Outcomes of surgical treatment of posterior cruciate ligament tibial avulsion fractures through an open posterior approach

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Received 11 December 2018
Accepted 27 December 2018

The Egyptian Orthopaedic Journal 2018, 53:230–236

Background
Avulsion of the tibial insertion of the posterior cruciate ligament (PCL) is believed to be an uncommon injury. A nondisplaced bony avulsion can be treated conservatively with a plaster cast, holding the knee flexed and the tibia pulled forward to diminish tension on the PCL. There is general consensus that a displaced bony PCL avulsion should be surgically reduced and fixed immediately to stabilize the knee joint and prevent nonunion.
Hypothesis
Our hypothesis was that surgically reduced and fixed displaced bony PCL avulsions stabilize the knee joint and prevent nonunion.
Patients and methods
This prospective study was performed between January 2010 and August 2013. A total of 11 patients (three females and eight males) with PCL avulsion fracture of the tibial attachment (six isolated and five associated with other ligamentous injuries, meniscal injuries or bony fractures) were treated surgically through a posterior approach at the trauma unit of our university hospital. The mean age of patients was 24.72 years (range, 18–33years). Fixation with a single screw and washer was used in nine cases with a large bony fragment and multiple screws in two cases with comminuted fragments. The operating time was 60 min (range, 45–70 min). All patients were followed for an average of 22 months (range, 19–26 months), and at the end of the follow-up period, patients were evaluated using and Lysholm scoring system.
Results
All 1-year postoperative radiographs demonstrated union at the fracture site. At the end of the follow-up period, the mean Lysholm score was 88.7 points (range, 70–100 points) with a good overall outcome.
Conclusion
Treatment of displaced large PCL avulsion injuries with a single lag screw and washer or multiple screws through the open posterior approach results in good clinical and radiographic outcomes.

Keywords:
knee, posterior cruciate ligament, posterior cruciate ligament avulsion fracture, surgical technique

Egypt Orthop J 53:230–236

1110-1148

Introduction

The posterior cruciate ligament (PCL) plays a major role in knee stabilization [1]. Although biomechanical studies have shown its role as the major knee stabilizer, clinical studies have shown increasing incidence of its injury [2,3]. It acts as a primary restraint against posterior tibial displacement and, in concert with the anterior cruciate ligament (ACL), to regulate external rotation of the knee during extension [4].

The most commonly reported mechanism of isolated PCL injury is a posteriorly directed blow to the anterior aspect of the proximal tibia with the knee flexed at 90° [5]. Another mechanism is sudden hyperextension associated with varus or valgus force or hyperflexion of the knee [6]. Sports-related injuries and motor vehicle accidents with dashboard injuries account for most isolated PCL injuries [7]. Other dashboard-related injuries, such as fractures of the femoral shaft or neck, posterior hip dislocations, and other internal derangements of the knee, may coexist with PCL injury [8]. Clinical examination shows posterior sag and a positive posterior drawer test if the PCL is ruptured or avulsed. In case of avulsion, radiological examination will reveal a bony fragment at the tibial attachment of the PCL.

A PCL disruption may occur as avulsion at the femoral origin or tibial insertion or as a midsubstance tear [8–10].

Avulsion of the tibial insertion of the PCL is believed to be an uncommon injury. A nondisplaced bony avulsion can be treated conservatively with a plaster cast, holding the knee flexed and the tibia pulled forward to diminish tension on the PCL. There is general consensus that a displaced bony PCL avulsion should be surgically reduced and fixed immediately to stabilize the knee joint and prevent nonunion [7].

In contrast, midsubstance tears of the PCL are treated either nonoperatively when isolated or by reconstruction when associated with multidirectional instability; in these cases, a good result is often less expected (40–60%) [11,12].

All publications on the repair of acute bony avulsion of the tibial attachment of the PCL report excellent clinical results [13,14].

This study aimed to evaluate the results of open reduction and screw fixation of PCL tibial avulsion fractures.

