Percutaneous Deep Vein Arterialization Using Zero Iodinated Contrast Technique for Limb Salvage in a Patient With Kidney Transplant and Impaired Renal Function

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Abstract

No-option chronic limb-threatening ischemia (CLTI) refers to patients in which revascularization is not possible with standard endovascular or surgical revascularization strategies. Not infrequently, patient comorbidities and medical conditions preclude interventionalists from utilizing iodinated contrast for visualization during endovascular treatment of no-option CLTI. We present the case of a 64-year-old man with renal insufficiency and CLTI complicated by a nonhealing ulcer who was successfully revascularized using deep venous arterialization with zero iodinated contrast technique. The patient remained wound-free at a 2-year follow-up.

Chronic limb-threatening ischemia (CLTI) is the end stage of peripheral arterial disease (PAD), characterized by angiographic evidence of arterial insufficiency combined with either rest pain, gangrene, or limb ulceration for more than 2 weeks.[1] No-option CLTI refers to patients in which revascularization is not possible with standard endovascular or surgical revascularization methods. A "desert foot" refers to severe below-ankle or inframalleolar arterial disease without any named vessels to the foot.

In patients with diabetes mellitus (DM), the development of chronic kidney disease (CKD) is associated with neuropathy and PAD, further increasing the risk of limb amputation.[2,3] We present the case of a patient with no-option CLTI, DM, and CKD treated endovascularly with percutaneous deep venous arterialization (pDVA) using a zero iodinated contrast technique (ZCT) to preserve deteriorating renal function and salvage a functional limb. The institutional review board did not require approval for publication.

Case Report

A 64-year-old man with a history of hypertension, dyslipidemia, DM, pancreatic insufficiency, coronary artery bypass graft surgery, kidney transplant with post-transplant CKD stage 3b (glomerular filtration rate of 39 mL/min), and PAD presented with no-option CLTI and nonhealing Rutherford classification 6 gangrenous ulceration of the left fifth toe.

Eight years before the current presentation, the patient received a stent in the left popliteal artery (POP) followed by unsuccessful angioplasty of the tibioperoneal trunk (TPT). Subsequently, he underwent bypass from the left POP to the dorsalis pedis artery (DP) bypass using a cryopreserved vein to treat nonhealing foot wounds, but he ultimately required amputation of the left first-to-third digits. Three years later, he had a right below-knee amputation due to severe PAD. He presented now with left fifth-toe gangrene classified as Rutherford 5 with a Wound, Ischemia, foot Infection (WIfI) score of W2-I2-fI1, indicating a substantial
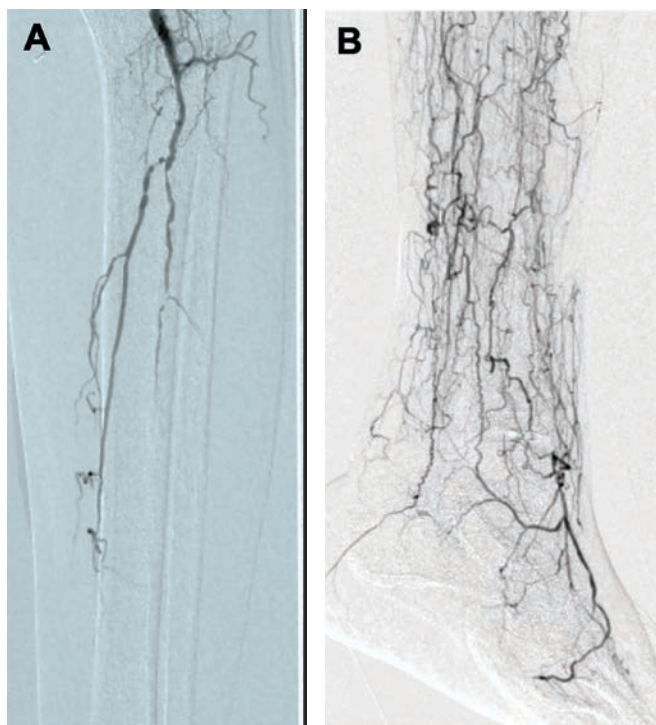
FIGURE 1. Iodinated contrast angiogram from a prior intervention. **A)** Chronic total occlusion of all tibial vessels. **B)** Short segment of the patent dorsalis pedis artery with contrast filling but without visualization of the distal branches or plantar arch of the foot.

risk of a major amputation. Prior foot x-ray demonstrated a medial arterial calcification (MAC) score of 4, which is a strong independent predictor of major amputation in patients with CLTI. He underwent a peripheral angiogram with 20-cc iodinated contrast at an outlying facility that revealed adequate inflow with a 75% stenotic lesion in the distal left POP (**Figure 1**). The POP-DP bypass and all 3 tibial vessels were chronically occluded, and he had an exuberant collateral formation in the foot.

