

Case Report

Early diagnosis and treatment of trauma in knee joints accompanied with popliteal vascular injury

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Abstract: Objective: The objective of the present study was to investigate the early diagnosis and treatment of trauma in the knee joints accompanied with popliteal vascular injury. Methods: Fifteen cases of patients with trauma in knee joints accompanied with popliteal vascular injury. These patients included 8 males and 6 females between the ages of 27 and 62, the average age being 39.2. Data of clinical symptoms and signs; blood oxygen saturation, color Doppler examination; vascular intervention by DSA angiography; and surgical operations were analyzed to clearly identify their role in early diagnosis and treatment. Results: In the patient group for this study there were: 1 death case; 4 stage I amputation cases; 4 stage II amputation cases due to failure to salvage limbs; and 6 cases with patients who had successful limb salvage. The six cases of limb survival patients were followed up for 12 to 60 months, with an average follow up time of 28.3 months. The excellent rate of joint function of these patients with successful limb salvage was 83.3%. Conclusions: For patients with injured limbs, unclear dorsalis pedis artery palpation, decreased skin temperature, and decreased oxygen saturation of the toes, clinical manifestations combined with proper auxiliary inspection (such as color Doppler and blood vessel angiography of interventional DSA) enabled early diagnose of peripheral trauma in the knee joint accompanied with popliteal vascular injury.

Keywords: Knee joint, fracture, dislocation, popliteal vascular injury

Introduction

Severe damages to knee joint often result in combined injuries. These injuries are often associated with severe soft-tissue compromise, fracture, neurological structures injury and even damage of popliteal vascular [1-3]. Furthermore not a few patients have been proven to be missed diagnosis in popliteal vascular injury. Concern about popliteal vascular injury and early recognition of the possibility of vascular injury is crucial for the salvage of the extremity [4]. Indicated that difficult to diagnose and with prolonged ischaemia lead to substantial complications. In severe traumatic knee joint with vascular damage, it is often a difficult decision to attempt heroic efforts aimed at limb salvage or to amputate primarily. Immediate amputation is the correct management for severe knee joint damage, but on other occasions the decision between this and attempts at salvage can be difficult and awesome to orthopaedic surgeon. Sometimes "successful" reconstruction takes place that still remain dys-

function of the injured limb; loss of sensation in the pelma; trophic ulcers. And the severe functional deficits ultimately lead to secondary amputation. This may not occur until months after make efforts by orthopaedic surgeon to save a limb [5]. Limb-salvage failure in patients eventually could lead to a long treatment cycle, long hospital stay and high cost. These are serious physical and mental harms to patients [6] reported that the limb-salvage failure patients had an average of 1.2 operations and 50 months of treatment, including eight months in hospital.

The objective of this study was to identify variables that may ultimately influence the early diagnosis and outcome of a severe traumatic knee joint with popliteal vascular injury. This presumably would assist the orthopaedic surgeon to identify popliteal vascular injury early and in the initial decision making process about whether to pursue limb salvage or to amputate primarily.

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Table 1. Intraoperative and postoperative data of three group patients

Medical case	Gender	Age	Surgery time	Volume of blood transfusion	Hospital stays	Lib salvage index	Wound infection	Medical costs (Million yuan)
Medical case 1	Male	56	1	400	8	10	No	1.5654
Medical case 2	Female	62	0.8	200	13	11	No	1.725
Medical case 3	Male	60	1.1	800	12	12	No	1.931
Medical case 4	Male	57	0.9	300	11	10	No	2.474
Medical case 5	Female	37	3.8	1100	21	10	No	4.005
Medical case 6	Male	26	6.6	1300	18	9	No	13.9092
Medical case 7	Male	32	12.3	800	27	8	No	9.703
Medical case 8	Male	29	9.3	1700	32	7	Yes	9.8427
Medical case 9	Female	40	2.8	800	17	7	No	4.463
Medical case 10	Female	38	3.4	600	15	5	No	4.5543
Medical case 11	Male	27	2.9	1000	12	8	No	4.032
Medical case 12	Female	29	3.8	800	19	6	No	3.3653
Medical case 13	Male	28	3.3	600	21	5	Yes	4.6327
Medical case 14	Female	29	3.9	400	16	7	No	7.3987

Note: group 1: 1-4 patients; group 2: 5-8 patients group 3: 9-14 patients.