Patients and methods

From January, 2010 to August, 2013, there were 11 cases of PCL tibial avulsion injuries that presented to trauma unit of our university hospital and were treated using an open posterior approach. This study was approved by ethical committee of Zagazig University. All patients signed an informative consent form. Four PCL avulsion injuries were the result of motorcycle crashes, three resulted from motor vehicle accident, two were from bicycle injuries, and two were the result of a fall from a height. Six patients in the study had isolated PCL avulsion injuries whereas the other five patients had associated injuries. All avulsion injuries were examined clinically and confirmed radiographically. Each patient was assessed using the Lachman, anterior drawer, and posterior drawer tests to evaluate for cruciate injury, as well as varus and valgus stress in both extension and at 30° to assess the competence of the collateral ligaments. External rotation recurvatum and dial tests were performed to assess for posterolateral corner insufficiency. Computed tomography was done for all patients to delineate fracture configuration. MRI was obtained preoperatively to evaluate for associated capsuloligamentous injury if the clinical examination was not conclusive. Moreover, we used MRI to evaluate presence or absence of midsubstance PCL injury. In the operating room, each knee was examined under anesthesia to evaluate associated ligamentous injury. The mechanisms of injury and associated ligamentous and soft tissue injuries were documented.

Operative technique

All the patients in the study were given spinal anesthesia and were given 1 g of third-generation cephalosporins immediately before surgery. A tourniquet was used in all cases. All patients were placed in the prone position with proper padding of the pressure areas, and the lower extremity was held in 30° flexion at the knee joint over a bolster. We used the posterior approach to the superomedial region of the tibia described by Banks and Laufman [15].

The transverse segment of the hockey-stick incision began at the lateral end of the flexion crease of the knee, and extended across the popliteal space, then turned the incision distally along the medial side of the calf for 7–10 cm. The angular flap of skin and subcutaneous tissue was developed, and the deep fascia was incised in line with the skin incision. The cutaneous nerves and superficial vessels were identified and protected (Fig. 1a, b).

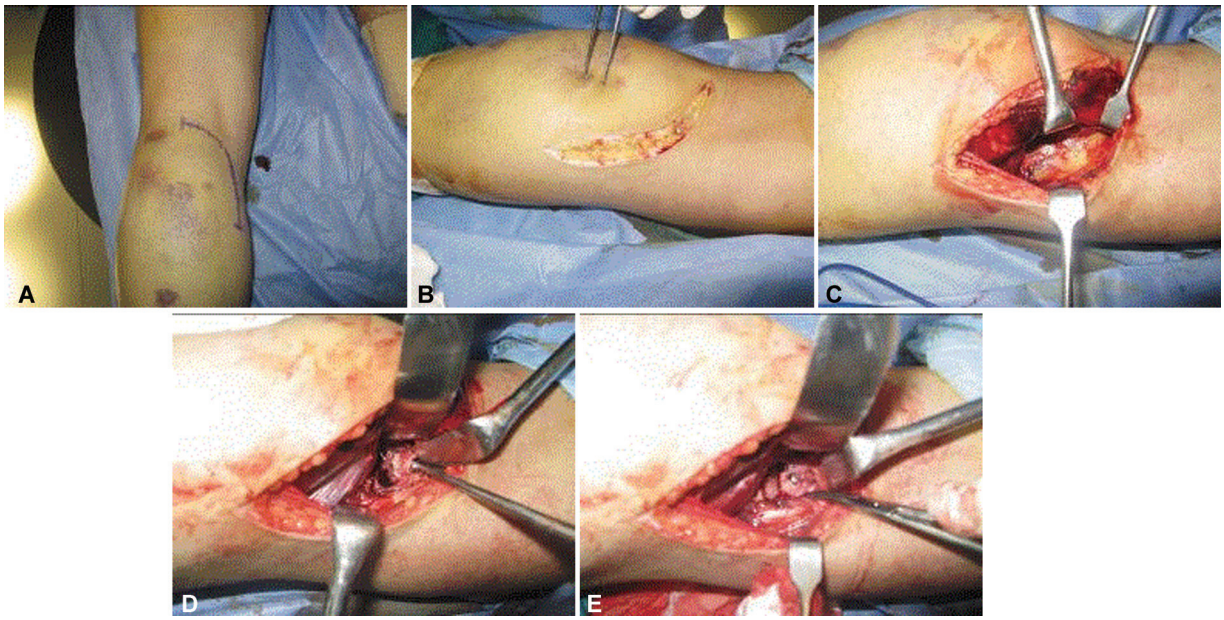
The interval between the tendon of the semitendinosus muscle and the medial head of the gastrocnemius muscle was identified.

