Posterior Knee Endoscopy

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Tun Hing Lui, Adrian Góralczyk, Konrad Malinowski, Lukas Rasulić, Milan Lepić, Rui Yang, and Yi Long

Abstract

Popliteal cyst is a common condition of popliteal region and usually coexists with intra-articular pathologies. Typically it is an extension of the natural gastrocnemius-semimembranosus bursa caused by one-way joint fluid leakage to the bursa through existing valvular mechanism. If symptomatic, the popliteal cyst should be treated surgically. The most effective treatment involves correction of intra-articular pathologies, elimination of the valvular mechanism, and excision of cystic walls. In this chapter we present an arthroscopic technique of typical popliteal cyst treatment addressing each step of pathophysiological pathway of cyst formation.

The sural nerve is the most commonly used donor nerve in peripheral nerve and brachial plexus surgery. The grafts may reach up to 40 cm in length from one sided sural nerve harvest depending on the leg size. Graft harvesting procedure results in an acceptable donor site deficit, but the incision extending over the whole lower leg may both compromise cosmetic appearances and predispose subsequent regional complications. Endoscopic harvest preserves the best of both worlds, maintaining the small incision, with complete graft extraction and preservation.

The outside-in method is widely performed for suturing the anterior horn of the lateral meniscus, however, it has some disadvantages including skin incision and superficial knots. The all-inside devices were hard to be applied in anterior half of lateral meniscus (AHLM) due to the limited angle under arthroscopy. The safe Larai portal is developed as a feasible alternative to repair tears of the AHLM by all-inside devices under direct arthroscopic visualization.

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Keywords

Popliteal cyst · Baker's cyst · Endoscopy · Valvular mechanism · Fluid overproduction · Cyst excision Peripheral nerve · Brachial plexus · Nerve repair · Sural nerve · Larai portal · All-inside · Arthroscopy · Anterior half of lateral meniscus · Meniscus tear

12.1 Endoscopic Treatment of Popliteal Cysts

Adrian Góralczyk and Konrad Malinowski

12.1.1 Introduction

A popliteal cyst, commonly called Baker's cyst, is a frequent pathology meet in everyday orthopedic practice. Affected patients usually complain on symptoms as posterior knee pain, knee stiffness, limited knee flexion at the end of the day or palpable mass, and feeling of fullness in the popliteal region, depending on the size and location of the cyst [1, 2]. However, it is important to remember that in adults almost all popliteal cysts are secondary and thus should be treated rather as an indicator of intra-articular pathologies than the disease itself [2]. In fact, the popliteal cyst usually is an enlargement of a natural gastrocnemius-semimembranosus bursa located in the posteromedial part of the knee [3]. The pathomechanism of its development is well-investigated and two main factors, namely excessive joint fluid production and valvular mechanism in the posteromedial joint capsule play the key roles in this process [2–4]. Common knee pathologies as meniscal tears, chondral lesions, or different types of instabilities are observed in as much as 94% of patients with popliteal cysts [5, 6]. All of them are responsible for an overproduction of synovial fluid and increase in an intra-articular pressure which lead to fluid extravasation to gastrocnemius-semimembranosus bursa through the existing in almost a half of population natural connection in the posteromedial capsule [7]. Further, the posteromedial fold that in most cases works as a valve allows only for a unidirectional fluid flow to the bursa during knee extension and precludes its evacuation during knee flexion [7]. To summarize, *synovial fluid overproduction, increased intra-articular pressure, and valvular mechanism allowing for unidirectional fluid flow are responsible for development and enlargement of popliteal cyst leading to symptoms.*

Conservative treatment involving fluid evacuation, intra-articular or intra-cystic steroids injections, or sclerotherapy is just a temporary solution and is not effective, especially in case of osteoarthritic changes [3, 8]. Surgical treatment is a gold standard of popliteal cyst management and many surgical techniques were developed for addressing this pathology. Open surgical procedures are associated with extensive approach, high risk of important anatomical structures injuries, potential risk of wound complications, prolonged recovery time and provide an unacceptable risk of cyst recurrence [1, 4, 5]. One of the main reasons of ineffectiveness of classic surgeries has been explained in the literature through the lack of addressing concomitant intra-articular pathologies involved in cyst development [9]. The importance of managing articular lesions concurrently with treatment of the cyst itself has been broadly outlined in the literature and thus, arthroscopic techniques have become the treatment of choice [3, 5, 6, 9, 10]. On the other hand, elimination of only the intra-articular lesions appears to be not enough to resolve the problem with popliteal cyst [5]. Arthroscopy allows for concomitant pathologies treatment, provides easy access to cyst decompression, and is characterized with minimal invasiveness and fast recovery [11, 12]. The controversies appear around the method of dealing with valvular mechanism. Whereas some authors suggest that valvular mechanism should be corrected by closing the posteromedial fold, others favor broad opening of the posteromedial fold that allows to re-establish the natural bidirectional fluid flow between the knee joint and gastrocnemius-semimembranosus bursa [1, 5]. We support the second approach because the data suggests that valvular-closing surgeries provide lower success rate (84.6% vs 96.7%), higher recurrence rate due to persistent high pressure in the cyst and finally, the connection between the knee joint and bursa is a normal anatomical variant [5, 7, 9, 13]. The last point of a broad discussion is whether ones should excise or not the cyst walls. The literature suggests that cyst walls excision may be associated with lower rate of recurrence (0 vs 8%), higher rate of overall success (98.2% vs 94.7%), but also with more intraoperative and postoperative complications (6.5% vs 1.6%) and longer operative time [4, 9, 14]. However, it is suggested that cyst wall excision should be popularized especially among the experienced and skilled knee surgeons [9]. To summarize,

the most up-to-date data evidence that the most effective management on popliteal cyst is an arthroscopic treatment of concomitant intra-articular pathologies with opening of the valvular mechanism and cystic walls excision [3, 7–19].

Based on a 17-years experience in arthro/endoscopic treatment of popliteal cysts of the senior author (K.M) we support the approach to address the whole pathophysiological pathway of popliteal cyst development. In our opinion that is only way to treat our patients effectively. In this chapter we present a simple, safe, and effective technique of typical popliteal cyst arthroscopic treatment with valvular mechanism opening and cyst wall excision. We also show how to manage with demanding, atypical popliteal cysts. At the end we present some pearls and pitfalls which facilitate effective and safe maneuvering in the "dark side of the knee."

12.1.2 Indications

Presented procedure is indicated for symptomatic popliteal cysts diagnosed with clinical and radiological examination (Fig. 12.1).

12.1.3 Contraindications

The procedure should not be performed in case of cysts which are not typical "popliteal" ones: an aneurysm, a varicose, cysts developed in location other than gastrocnemius-semimembranosus bursa, as well as in patients with limited knee flexion below 80–90° and unacceptable general risk of surgery.

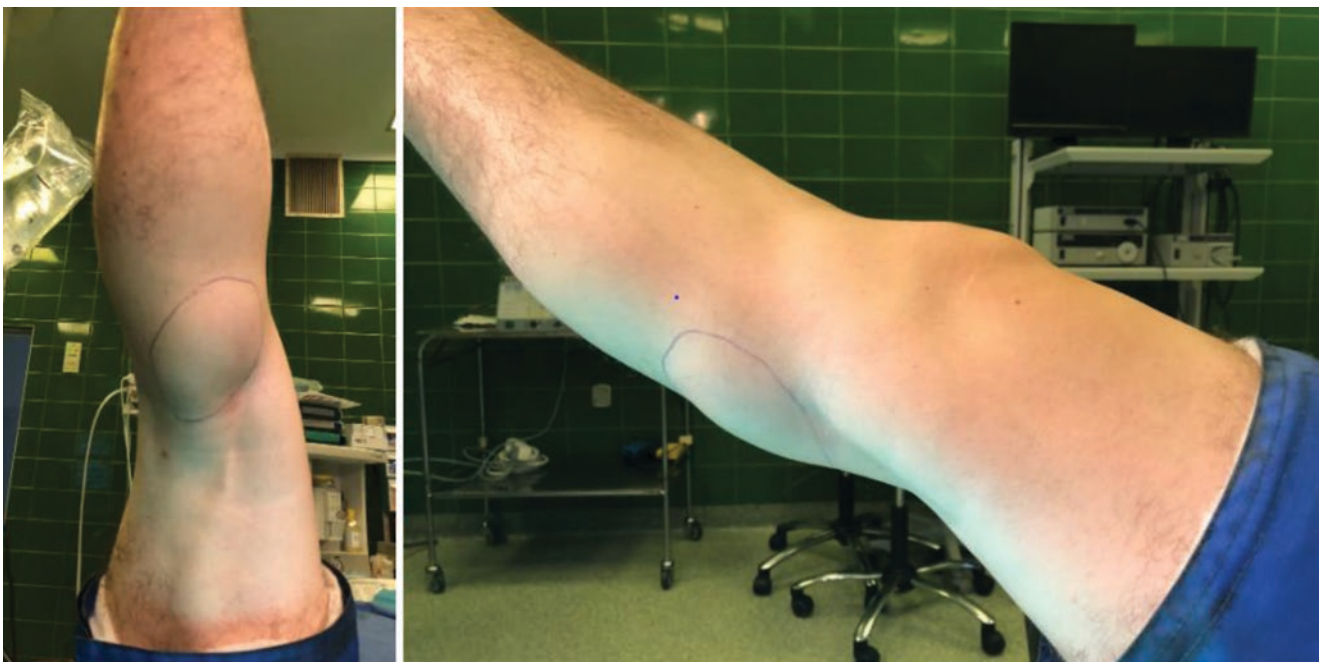

Fig. 12.1 Typical clinically symptomatic cyst in the popliteal region of the right knee