Otherwise, an ischaemic in limb resulted from vascular injury is also difficult to treat. It is a rare complication of injury to a limb but must be excluded in every patient. Holden reported that direct blow or traction injury to an artery might cause an incomplete tear of the vessel wall. An intimal tear allowed stripping off the intima, and the thrombosis extended it blocked not only the main vessel but the collateral branches as well. And it can result in limb ischaemia [7].

Open vascular injury present with an obvious signs, but closed traction injury can lead the examiner to underestimate the severity of the injury, thereby risking the limb.

The treatments for trauma in knee joints accompanied with popliteal vascular injury are difficult [8]. These damages have the characteristics of being easily missed diagnosis and the clinical care and treatment can be difficult [9]. In the short-term, major hemorrhagic shock, limb ischemic necrosis, acute renal failure, severe infection and clostridial myonecrosis may occur. There is even the possibility of life endangerment [10]. Even limb-salvage is successful, although more attention has been paid both in China and internationally to the peripheral trauma of the knee joint accompanied with popliteal vascular injury, the early diagnosis and treatment of such injuries continues to be infrequently reported. Therefore, retrospective

studies have been conducted to evaluate the early diagnosis and treatment of peripheral trauma of the knee joint accompanied with popliteal vascular injury, which have positive significances [11].

Clinical data and methods

General data

Seven hundred and eighty-three patients with peripheral trauma of the knee joints were admitted and treated by our hospital during the period from January, 2007 to January, 2013. Among these patients, there were 15 cases (1.9%) which were accompanied with popliteal vascular injuries. The reports were as follows: there were 9 male and 6 female cases, between the ages of 27 and 62 years, with a mean age of 39.2 and the age distribution is shown in **Table 1**; there were 7 left side and 8 right side cases; and there were 9 closed injuries and 5 open injuries cases. The causes of the injuries were as follows: 11 cases of traffic accidents, 2 cases of falling from heights, and 1 case involving a knife stabbing injury. Two patients had combined life-threatening injuries to the head, thoracic and abdominal organs. Four cases involved multiple fractures with the knee joint and its surrounding trauma included; 6 cases of upper tibia and fibula fractures; 6 cases of fractures of the femoral intercondylar and supracondylar fractures of the patella; 1 case

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of patellar fracture; 3 cases of dislocations of the knee joint; 5 cases of injuries of the ligaments of the peripheral knee joint (cross ligament, collateral ligaments) and 1 case of meniscus injury. The sites of the vascular injuries were as follows: 9 cases of upper popliteal static bifurcation; 3 cases of bifurcation fracture; and 3 cases of lower bifurcation. The vascular injury types were as follows: 10 cases of open fracture or embolization and 10 cases of closed embolism. The combined nerve injuries were as follows: 1 case of sciatic nerve rupture; 1 case of secondary pumping off; 1 case of fracture of the tibial nerve and the common peroneal nerve simultaneously; 1 case of pumping off of the tibial nerve; 2 cases of complete fractures of the common peroneal nerve; and 1 case of pumping off.

Diagnostic criteria of trauma in knee joints accompanied with popliteal vascular injury: all the patients with trauma in knee joint were final diagnosed popliteal vascular injury by color Doppler or lower extremity vascular interventional angiography or surgical exploration.

Included criteria: ① who met the definition above-mentioned, ② age from 18-80 years, ③ any gender, ④ unilateral limb injury.

Excluded criteria: ① the patient without operation, ② Incomplete medical records, ③ death in or before operation.

Examine project: all the clinical signs comprise palpation dorsal artery of foot, skin temperature, skin color, periphery turgor, saturation of blood oxygen of toes, Color Doppler of lower extremity vascular interventional angiograph were obtained when necessary. All the patients were evaluated by PSI.

Treatment protocol

Appropriate treatment protocol was selected according to the inspection of the systemic and local damage of each patient, the imaging examination and PSI score [12].

Stage I amputation group: In the cases of severe lower extremity amputation destruction for losing replanted conditions, old age, combined life-threatening injury, severe limb nerve damage that cannot be repaired or is accompanying severe basic diseases, then amputation

is first considered in order to save the patient's life.

