

Microsurgical vascular bypass in the setting of pediatric limb length discrepancy

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ABSTRACT

Management of pediatric iatrogenic arterial occlusions can be challenging clinically, leading to chronic complications such as claudication and limb length discrepancy. We report the case of a 6-month-old female patient who had experienced iatrogenic right external iliac and common femoral arterial occlusion. At the age of 8 years, she had developed claudication and a limb length discrepancy of 3.2 cm. She underwent common iliac artery to superficial femoral artery and profunda artery bypass via a branched autologous reverse great saphenous vein using microsurgical techniques for the distal anastomoses. In the present report, we have focused on the musculoskeletal improvements, benefits of microsurgery in pediatric vessels, and maximization of epiphyseal perfusion. (*J Vasc Surg Cases and Innovative Techniques* 2020;6:641-5.)

Keywords: Pediatric; Vascular trauma; Limb length discrepancy; Bypass graft; Microsurgery; Limb ischemia

Lower extremity vascular occlusion after arterial catheterization in pediatric patients is a well-documented complication with a reported rate of $\geq 33\%$ in some studies.¹ With one study describing 11,000 pediatric cardiac catheterizations occurring nationally within a 6-year period, thrombotic complications can be regularly encountered.² However, clinically significant repercussions of this vascular occlusion have been difficult to predict because sufficient collateralization will often develop in children.¹ Thus, one study at a single institution reported that only 2% of iatrogenic groin injuries had necessitated operative repair during a 15-year period.³ Limb length discrepancy (LLD) in pediatric patients is one such sequela of chronic lower extremity ischemia that could ultimately require surgical intervention. The indications and efficacy of vascular repair in these patients have been described, with various results.⁴⁻⁶ The child's parents provided written informed consent for the publication of their daughter's case.

CASE REPORT

The patient was a white girl who had been born at 28 weeks with aortic coarctation. At 6 months of age, she had undergone angioplasty repair via right femoral artery catheterization, which was complicated by occlusion of the right external iliac artery and common femoral artery and was managed conservatively. At 11 months of age, she was noted to lack palpable right femoral, posterior tibial, and dorsalis pedis pulses and to have a shorter right leg compared with the left. Initially, the LLD was managed with orthopedic shoe lifts and observation with serial radiographic bone length studies (Table). These scanograms provided a reproducible and precise comparison of the limb length over time by the ability to measure both the distance from the top of the femoral head to the femoral medial condyle and the distance from the tibial plateau to the tibial plafond on the radiographic images using a stationary ruler (Fig 1). As she aged, the patient developed right leg claudication, differences in shoe size, coordination issues, and a peak LLD of 3.2 cm (Fig 2). This peak LLD consisted primarily of differences in femur length (1.4 cm) and not tibia length (0.6 cm). The evaluation at this time was still notable for nonpalpable, biphasic Doppler signals throughout her right lower extremity and nonvisualized right external iliac and common femoral arteries, with distal reconstitution of the femoral arteries via collaterals seen on a computed tomography angiogram (Fig 3).

At 8 years of age, she underwent right common iliac artery to superficial femoral artery (SFA) and profunda femoris artery (PFA) bypass using an autologous reversed great saphenous vein (GSV) graft performed by a joint pediatric, vascular, and plastic surgery team. The right iliac vessels were exposed through a retroperitoneal approach and the right femoral vessels exposed through a groin incision. Approximately 35 to 40 cm of the right GSV—which had a diameter >3 mm—was harvested and introduced, in reverse fashion, through a tunnel that spanned the distance from the retroperitoneal incision to the femoral vessels in the groin. The graft was flushed with a mixture of heparinized

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Table. Radiographic bone length results

Patient age	RLE length, cm	LLE length, cm	Discrepancy (RLE – LLE), cm
2 years, 7 months	35.9	37.5	–1.6
5 years, 7 months	49.8	52.3	–2.5
6 years, 9 months	54.9	58.1	–3.2
8 years, 0 months	RLE vascular repair		
8 years, 1 month	60.3	63.1	–2.8
8 years, 9 months	63.4	65.3	–1.9
9 years, 9 months	67.9	70.1	–2.2
10 years, 9 months	72.3	74.4	–2.1
10 years, 11 months	Left tibial epiphysiodesis		
11 years, 4 months	74.9	76.6	–1.7
11 years, 10 months	77.0	78.5	–1.5
12 years, 4 months	78.8	79.3	–0.5
12 years, 10 months	81.7	82.0	–0.3
13 years, 11 months	82.1	82.3	–0.2

LLE, Left lower extremity; RLE, right lower extremity.

