Shunt diseases such as arteriovenous malformation and arteriovenous fistula (AVF) often cause ischemia through steal physiology. Symptoms vary according to the location of disease, and some require treatment to reduce or to eliminate steal of blood flow. Endovascular therapy is often the treatment of choice. These diseases often have multiple channels from arteries to veins, and it can be difficult to embolize all channels. Therefore, in most cases, physicians have to arbitrarily decide when to finish the procedure. Currently, the procedural end point is decided subjectively on the basis of angiography findings. To date, there has been no way to quantify blood flow in angiography. Color-coded digital subtraction angiography (ccDSA) can provide physicians with an objective assessment of angiographic images. The ccDSA image is created from conventional DSA images on the workstation (Syngo Workspace, Siemens AG, Forchheim, Germany) within seconds. The contrast medium bolus geometry (maximum opacification) of each pixel from the injection is color coded and displayed in a single composite image. On this image, the region of interest (ROI) is set on the vascular system, and then the time-contrast intensity curve at the ROI is obtained automatically. This time-contrast intensity curve can provide perfusion parameters such as peak contrast concentration, time to peak (TTP), and area under the curve (AUC). AUC reflects the amount of contrast medium that passes the ROI. If the ROI is fixed at the same level with the same injection speed and the same volume of contrast medium, these parameters of different times can be comparable. The ratio of AUC at two ROIs can give a quantitative estimate of blood flow. The application of these parameters given by ccDSA for clinical treatment has been reported in neuroradiology. To date, there has been only one publication using ccDSA in the peripheral vasculature, which reported use of TTP only. There have been no published reports on the application of AUC to measure the blood flow in peripheral endovascular therapy. We present the first case in which analysis of AUC data determined the end point of the endovascular revascularization. The patient was informed, and consent for publication was obtained.

CASE REPORT

A 70-year-old woman presented with an ulcer on her third toe. Local wound care had not improved the ulcer for 4 months. The ankle-brachial index of her left leg was 0.35. Computed tomography with contrast enhancement revealed diffuse stenosis of the left superficial femoral artery (SFA) and early enhancement at the left common femoral vein in the arterial phase (Fig 1). Left iliac and common femoral arteries were normal. The early venous enhancement was determined to be caused by AVF. The left external iliac vein was occluded, which was thought to cause the AVF. It was difficult to judge whether femoropopliteal occlusive disease or AVF was the main cause of the ulcer. The treatment plan was to address the femoropopliteal occlusive disease first and then to reduce the shunt steal if necessary. A 6F sheath was inserted from the right groin and advanced to the left common femoral artery (SFA) and arteriovenous fistula treated using color-coded digital subtraction angiography

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ABSTRACT

Any quantitative assessment of blood flow using conventional angiography remains impossible with current technology. Physicians decide the clinical end point of a procedure by subjective interpretation. Color-coded digital subtraction angiography has been invented to meet this demand and is used primarily in neuroradiology. This report presents the endovascular treatment of a rare complex combination of peripheral artery disease and arteriovenous fistula using guidance of blood flow parameters, such as area under the curve. (J Vasc Surg Cases and Innovative Techniques 2019;5:264-8.)

Keywords: Color-coded DSA; Peripheral artery disease; Arteriovenous fistula

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using 6 mL of contrast medium with an injection speed of 3 mL/s revealed diffuse stenoses of the left SFA and high-volume steal syndrome through the AVF. The image of the ccDSA from conventional DSA was automatically created. The next step was to define the ROI, and then the time-contrast intensity curve at the ROI was obtained automatically. In this procedure, three ROIs were defined on the color-coded image: the tip of the sheath (as a reference), the common femoral vein (as an indicator of shunt flow), and the proximal side of the SFA (as an indicator of blood flow for the lower extremity). These ROIs were selected at a point with adequate width of vessel and no overlapping branches. With this time-contrast intensity curve, AUC at each ROI was automatically calculated, and the ratio of AUC between the reference and each ROI was displayed. As a result, ccDSA performed before treatment provided the ratio of shunt blood flow to the reference (shunt flow, 0.67) and the ratio of the blood flow for the lower extremity to the reference (SFA flow, 0.45; Fig 2).

As planned, balloon angioplasty was performed (Coyote, 4-mm diameter, 22-cm length; Boston Scientific, Marlborough, Mass), with good luminal expansion achieved. After a second angiography study, the shunt and SFA flows were 0.69 and 0.70, respectively (Fig 3). In addition, TTP at the proximal side of the SFA had not dramatically changed (3.78 seconds to 3.32 seconds). The SFA flow increased but did not reach 1.0 and was judged insufficient to heal the ulcer. Therefore, the AVF was embolized. A microcatheter (PX SLIM; Penumbra, Inc, Alameda, Calif) was advanced into one of the feeders of the AVF, and coil embolization was performed with detachable coils (Ruby coil; Penumbra, Inc) and a 1:1 mixture of n-butyl-2-cyanoacrylate and ethiodized oil (Lipiodol). Another feeder was also occluded with a Ruby coil. Angiography was performed, and the shunt flow appeared to have been reduced (Fig 4). Then AUC ratio calculation was performed. Shunt flow ratio was 0.35 and SFA flow ratio was 0.93 (Fig 5). An improvement in the TTP (3.32 seconds to 2.72 seconds) was also demonstrated. Reduction of the shunt flow was clearly achieved, and SFA flow improved nearly to 1.0, which suggested unrestricted blood flow to the lower extremity.

After treatment, the ankle-brachial index markedly improved (0.35 to 0.90) and was adequate to heal the patient’s ulcer. Unfortunately, the patient suddenly died of aspiration pneumonia 1 month after treatment. Therefore, whether this treatment was effective long term remains unclear.

DISCUSSION

As shown in this case, ccDSA provides quantitative assessments of blood flow. With this technology, the contrast medium bolus geometry of each pixel is color

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**Fig 1.** Preoperative computed tomography demonstrated the diffuse stenosis of the left superficial femoral artery (SFA; dotted line) and early enhancement at the left common femoral vein (arrow).
coded and displayed in a single composite image from the conventional DSA image. The area under the time-contrast intensity curve is automatically calculated and displayed as the ratio to the reference. If the reference is fixed at the same level with the same injection speed and the same volume of contrast medium, AUC at different times can be compared. As a result, the physicians can identify change of blood flow comparing preprocedure and postprocedure AUC.

The clinical application of this technology has been reported principally in neuroradiology. In the field of peripheral artery disease, there has been only one...
publication concerning ccDSA. It reported the relationship between only TTP and the improvement of ankle-brachial index after lower extremity percutaneous angioplasty.

This assessment has a few limitations. When the ROI is in the abdomen, the acquisition of a DSA image can be disturbed by motion artifact caused by respiratory and gastrointestinal motility. In addition, the AUC of ROI cannot be too far away from the reference. As mentioned, AUC is calculated as the ratio to the reference, which is located on the same viewing field as the ROI. In critical limb ischemia patients, the ulcer is more likely to be caused at the tip of the foot. Therefore, the change of blood flow at the ulcer itself is difficult to assess with ccDSA technology. Further technologies are needed to evaluate the change of blood flow in farther distal sites in the lower extremity.
CONCLUSIONS

In this rare case of femoropopliteal occlusive disease and AVF, ccDSA provided accurate information about blood flow during endovascular intervention. This technology has potential to help physicians judge the appropriate clinical end point during complex endovascular procedures.

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