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ORIGINAL ARTICLE • KNEE - ARTHROPLASTY

# A comparative study comparing area of extension of posterior knee capsule via posteromedial injection: a cadaveric study

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## Abstract

**Background** Periarticular multimodal drug injection (PMDI) has gained popularity as common postoperative pain protocols in knee arthroplasty. PMDI sites can vary, but posterior capsule (PC) is a common injection site because of its abundance of pain nociceptors.

**Purpose** To prove the hypothesis whether posteromedial drug injection alone is sufficient to provide enough effect covering the PC in order to reduce risks of neurovascular injury. Secondary outcomes are to find proper volume of injection and safe zone for PMDI injection.

**Methods** Ten fresh cadaveric knees were allocated into two equal groups, which differed in volume of dye injection: 25 ml and 50 ml. Dyes were injected into posteromedial capsule compartment, and the limbs were stored in a freezer for 2 weeks. Then the posterior compartment was carefully dissected to examine spreading of the dye solution.

**Results** No dye staining was seen superficially beneath subcutaneous tissue of the knees. In deeper layer, the dye mostly occupied medially along the fascia covering semimembranosus muscles. However, dispersion was limited distally by intermuscular septa and popliteal vessels. The 50-ml injection group provided wider extension in the superficial layer, but not in the deep layer.

**Conclusion** The intermuscular septa and the fascia of popliteal vessels were shown to be the boundary between posteromedial and posterolateral compartments of the knee. Separate PMDI for both compartments is necessary to occupy the entire PC. We suggest that 1.5 cm lateral to lateral border of PCL insertion, just above popliteus tendon, is the safe zone for injecting PMDI into the posterolateral capsule.

**Keywords** Periarticular multimodal drug injection · PMDI · Total knee arthroplasty · Popliteal injury

## Introduction

Knee osteoarthritis is a common major problem that could deteriorate the patient's functional status [1, 3, 6], and total knee arthroplasty (TKA) is a well-known procedure to resolve this problem by removing the eburnated cartilage and replacing with prosthetic implants [14]. This procedure would mitigate the knee pain and improve quality of life [13]. Periarticular multimodal drug injection (PMDI) after TKA has gained popularity in recent years to alleviate postoperative pain [2, 11, 15, 18, 22]. In addition, PMDI also reduces requirements of epidural or parenteral postoperative analgesia [8, 20], consequently reducing opioid side effect and allowing early ambulation.

PMDI sites could be varied with surgical preferences and experience, e.g., at collateral ligaments, quadriceps muscle and posterior capsule (PC). Of those, PC is one of the most common sites for its elevated concentration of mechanoreceptors [4, 8]. However, since structures behind the knee capsule are intricate and show variations, blind injection through the PC to infuse analgesic drugs might cause iatrogenic injury to the neurovascular structures [5, 7, 17, 21]. Two surveys by the United States National Inpatient Sample found that 0.003–0.057% of TKA procedures were complicated by injury to the popliteal artery [10, 12]. Anatomical

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studies confirmed that although the location of the popliteal artery is inconsistent, it is located just lateral from the midline and about 2 cm posterior to the PC in knee flexion in more than 95% of patients [17].

To achieve entire PC infiltration of drug solution, most surgeons use both posteromedial (PM) and posterolateral (PL) injections [9, 16, 19] which might be potentially more harmful to vital popliteal structures, sciatic nerve and its branches. This research is aimed to study whether PM injection alone provides enough drug infiltration in the entire PC and so minimizes potential risks of popliteal structural damage.

## Materials and methods

This cadaveric experimental study had been approved by the Khon Kaen University Ethics Committee for Human Research. The study was performed at Srinagarind Hospital of Khon Kaen University from September to November 2017.

A total of ten fresh cadaveric knees were used (four males and six females). The average height of the cadavers was 163.2 cm, and average weight was 65.8 kg. The fresh cadavers are cadavers of individuals who have died in non-traumatic circumstances between 1 and 2 days beforehand. The fresh cadavers are stored in a freezer at the temperature of − 20 °C and thawed at the temperature of 4 °C for 2 days.