Additionally, given that his arm veins were used for his multiple dialysis accesses, he was not a candidate for conventional surgical strategies utilizing autologous conduits for a distal bypass. As he had the combination of macrovascular disease, microvascular disease, and medial artery calcification without autologous venous conduits for bypass and viable endovascular revascularization options, he was classified as no-option CLTI. He was subsequently referred for consideration of pDVA.

Revascularization was done with ZCT using CO_2 angiography, extravascular ultrasound (EVUS), and intravascular ultrasound (IVUS) to preserve his residual renal function given his post-renal transplant CKD. EVUS-guided antegrade left common femoral artery (CFA) access was obtained with a 6F Destination sheath (Terumo) as well as left lateral plantar vein (LPV) access with a Micropuncture catheter (Cook). Baseline angiographic images were obtained with CO_2 angiography using the CO_2mmander Elite device (AngioAdvancements), injecting 10cc for every selective angiogram (**Figure 2**). Notably, there was a short segment of patent proximal DP without visualization of the distal DP or the patent plantar arch of the foot to adequately perfuse the forefoot and heal a transmetatarsal amputation (TMA) (**Figure 2b**). IVUS-guided orbital atherectomy (Philips Eagle Eye Platinum ST) of the POP, TPT, and proximal posterior tibial artery (PTA) with a 1.5 Classic Diamondback catheter (Abbott) was performed. Thereafter, we performed IVUS-guided balloon
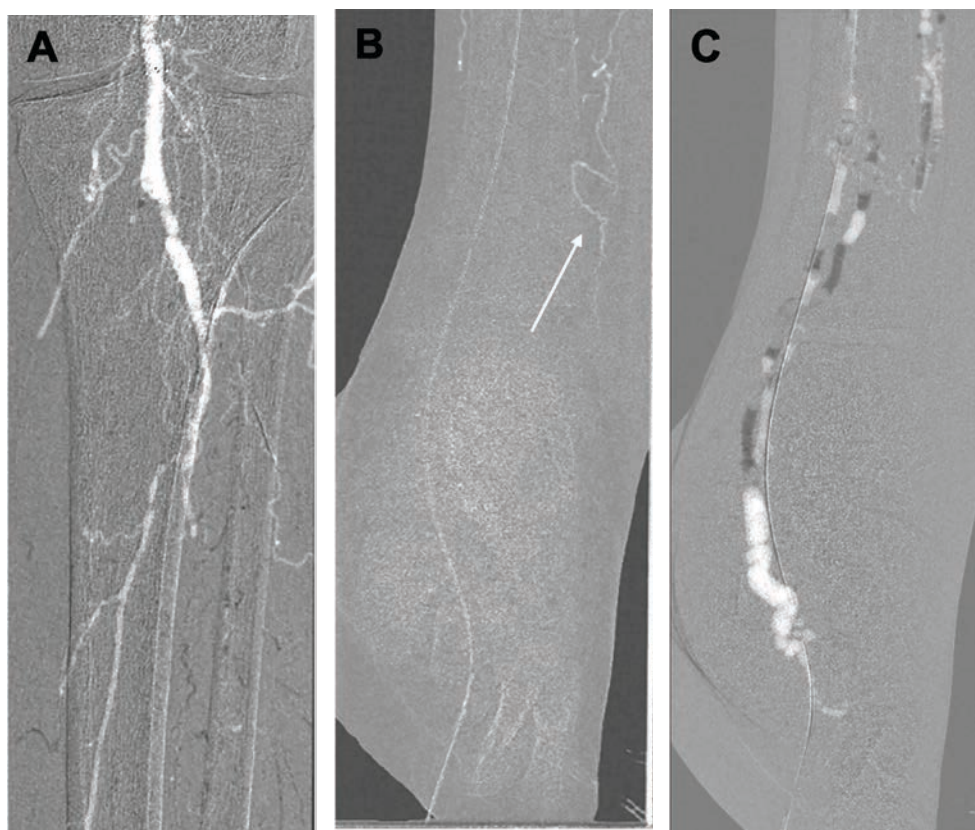
FIGURE 2. Initial carbon dioxide angiography. **A)** Redemonstrated chronic total occlusion of all tibial vessels. **B)** Absence of named vessels to the foot. There is a short segment of patent proximal dorsalis pedis (DP) artery (white arrow), but no distal DP segment or other distal branches that could theoretically heal a transmetatarsal amputation. **C)** Angiogram of the left plantar vein.
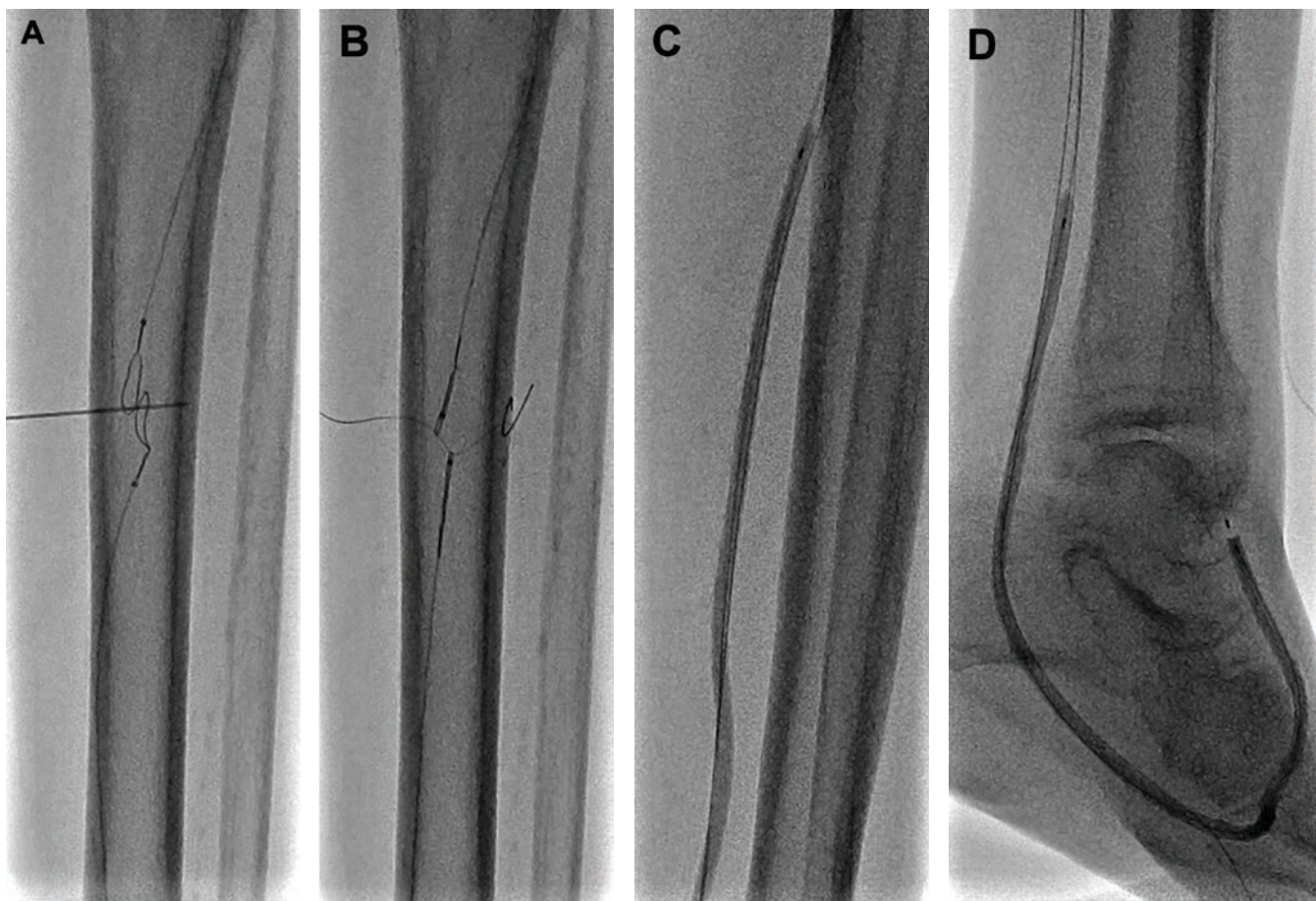
FIGURE 3. Venous arterialization simplified technique for creating the percutaneous arteriovenous fistula (AVF). **A)** One loop snare in the posterior tibial artery aligned with another loop snare in the posterior tibial vein. The loop snares were punctured percutaneously with a 21-gauge needle. **B)** A 0.014 guidewire was advanced, and the needle was removed. The wire was eventually externalized in both venous and arterial sheaths. **C)** Balloon angioplasty of the AVF. **D)** Valvotomy of the venous plantar arch.