12.1.4 Author Preferred Technique

12.1.4.1 Preoperative Planning

Each patient scheduled for an arthroscopic treatment of popliteal cyst should have an MRI performed to diagnose concomitant intra-articular lesions and to determine the main features of the cyst. One should focus on the size of the cyst, its connection with the joint cavity, its location-neighborhood of popliteal neurovascular bundle, and other important muscular and tendinous structures (Fig. 12.2). It allows to plan adequate arthroscopic portals placement and exclude atypical cysts, which could be contraindications for surgery. If any doubt occurs, Doppler ultrasound exam may be helpful to determine the position of lateral wall of the cyst in relation

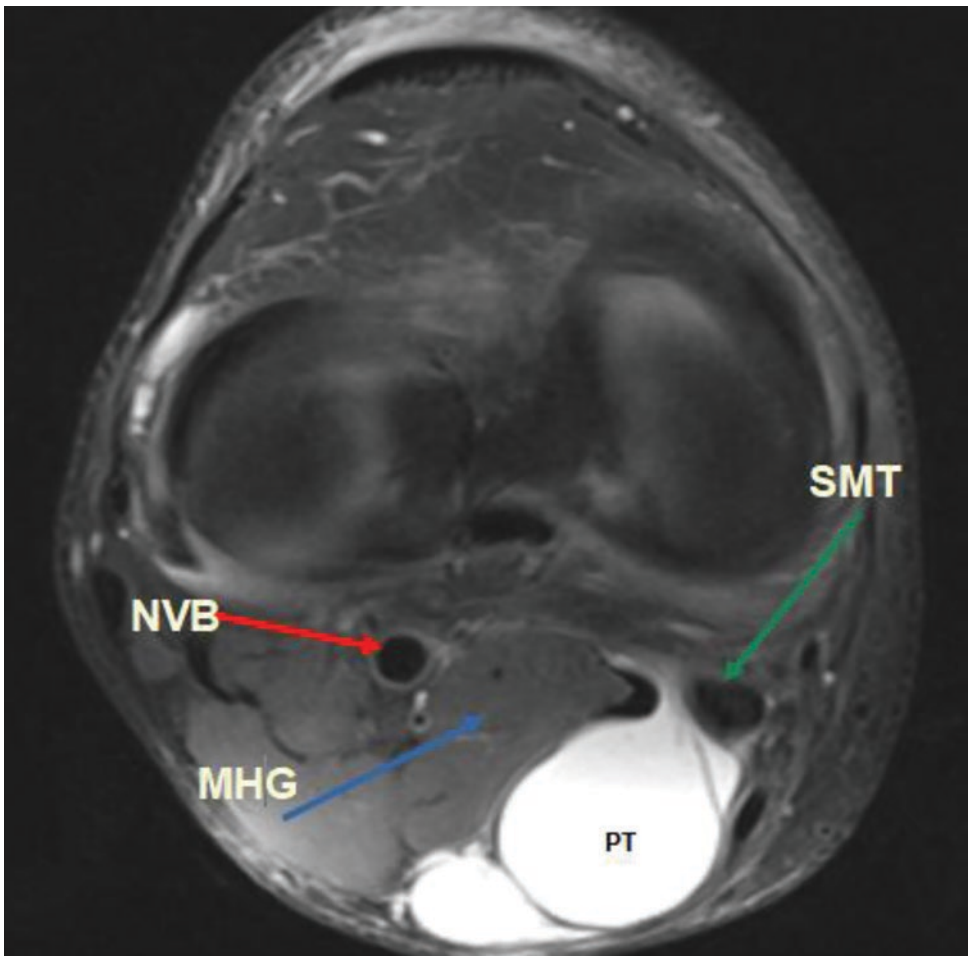

Fig. 12.2 Axial MRI scan of the right knee. Popliteal cyst (PT) with connection to the knee joint. The cyst is located typically between the medial head of gastrocnemius (MHG) and semimembranosus (SMT). Note that the lateral wall of popliteal cyst is separated from popliteal neurovascular bundle (NVB) by the medial head of gastrocnemius

to popliteal neurovascular bundle (Fig. 12.3). Remember that *typical popliteal cyst should be well separated from the popliteal neurovascular bundle with medial head of gastrocnemius.*

12.1.4.2 Patient Positioning

For typical popliteal cysts the patient is positioned supine with the knee placed in a leg support that it is possible to flex the knee above 90°. A non-sterile thigh tourniquet is placed

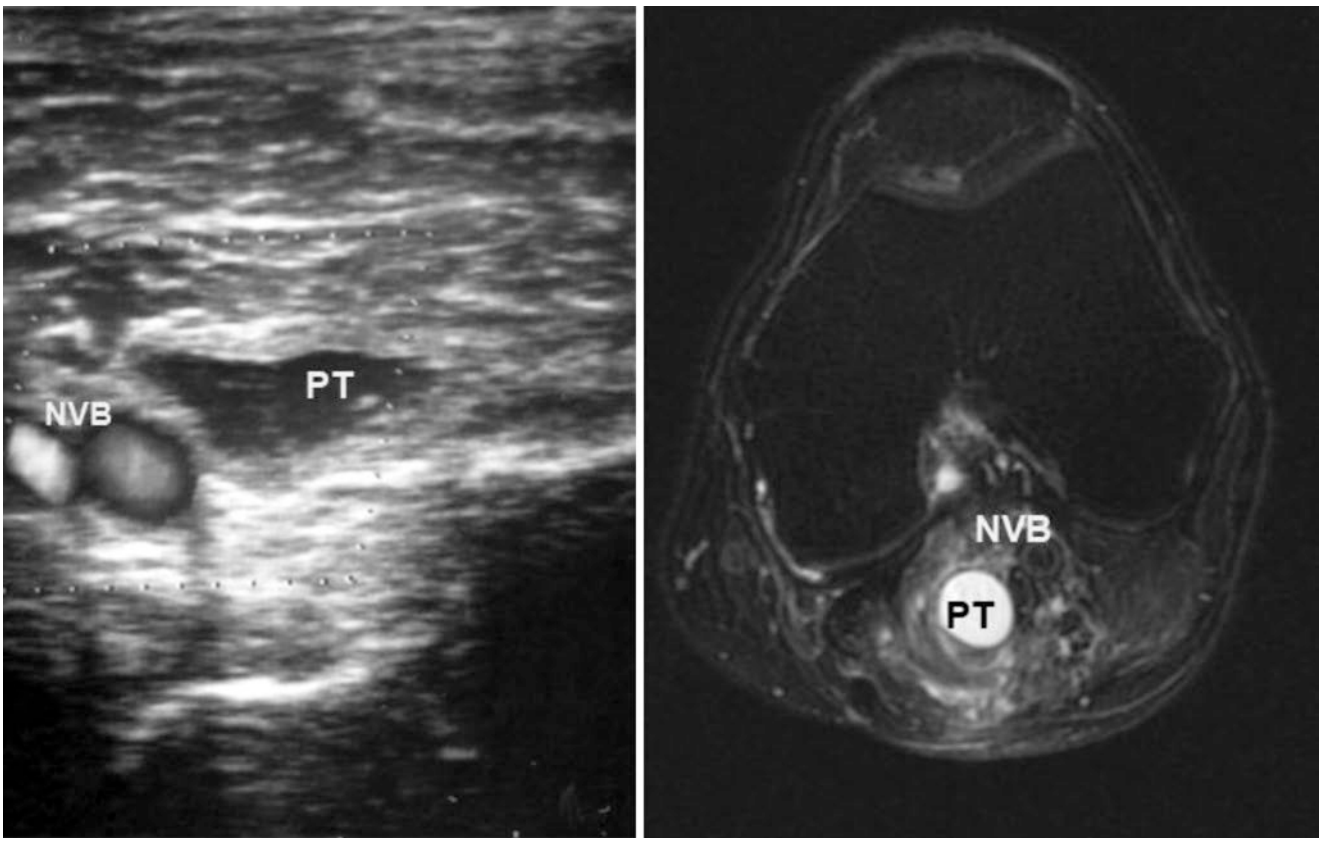

Fig. 12.3 Ultrasound examination (left) and axial MRI scan (right) of the popliteal cyst (PT). The lateral wall of the cyst is located in a close proximity to the popliteal neurovascular bundle (NVB). Atypical location of the cyst is visible on MRI