The knees were prepared and injected by a single experienced orthopedic surgeon (PL) who routinely used PMDI technique in clinical practice. White latex (hygienic latex adhesive, TOA®) and water were mixed together in a ratio of 1:9, and a small amount of black India ink was added to form black dye latex solution. The solution was prepared in two different fractions. We selected the volume of 25 ml which generally represent the standard amount of single posterior compartment injection (although there is no actual standard volume), and we chose the volume of 50 ml, which hypothetically exceeds the volume of single posterior compartment, in order to find the boundary of the spread solution in the posterior compartment, if the posterior compartmental septal is not present.

A midline skin incision was made, the anterior knee capsule was opened via a medial para-patellar approach and the patella was retracted laterally. To enable exposure of the injection landmark, the medial femoral condyle and medial tibial plateau were partially resected. The entire anterior cruciate ligament, femoral origin of the posterior cruciate ligament (PCL) and medial and lateral menisci were also removed to clearly identify the insertion of the PCL at the tibial plateau. One knee of each cadaver was randomly selected by tossing a coin to allocate to receive dye injection at either 25 ml or 50 ml and the other knee to receive the other fraction. The injecting landmark was located at 1.5 cm medial to medial border of the PCL insertion at tibia (Fig. 1). A 18-gauge needle (1½ inch long) was used to instill the dye solution into the PC at 1.5 cm in depth (Fig. 2), and the solution was slowly pushed without definite resistance from the syringe until depleted. The needle was removed, and the dye solution was checked for leakage (reflux); if this was of significant amount, the needle hole was obliterated by suture with nylon.

The anterior skin incision was closed by non-absorbable suture (Nylon, 3-0), and the limbs were stored in a freezer at − 20 °C for two more weeks to allow full setting of the latex dye solution with tissues. Then the limbs were rewarmed to 3 °C. The posterior knee skin was opened using C-shaped incision and dissected carefully layer by layer down to the PC to visualize the spreading of dye solution.

## Results

In the superficial layer (the outer fascial layer) just deep to the subcutaneous tissue, no content of the dye solution was shown in both PM and PL aspects of the superficial muscular fascia of the knee (Fig. 3).