angioplasty of the distal POP with a 5- x 80-mm Ultraverse balloon (BD) and balloon angioplasty of the TPT and PTA with a 4- x 120-mm Ultraverse balloon.

Venoplasty of the posterior tibial vein (PTV) was performed with a 4- x 150-mm Ultraverse balloon after exchanging the Micropuncture sheath for a 4-5F Glidesheath Slender sheath (Terumo). An arteriovenous fistula (AVF) was created with the double snare venous arterialization simplified technique[4,5] using 2 10-mm overlapping Amplatz Goose Neck intravascular snares (Medtronic) (**Figure 3**). One snare was advanced in the PTA and the other in the PTV. The snare loops were aligned and punctured percutaneously with a 21-gauge needle. The needle was removed after advancing a 0.014 Cougar XT guidewire (Medtronic), which was then externalized in both venous and arterial sheaths. Thereafter, the AVF was serially dilated with 2.5- x 40-mm, 3- x 40-mm, and finally 4- x 40-mm Ultraverse balloons.

Valvulotomy in the LPV was performed with a 4- x 120-mm UltraScore scoring balloon (BD). A 5- x 250-mm Viabahn covered stent (Gore) was placed across the fistula and down the PTV to the LPV. The Viabahn covered stent in the PTV was post-dilated with a 5- x 100-mm Ultraverse balloon, and the short segment in the PTA was post-dilated with a 4- x 40-mm Ultraverse balloon. The final angiography was performed with CO_2 showing excellent blood flow to the foot (**Figure 4**). Hemostasis of the LPV access was achieved with a combination of an intravascular balloon endoclamp and external manual compression. Hemostasis of the left CFA was achieved with a Perclose Proglide closure device (Abbott).

The patient was discharged without a change from his baseline creatinine of 2.0 mg/dL. As is our institution's protocol, we discharged the patient on atorvastatin and a 1-month regimen of aspirin, clopidogrel, and rivaroxaban with planned subsequent de-escalation to only aspirin and rivaroxaban for prophylaxis of in-stent venous thrombosis. He followed up weekly in our wound care clinic for several minor debridements and eventually had a TMA 2 months later (**Figure 5**). His tissue oximetry improved from 18 to 56 mm Hg. His wound healed 9 months after the pDVA procedure, and he was in remission 2 years after the index procedure.

Discussion

This case report describes a patient classified as no-option CLTI based on the following factors: This patient did not have any autologous venous conduits for surgical bypass. Foot X-ray revealed moderate-to-severe calcification with a MAC score of 4. He had W2-I2-fI1, indicative of a high amputation risk without revascularization. On CO_2 contrast angiography, there was a segment of a patent proximal DP, but without evidence of distal branches or microvasculature that are needed to theoretically perfuse the forefoot and heal a TMA. Therefore, together with a history of prior failed revascularization attempts and severe small artery disease, the decision was made to defer another attempt at retrograde revascularization and instead pursue pDVA.

Nearly 15% to 20% of patients presenting with CLTI are not candidates for revascularization with standard surgical or endovascular techniques because of heavily calcified vessels without adequate surgical targets or conduits due to the presence of microvascular disease.[6] This is mostly seen in patients with DM,

FIGURE 4. Completion angiogram showing significant improvement in flow to the foot.

CKD, inframalleolar disease, and severe microvascular disease. Without revascularization, these patients face an extremely high amputation rate.