The semitendinosus was retracted medially and the medial head of the gastrocnemius laterally; the popliteus and flexor digitorum longus muscles lied in the floor of the interval (Fig. 1c). Subperiosteal dissection of the popliteus muscle was done to identify the fracture line.

The PCL avulsion was identified; the bony base of the avulsion was debrided (Fig. 1d). If necessary, the knee was bent slightly to bring the avulsion fracture closer to the surface and relax the tension on the hamstrings and gastrocnemius heads, which allowed for easier retraction and exposure. With this maneuver, adequate exposure was obtained in all patients without the need for division of the gastrocnemius. Once exposure was obtained, the bony fragment was pushed down to its bed and secured with provisional K-wire fixation. Appropriate position was then verified using the fluoroscope.

The fragment was fixed with a partially threaded lag screw and washer to achieve compression. The size of the screw used was 4 mm (Fig. 1e). Following fixation, position was reassessed using the fluoroscope; if determined to be adequate, the dissected soft tissue from the popliteus muscle was resutured over the bony

Figure 1



The posterior approach to the PCL tibial avulsion fracture. (a, b) The surgical incision. (c) Retraction of the gastrocnemius laterally without cutting it. (d) Subperiosteal dissection of a part of the popliteus to expose the fracture. (e) Fixation of the fragment using a 4-mm screw and washer. PCL, posterior cruciate ligament.

fragment, and then incision was irrigated and the wound was closed in layers after the application of a suction drain. The suction drain was removed after 48 h and the stitches were removed after 2 weeks of surgery.

A preoperative radiograph, computed tomography, MRI, and fluoroscopic images of a 28-year-old male with a PCL avulsion fracture treated with lag screw fixation through an open posterior approach are shown in Fig. 2.

Postoperative treatment

Average hospital stay for the patients in this study was 3 days. Postoperative care consisted of early range of motion (ROM) with a controlled hinge knee brace for 6 weeks. There were two patients whose fracture was multifragmented and extended to the lateral aspect of the knee joint in which a long leg cast was used for 3 weeks postoperatively. Patients with associated injuries were managed conservatively in a controlled hinge knee brace except for the patient who had grade II open fracture patella, who was treated surgically on an urgent basis via debridement and tension band fixation for the fracture patella, and 2 days later this was followed by fixation of the PCL avulsion injury.

The patients were assessed clinically and radiographically at 6 weeks, 3 months, 6 months, and at 1 year.

Clinical examination for each visit except the 2-week postoperative visit included assessment of the knee ROM, using goniometer as well as assessment using the Lachman, anterior drawer, and posterior drawer tests to evaluate for cruciate injury, as well as varus and valgus stress in both extension and at 30° to assess the competence of the collateral ligaments. External rotation recurvatum and dial tests were also performed to assess for posterolateral corner insufficiency. Radiographic examination included anteroposterior and lateral radiographs of the knee joint for evaluation of the union and hardware complications.