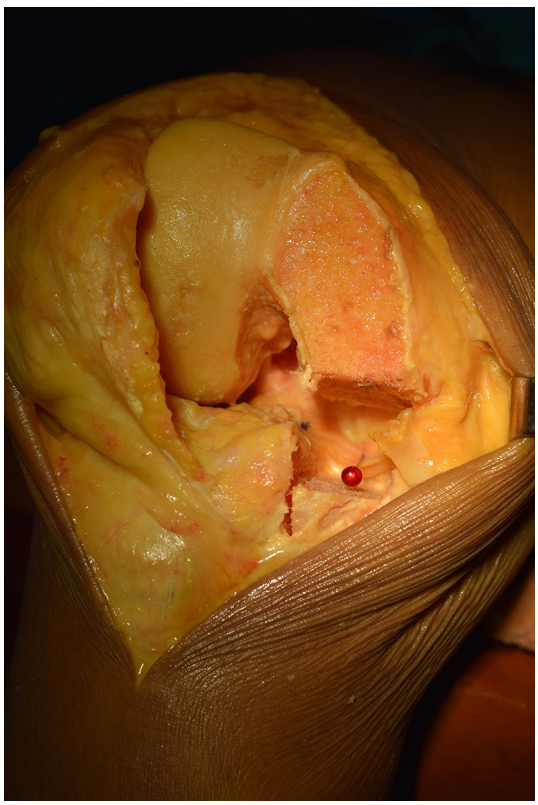

**Fig. 1** Injection site at PM capsule, 1.5 cm medial to medial border of PCL insertion at tibia

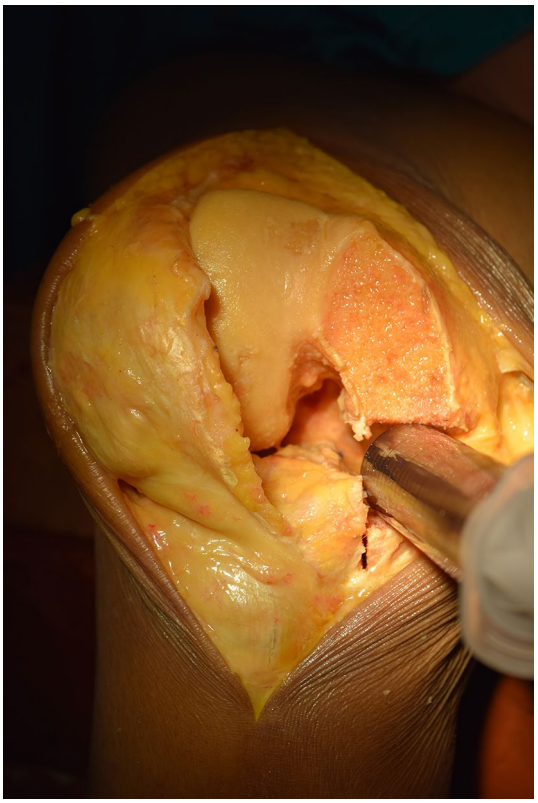

**Fig. 2** Dye solution being injected into the PM capsule

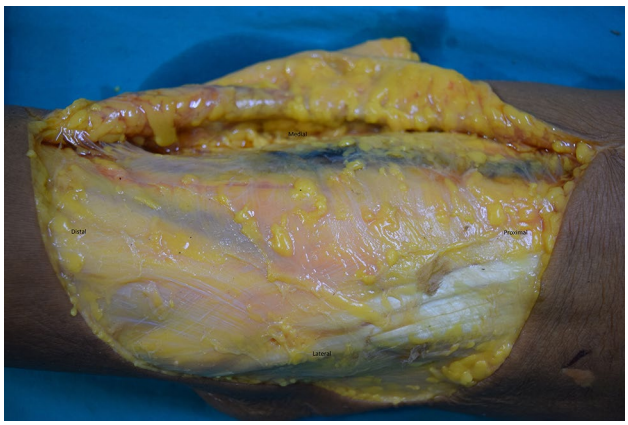


**Fig. 3** No spreading in the superficial layer

In the middle layer, after resecting the muscular fascia, the dye solution occupied medially along the line of the entire fascia covering the semimembranosus muscle, some parts of the sciatic nerve and proximal part of the biceps femoris muscle (Fig. 4). The spreading was limited distally by the septa from tibial nerve branches and popliteal vessels adhering to the posterior femoral condyle (Figs. 5, 6).

With deeper dissection, clear dye solution staining over the medial gastrocnemius head and its bursa was seen; some