Almost 1 in 4 patients with CKD are diagnosed with PAD. In a nationwide analysis, it was found that over 20% of patients hospitalized with CLTI have CKD.[7] In comparison to patients with CLTI but without CKD, patients admitted with both CLTI and CKD have higher in-hospital mortality with higher rates of amputation and are less likely to undergo revascularization.[3] Additionally, CKD is a significant predictor of poor outcomes after lower extremity bypass surgery.[8] Of note in this study, endovascular revascularization had lower in-hospital mortality than surgical revascularization for CLTI with CKD.

The pattern of atherosclerotic occlusion in DM, which is a common risk factor for both PAD and CKD, typically shows a propensity toward infrapopliteal vessels and microcirculation.[9] Amputation remains a major morbidity in patients with CLTI. In the EUCLID trial, out of 643 patients enrolled with CLTI, 54 (8.4%) underwent major amputation and 33 (5.1%) underwent minor amputation, with an annual mortality rate exceeding 22%.[10] Diabetic dialysis patients have a nearly 3-fold increased risk of amputations compared with those without DM, and this high amputation rate is coupled with a 50% mortality within 2 years of amputation.[11]

Much research has been conducted to assess the effectiveness of pDVAs in reducing amputation rates. The PROMISE I and PROMISE II trials aimed to assess the effectiveness of transcatheter arterialization of deep veins (TADV) as a limb-saving option in patients with advanced vasculopathy and no-option CLTI.[12,13] The findings showed that the amputation-free survival (AFS) rate was 36.8% among those with dialysis-dependent CKD, compared with 72.7% among those without dialysis-dependent CKD. The mortality rate was 36.2% for patients with dialysis-dependent CKD, while it was 8.6% for those without it. This indicates that a smaller proportion of patients with dialysis-dependent CKD experienced AFS, and a more sizable proportion experienced death. Although the limb preservation rate was comparable among patients with and without dialysis-dependent CKD, the mortality rate was greater in the dialysis-dependent group. Consequently, when contemplating the provision of TADV to individuals with dialysis-dependent CKD, it is crucial to consider factors such as life expectancy and patient preferences. The PROMISE-UK trial demonstrated rates of AFS (67%) and limb-salvage (81%) at 1 year,[14] which is broadly concordant with the results of PROMISE I and PROMISE II. Dedicated pDVA systems have been developed that accomplish comparable rates of AFS rates and wound healing at 2 years.[15] A 2024 meta-analysis of pDVAs found AFS rates of 72.6% at 6 months and 66.0% at 12 months.[16] The same study found rates of reintervention and complete wound healing at 12 months being 41.7% and 46.0%, respectively.
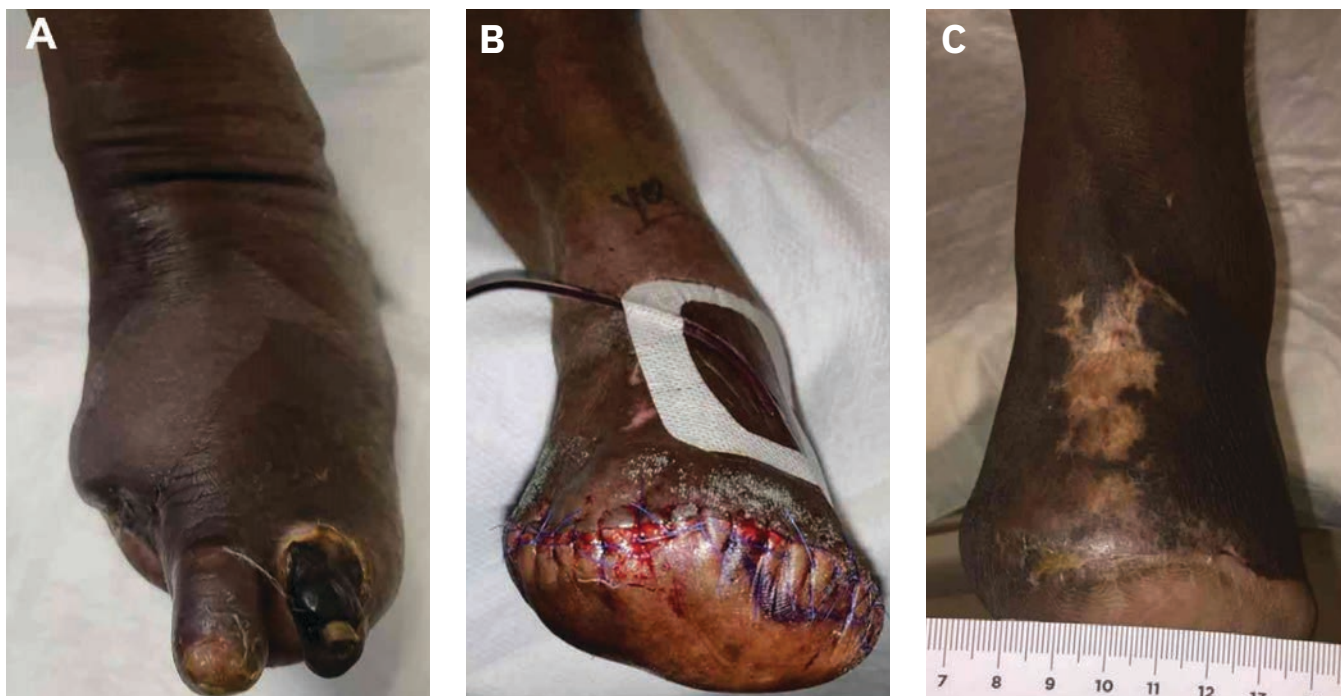
FIGURE 5. A) Foot at initial presentation. B) Foot after transmetatarsal amputation. C) Foot healed at 9 months.