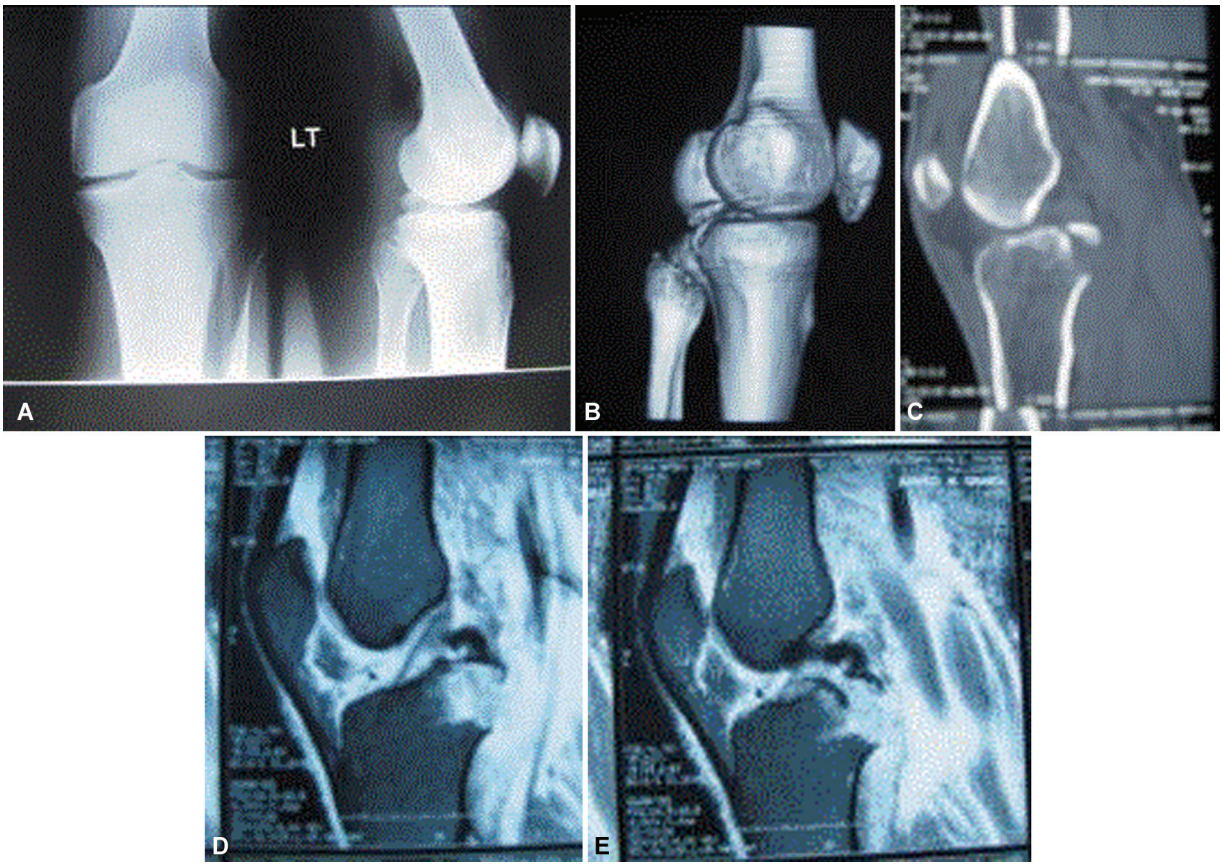
In general, patients at 3 months demonstrated radiographic evidence of union, had clinically stable knees, and were then released to ambulate without their braces. All patients were assessed 1 year after surgery using the Lysholm scoring scale [16] which was conducted to evaluate the outcome after knee ligament surgery.

Return to heavy labor or sports was restricted until after 6–9 months when sufficient strength and ROM had returned.

Results

This study included 11 patients who were available for follow-up at least 1.5 year after fixation of their PCL tibial avulsion fractures through an open posterior approach. The average follow-up period was 22 months (range, 19–26 months). The mean patient age was 24.72 years (range, 18–33 years). Three patients were females and eight were males.

Figure 2



A preoperative radiograph, computed tomography, MRI, and 3-month radiographic images of a 28-year-old male with a PCL avulsion fracture treated with lag screw fixation through an open posterior approach. (a) Preoperative radiographs, anteroposterior, and lateral. (b, c) Sagittal computed tomographic images of the fracture. (d, e) Sagittal MRI images of the fracture. (f) Radiographic images (anteroposterior and lateral) showing united fragment. PCL, posterior cruciate ligament.

All patients were surgically treated within 15 days of their injury (mean, 9 days). The operating time was 60 min on average (range, 45–70 min). The PCL avulsed fragment was fixed by one screw (4 mm) and washer in eight patients and by multiple screws in three patients. No neurovascular complications were noted in any of the patients involved in our study. None of the patients were lost to follow-up. The posterior drawer test was positive in two patients with comminuted avulsion fracture. A positive reversed pivot shift sign was negative in all patients.

Radiographic examination at the last follow-up showed complete healing of the fractures in all cases. No patient had significant hardware-related complaints, and implants were not removed.

All 1-year postoperative radiographs demonstrated union at the fracture site.