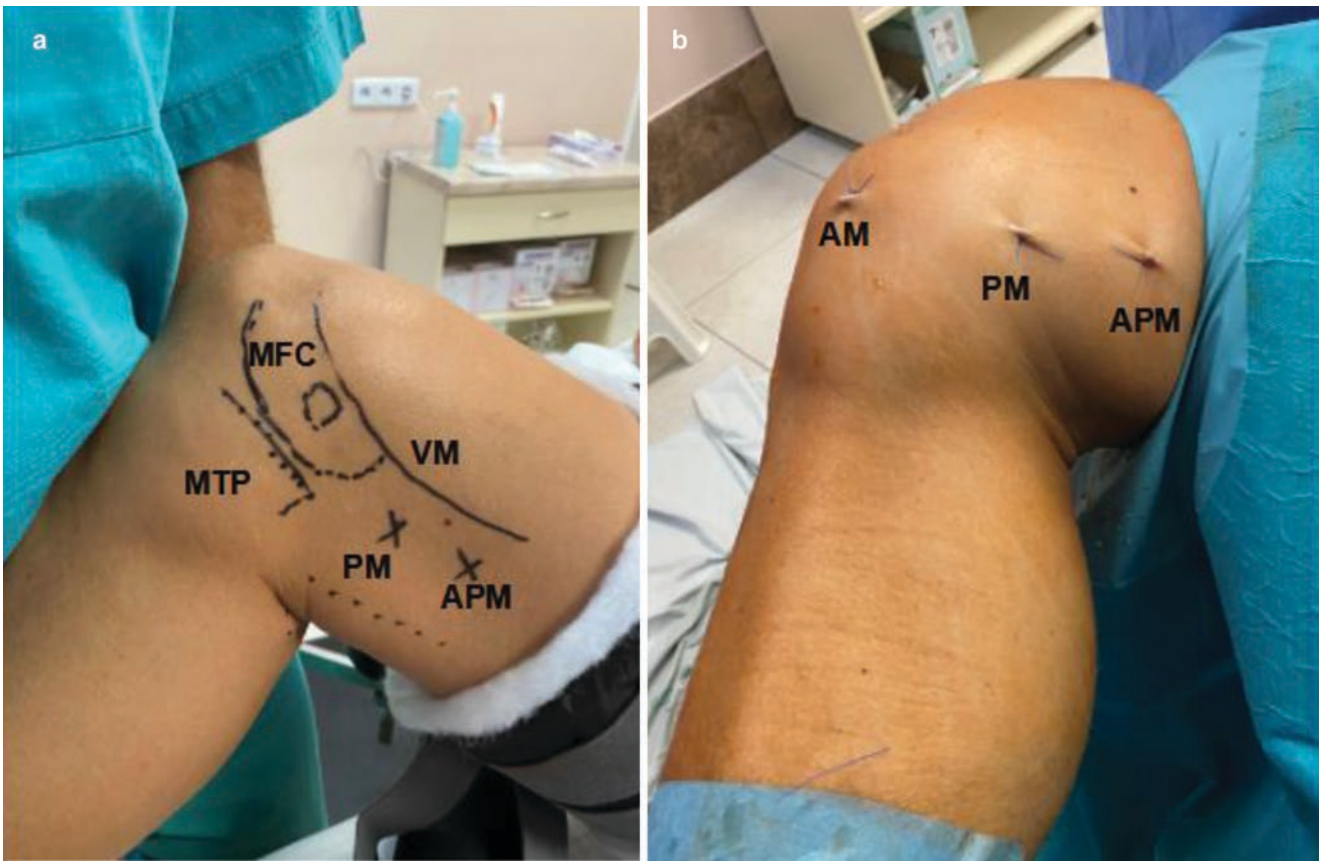

Fig. 12.4 (**a**) The right knee before surgery. The positions of posteromedial (PM) portal and additional posteromedial (APM) portal are located between the vastus medialis (VM, solid line) and hamstrings tendons (dashed line) 3–7 cm proximal to the medial joint line. *MFC* medial femoral condyle, *MTP* medial tibial plateau. (**b**) The medial side of the right knee after surgery. The positions of anteromedial (AM), posteromedial (PM), and additional posteromedial (APM) portals are presented

high at the thigh and inflated to avoid excessive bleeding and disrupted visualization through the procedure. The knee is prepared and draped in a sterile fashion (Fig. 12.4). For atypical popliteal cysts which are large, descends to the calf, or lie adjacently to the popliteal neurovascular bundle the patient may be positioned prone when all intra-articular procedures are finished. The procedure is performed under regional or general anesthesia.

12.1.4.3 Diagnostic Arthroscopy and Treatment of Concomitant Intra-articular Pathologies

The diagnostic arthroscopy is performed through standard anterolateral and anteromedial portals. If concomitant intra-articular lesions exist, they should be treated at first. If the cyst is addressed before intra-articular pathologies, the risk of fluid extravasation into the cyst and, theoretically, risk of compartment syndrome development increases. *Pay attention to properly diagnose and treat concomitant lesions. If left untreated, the chance for resolve the popliteal cysts decreases.*

12.1.4.4 Typical Popliteal Cyst Treatment

At the beginning of the "popliteal" part of the procedure the arthroscope should be placed in the posteromedial compartment of the knee. To do it, the so-called trans-notch maneuver is performed. With the knee in a slight flexion a mild valgus stress is applied and the arthroscope introduced through the anterolateral portal is pushed through the space between posterior cruciate ligament (PCL) superiorly, lateral wall of medial femoral condyle (MFC) medially, and posterior horn of medial meniscus (MM) inferiorly, to the posteromedial

compartment (Fig. 12.5). The rest of procedure is performed with the knee flexed to 90°. In cases of typical connection between the knee joint and gastrocnemius-semimembranosus bursa, posteromedial fold and medial border of tendinous part of gastrocnemius should be visualized (Fig. 12.6). The entrance to the cyst is usually located just behind the fold, between the medial margin of the medial head of gastrocnemius and the lateral margin of the semimembranosus. The valve and the entrance to the cyst should be identified percutaneously using a spinal needle (Fig. 12.6). In the next step the posteromedial portal is created under visual control just above the posteromedial fold, 5–8 mm medially to the medial margin of medial head of gastrocnemius. Transillumination may be helpful to determine the position of saphenous vein and nerve to avoid their injury during portal formation. Under visual control the shaver and radiofrequency probe are sequentially introduced through posteromedial portal and used to excise the posteromedial fold and other tissue that

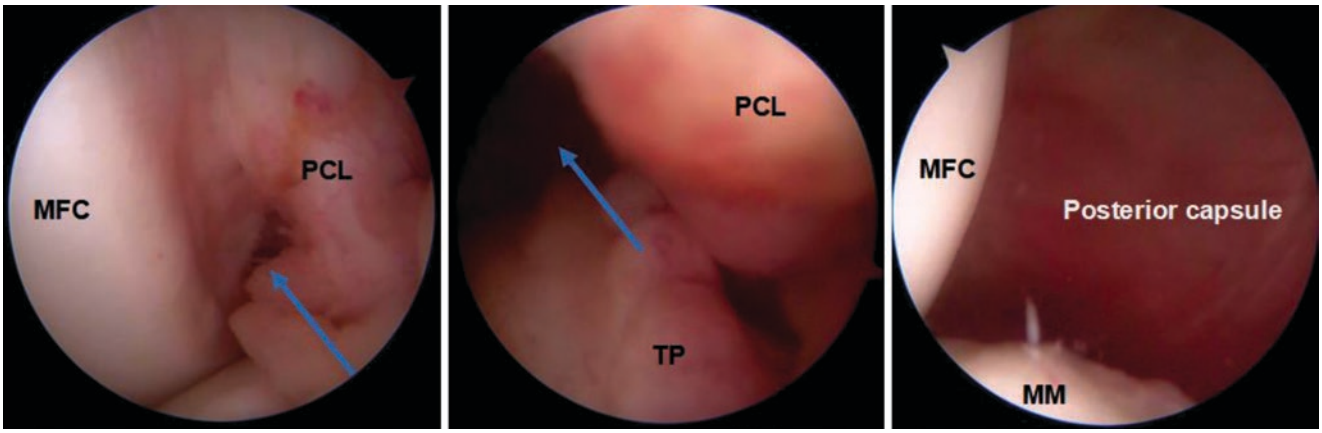

Fig. 12.5 Arthroscopic view from anterolateral portal in the left knee. Following steps of "trans-notch" maneuver. With the knee in a slight flexion a mild valgus stress is applied and the arthroscope introduced through the anterolateral portal is pushed through the space between posterior cruciate ligament (PCL) superiorly, lateral wall of medial femoral condyle (MFC) medially, and posterior horn of medial meniscus (MM) inferiorly, to the posteromedial compartment. The blue arrow determines a proper course of arthroscope. *TP* tibial plateau

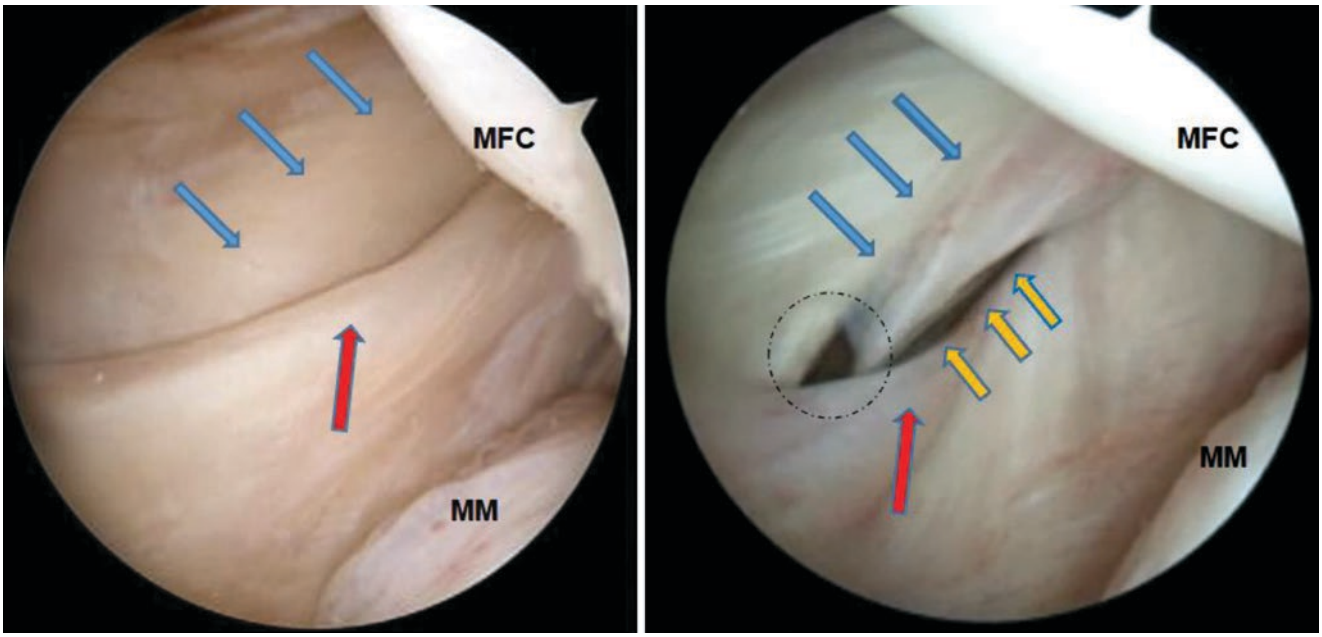

Fig. 12.6 Arthroscopic view from the anterolateral viewing portal after trans-notch maneuver in the right knee. Posteromedial compartment. The entrance to the cyst (black dotted circle) is usually located just behind the posteromedial fold (red arrow), medially to the course of medial head of gastrocnemius (blue arrows). The needle (yellow arrows) pierced through skin may be helpful to depress posteromedial synovial fold to determine the cyst entrance. *MFC* medial femoral condyle, *MM* medial meniscus