IVUS helps characterize lesion morphology, guide stent sizing, and assess procedural outcomes, which may contribute to technical success, improved stent patency, reduced amputation rates, and minimized contrast use in angioplasty, atherectomy, and lumen re-entry.[17-21] A recently published randomized controlled trial revealed that using IVUS plus angiography in femoropopliteal interventions resulted in a significant decrease in restenosis compared to angiography alone, but without significant improvement in clinical outcomes such as clinically directed targeted lesion revascularization.[22]

The use of CO_2 contrast also has multiple advantages, including no renal toxicity or anaphylactic reactions, making it the preferred agent in patients with renal impairment or contrast allergy. In addition, the low viscosity of CO_2 allows it to be injected through microcatheters and needles, between the catheter and guidewire, and within the side port of sheaths and stent delivery systems. Because CO_2 is immiscible with blood, it prevents clots from forming within the catheter. CO_2 is eliminated immediately in the lungs (provided it is loaded and injected with the proper technique that prevents gaseous contamination, which could lead to a gas embolism), allowing unlimited volumes of CO_2 to be used. CO_2 is also inexpensive compared with nonionic iodinated contrast medium.[23]

As in-stent thrombosis is a recognized complication of pDVAs, its probability of occurrence can and should be reduced by placing patients on adequate antithrombotic medications postoperatively. Our institution implements a regimen of dual-antiplatelet therapy with 1 anticoagulant for 1 month, then de-escalates to aspirin and rivaroxaban indefinitely. For patients with freshly implanted drug-eluting stents, de-escalation would occur with clopidogrel and rivaroxaban instead. This proposed medication regimen is one practical option, although there is a lack of consensus on the most appropriate strategy against in-stent arterial or venous thrombosis.[24]

Current care of patients with CKD is adversely impacted by delays in PAD diagnosis as well as delays in referral to a vascular specialist. Early identification and aggressive risk-factor modification of patients with CKD who are prone to PAD may help prevent limb loss and amputation.[22] Multidisciplinary teams have proven to reduce the progression of diabetic ulcers and prevent amputations in these patients.[25,26] Advances in endovascular and surgical intervention as well as medical management are also promising in improving outcomes for these patients. Even in patients with no-option CLTI, or "desert foot," novel approaches such as pDVA with alternative imaging modalities such as IVUS, EVUS, and CO_2 angiography may be effective in limb salvage.[27,28]

Conclusion

pDVA can be safely performed for limb salvage for no-option CLTI patients with severe renal impairment using a ZCT with CO_2 angiography, EVUS, and IVUS. CO_2 angiography is a favorable alternative to iodinated contrast in patients with CKD. Utilization of IVUS may improve procedural success.

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