The Suprapatellar Pouch of the Knee and its Disorders
U. H. Deliwal*, H. R. Jadeja*, C. L. Rathod*, N. Loya*
*Assistant Professor, Govt. Medical College and Sir T. Hospital, Bhavnagar.

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ABSTRACT
Proper recognition and treatment of pathological conditions of the suprapatellar pouch of the knee is dependent on the knowledge of normal pouch anatomy and of the various conditions which affect this area of the knee and contribute to knee pain. This article includes a comprehensive review of the surgical anatomy of the pouch, current surgical techniques and review of the common conditions that have a predilection for this often overlooked area of the knee.

INTRODUCTION
The suprapatellar pouch is a large continuation of the synovial membrane of the knee joint proximal to the trochlea. Its proximal border is positioned approximately 4 cm proximal to the superior border of the patella, lying deep to the quadriceps tendon [1]. Within the anatomic boundary of the suprapatellar pouch congenital, traumatic, inflammatory, and neoplastic pathology can exist. Congenital anomalies include partial or complete suprapatellar plica, with a reported incidence ranging from 9 to 89% [2-5]. However, its role in anterior knee pain is controversial [6,7]. Inflammatory pathology of the suprapatellar pouch includes both systemic and local conditions such as synovitis, which may be secondary to rheumatoid arthritis [8,9] or Crohn’s Disease [10]. Traumatic suprapatellar pouch pathology can result from pouch rupture [11-13], previous surgery [14,15], or the presence of loose bodies [16] within the pouch. These processes have the potential to cause inflammation and subsequent arthrofibrosis [17]. Neoplasms that exist in the suprapatellar pouch include pigmented villonodular synovitis and giant cell tumor, hemangiomas, synovial chondromatosis, synovial cysts, and most commonly lipoma arborescens. There has been no published data on the rate of incidence of traumatic, inflammatory, or neoplastic lesions in the suprapatellar pouch, though case reports exist.

Given that arthroscopy of the knee is the most common procedure in orthopedic surgery, it is essential to be able to identify and address all potential causes of pathology during this procedure [18]. One portion of the procedure that has been given very little attention, which may be responsible for incomplete post-operative pain resolution in some cases, is pathology of the suprapatellar pouch. This article provides an anatomic orientation and systematic approach to the diagnosis and treatment of suprapatellar pouch pathology.

NORMAL ARTHROSCOPIC ANATOMY
The entire suprapatellar pouch can be easily visualized using a standard 30° arthroscope. Proper examination of the pouch contents requires identification of the superior pole of the patella. The quadriceps tendon should be visualized inserting into the superior pole. The quadriceps tendon can then be visualized proximally, running along the roof of the pouch to a point approximately 4 cm proximal to the superior pole of the patella. A measuring probe can be used to confirm proper pouch length (Fig. 1). Alternatively, the surgeon can apply pressure with his finger to the superior pole of the patella, which can be visualized arthroscopically. An additional 2-3 fingers (approximately 4 cm) can then be laid down on the skin to ensure that pouch is of sufficient length. The walls of the pouch should be smooth with normal appearing synovium.
Inability to visualize the quadriceps tendon along the entire roof of the pouch is abnormal (Fig. 2a). Pouch lengths significantly less than 4 cm and visible adhesions are also abnormal.

### 3.1. Plica

Suprapatellar plica, also known as plica synovialis suprapatellaris, are congenital remnants of the suprapatellar pouch that can range from minimal to complete plica, with respective results ranging from free communication to complete isolation, or compartmentalization, of the suprapatellar pouch from the knee joint.

Within the first few weeks of fetal development, the knee is a tri-compartmental structure composed of medial and lateral tibio-femoral and suprapatellar compartments, separated by synovial foldings [19]. Due to intrauterine mechanical forces, these membranes involute and a single knee cavity is attained by the 3rd month of fetal life [5], forming a freely communicating suprapatellar pouch. Synovial plicae refer to the mesenchymal remnants after failure of complete decougmentalization of the knee, and can exist as superior, inferior, medial, or lateral plica with respect to the patella [2,20].

Though there are a number of classification systems for suprapatellar plica, including the Dandy [4] and Zidorn [21] systems, most can be classified based on the classification developed by Deutsch et al. [22] who differentiate the plica according to 3 different types. Type A is a complete plica that isolates the pouch from the knee joint (Fig. 2a). Type B is a complete plica except for a central portal, which in some cases may act as a one way valve [2] (Fig. 2b). In Type C an incomplete crescent shaped plica that is variable in size and confined only to the superomedial side [2,4,6,16,22] (Fig. 2c).