could act as a valve to enlarge the communication between the cyst and the joint and to restore the bidirectional fluid flow (Fig. 12.7). It is extremely important to keep the working side of instruments directed anteriorly and medially, away from popliteal neurovascular bundle and not to use an aggressive shaver tip. In the last step of procedure, the arthroscope is pushed forward inside the cyst. The shaver is introduced subcutaneously through posteromedial portal, carefully moved dorsally along the medial wall of the cyst with the visual control of the position of its tip, introduced to the cyst through the medial wall and used to excise it (Fig. 12.8). Other walls are also resected using the shaver. At

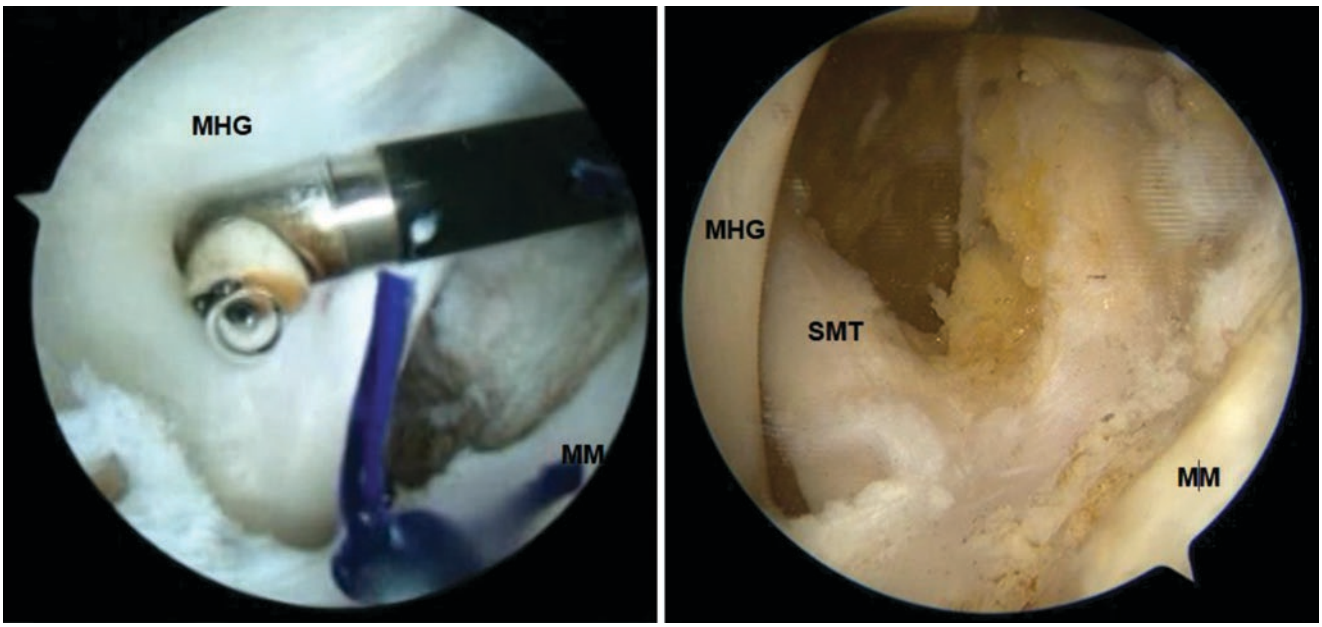

Fig. 12.7 Arthroscopic view from the anterolateral viewing portal in the right knee. Posteromedial compartment. Radiofrequency probe is used to remove posteromedial fold and all soft tissue limiting bidirectional fluid flow between the popliteal cyst and the knee joint. On the right the bidirectional fluid flow has been restored. *MHG* medial head of gastrocnemius, *SMT* semimembranosus tendon, *MM* medial meniscus (on the left after repair the RAMP lesion)

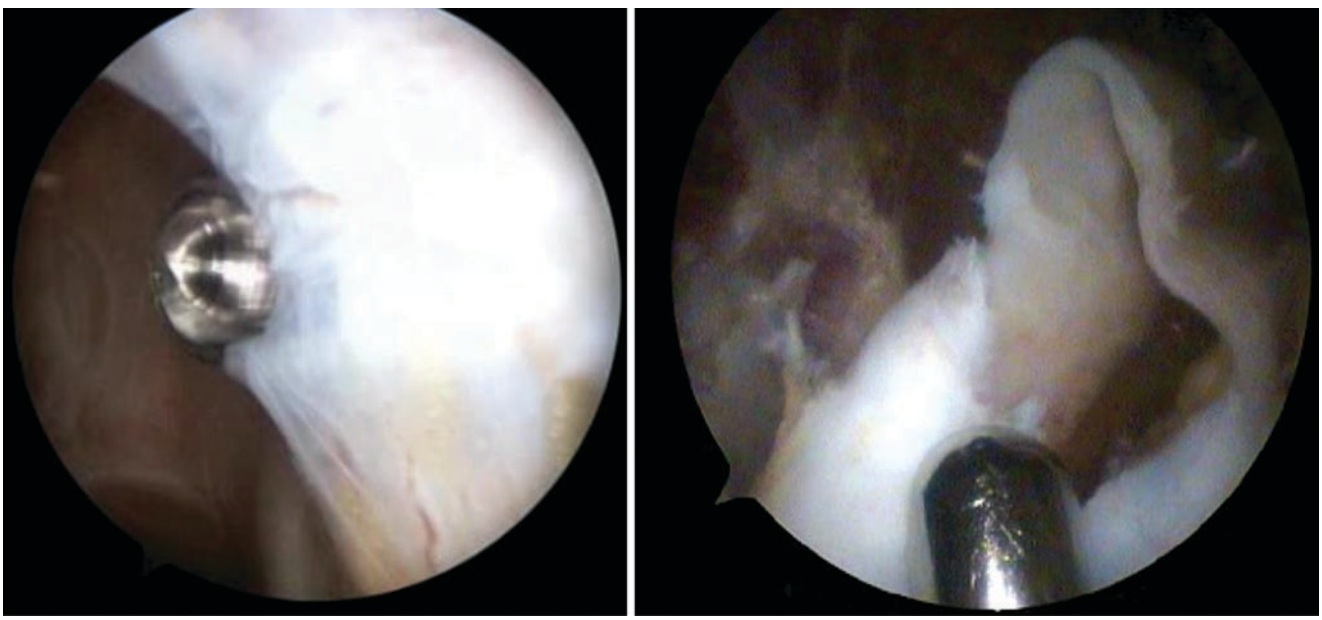

Fig. 12.8 Arthroscopic view from the anterolateral viewing portal in the right knee. Arthroscope inside the popliteal cyst. The shaver introduced through posteromedial portal subcutaneously is used to remove cystic walls. Note that the non-aggressive tip of the shaver is directed away from popliteal neurovascular bundle

the end of the procedure, the arthroscope is moved back and the bidirectional fluid flow is inspected. Each tissue which may limit unrestricted fluid flow should be removed with shaver or radiofrequency probe.

Sometimes the posteromedial fold and the entrance to the cyst are not clearly visible, but the existence of popliteal cyst is known based on preoperative imaging. In this situation the posteromedial portal should be placed 5–8 mm medially to the medial margin of the medial head of gastrocnemius just above the level of posterior horn of MM. The shaver and radiofrequency probe should be introduced and used to carefully excise the posterior joint capsule vertically, just medial to tendinous margin of medial head of gastrocnemius and lateral to the semimembranosus tendon, where the entrance to the cyst is usually located. The dissection should be continued along the course of gastrocnemius. The walls of the cyst should be removed as presented previously.

12.1.4.5 Tips for Managing Difficult Popliteal Cysts [20]

Large popliteal cyst extending to the thigh

If the cyst is large and extends to the thigh an additional posteromedial portal may be created to facilitate its excision. It is located in the "soft spot" 3–7 cm proximal to the posteromedial portal above the hamstrings and below the vastus medialis. The switching stick is introduced straight to the cyst through posteromedial portal to determine the direction for further work with the shaver. The arthroscope is inserted to the cyst through additional posteromedial portal over the switching stick inserted again under direct visualization. The shaver and radiofrequency probe are used to excise the cystic walls and resect the valvular mechanism limiting the unrestricted bidirectional fluid flow (Fig. 12.9). In such a procedure when two posteromedial portals are used, the surgeon is partially turned away from the monitor. To make this situation more comfortable one could move the monitor to the head or affected side of the patient and make a maximal abduction of the leg.