Stage II amputation group: When limb salvage failure: Following the blood vessel prosthesis of stage I, disease development is closely observed. The injured limb dorsalis pedis and posterior tibial artery pulse, skin temperature and oxygen saturation at the end of the injured limb were closely monitored. If necessary, a lower limb color Doppler examination or an arterial DSA interventional angiography was carried out. For the patients clearly identified with impaired blood transporting; postoperative acute renal failure; severe wound infection; osteomyelitis; infected nonunion; limb peripheral nerve injury which could not be repaired; and functional reconstruction, the stage II amputations were conducted.

Limb salvage surgery group: For the younger patients with lower limb salvage conditions, who had no life-threatening combined injuries or serious basic diseases, as well as patients and their families with a strong requirement for limb salvage, limb salvage surgery is recommended. The patients of whom experienced combined fractures, soft tissue and ligament injury, the stage I or II treatments should be carried out, taking into consideration the circumstances for each patient.

Observations item: the presence of palpation dorsal artery of foot, skin temperature, skin color, periphery turgor, saturation of blood oxygen of toes. the ranges of saturation of blood oxygen of toes, the operative time, the blood loss, the hospital stay, the PSI score, the medical expenses.

Statistical treatment: The data for the continuous variables were presented as means and ranges, whereas for the categorical variables, the data were presented as counts and percentages. Differences in proportions such as the presence of palpation dorsal artery of foot, skin temperature, skin color, periphery turgor, saturation of blood oxygen of toes were compared by the Fisher's exact test. Continuous variables were analyzed using the Student's t-test for data (such as the ranges of saturation of blood oxygen of toes, the operative time, the blood loss, the hospital stay, the PSI score, the medical expenses) with two levels of the nominal variable and analysis of variance when

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Table 2. The Merchant score of the six patients with successful limb survived

Medical case	Daily life function (35 points)	The degree of pain (35 points)	Gait (10 points)	Knee stable condition (10 points)	Range of motion (10 points)	The total score (100 points)
Medical case 9	30	30	8	8	8	84
Medical case 10	28	25	7	8	7	75
Medical case 11	32	31	9	10	9	91
Medical case 12	33	31	8	10	9	91
Medical case 13	20	20	5	7	6	58
Medical case 14	33	33	9	10	10	95

Note: Excellent > 90, Good > 80, OK > 60, fail < 60.

three or more levels were present for that variable. $P < 0.05$ was considered statistically significant.

Results

Among the 15 patients in this study, 1 patient (6.7%) was excluded from the present group because of excessive loss of blood and severe shock, leading to death. There were 2 cases where missed diagnosis of vascular injuries occurred; 4 cases of stage I amputation (28.6%); 4 cases with stage II amputation due to failure to salvage limbs; and 6 cases of patients with successful limb salvage. The follow-up time was 12 to 60 months, with an average time of 28.3 months. The rate of joint function for the patients with successful limb salvage was excellent at 83.3%. The specific situations were as follows:

Among the 4 patients with stage I amputation (28.6%) there were: 2 cases of patients beyond repair by reconstruction due to the severity of damage to the lower extremities; 1 elderly patient with shock; and 1 case in which the patient had combined life-threatening brain, thoracic and abdominal organs injuries. Their respective operations were successful.

The failure of limb salvage in stage II amputation represented 4 cases (28.6%). All vascular injuries of these patients were located between the popliteal artery to the anterior tibial, posterior artery bifurcation, or below. All were within 36-120 hours after stage I vascular repair after reperfusion was completed. Steps were taken to confirm the following: the injured limb skin temperature was low; pedis and posterior tibial arteries were not beating; and the blood oxygen saturation of the injured limb toe monitoring

was very low or undetectable. DSA interventional angiography and vascular color Doppler ultrasound examinations were conducted in order to identify vascular obstructions, occurrence of acute renal failure, severe osteomyelitis combined with important peripheral nerves which were unable to be repaired and reconstructed, and then stage II amputation operations was conducted.