**Fig 1.** Scanogram composite with *dotted lines* marking the points of measurement from which to determine the limb length: top of the femoral head (A), tibial plateau (B), and tibial plafond (C).

Plasma-Lyte (Baxter International, Deerfield, Ill) while the patient was systemically heparinized with the standard 80 U/kg. The proximal anastomosis was created between the distal end of the GSV and the right common iliac artery using interrupted sutures. During exploration of the vessels, the SFA and the PFA were found to be scarred and underperfused, with the SFA measuring 2.0 to 2.5 mm in diameter and the PFA 1.5 to 2.0 mm in diameter. This, therefore, lent well to a microsurgical approach. Using the GSV and one of its branches that was preserved at the original saphenofemoral junction, two distal microvascular anastomoses were created using 8-0 Prolene suture (Ethicon, Inc, Somerville, NJ) under the operating microscope. The first anastomosis performed was between the GSV and SFA as a geometric three-dimensional end-to-side microvascular anastomosis using a segmental running suture technique with three or four segments.⁷ The second anastomosis included the branch of the GSV and the PFA, in identical fashion (Fig 4). At conclusion of

the surgery, an angiogram was performed (Fig 5), and a strong pulse was observed in each outflow artery with palpable posterior tibial and dorsalis pedis pulses.

After the surgery, the patient's ankle-brachial index was measured and found to be normal in her right lower extremity (posterior tibial, 1.00; dorsalis pedis, 0.97), and her claudication had completely resolved. She took postoperative 81 mg aspirin for 1 month, and the graft was monitored using serial duplex ultrasound studies at 1, 5, and 9 months postoperatively and then annually. Over time, her shoe sizes became symmetric, and the LLD continuously improved (Table). At 3 years after the bypass grafting, she underwent left tibial epiphysiodesis. During the ensuing years of maturity, both lower extremities had grown substantially, with the LLD improving to nearly equal limb lengths—a 0.3-cm difference—by 5 years postoperatively (Fig 2). Graft surveillance at 6 years postoperatively demonstrated a widely patent bypass graft and anastomoses.

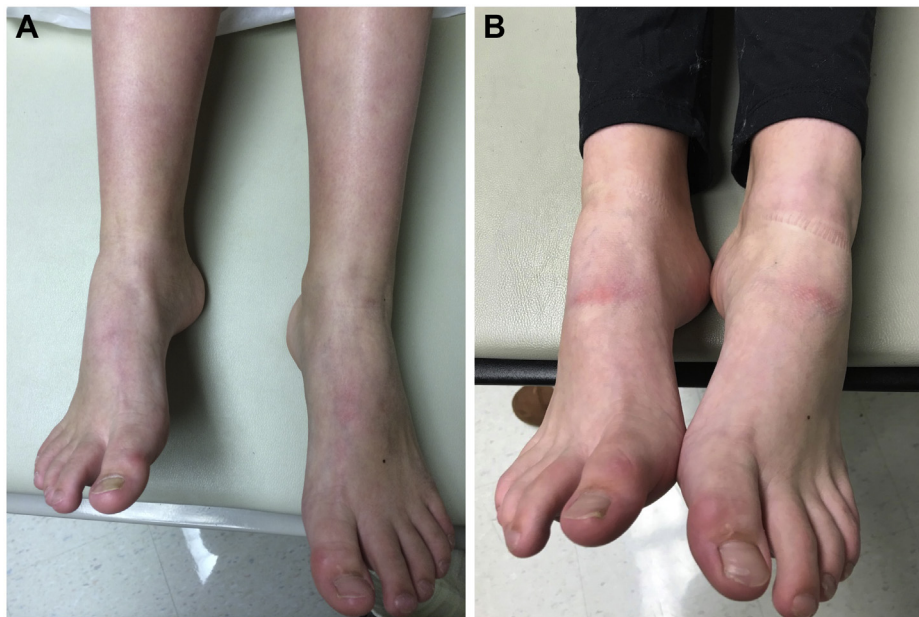


Fig 2. **A**, Preoperative clinical demonstration of limb length discrepancy and foot size discrepancy. **B**, Six-year postoperative clinical demonstration of improved limb length discrepancy and foot size discrepancy.