Popliteal cyst caused by posterior medial meniscus pathology

If the popliteal cysts seem to have a connection with the cyst of posterior horn of MM and the body of meniscus looks like empty inside, based on the preoperative imaging, both pathologies may be treated at once. With the arthroscope introduced through the anterolateral portal, the scalpel is inserted through the anteromedial portal and used to open inner margin of MM body horizontally. Then the shaver and hook probe are used to enlarge the tunnel in the MM what provides bidirectional fluid flow between the popliteal cyst

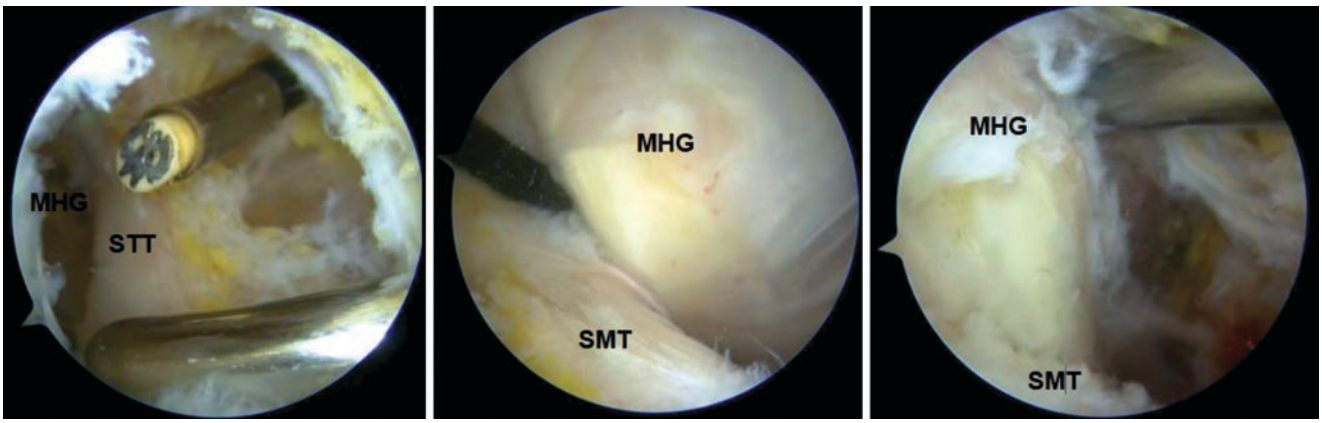

Fig. 12.9 The technique of two posteromedial portals in the right knee. Arthroscopic view from an anterolateral viewing portal (on the left), from an additional posteromedial portal (in the middle) and from the posteromedial portal (on the right). All these portals may be interchangeably used to introduced arthroscope, radiofrequency probe, and switching stick. *MHG* medial head of gastrocnemius, *STT* semitendinosus tendon, *SMT* semimembranosus tendon

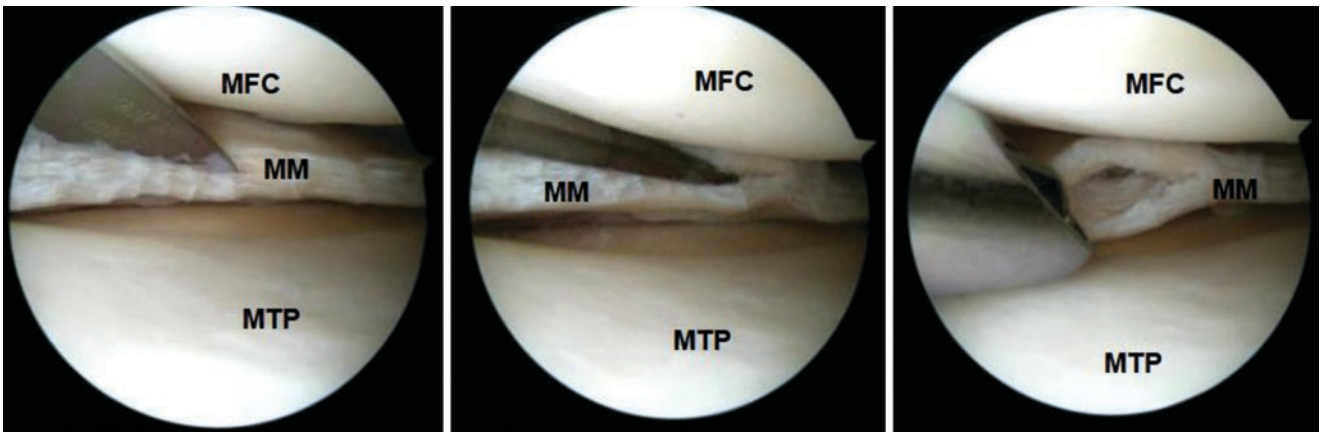

Fig. 12.10 The view from the anterolateral portal in the left knee. Modified Sansone-De Ponti technique. Simultaneous treatment of popliteal cyst and the cyst of posterior horn of medial meniscus (MM). The horizontal incision is made in the body of the meniscus. The shaver is used to enlarge the tunnel, what decompresses both cysts. *MFC* medial femoral condyle, *MTP* medial tibial plateau

and the joint cavity. One could remove meniscal cyst thorough this trans-meniscal approach (Fig. 12.10).

Large popliteal cyst descending to the calf

If the popliteal cyst is large and descends to the calf, a special approach is required. The patient should be positioned prone. The ultrasound imaging should be used to determine the cyst and mark its boundaries. Then, at the medial side of lower boundary of the cyst a small skin incision is performed, the subcutaneous tissue is dissected bluntly, and the scope is introduced between the skin and cystic wall. Then the lateral portal is created under visual control. The needle is advanced percutaneously to the cyst until the fluid leakage is observed. It confirms the proper direction of the portal. Then the transcystic portals are made and the shaver is used to excise cystic walls under direct arthroscopic control.

The same approach or two posteromedial portal technique may be utilized to treat popliteal cyst which lateral wall lies close the popliteal neurovascular bundle. However, a resection of the deep part of the lateral wall of this kind of cyst may be very dangerous and finally, it does not improve significantly clinical results.

12.1.4.6 Complications and Management

Maneuvering in the posteromedial compartment of the knee may lead to some serious and minor complications.

- Injury to popliteal neurovascular bundle
- To avoid it, use a non-aggressive tip of the shaver, always have the tip of the shaver visualized and directed anteriorly and medially, away from popliteal neurovascular structures. You can also resign from excising the lateral wall of the cyst, to make the procedure safer. Always check orientation of the scope because the landmarks are less obvious in popliteal space. Palpation and feeling of the instruments through the skin is very helpful. The neurovascular bundle in our procedure should be separated from the cyst by the muscle belly of medial head of gastrocnemius and some loose adipose tissue around. An old orthopedic sentence says: "Do not touch a red and yellow tissue if you want to stay out of trouble". When the injury to the popliteal neurovascular bundle occurs, the consultation of vascular surgeon may be needed.
- Injury to saphenous nerve and vein
- To avoid it, use a transillumination and keep the knee in 90° of flexion when creating the posteromedial portals.
- Compartment syndrome in the calf
- It is a theoretical complication, which may occur. To avoid it, treat concomitant intra-articular lesions at first, and then start to manage with popliteal cyst. Carefully check arthroscopic pump pressure and regularly assess a calf condition manually.
- Popliteal hematoma
- It usually occurs when an aggressive shaver tip is used to remove cyst walls lying on muscle bellies which are accidentally scratched or some minor subcutaneous veins are damaged. To avoid this, do not touch a "red" part of muscles, use a non-aggressive shaver's tips, and coagulate all bleeding points before you finish. This minor complication usually resolves over time. Cold compresses and vascular agents may be helpful to accelerate this process.
- Infection
- That is not an isolated problem and occurs along with joint infection. As in any case of arthroscopic surgery, an antibiotic prophylaxis and sterile conditions are applied to avoid this complication.

12.1.4.7 Postoperative Care

The special rehabilitation protocol for popliteal cyst treatment does not exist. The rehabilitation is determined by the main intra-articular pathology which caused popliteal cyst development and was treated simultaneously with the cyst.

To avoid postoperative contracture it is recommended to gain a free range of motion in the range of 0–90° on the first postoperative day.

12.1.5 Outcome

The senior author (K.M) in the last 17 years treated more than 1000 cases of patients with popliteal cysts. Since 2006–2012, 136 cases met our restricted inclusion criteria for simple technique of endoscopic typical popliteal cyst excision. 111 of them were available on follow-up. The surgical procedure involves treatment of intra-articular lesions, correction of valvular mechanism and cyst walls excision using single posteromedial portal in supine position. The patients were observed at 6, 12 months postoperatively and then once a year. The average follow-up was 37 months (6–71). The recurrence of the cyst was observed in 14 patients (12.3%), but in 12 of them the cyst was completely asymptomatic and found only in the ultrasound examination as a slit or small residual extension of gastrocnemius-semimembranosus bursa. The recurrence was strongly associated with severe cartilage lesions and residual instabilities, which could not be effectively addressed during primary surgery. In this study group no serious complications were observed. Transient complications involve calf swelling (9), popliteal hematoma (6), sensory deficit (2), superficial soft tissue infection (1), superficial vein damage (1).