All patients demonstrated a full ROM in both knees after the surgery except for one patient who developed postoperative arthrofibrosis. He was a 26-year-old patient who had sustained an ACL tear, medial collateral ligament tear, PCL avulsion injury, and grade II open fracture patella. At his initial operation, only the open fracture patella and PCL avulsion injury were treated acutely, and a plan was made for delayed ACL reconstruction once his open anterior wound had healed. At 8 weeks postoperatively, his flexion was limited to 80° and he was taken back to the operating room for manipulation. Manipulation under anesthesia following surgery demonstrated that his ROM had increased to 140°. At 1-year follow-up, the patient has maintained knee ROM from full extension to 135° of flexion. He selected not to undergo ACL reconstruction because he does not feel symptoms of instability.

Table 1 Demographic data of the patients

Type of fracture (single large fragment/ comminuted)	9/2
Mean age in years (range)	18–33 (24.72)
Sex (male/female)	8/3
Mean time from injury to surgery in days (range)	4.90 (4–19)
Mean follow-up duration in months (range)	22 (19–26)

Table 2 Demographic data of the patients

Cases	Sex	Age (years)	Type of fracture (single fragment/ comminuted)	Side	Interval to operation (days)	Mechanism of injury	Associated injury[a]
1	M	19	Single fragment	L	4	Motorcycle	Open fracture patella ACL MCL grade II
2	M	24	Single fragment	L	11	Bicycle	–
3	F	26	Comminuted	R	5	Motor vehicle	ACL
4	M	18	Single fragment	L	6	Fall	MMT
5	M	24	Single fragment	R	9	Motorcycle	–
6	M	23	Single fragment	L	4	Motor vehicle	PLC
7	F	27	Single fragment	R	10	Bicycle	–
8	M	33	Single fragment	R	7	Motorcycle	–
9	M	18	Single fragment	R	8	Fall	–
10	F	18.5	Single fragment	L	19	Motorcycle	–
11	M	22.5	Comminuted	L	6	Motor vehicle	ACL–MCL

ACL, anterior cruciate ligament; F, female; L, left; M, male; MCL, medial collateral ligament; MMT, medial meniscus tear; PCL, posterior cruciate ligament; PLC, postero-lateral corner; R, right.

Table 3 Lysholm score at the end of the follow-up period

Patient's number	Lysholm score
1	100
2	97
3	95
4	88
5	85
6	95
7	70
8	85
9	95
10	82
11	95

Score	Outcome
98–100	Excellent
93–97	Good to excellent
82–92	Fair to good
66–81	Fair
≤65	Poor

At the end of the follow-up period, the mean Lysholm score was 89.7 points (range, 70–100 points) with a good overall outcome; six patients showed good to excellent outcomes, whereas five patients had fair to good outcomes and one patient showed a fair outcome (Tables 1–3). All the patients were satisfied with the results.

Discussion

PCL injury patterns are complex and are related to diverse mechanisms of injury and to the structure of the PCL. The major functions of the PCL are to resist posterior tibial translation, varus and valgus forces applied to the knee, as well as external rotation of the tibia [17]. Regarding the treatment of the PCL tibial avulsion, nonoperative treatment is a choice, but loss of the ROM of the knee with some residual PCL laxity can be a significant problem in the long term [18]. Furthermore, osteonecrosis or nonunion of the fragment of the tibial insertion of the PCL is another concern because a part of its base is framed by the fragment of the lateral tibial condyle; this is disadvantageous to blood supply [19].

Surgical approaches to the avulsed PCL may be open or arthroscopic, but safety and simplicity of the approach remain a major concern.

Previous approaches, however, commonly recommend division of the medial head of the gastrocnemius to enhance exposure of the PCL avulsion, which can lead to postoperative weakness of this muscle and unnecessarily increase in the morbidity of the operation. They were relatively extensive and require exploring the neurovascular elements of the popliteal space.

The complexity of previous approaches has driven many authors to recommend percutaneous fixation of the fragment under arthroscopic control [5,20,21]. The approach used in this study exposes PCL avulsion fracture by using the interval between the medial gastrocnemius muscle and the semitendinosus tendon. This approach avoids dissecting the neurovascular structures in the popliteal fossa and provides adequate exposure to the lateral base of the PCL and the capsule. The approach is anatomic and saves the medial head. In this study, adequate exposure of the posterior capsule and avulsed PCL was achieved in all 11 patients, and there were no neurovascular complications. Additionally, the exposure obtained through this posterior approach facilitates the placement of an appropriately sized lag screw and washer perpendicular to the fracture plane. This fixation provides adequate stability at the fracture site and enables patients to begin the ROM exercises immediately in the postoperative period.