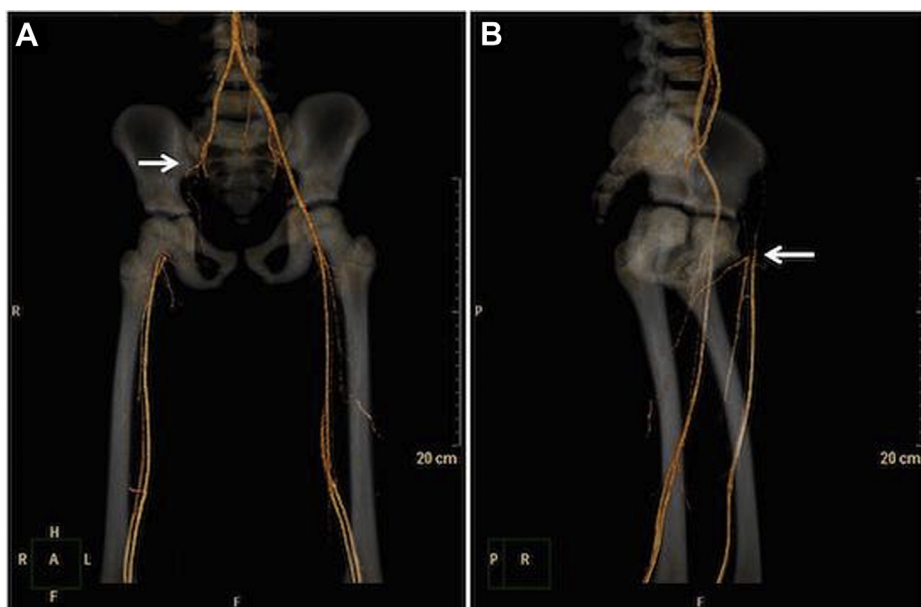


Fig 3. **A**, Computed tomography angiogram demonstrating complete occlusion of the right external iliac artery with reconstitution of the superficial femoral artery and profunda femoris artery. **B**, Lateral view of computed tomography angiogram demonstrating the separation between the reconstituted superficial femoral artery and profunda femoris artery.

DISCUSSION

The various definitions of LLD have contributed to the difficulty in determining its incidence and significance in patients. Taylor et al¹ defined LLD as a >1.5 cm discrepancy with a reported rate of 8% (4 of 51) in those children who had developed arterial occlusion. Flanigan et al⁸ had defined LLD as a difference >0.5 cm and reported a rate of 14% in children with

arterial occlusion overall. However, the rate had increased to 33% when considering only those children with ischemia lasting >30 days.⁸

Regardless of how LLD is defined, its clinical significance drives the indications for vascular repair. The value of 1.5 cm was chosen by Taylor et al¹ because that value “would clearly result in a discrepancy of 2.0 cm at maturity”—the discrepancy at which gait disturbances are often

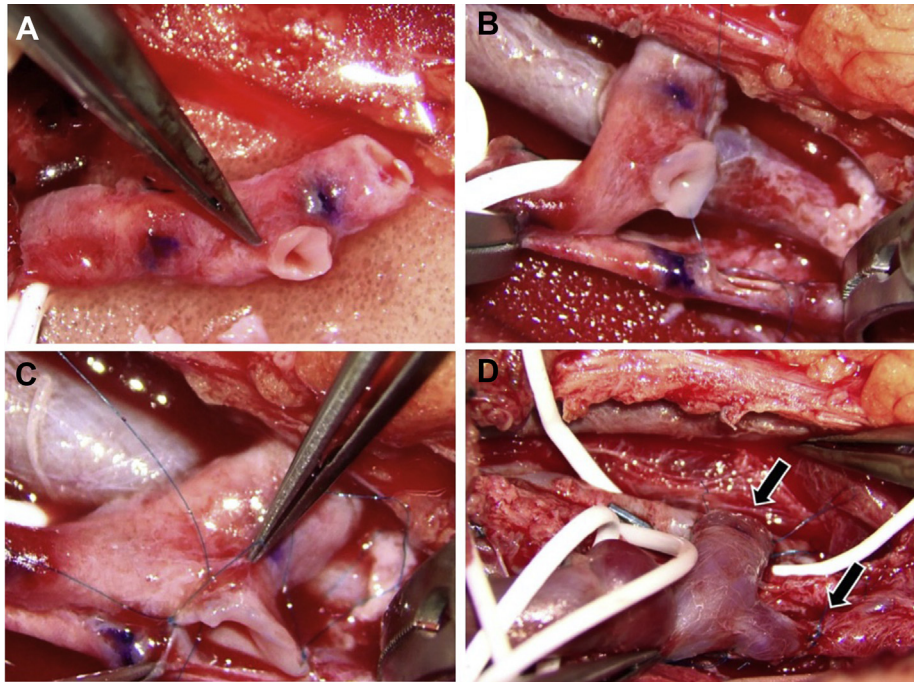


Fig 4. **A**, Proximal branch of the great saphenous vein. **B**, Geometric end-to-side anastomosis to the superficial femoral artery. **C**, Sewing the front wall of the end-to-side microanastomosis. **D**, Completed anastomosis to the superficial femoral artery and profunda femoris artery (*black arrows*).