There were six cases of successful limb salvage patients. Under the improved preliminary examination conditions, the damaged limbs were examined and repair of blood vessels and limb salvage therapy was administered. Staged or synchronous treatment of injuries of the peripheral knee joint, such as the femoral intercondylar and supracondylar fracture debridement at the same time or open reduction, combined external fixed support plate was used in 1 case, and plate and screw internal fixation in a second case. One case had Femoral supracondylar retrograde interlocking nail fixation; Proximal tibial and fibular fracture debridement or open reduction, plate and screw internal fixation in another case; soft tissue defect in peripheral knee joint for free skin graft in 2 cases; partial medial head of gastrocnemius muscle flap and free skin graft in 1 case; saphenous nerve retrograde island flap repair in 2 cases; and the free anterolateral thigh flap in 2 cases. Ligament repair in stage I around knee joint was performed in 1 case; there was 1 case of stage II reconstruction; bone defects of stage II of autologous iliac bone grafting occurred in 3 cases; and vascularized free iliac bone flap transplantation was performed in 1 case. All fractures were healed successfully in 1 year. All skin grafts and flaps survived. The repair to ligaments of the knee joints also all healed successfully. The results showed an excellent rate



Figure 1. Amputation operation. A. Fracture of the upper segment of the left tibiofibula and serious dislocation. B. The pathological anatomy after amputation of the left leg showed that the anterior tibial artery anastomosis following still exhibited wide embolism and vascular occlusion. C. The performance of the left knee joint after amputation, and the wound healed successfully.

of knee joint function at 83.3%. The specific indicators are shown in **Table 2**.

Typical cases

Typical case 1 is an older male patient, 62 years of age. He was injured as a result of a traffic accident. His left upper leg experienced pain and bleeding. His activity was limited for 2 hours before hospital admission. The physical examination upon admission indicated that the patient's left upper anterolateral leg had an open wound with a size of approximately 2 cm, which was deep and indicated a broken ended bone fracture. The wound was slightly polluted. The skin temperature below the left knee was significantly low. The left acrotarsium and posterior tibial artery were not palpable. The soft tissue of the left upper leg was severely swollen. The tension of the soft tissues was high. X-rays indicated that there were fractures to the upper segment of left tibia and fibula and

serious dislocation. In the emergency ward, debridement of the open fractures of the left tibia and fibula, reduction, as well as plate and screw internal fixation were conducted under endotracheal intubation and general anesthesia. Surgical exploration determined that the popliteal artery and vein were entrapped on the broken fracture end of the upper left fibula with the anterior tibial and posterior vein at the crotch. The vein was completely fractured and embolized. The arteriae tibialis anterior and arteriae tibialis posterior exhibited embolism like changes. The longitudinal arc incision of the upper segment anterior-lateral of the left shank was moderately extended to the proximal end, and anterior tibial muscle was extended to the inner side. The peroneal muscle and nervus peroneus communis were extended to the outer flank to expose the crotch between the popliteal artery, arteriae tibialis anterior and arteriae tibialis posterior. The popliteal vein was ligated. The arterial embolism was removed

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Figure 2. Before and after the operation to his right knee. A. X-rays of the right knee showed dislocation of the right knee joint. B. Surgical exploration indicated that there was approximately 4 cm of embolization of the right lower popliteal artery. C. The MRI of the right knee joint demonstrated that the anterior and posterior cruciate ligament of the right knee, and the medial and lateral collateral ligament were completely ruptured. D. The function of the right knee joint was normal in the 1 year follow-up after operation.

and the anterior tibial artery was coincided. The total operation time was 8 hours. The PSI index was 10 points; intraoperative blood loss was 1000 ml; intraoperative transfusion of red blood cell suspension was 6 U; and transfusion of plasma was 600 ml. An intraoperative fluid infusion of 2000 ml was conducted. Close observation of disease conditions was maintained after the operation. It was discovered that the foot dorsal of the injured limb and posterior tibial artery was not consistently palpable. The temperature of skin was significantly lower than the uninjured side. Oxygen saturation of the peripheral injured limb was not detected via blood monitoring. The patient experienced what appeared to be a choking sensation in his chest, a cough, sputum, and chest CT showed a pulmonary contusion like change. The blood gas analysis indicated that the partial pressure of oxygen was 65 mm Hg, partial pressure of carbon dioxide was 35 mm Hg, and oxygen saturation of blood was 85%. Considering the failure of repair to the vessels of the injured limb, ischemia-reperfusion induced pulmonary injury and the presence of

the disease, the case was critical. The stage II amputation was conducted using endotracheal intubation and general anesthesia within 48 hours of the injury occurrence. Breathing was maintained by respirator for 6 days following the operation. The wound was healed successfully in 14 days and the patient was discharged after stitches were removed (**Figure 1**).