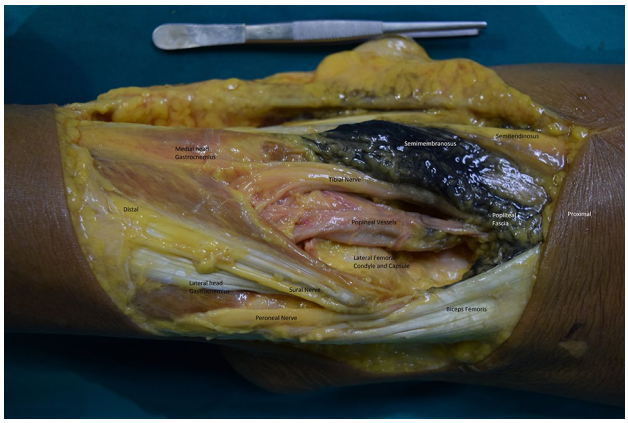


**Fig. 4** Spreading in the middle layer

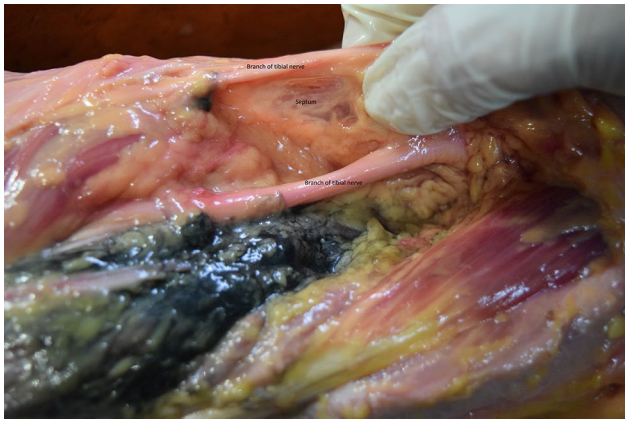


**Fig. 5** Nerve septum, separation between the PM and PL compartments

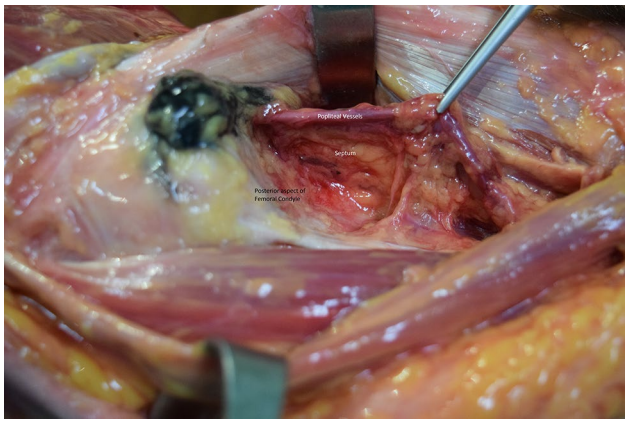


**Fig. 6** Vessels septa, separation between the PM and PL compartments

infiltrated beneath the semimembranosus and some over the medial capsule, but obviously there was no dye solution staining in the deep PL compartment (Fig. 7).

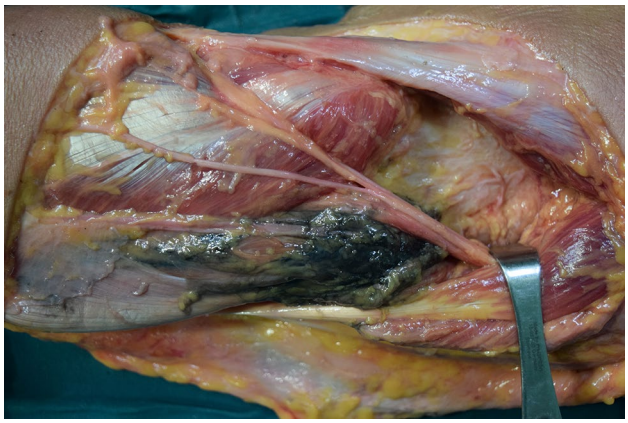

**Fig. 7** PL compartment; no staining was seen

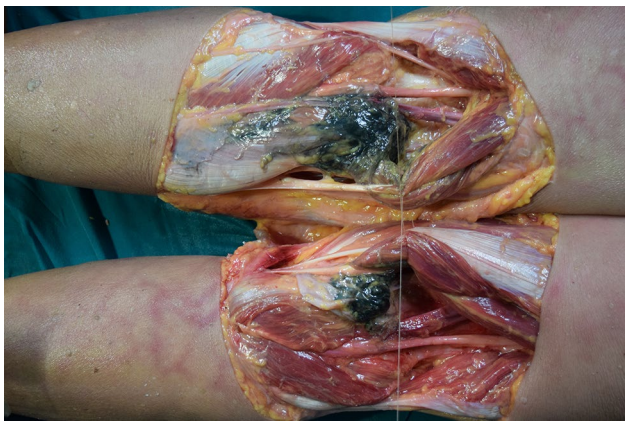

**Fig. 8** Comparison of dye solution spreading between using 50 ml (left) and 25 ml (right)

Distribution of the dye solution in ten knees was very similar throughout all specimens in each group. The difference notified between these two groups was the wider extension in proximal and distal directions of dye solution in the 50-ml group compared to the 25-ml group (Fig. 8).

In order to clearly identify the safe zone for injecting PMDI into the PL capsule, we directly examined the PL capsule via simultaneous anterior and posterior approaches. The finding indicated that at 1.0–1.5 cm lateral to lateral border of PCL insertion at tibia, which was just above the crossing of the popliteus tendon, and at 1.5 cm in depth; was the safe zone for injecting PMDI into the PL capsule (Figs. 9, 10, 11).

## Discussion

From this study, all of the specimens after opening the superficial muscular fascia showed some dye solution staining entirely over the PM area and some part of PL area which