12.1.6 Summary

- Popliteal cyst is usually an extension of natural gastrocnemius-semimembranosus bursa which lies in the posteromedial part of the knee. In most cases it is associated with concomitant intra-articular lesions.
- Popliteal cyst develops when intra-articular pressure increases due to joint fluid overproduction and the fluid leaks into the bursa through the valvular mechanism localized in the posteromedial capsule, which allows only for a unidirectional fluid flow.
- The most effective surgical technique for addressing the popliteal cyst involves an arthroscopic treatment of intra-articular lesions with correction of valvular mechanism, which restores a bidirectional fluid flow followed with excision of cystic walls.
- Maneuvering in the posteromedial compartment of the knee may be dangerous and to avoid complications some specific rules for using arthroscopic instruments must be applied.

Table 12.1 summarizes complex approach to treatment of popliteal cyst [20]. Used from *Arthroscopy Techniques*. It is an open access book published by Elsevier.

Table 12.1 Complex approach to treatment of popliteal cysts (Reprint from K. Malinowski et. al, Possible Approaches to Endoscopic Treatment of Popliteal Cysts: From the Basics to Troublesome Cases. *Arthrosc Tech*. 2019;8(4):e375-e382)

Pearls		
Step		
1	Preoperative magnetic resonance imaging (MRI)	Assess the location of popliteal cyst, valvular mechanism, position of the popliteal cyst against popliteal neurovascular bundle. The regular popliteal cyst should be well separated from the neurovascular bundle with medial head of gastrocnemius muscle. Identify intra-articular lesions and treatment possibilities.
2	Preoperative ultrasound examination	Do it when the popliteal cyst is large and there is a need of additional posteromedial and popliteal portals creation. Draw safe area on the skin.
3	Arthroscopy	Treat concomitant intra-articular lesions and the popliteal cyst with communication-enlargement surgery.
4	*Match the approach to the type of the cyst*	
	Typical popliteal cyst in gastrocnemius-semimembranosus bursa with visible valvular mechanism	Patient position: supine. Viewing portal: anterolateral with trans-notch maneuver. Working portal: posteromedial portal
	The popliteal cyst without visible connection with the joint. Large popliteal cyst ascending to the thigh. The popliteal cyst close to the popliteal neurovascular bundle on the thigh	Patient position: supine Viewing portal: anteromedial portal with trans-notch maneuver, then additional posteromedial portal. Working portal: posteromedial portal
	The popliteal cyst without connection with the joint caused by pathology of posterior part of medial meniscus	Patient position: supine Viewing portal: anterolateral Working portal: anteromedial
	Large popliteal cyst descends to the calf. The popliteal cyst more central close to the popliteal neurovascular bundle on the calf	Patient position: prone Viewing portal: medial popliteal Working portal: lateral popliteal
Pitfalls		
1) Using aggressive shaver for cyst wall removal 2) Directing tip of working instrument toward neurovascular bundle 3) Resecting muscle fibers or loose connective tissue 4) Working without correct visibility 5) Losing control of working depth and direction 6) Losing anatomic position of the scope 7) Resecting tissue too lateral from the medial border of gastrocnemius 8) Leaving part of posteromedial fold or any tissues that could impair bidirectional fluid flow		

12.2 Endoscopic Harvest of Sural Nerve Graft

Lukas Rasulić and Milan Lepić

12.2.1 Introduction

Sural nerve is the most frequently used donor nerve in peripheral nerve and brachial plexus reconstruction procedures, as well as in orthopedic surgery, for iatrogenic and associated peripheral nerve injuries [21, 22]. Open surgery for sural nerve harvesting is usually done by making an incision over the whole length, or a series of small incisions along the pathway of the nerve. Both procedures have their advantages and flaws: while the long incision is related to extensive scarring, the series of incisions usually does not provide enough visualization and may be related to inadvertent damage, whereby the latter procedure was introduced only lately and requires further corroboration [23]. The imperfections of the open method served as a platform for an interesting application of endoscope in peripheral nerve surgery. The method for endoscopic sural nerve harvesting was first introduced by Kobayashi et al. in 1995 [24], and since then the technique has passed through many stages of improvement The procedure usually lasts no longer than 25 min, and with the latest technique it requires only one skin incision of 12 mm [25].

12.2.2 Anatomical and Physiological Considerations

Except for unmyelinated autonomic fibers, the sural nerve is a purely sensory nerve, providing cutaneous innervation. It is typically formed through the union of the lateral and medial sural cutaneous nerves, which originate from the common fibular (branch of the peroneal nerve) and tibial nerves. Rarely, the sural nerve is formed solely from the tibial nerve (medial sural cutaneous nerve) and even less commonly from the peroneal (lateral sural cutaneous nerve) [26].

The medial sural cutaneous nerve passes between the two heads of the gastrocnemius muscle, and runs through the deep fascia of the posterior compartment of the leg. At the midcalf level it conjures with the peroneal communicating branch and a lateral sural cutaneous nerve from the peroneal nerve. The nerve passes lateral to the calcaneal tendon, near the short saphenous vein, along the lateral border of the Achilles tendon and posterior to the lateral malleolus and the calcaneus. There, the nerve provides sensory supply to the posterior and lateral skin of the distal third of the leg, before passing distally along the lateral side of the foot and the little toe, to supply the overlying skin. The nerve anastomoses with the superficial fibular nerve on the dorsum of the foot [27]. Figure 12.11 illustrates the anatomy of the sural nerve(s).

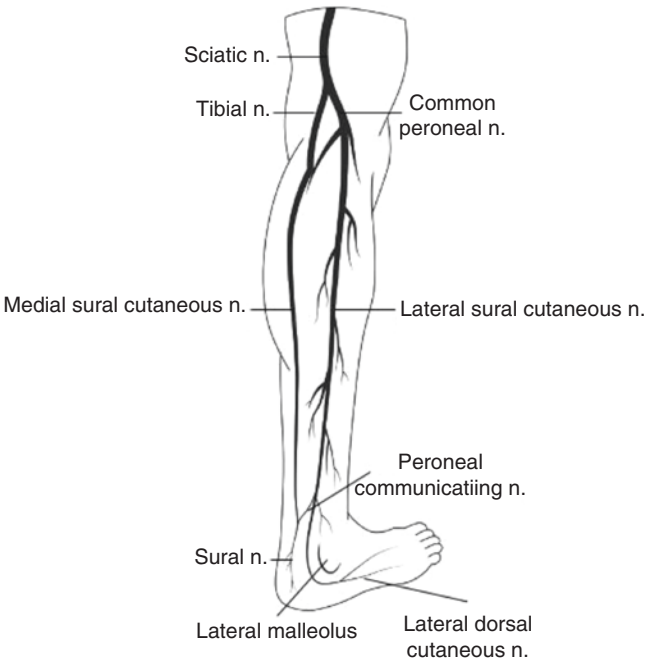

Fig. 12.11 The sural nerve anatomy

12.2.3 Indications

Grafts from the sural nerve are considered the most appropriate for the use in peripheral nerve and brachial plexus surgery. Whenever the nervous tissue defect (nerve gap) is longer than 1–2 cm, the graft is needed to achieve the distal end for direct repair, as well as in nerve transfers, when donor nerve length is not sufficient for the coaptation with the target nerve.

Short grafts have better reinnervation potential. A single piece long graft may be divided into a few pieces, shorter in length, which may be used to adequately match the donor and target nerves thickness when appropriate. The use of up to eight pieces was reported when using the viable C5 nerve root, four to repair the musculocutaneous nerve and the other four to repair the axillary nerve [28].

12.2.4 Contraindications and Limitations

General limitations and contraindications applying to the peripheral nervous system reconstructive procedures apply to the use of sural nerve grafts as well.

Timing is important. The denervated muscle atrophies and develops fibrosis, losing its contraction capacity and reinnervation potential through the vanishing of functional units. Motor reinnervation procedure in the absence of functional motor units in the target muscle is redundant [29].

The most common specific contraindication for the use of a sural nerve graft is the presence of peripheral neuropathy, compromising the sensation of the lower extremity. This pathological state raises concerns for the sural nerve harvest, primarily due to the donor site morbidity, which may cause more severe complications, and secondarily due to the questionable viability and nerve soundness.

Patients with previous surgery or trauma involving the posterior aspect of the leg within the sural nerve pathway should be investigated for possible damage and nerve indemnity.

Some authors consider the nerve defect longer than 6 cm as a threshold for the use of a vascular graft; although debatable, this should be taken into account in the decision-making process. In these circumstances, free vascularized nerve grafts are preferred over traditional nerve grafts. Another indication for the free vascularized nerve graft is for the patients considered to have poor regional vascularization, as well as those with significant scarring and fibrosis [31].

12.2.5 Surgical Procedure

12.2.5.1 Preoperative Considerations

Although the sural nerve harvest is usually only a small part of a complex reconstructive procedure, the functional sacrifice in a previously healthy region is subject to a serious medico-legal arrangement. The procedure must be explained to the patient and a family member in detail. Even though the donor site morbidity (anesthesia of the lateral calf and dorsum of the foot) may recover in the future, understanding that it may be a permanent sacrifice is of utmost importance.

12.2.5.2 Equipment

The endoscopic procedure is not demanding in terms of equipment, as there is no dedicated system for the sural nerve harvesting. Apart from the rigid endoscopes, flexible instruments are usually utilized, and there is also a recently introduced technique with the endoscopic system primarily designed for greater saphenous vein harvesting [25].

The application of this system in sural nerve harvesting procedure is even less complicated than is the case for its primary purpose (vein graft harvesting), due to the lack of bleeding, the toughness of the nerve in comparison to the vein, the resistance to the minor force, and potential adherence of the vein. The system uses a bisector rotating carriage with a large profile cutting toggle and C-Ring slider to separate the nerve, with a common CO_2 insufflation, and a 0-degree 5-mm camera [25].

12.2.5.3 Technique

As a rule, patients are positioned to the prone position for the sural nerve harvesting procedure. Exceptionally, endoscopic harvesting can also be performed from a supine position.