Typical case 2 is an older male patient, aged 56 years. The traffic accident this patient experienced caused injuries and swelling and deformity in his right knee, and he was admitted after his movement was limited for 1 hour. The physical examination upon admission showed the right knee joint had dislocation deformity towards the back, the floating patella test of right knee was positive, and the stress experiments of the internal and external right knee, as well as the drawer test from starting to finishing were positive. The right dorsal and posterior tibial arteries were not palpable. The temperature of the skin below the right knee was obviously low. The flexibility of the right toe tip was poor. The X-rays showed dislocation of the right knee joint. In the emergency ward, a right

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popliteal S shaped incision (the length was about 25 cm) was performed using endotracheal intubation and general anesthesia, in order to explore and confirm that the embolism in the length of the inferior segment of the popliteal artery was approximately 4 cm. The embolized vessel was subsequently removed. Flexion (50 degrees) was coincided with the popliteal artery. The operation duration was 2 hours, and the PSI index was 4 points. The right lower limb flexion plaster protection was in place for 16 days following the operation. During hospitalization, subcutaneous injections of 0.4 ml heparin with low molecular weight were given once per day. After the patient's condition was stable, a MRI examination of the right knee joint was conducted to confirm that the right knee anterior and posterior cruciate ligament essence was completely fractured, and the right knee lateral and collateral ligament was ruptured. On the sixteenth day after the injury, right knee joint exploration was conducted using endotracheal intubation and general anesthesia. The anterior and posterior cruciate ligament, medial and lateral collateral ligament of absorption lines and anchor repair were also carried out. Ten days following the operation, the wound was healed and the patient was discharged. The postoperative follow-up was conducted for 1 year, and the vessels of the injured limb showed no recurrence of embolization. The range of flexion extension function of the right knee joint was 0-120 degrees, and the right lower limbs did not experience limpness or sensory disturbances (**Figure 2**).

Discussion

It is important to pay close attention to the clinical signs and the necessary auxiliary examinations for early diagnosis of peripheral trauma of knee joints accompanied with popliteal vascular injury. In order to ensure early diagnosis, the following characteristics should be identified: the injured limb dorsalis pedis artery and the posterior tibial artery palpation are not clearly obviously; the limb skin temperature below the injured knee, especially that of the foot, is often significantly lower than that of the healthy limbs; the peripheral feeling of the toes of the foot below the injury is poor, or even nonexistent; the blood oxygen saturation monitoring of the injured limb's toes indicates that the blood oxygen saturation is minimal or even nonexistent; and the examinations of the injured limb

via vascular intervention of DSA imaging, color Doppler ultrasonography and spiral CT reconstruction often confirm early stage vascular injury.

Causes inducing the early missed diagnosis of these kinds of vascular injuries of patients include: the patients often have an open injury, multiple injuries and other damages endangering life, which easily distract the attention of the doctor; not enough attention to detail and comprehensiveness of the physical examination, especially when the dorsal and posterior tibial arterial palpation is not clear and the decrease of the skin temperature of the injured limb failed to induce enough attention, and these symptoms were mistakenly thought to be signs of shock or caused by vascular spasms; and inadequate focus on the dynamic observation of the disease condition. Vascular intimal injury and partial vascular embolism were induced in some patients due to the blunt force nature of the injury. In the early stages, a palpable arterial weak pulse may be present, however, this could later lead to missed diagnosis due to the continuous tracking through dynamic observation not being maintained. In this study, there were 2 cases (14.3%) of missed diagnosis, and 1 case of final amputation. In regards to one other patient, the physicians noted a weak pulse of the dorsalis pedis artery during the early admission stage, however, the dynamic observation was not continued in the later stages. Forty-eight hours after the injury, it was found that the skin temperature of the injured limb had decreased, and dorsal and posterior tibial artery was completely non-palpable. It was confirmed by an artery color Doppler examination and acute exploration, and excision of the arterial embolism was then performed. The limb protection was successful by coinciding the flexion of knee joint with the vessel treatment. The internal fixation reduction of the fracture was carried out in stage II. The patient follow-up was conducted for 1 year. The limb function results were satisfactory. However, this type of situation could easily lead to doctor-patient disputes. Therefore, close attention should be paid in order to avoid such future situations.