The difficulties with this approach comes from the fact that it can only be performed from a prone position; if associated injuries require a supine position for treatment; the patient will need to be repositioned, reprepared, and redraped. This approach also requires the surgeon to be confident in their understanding of the complex anatomy in the posterior knee and theoretically puts the posterior neurovascular structures at increased risk of injury, although no complications relating to damage to any of these structures occurred in our patients. As a result of these potential problems, many other open as well as arthroscopic approaches to the treatment of these injuries have been described [5,22–26].

Another common open approach to the treatment of PCL injuries is the posteromedial approach of Burks and Schaffer [22]. This approach uses the interval between the medial gastrocnemius muscle and the semimembranosus tendon. This approach avoids dissecting the neurovascular structures in the popliteal fossa as well, but it does not provide adequate exposure to the lateral base of the PCL and the capsule; the mass of the retracted tissue makes it difficult to place a screw perpendicular to the fracture plane, which could potentially lead to less stable fixation.

In addition to open approaches to this area, many arthroscopic techniques for the treatment of these injuries have also been described. These techniques avoid the need for direct dissection in the popliteal fossa, allow for fixation of smaller fragments than that which can be achieved with a lag screw technique, and allow for associated intra-articular injuries to be addressed without delay for repreparation or redraping. However, arthroscopic techniques are associated with a steep learning curve, [26] do not entirely eliminate the risk of neurovascular injury, and may not be indicated for all patients with PCL avulsion injuries.

All patients available for follow-up at 12 months demonstrated good functional strength of their plantar flexors when compared with their noninjured contralateral lower extremity.

Most of the authors who have reported functional results following open repair of PCL avulsion injuries describe a postoperative rehabilitation protocol that includes cast immobilization for a period of 6 weeks [27], and joint stiffness has been noted as one of the serious complications of this treatment [28]. It is for this reason that Yang *et al*. [3] recommended the use of functional bracing postoperatively based on their experience with five patients.

It is our belief that ROM may be improved with the use of functional bracing compared with cast immobilization, although to our knowledge no study directly comparing the two with adequate numbers has been performed. Stable fixation is a prerequisite for this postoperative protocol. All 11 patients were treated in hinged knee braces and started on ROM exercises 2 weeks postoperatively. This did not have a negative effect on the stability of our fixation as all patients had grade I or II posterior draw tests, and union without further radiographic displacement or hardware failure was achieved in all patients followed beyond 12 weeks. Our results indicate that patients following this procedure generally do well.The only complication noted in this study was arthrofibrosis, which occurred in one patient. The patient had an associated ACL, open grade II fracture patella, and medial collateral ligament injuries; this required prolonged immobilization that contributed to his poor ROM. This outlines the necessity of early postoperative ROM.

Screw irritation has been proposed by Shino *et al*. [25] as a significant problem in patients following screw fixation of PCL tibial avulsion fractures; they advocate removal of hardware in all patients. The authors believe that screw removal is essential owing to patient complaints of pain on deep flexion hypothetically from screw thread irritation of the PCL substance. Hardware removal also subjects these patients to a second surgery and we are not convinced that this is necessary for most patients; pain on deep knee flexion was not a major complaint for our patient population.

The rarity of PCL avulsion injuries, however, makes it extremely difficult to design an appropriate prospective study. Follow-up was less than 2 years for most patients, and there was significant variability in the time to last follow-up (range, 12–24 months) for the group of patients studied. In our experience, patients with this injury tend to plateau functionally at 1 year and do not make significant improvements beyond that time period.

Conclusion

The treatment of displaced large PCL avulsion injuries with placement of an appropriately sized lag screw and washer through the open posterior approach results in

good clinical, radiographic outcomes. With this approach, the gastrocnemius muscle does not need to be divided. Dividing this muscle may add unnecessarily to the morbidity of this operation and should be avoided. Early postoperative rehabilitation under the direction of physical therapy and with the use of functional bracing, rather than cast immobilization, is essential in preventing arthrofibrosis. At 12 months after surgery, patients reported good clinical outcomes, had stable knees to posterior draw testing, did not demonstrate gastrocnemius weakness or significant ROM deficits, and achieved union of their fracture.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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