of the shoulder in particular, the need for simple but effective knot tying in tight spaces has become a crucial issue for the success of the surgical procedure. Particularly in the shoulder, the difficulty arises from the need to deliver an effective knot through soft tissue tunnels or cannulas over a distance. The knot cannot be tied until delivered through the soft tissues and has to be tied effectively with the use of finger extenders.

Despite the vast array of different knot options, there are only few knots that are suited for the use in arthroscopic surgeries. The knots have to meet two major criteria: (*i*) the knot must be easily tightened and locked once it has been delivered to the target tissue and (*ii*) the knot may not slide once it has been tied.

The major difficulty with arthroscopic knot tying arises out of the need to tie the knot across a distance through a soft tissue envelope. During the process of knot tying, the tension of the knot has to be maintained without incorporating distant tissues into the suture loop.

The purpose of this chapter is to provide the basic background of arthroscopic knot tying with basic steps that may reduce problems encountered during knot tying.

BASIC NOMENCLATURE/DEFINITIONS

Any suture passing through tissue will end up with two separate limbs. One limb will be held tight and serves as the *post* around which the knot will be tied. The other limb stays loose and will be looped around the post creating the knot. This limb is called the nonpost or wrapping suture. The post limb defines where the knot is going to be placed in the tissue since the thrown knot will glide along the postdown towards the tissue. Although the post and the nonpost can be arbitrarily chosen by the surgeon, it is important to consider the placement of the final knot. For labral repairs or superior labral, anterior-posterior (SLAP) repairs, for example, one would not like to have the knot sit directly on the glenoid surface but rather on the labral surface where the knot is less likely to interfere with joint mechanics. It is therefore important to choose the suture limb penetrating the labrum (or farthest from the joint) as the post in order to guide the knot down onto the labral surface away from the glenoid cartilage. In rotator cuff repair fixation, the post is the limb that passes through the tendon.

Furthermore, it is important for knot security to understand the concept of *switching the post*. When switching the post, the surgeon alternates the post for each successive loop. Another important concept is that of *tying alternating over and underhanded knots*. This refers to the

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Please refer to pages 31–32 for the figures in this chapter.

direction in which the loop passes around the post and refers to the free suture limb passing over or under the post when the knot is thrown.

BASIC KNOTS

Arthroscopic surgeons encounter two basic suture configurations that require fundamentally different knot-tying techniques. The suture from an anchor that has been passed through soft tissue can either be sliding free through the tissue or eyelet of the anchor or it can be tethered at the anchor or within the tissue itself. If the suture is sliding free, the surgeon has the option to either tie a sliding or a nonsliding knot. If the suture is tethered, only a nonsliding knot can be tied. Since any suture can end up being tethered at the anchor eyelet or inside the tissue, the surgeon is well-advised to have at least one sliding and one nonsliding knot in his armament.

Sliding Knots

Sliding knots can only be used with sutures that are free gliding through soft tissues and/or the suture anchor eyelet. Before a sliding knot is utilized, it is imperative that the free passage of both suture limbs is verified.

The basic principle of a sliding knot is that the knot is assembled entirely outside the cannula or joint around the post limb of the suture. The knot typically is dressed and tightened around the post. Once the knot is dressed, it slides down the post limb by pulling on the post limb until the sliding knot sits directly on top of the soft tissue. Sliding knots have a better ability to maintain their tension than nonsliding knots, and are therefore preferentially used in situations where tissue needs to be tied under tension. Multiple different sliding knots have been described, such as the “Duncan loop” (1), the “Tennessee Slider,” the “Roeder” (2), the “SMC” (3), the “Weston” (4) knot, and others (5). At this point we will not describe these knots individually. At the end of this chapter we will describe our preferred sliding knot. Any of the aforementioned sliding knots will be appropriate if tied correctly. It is therefore important for the arthroscopic surgeon to be able to tie at least one of these knots well and reproducibly.

Sliding knots can further be subdivided into locking and nonlocking knots. A nonlocking sliding knot can be delivered to the tissue and can be initially tensioned. It will, however, not maintain its initial tension unless it is secured by alternating half hitches that need to be tied subsequently. An example of a nonlocking sliding knot is the “Duncan loop.”

Locking sliding knots have the advantage that they can be delivered to the tissue and can be tensioned in situ without having to add additional half hitches for knot security. The sequence to allow for the knot locking involves usually a reversal of the post such that the loop captures the post. Once this maneuver has been performed, the knot cannot be tightened further. Also, the knot will loose some of its initial tension due to the fact that the post/nonpost reversal will allow the knot to fold back onto itself and therefore increase the size of the initial suture loop minimally.

A third group of knots are sliding knots that can only be advanced in one direction along the post. These so called *ratchet knots* have the advantage of a sliding knot that locks once the soft tissue pressure acts against it. These knots, however, still require a set of alternating half hitches for adequate knot security. An example of the ratchet knot is “Nicky’s knot” (6) or the “Giant knot” (7).

Nonsliding Knots

If the suture limbs do not readily pass through the tissue or suture anchor, a nonsliding knot has to be used. Nonsliding knots are tied outside the cannula as single over or underhanded loops and then sequentially passed through the cannula to the tissue. The difficulty with these knots is that they have to be tensioned carefully at the tissue and the tension has to be maintained while the next loop is being passed down through the cannula. One example of a nonsliding knot is the simple “square knot.” It is the most difficult knot to tie arthroscopically, since it requires equal tension on both limbs to prevent the knot from converting into a stack of half hitches that will not maintain its tension. It is therefore rarely used. Another example of a nonsliding knot is the “Revo knot” (8).