Suprapatellar plica have been shown to exist with an incidence rate ranging from 9 to 89% [2-5], however the incidence of pathology as a result of plica is controversial [6,7]. Many believe that the pathophysiology of suprapatellar plica stems from an event that leads to inflammation, with resultant alteration of the extensible qualities of the plica.

**Figure II.** Estimation of knee volume capacity. a) Insufflation of the knee with 60 cm$^3$ of saline will slowly drip out of a standard 18-gauge needle in a knee with normal volume capacity. b) Knees with a significant volume deficit will result in pressurized backflow after 60 cm$^3$ insufflation. c) Arthroscopic imaging demonstrates hypertrophic synovitis in Suprapatellar pouch in PVNS. d) Histopathologic Microscopic appearance of PVNS showing hemosiderin laden multinucleated giant cells that have osteoclastic features, and macrophages.
[6,23,24]. Thickening, edema, and fibrosis ensue, which may lead to increased force on the articular surfaces of the patella and medial femoral condyle and eventual degenerative changes [6,23,24]. Strover et al. [25] arthroscopically demonstrated the pathomechanics of the suprapatellar plica as impingement of the plica on the medial femoral condyle and its entrapment between the quadriceps mechanism and the femoral trochlea, when the knee is flexed beyond 70°.

It can be argued that alterations in joint volume due to large suprapatellar plica can cause significant alterations in fluid distribution and therefore increased forces on the articular sur-faces. Volume changes may be another etiology of pain due to plica. Regardless of the pathophysiology, suprapatellar plica can become pathologic and produce symptoms.

3.1.1. Clinical presentation
A patient with suprapatellar plica syndrome may present with chronic, intermittent, dull pain in the superior portion of the anterior knee and will describe it as worse with patello-femoral loading activities, such as descending stairs [5]. Other symptoms may include knee or suprapatellar pouch effusion, a feeling of tightness in the superior knee that is worse with flexion, or a popping sound and catching on knee flexion and extension [6].

On physical examination, patients may have tenderness to palpation over the superior pole of the patella and suprapatellar pouch. Patients may also exhibit decreased range of motion of the patella in the inferior direction. Additionally, suprapatellar plicae may be palpable as a band of tissue between the superior pole of the patella and the medial femoral condyle with flexion and extension of the knee, and is described as having a distinctly high-pitched snap with manipulation of the knee [5].

Radiographs, arthograms, fluoroscopy, CT, MRI, and arthroscopy have all been used as tools for the diagnosis of suprapatellar plicae [26]. Deutsch et al. [22] described the lateral view, with the knee in full extension allowing full distension of the pouch, as the optimal diagnostic view using double contrast arthrography for the visualization of suprapatellar plicae [22]. Alternatively, suprapatellar plica are best visualized on the sagittal view as a band-like, low-signal intensity structure posterior and superior to the patella on MRI. Arthroscopy is the gold standard for diagnosing pathological plicae [26].

3.1.2. Treatment
Once the diagnosis of a suprapatellar plica syndrome is established via history, physical exam, and diagnostic techniques, either a non-surgical or surgical approach can be taken. In patients with symptomatic plicae, non-surgical approaches have generally been less effective than surgery. Some reports indicate no long-term improvement with a non-operative approach in those with pathologic plica [27], though others have reported success with non-operative measures [24]. Non-operative measures include a period of non-patello-femoral loading activities, cryotherapy, ultrasound, microwave diathermy, patellar bracing, and NSAIDs [28-30]. Some have also advocated the use of intra-plical steroid injections with symptomatic relief in approximately 3 of 4 patients [31]. If non-operative measures fail, surgical treatment is indicated [32].

3.1.3. Technique: estimation of joint volume
Normal knee volume is approximately 88 cm³ per our volume Intra-articular injection of 60 cm³ of physiologic saline prior to arthroscopy will allow estimation of joint fluid capacity. Irrigation will slowly drip out of a standard 18-gauge needle after 60 cm³ insufflation in a joint with normal capacity (Fig. 3a). However, knees with significant plica or arthrosis will result in pre-surized backflow after 60 cm³ insufflation (Fig. 3b). This phenomenon should alert the surgeon that the joint capacity is abnormal and identification of pathologic processes including significant plica is warranted.

3.1.4. Technique: arthroscopic evaluation and treatment
Suprapatellar plicae can be easily visualized using a standard 30° arthroscope. The arthroscope is positioned at the superior pole of the patella and the quadriceps tendon should then be visualized proximally. If no quadriceps tendon can be visualized, a complete suprapatellar plica is likely present. Alternatively, Strover et al. [25] described
using a lateral suprapatellar portal, at least 1 cm proximal to the superior pole of the patella, with a 70° arthroscope situated proximal to the plica while looking distally toward the patello-femoral joint. This approach allows visualization of the medial edge of the suprapatellar plica and femoral trochlea from a proximal perspective. Evaluation of the dynamic relationship between these structures and the suprapatellar plicae can then be performed.