Early treatment experiences of popliteal vascular injury include understanding of the amputation indications. Examples of this would be: for the patients with the PSI score above 10,

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amputation is preferred; for the patients with less than 6 points, the success rate of the limb salvage is high; for the patients with 6-10 points, limb salvage or amputation should be considered comprehensively according to the systemic and local conditions of the patients, and the levels of medical techniques. Otherwise, the so-called "salvage success" will bring loss of plantar sensation; movement disorders of foot flexion extension; repeated ulcers dominated by muscle ischemic atrophy and loss of nerve in the pelma; severe carious osteitis and infectious nonunion in the late stages caused by the deletion of sciatic and tibial nerve function which eventually leads to future amputations in stage II; added multiple operational trauma of the patients; prolonged hospitalization; wasted medical resources and increased to the economic and psychological burdens of the patients ($P < 0.05$). On the basis of the referenced PSI indexes, the patients with advanced ages and poor health and/or experiencing life-threatening trauma, severe shock and important nerve injury (such as to the sciatic and tibial nerves) that cannot be repaired, combined with severe basic diseases (such as heart disease, diabetes, lung infection), then amputation is preferred in order to preserve life [13]. In these cases, the patient needs to understand and must not be blind to the overall situation, in order to protect limbs and avoid the loss of life of the patients, and this must be handled extremely well.

There is still some controversy regarding the selection of the order in which the vascular repairs and fracture reduction and fixation should be completed. In our experience, when the limb ischemia time is short, such as 1 hour, the reduction and fixation of the fractured ends should be done first, and then repairs or reconstruction of vessels should be carried out afterwards. For the condition when the ischemia time of more than 1 hour, or there is a relatively stable end of the bone fracture, repair or reconstruction of the vessels should be carried out initially, and then the fracture reduction and internal or external fixation of stage I and II should be conducted. In regards to the selection of the vascular exploration approach, a popliteal S shaped incision can be selected for the exploration of popliteal artery and vein injuries. For the injuries of the crotch between the popliteal artery and vein and the anterior tibial

and posterior vein, there is at this point no especially mature and satisfactory exposure pathways. The blocking of the upper segment fibular often leads to difficult exposure of the vessels at this site. The quality of vascular anastomosis is poor and the success rate is low. In this study, the failure of the damaged vascular anastomosis at the crotch between the popliteal artery and anterior and posterior of tibial artery occurred in 5 cases of patients, resulting in an amputation rate as high as 80%. An improved scheme was considered which included the following: a supine position; the front lateral longitudinal arch operation incision of the upper leg was taken to cut off the superior segment of the fibula (a length of approximately 10 cm); the nervus peroneus communis and peroneal muscle was stretched to the lateral side; and the anterior tibial muscle was retracted medially to expose the crotch between popliteal artery and anterior and posterior tibial artery in order to expose the vessels of the operational field and anastomosis operation. In regards to the vascular embolization of more than 6 cm, there is no method to achieve the objective of direct vascular anastomosis by the release of the vessel and the flexion and extension of the knee joint. Autologous or the proposed abandonment of the artery's bridging repair or artificial vascular reconstruction should be considered. In the case of lower limb ischemia for more than 6 hours, there was a risk of limb ischemia reperfusion injury after vascular anastomosis. In the present study group, two case patients had revascularizations after more than 6 hours, with different degrees of complications including myoglobinuria, oliguria and acute renal failure. There also may have been ischemia reperfusion lung injury [14] or multiple organ failures, as well as even anaerobic infection [15], gangrene, septicemia and other life-threatening risks. It is therefore suggested that amputation is preferred in order to preserve the patient's life in the situations of popliteal vascular injury lasting more than 6 hours [16].

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