Before the patient is prepared and draped, it is essential to mark the landmarks and outline the sural nerve for the endoscopic procedure. The most reliable starting point to locate the nerve is at the classic spot, posterior to the lateral malleolus approximately half way between the malleolus and the Achilles tendon.

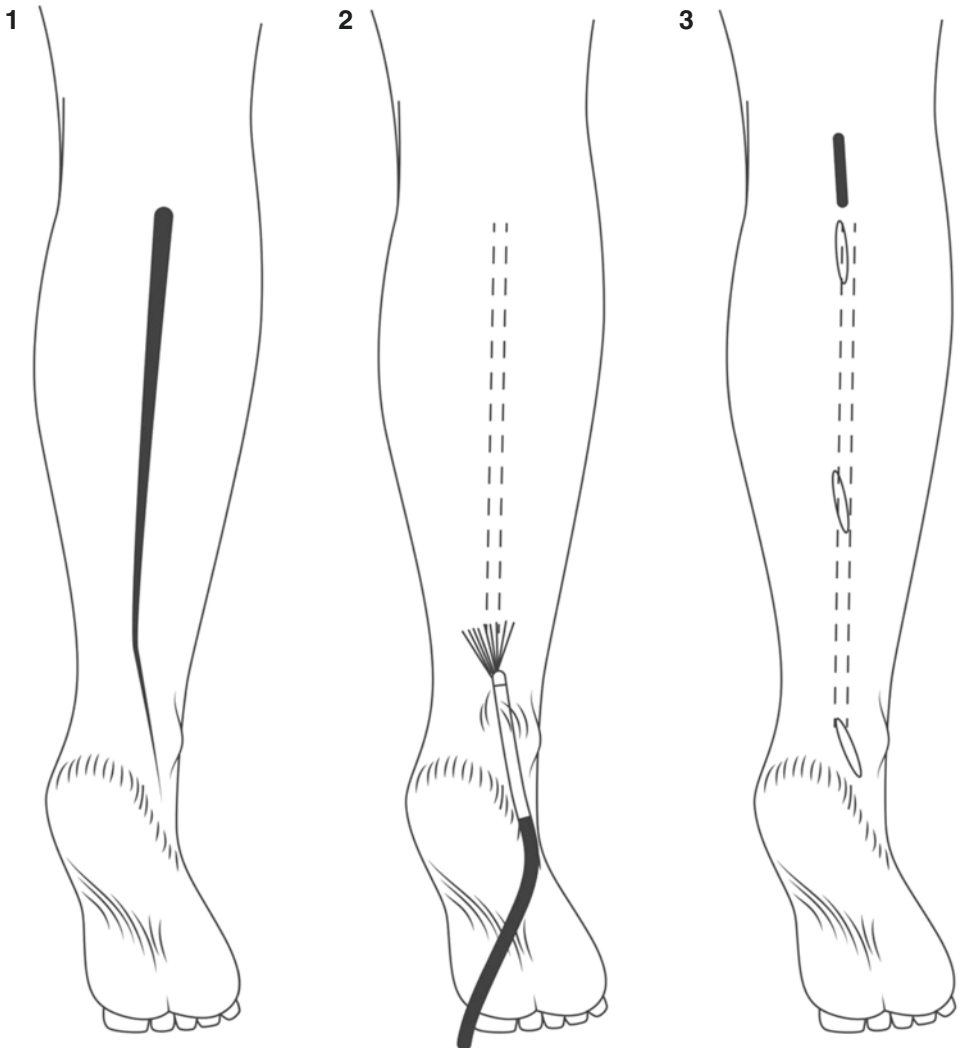

Fig. 12.12 Classical endoscopic sural nerve harvesting procedure. (1) Outlining the sural nerve on the skin. (2) Introduction of the endoscope through the incision at the starting point. (3) Harvested graft through three incisions

Classical endoscopic procedure (Fig. 12.12) is performed with the introduction of the endoscope through the 2 cm vertical incision at the starting point, along the outlined pathway to reach the length of the endoscope. Another incision is made, and the sural nerve is marked, before the procedure is repeated. Depending on the length of the endoscope, 3–4 incisions are needed to harvest the full-length sural nerve graft. The sural nerve is then resected and pulled out, and the incisions are closed. This technique allows for better bleeding control than when using a vein stripper [32].

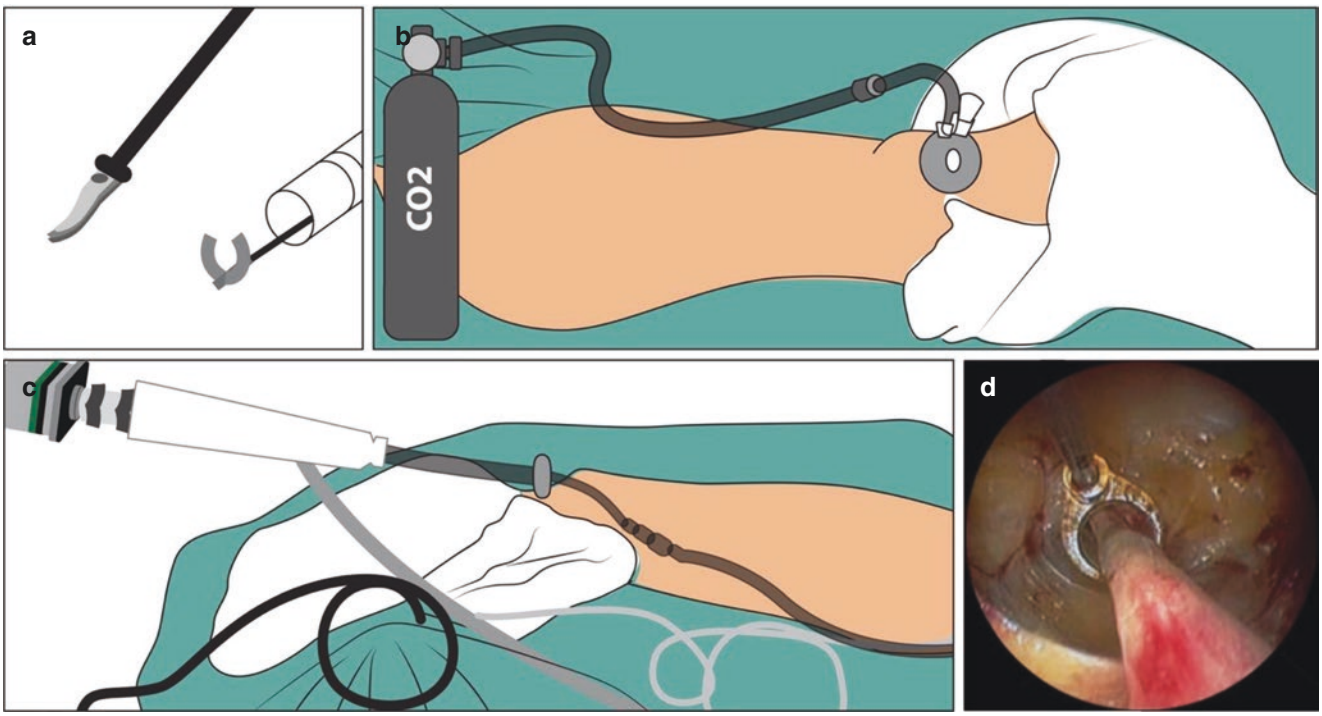

Fig. 12.13 Sural nerve harvesting using the greater saphenous vein graft endoscopic system

The procedure using the greater saphenous vein graft endoscopic system (Fig. 12.13) is performed through a 12 mm vertical incision at the starting point. The sural nerve is identified and dissected proximally to prepare for the insufflation and dissection. A 12 mm trocar is inserted to create a seal for CO_2 insufflation through the side port. The dissector with conical tip is introduced for initial dissection, before CO_2 insufflation to 12 mmHg to expand the tunnel.

Guided with the camera, the dissector is advanced along the four surface sides of the sural nerve at the desired length, with careful dissection of all branches. The conical tip dissector is then replaced with a bipolar bisector. The C ring is advanced along the nerve, to allow for branches identification and retraction, before cauterizing and cutting with the bipolar bisector. It is important to keep the distance of at least 2 mm between the bipolar bisector and the sural nerve graft to prevent thermal damage. The graft is separated with scissors, while the distal and proximal stumps are coagulated to prevent neuroma formation.

Hemostasis is achieved with the bipolar bisector, and the equipment and the graft are pulled out before the incisions are closed.

12.2.6 Advantages and Disadvantages

The strongest advantage of the sural nerve graft harvesting procedure with the use of endoscope is that it allows for the

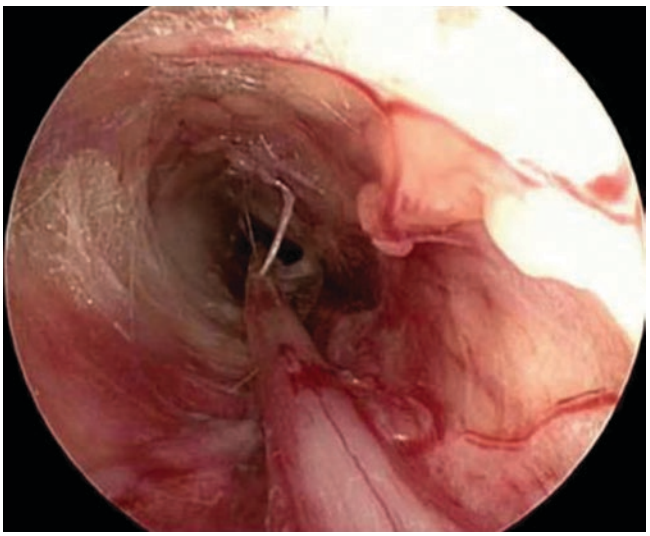

Fig. 12.14 Endoscopic visualization of the sural nerve (at 6 o'clock position)

intraprocedural visualization of the nerve for its viability and deflects an injury (Fig. 12.14). Also, it is done through a small incision, nevertheless allowing for complete nerve harvesting.