Fig 5. Intraoperative angiogram of the bypass. The *distal arrows* demonstrate the filling of the superficial femoral and profunda femoris arteries. The *dashed arrow* indicates the epiphyseal plate of the femoral head.

recognized.¹ Once a patient has become symptomatic, reached a critical LLD that elevates the risk of scoliosis, or nears a growth spurt, repair should be considered.^{5,6}

Because of her LLD, our patient struggled with coordination in physical activity and required different size

shoes. Consistent with the indications described, the decision to surgically intervene was determined by her age, worsening symptoms, and upcoming pubertal growth spurt. The surgical approach was chosen with the consideration that both the right external iliac artery and the right common femoral artery were chronically occluded (Fig 3). To maximize the vascular supply to the proximal growth plate (epiphyseal plate of the femoral head via the PFA) and distal growth plates (knee, ankle, and foot from the SFA), reconstruction of both the PFA and the SFA was executed. Given the small size of the vessels, a microsurgical technique was believed to be optimal for greater precision and an increased likelihood of long-term patency. In addition to those benefits enumerated by Ooi et al,⁷ use of the segmental running suture ideally allowed for dilation of the anastomosis with patient growth, given her impending growth spurt. In addition, the end-to-side approach helped preserve the collateral circulation proximal to the anastomosis, as elaborated by Linton and Menendez.⁹

Multiple small studies and reports have analyzed the outcomes of LLD after vascular repair in children, with different results.^{3-6,10} Cardneau et al⁴ reported the lack of statistically significant improvements overall after surgery for 10 children with LLD in their study. However, a recent and larger study from Eliason et al⁶ had analyzed 33 pediatric patients with chronic limb ischemia, of whom 21 (64%) had a LLD with a mean discrepancy of 1.32 cm. After surgical intervention, performed, on

average, 8.8 years after the inciting vascular occlusion, the patients' LLD had shown a statistically significant improvement to a mean of 1.06 cm. In our patient, operative repair was performed nearly 8 years after the initial injury. However, only 1.5 years after the operation, the patient's LLD had improved to 1 cm and she had experienced complete resolution of claudication and foot size difference, demonstrating a clinically effective repair. At that time, subsequent contralateral tibial epiphysiodesis was performed to enhance the effects of the vascular repair on the eventual normalization of her LLD. In accordance with the "White-Menelaus" arithmetic method, this more minimal intervention that solely targeted the proximal tibial growth plate—rather than both the distal femur and tibia—should have reduced the growth rate in the left leg by ~0.64 cm annually compared with the shorter right leg.¹¹ In the 2 years after the epiphysiodesis, the right leg's growth had exceeded this expected rate difference, demonstrating the beneficial effects of the bypass graft. The graft's branching distal end, which allowed for revascularization of the PFA, maximized the growth potential of the right leg because the proximal femoral growth plate—supplied by the PFA—contributes 30% of growth to the femur.¹²

The most common surgical repair in the report by Eliason et al⁶ had incorporated an autologous reverse GSV as a bypass graft. Although reverse GSV grafts in these children have demonstrated long-term patency rates of $\leq 93\%$ in some studies,⁴ continued surveillance is required because complications requiring reoperation, such as dilation or occlusion, have been shown to occur at a rate of $\leq 31\%$.⁶ The GSV graft used in our patient had the added complexity of a branching with two distal anastomoses, which had not been described in any of the previously reviewed studies. Nonetheless, this branching graft demonstrated beneficial outcomes without documented clinical or imaging complications at the last follow-up examination. Ultimately, our technique is highlighted to illustrate our own approach; however, any successful revascularization would be expected to improve growth plate perfusion and yield corrections in LLD.

CONCLUSIONS

Although debate remains concerning the exact indications and timing for vascular repair in pediatric patients with chronic lower extremity ischemia, the development of clinically significant symptoms such as claudication and LLD causing impaired coordination is an indication to proceed with surgical intervention. As described in the present case report, autologous reverse GSV grafting,

even when performed years after the initial vascular injury, can serve as an optimal repair for resolution of claudication and improvement of the LLD with minimal complications. The use of microsurgery to address the small size of the vessels and preservation of GSV branches to reconstruct both the SFA and the PFA were helpful techniques to target all epiphyseal plates and achieve the desired clinical outcome.

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