If a plica is identified and considered pathologic, it should be resected in its entirety. Use caution during resection to prevent damage to the overlying quadriceps tendon, which should be visualized during the entire procedure. Electrocoagulation is recommended for resection as strict hemostasis is imperative. The main complication of plicae resection is hemarthrosis, which is also postulated as a causative factor in plica syn-drome [29,33,34]. Generally, surgical outcomes for plica resection have been good. Bae et al. [5] reported symptomatic improvement in 84% of patients with arthroscopic excision of complete suprapatellar plicae. Harrewyn et al. had a 65% success rate with knees without arthritic changes and 40% success rate in those with early arthritis [34,35].

3.2. Inflammation and arthrofibrosis

Inflammatory pathology of the suprapatellar pouch includes both systemic and local inflammatory conditions such as rheumatoid arthritis [8,9], Crohn’s Disease [10], and trauma. Traumatic suprapatellar pouch pathology has been noted to exist as a result of surgery [14,15], or rupture [11-13].

Any inflammation within the knee joint, whether due to local or systemic processes, may result in arthrofibrosis. This fibrous tissue can entirely obliterate the pouch in severe cases [17]. Post-operative arthrofibrosis affecting the suprapatellar pouch has been demonstrated after total knee arthroplasty and arthroscopy [14,15,36,37]. The main clinical symptom is stiffness and resultant limitation of flexion [36,38]. A patellar clunk, similar in character to that heard from an ACL cyclops lesion, may also be present with flexion of the knee if the pouch is significantly fibroed [38]. Boldt et al. [39] has encouraged the use of ultrasound as a method to diagnose arthrofibrosis associated with total knee arthroplasty, where synovial membrane thickening greater than 3.0 mm and neo-vascularity are characteristic and easily identifiable findings.

3.2.1. Treatment

In symptomatic suprapatellar pouch fibrosis, both non-operative and surgical therapy may be utilized. Non-operative therapy consists of physical therapy and anti-inflammatory measures, such as NSAIDs and steroid injections [40,41].

3.2.2. Technique: arthroscopy

The arthroscopic appearance of arthrofibrotic adhesions is markedly different than that of plicae. Scar tissue appears unorganized, and often has a stringy appearance (Fig. 2c). Findings may range from a few wispy adhesions to complete obliteration of the pouch. Surgical therapy consists of arthroscopic lysis of the fibrous bands [36], which should be performed without a tourniquet to assure complete hemostasis. Slow resection with the use of electrocoagulation is recommended. Post-operative mobility of the patella in all planes should be significantly improved and documented. Post-operative care should include sufficient analgesia for immediate passive range of motion, cryotherapy and patellar mobilization. Full weight-bearing should be delayed for approximately 2 weeks to minimize post-operative inflammation.

3.3. Rupture

Though rare, a number of cases of spontaneous and traumatic suprapatellar pouch rupture have been reported [11,12]. Cases of pouch rupture secondary to inflammatory arthritis have also been described [9,13,42]. Once rupture occurs, the synovial fluid induces inflammation, which causes muscle necrosis and granulomata [9]. This is followed by the formation of a pseudo-capsule, which is composed of dense fibrous tissue with chronic inflammatory cells and fibrin deposits.

The potential for rupture of the suprapatellar pouch is proportional to the intrabursal pressure if the pouch is isolated from the knee joint, or the intracapsular pressure if there is free communication with the knee joint. Both of which are affected by synovial fluid volume [11]. Other
factors that influence the potential for rupture include change of the inherent properties of the synovium, such as in patients with chronic synovitis, trauma, and rapid change in the position of a knee with preexisting elevated fluid pressure [11,42]. If rupture occurs, it will tend to be at the apex of the superapatellar pouch, as this has been shown to be the weakest structural point [43].

3.3.1. Clinical presentation
Patients will present with symptoms that mimic deep vein thromboses, with pain, warmth, erythema, and swelling of the affected thigh [42]. This is similar to pseudothrombophlebitis, a term coined for the symptoms caused by rupture of a popliteal cyst into the calf [42]. If superapatellar rupture is suspected, it can be confirmed via ultrasound and MRI [44,45].

3.3.2. Treatment
A non-operative approach with the goal of decreasing intra-bursal pressure is recommended. This can include synovial fluid aspiration, anti-inflammatory measures (NSAIDs, intra-articular and systemic steroid, treatment of the underlying disease), and rest. Initiation of passive range of motion after a short period of immobilization may decrease the occurrence of arthrofibrosis. Though surgery is rarely necessary, it can be utilized if continued symptoms and arthrofibrosis exist [45] (see Technique: arthroscopy in arthrofibrosis section).