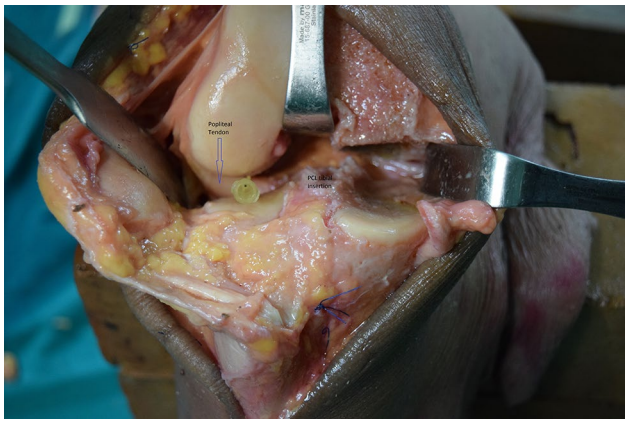


**Fig. 9** PL injection point, 1.5 cm lateral to PCL insertion (anterior view)

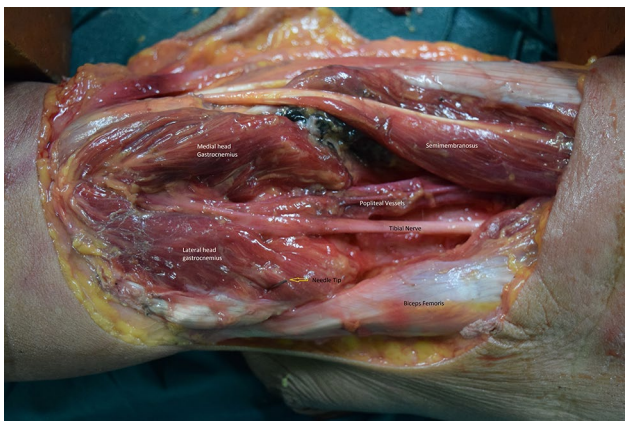


**Fig. 10** Needle tip seen in the PL knee (yellow arrow)

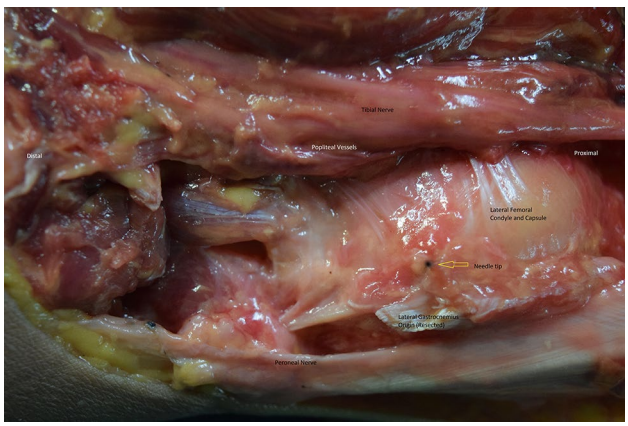


**Fig. 11** PL injection point, 1.5 cm lateral to lateral border of PCL insertion (resected lateral head gastrocnemius). The needle tip is in safe zone midway between popliteal vessels and tibial nerve and peroneal nerve

might result from either the connection of the soft tissue itself or the dye penetrated through the loose subcutaneous tissue. On the contrary, none showed dye solution presence in the deep layer of PL structures and its capsule. This might be explained by the natural barrier of the septa from tibial nerves and popliteal vessels dividing the two knee compartments, which corresponds to the previous MRI study of Maeseneer et al. [22].

The strengths of this study include the use of fresh cadavers of no more than 72-h postmortem and then the preservation of the cadavers in 4 °C to help resemble the tissue dynamics found in life. Moreover, the volume injection study compared between two different fractions were performed in each knee of the same cadaver that might reduce the confounding factors from the anatomical variation, size and hardness of soft tissue. The weaknesses of this study are the variation in the pressure while injecting the dye solution syringes, and the latex glue mixture which might cause some difference in viscosity of the solution when compare to the normal drug in PMDI injection which may affect spreading of the solution.

## Conclusion

We could turn down our hypothesis of the continuity between PM and PL compartments and affirmed that for better efficacy of postoperative analgesia, injecting PMDI into both PM and PL capsules might be necessary to infuse the drug throughout the entire PC. The quantity of dye solution (25 ml or 50 ml) did not result in difference in mediolateral extension of dye expansion in the deep layer after injection into the PM capsule alone. But from the wider extension in the middle layer of the 50-ml group, 50 ml could be more beneficial than 25 ml. Further clinical study is needed to prove this benefit of the larger volume of analgesic cocktail.

### Compliance with ethical standards

**Conflict of interest** Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

**Ethical approval** Cadaveric experimental study had been approved by the Khon Kaen University Ethics Committee for Human Research.

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