For many patients, especially young women, a long incision is not an option, since it only adds to the overall trauma of the nerve repair procedure. In particular, the presence of scars on the leg must be discussed ahead of the procedure.

Hemostasis is the most common limitation of the endoscopic procedures, but both presented methods deal well with this issue.

The most important unavoidable disadvantage is a relatively steep learning curve, which requires experienced endoscopic hands. Hence, for the surgeons switching from the open to the endoscopic approach, a supplementation with the cadaver lab training is a recommended way to go.

12.2.7 Complications

The general surgical complications are also common to the sural nerve harvesting procedures (poor wound healing and hypertrophic scarring). However, their probability is significantly lower with endoscopic techniques.

A painful neuroma at the site of nerve proximal section is a rare complication after sural nerve harvesting, and it is suggested to cauterize the proximal stump to prevent this complication [33].

The postoperative anesthesia of the dorsum and lateral aspect of the foot is a consequence rather than the complication. Some patients, however, may experience a hard time dealing with the sensory deficit. The pertinent anesthesia is expected to improve over a period of 1–2 years due to the collateral sprouting of the adjacent sensory nerves [31].

As they are unavoidable, these general complications should be considered natural history rather than procedural complications per se.

A procedure-specific complication occurs when the graft intended for the use with functional sacrifice at the donor site is damaged, especially when this damage remains unnoticed, in which case it might seriously compromise the whole complex reconstructive procedure.

12.2.8 Conclusion

The sural nerves grafts are probably the best possible option to use in peripheral nerve and brachial plexus reconstructive procedures. Both open and endoscopic harvesting procedures are still developing, each with its own imperfections.

The two endoscopic techniques presented have advantages over open surgery in terms of complete nerves visualization, mobilization, and adequate hemostasis. Providing a minimally invasive approach, with one or a few small incisions, the endoscopic techniques reduce common surgical complications and yield a far better cosmetic effect. Nevertheless, open surgery remains the most commonly used method, and is still a predominant standard for the graft harvesting in referential surgical centers worldwide.

12.3 Arthroscopic Management for the Anterior Half of Lateral Meniscus Through the Larai Portal

Rui Yang and Yi Long

Currently, the outside-in method is widely performed for suturing the anterior horn of the lateral meniscus, however, it has disadvantages in that an 1–2 cm long skin incision and knots tied subcutaneously over the capsule are needed [30, 34–38]. The all-inside method would overcome all these drawbacks. However, due to the limited angle under arthroscopy, it is difficult to suture the anterior half of lateral meniscus (AHLM) in tears by all-inside devices [39, 40]. Furthermore, it is much more challenging for arthroscopic surgeons to visualize and resect the inferior leaf of the AHLM through routine arthroscopic portals, especially the tears involved the anterior horn of the lateral discoid meniscus [41–43].

We proposed the Larai portal to observe the lesions and facilitate the application of all-inside devices in AHLM. We describe the portal "Larai" due to the following main points: (a) Lateral. This portal is established for lateral meniscus; (b) All-round. This portal can be acted as a working portal or viewing portal to observe and treat various tears extending to the AHLM; (c) All-inside. The portal permits all-inside instruments to pass through, providing a broader application for all-inside meniscal suture technique. The establishment of the Larai portal during the arthroscopy is performed in the figure of four position around the level of the knee joint line. The trajectory passes through the posterior septum from posteromedial to posterolateral compartments of the knee, and closely adjoins the posterolateral margin of the posterior cruciate ligament (PCL) to lateral compartment of the knee joint. The main surgical steps are as follows.

Surgery is performed in the supine position under combined spinal-epidural anesthesia. Routine diagnostic arthroscopy is performed using the standard anterolateral (AL) and anteromedial (AM) portals. If injuries to the AHLM are diagnosed based on preoperative local findings and imaging examination or arthroscopic examination, the Larai portal can be established. The knee is placed in the "figure of four" position with a 90° knee flexion to open the lateral compartment. First, a 1.0 mm long puncture needle is inserted from a point 1–2 cm lateral to the edge of the patellar tendon, closely adjoined to posterolateral margin of posterior cruciate ligament (PCL) under arthroscopic visualization, and pierced through the medial skin of distal thigh. Second, the trajectory was broadened from the medial skin of distal thigh along the indwelled long puncture needle by a 3.5 mm cannulated switching stick with blunt end. Third, the long puncture needle is pulled out after the tip of switching stick reached the lateral compartment of knee under arthroscopic visualization. Next, the slotted cannula inserted into the articular cavity along the switching stick, locating behind it with the slot toward to the front. The switching stick is then retrieved but the slotted cannula is maintained in the trajectory until the arthroscopic procedure is finished. At last, the AHLM can be observed, resected, or repaired as needed through this protecting cannula (Fig. 12.15).

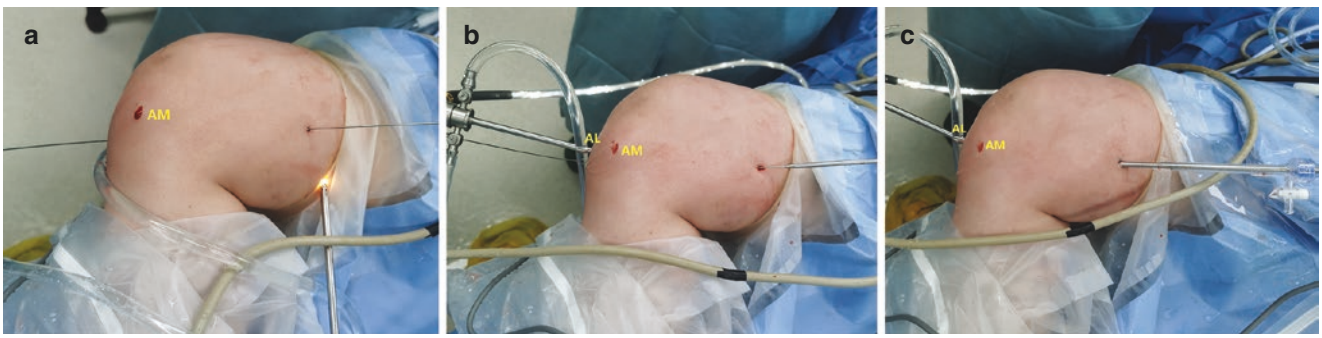

Fig. 12.15 The procedure of the Larai portal. (**a**) Inserting the 1.0 mm long puncture needle. (**b**) Broadening the trajectory by a 3.5 mm inner hollow core switching stick. (**c**) Inserting the slotted cannula along the switching stick. (**d**) Inserting the endoscope through the protecting cannula. (**e**) View from the Larai portal: the AHLM is trimmed by punch forceps through AL. (**f**) View from the AM: the AHLM is repaired by the FasT-Fix 360 system (Smith & Nephew, Andover, MA) through Larai portal. *AHLM* anterior half of lateral meniscus, *AL* anterolateral portal, *AM* anteromedial portal

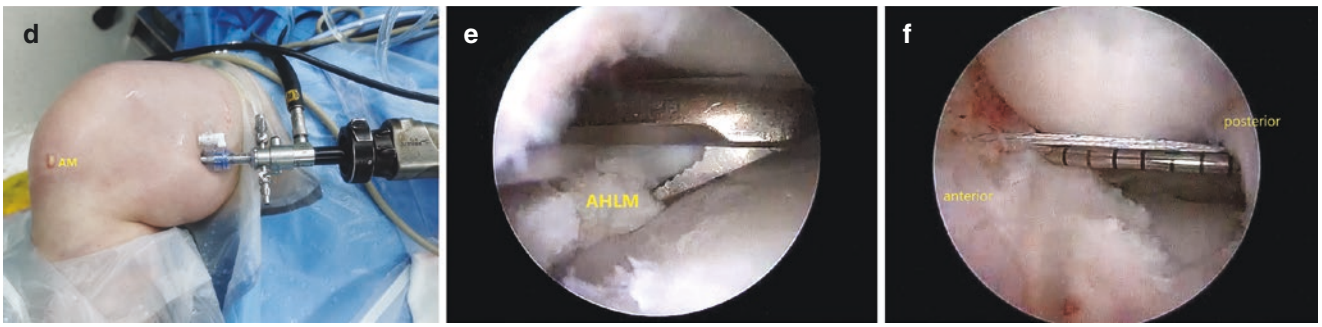

Fig. 12.15 (continued)

Some authors developed the all-inside methods that enables simple suture of the injury to the anterior horn of the meniscus through routine arthroscopic portal without using a specific instrument [44–47]. Meanwhile, various additional portals were proposed and described to visualize and resect the inferior leaf of the AHLM, including inframeniscal, lateral patellofemoral axillary, high anteromedial, or far anteromedial portal [48–52]. However, it is still insufficient to observe the deep-seated inferior leaf of the anterior horn meniscus and potentially increased risk of meniscus injury during the procedure. In addition, surgeons can hardly perform all-inside repair of the meniscal tears extending to the AHLM through these additional portals. The Larai portal which is a new portal permitting arthroscopic instruments to pass through from posteromedial side of the knee joint and provide a new route for all-inside repair of the AHLM tear under direct arthroscopic visualization.

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