3.4. Neoplasm
Lipoma arborescens is the most common tumor of the superapatellar pouch, however, other neoplasms including pigmented villonodular synovitis (PVNS) and giant cell tumor, hemangioma, synovial chondromatosis, and synovial cysts are rarely encountered.

3.4.1. Lipoma arborescens
Lipoma arborescens is a rare, benign synovial disorder in middle-aged men that has a predilection for the superapatellar pouch of the knee [46-49]. It is named for its characteristic frond-like, or arborescent, villous projections of fatty tissue within a villous synovium (Fig. 4a). Histologically, villous pro-liferation as well as hyperplasia of the subsynovial fat results in complete replacement of some synovial tissue with fat cells projecting into the villous extensions [49]. Patients may present with chronic, intermittent joint effusions, motion restriction, and variable pain [49]. MRI is the imaging modality of choice, with pathognomonic findings of frond-like synovial villous proliferation with the same signal density as fat on all sequences [50] (Fig. 4b). Arthroscopic resection, including synovectomy, is the treatment of choice. Recurrence has been reported, but full resolution should be expected with repeat synovectomy [51].

3.4.2. PVNS and giant cell tumor
Pigmented villonodular synovitis (PVNS) is a benign pro-liferative intra-articular disorder of the synovium that affects the knee 80% of the time [52]. It is thought to be a reactive lesion, but some have suggested that it may have a neoplastic etiology [53]. Localized nodular synovitis is also known as a giant cell tumor, and has been described as being the tenosynovial counterpart of PVNS, often presenting as a slowly enlarging painless mass [54,55]. Figure II shows Arthroscopic image of Synovial hypertrophy and The histopathology of PVNS includes synovial hyperplasia, hypervascularity, the presence of hemosiderin laden multinucleated giant cells that have osteoclastic features, and macrophages [56,57]. Though rare, there have been a number of reports that have described isolated PVNS in compartmentalized superapatellar pouches [2,58-60].

Patients with local PVNS and giant cell tumor in the superapatellar pouch may present with indistinct symptoms that suggest internal derangement [55,61]. MRI exhibits the characteristic decreased signal intensity of hemosiderin on both T1 and T2 weighted images [62,63]. Synovectomy is the treatment of choice, either via arthroscopy or arthroscopy [64,65]. Some authors advocate radiotherapy to reduce recurrence [66].

3.4.3. Synovial hemangioma
Synovial hemangioma is a rare, benign vascular tumor arising from synovium [67], and has a predilection for the knee [67]. Clinical symptoms include limitations in range of motion, and intermittent swelling and pain. MRI exhibits dilated vascular spaces with low velocity blood flow appearing as intra-articular lobulated masses of intermediate signal intensity on T1 images, and high intensity on T2 images [68,69]. Angiography can
be used to confirm the diagnosis as well as treat this condition via embolotherapy [69]. Surgical resection, ei-ther arthroscopic or open, may be required depending on the extent of the lesion [67-69].

3.4.4. Synovial chondromatosis
Synovial osteochondromatosis is defined as the presence of multiple intra-articular osteochondral bodies that arise as a result of proliferative and metaplastic changes within the synovium [54]. The etiology is unknown [70]. Patients can have joint pain, swelling, and motion limitations [70,71]. The presence of mult-tiple, uniform, intra-articular, osteochondral loose bodies on radiographs is diagnostic. MRI can be used to evaluate the extent of the synovium involved [49,72]. Treatment consists of arthroscopic removal of loose bodies and complete synovectomy [71,73].

3.4.5. Synovial cysts
Synovial cysts are synovial or fibrous lined cystic masses that may occur as a result of herniation or distension of synovial membranes in joints and bursae [74]. They are often associated with trauma or chronic inflammatory conditions [74]. Though often asymptomatic, suprapatellar pouch synovial cysts can present as cystic or firm masses in the suprapatellar region [75]. Synovial cysts usually have normal radiographic findings, but are easily identified on MRI due to their characteristic appearance of a well-circumscribed mass with homogeneous signal intensity.

which is low on T1 and high on T2-weighted images [74,76]. Cysts are treated with arthroscopic resection similar to resection of complete suprapatellar plica (see Technique: arthroscopic evaluation and treatment of plica).

CONCLUSION
Identification and treatment of pathological processes of the suprapatellar pouch is necessary to improve surgical results in patients with anterior knee pain. Proper identification of normal anatomic landmarks such as the superior pole of the patella and the quadriceps tendon are the cornerstones to thorough arthroscopic examination of the pouch.


