Duplex Ultrasound Technical Considerations for Lower Extremity Venous Disease

Imaging protocols and documentation requirements, key concepts for consideration, and a step-by-step protocol for process standardization.

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Over the past 2 decades, duplex ultrasound has impacted venous anatomic nomenclature, diagnosis, and treatment. With the growth of interventional procedures for venous disease, duplex ultrasound has become the cornerstone for diagnosis and treatment. However, there is an educational gap to properly performing reflux studies. The Intersocietal Accreditation Commission (IAC) has revised reflux study recommendations, most recently in 2019,[1] and these are enforced in the accreditation process for vein centers.

This article presents the proper documentation requirements and a practical protocol for venous duplex ultrasound testing for vascular technologists and interpreting physicians. Additionally, the technical aspects of the exam, anatomic variations, and hemodynamics are discussed with disease state considerations, all of which can have a profound effect on outcomes.

DEEP VEIN THROMBOSIS OR REFLUX?

Valvular reflux and obstruction (usually secondary to thrombosis) are the two key elements of examination during the lower extremity venous duplex ultrasound. The diagnostic techniques that identify venous obstruction are different from those required to identify valvular incompetence.

Tables 1 and 2 summarize the venous standards document of the IAC. These represent the suggested minimum documentation requirements; proper documentation often requires images in addition to those listed for completeness. The documentation should match the written protocols in the laboratory. Separate protocols for routine "limited" examinations may also be written. Additional documentation may be required for the proximal profunda femoris vein, anterior tibial veins, perforating veins, external and common iliac veins, and the inferior vena cava.

TABLE 1. DOCUMENTATION FOR THROMBOSIS/OBSTRUCTION

Transverse Grayscale Image (With/Without Transducer Compression)	Spectral Doppler Waveform (Spontaneity, Flow, Augmentation)
• Common femoral vein • Saphenofemoral junction • Proximal femoral vein • Mid femoral vein • Distal femoral vein • Popliteal vein • Posterior tibial vein • Peroneal vein	• Right and left common femoral veins • Popliteal vein • Additional as required per protocol

Note: Additional images to document areas of suspected thrombus: the gastrocnemius veins, soleal veins, and superficial veins (when clinically relevant) and symptomatic superficial veins/varicosities (areas of pain and tenderness). When identified, superficial venous thrombosis must be documented as (1) name of the involved vein; (2) tributary involvement, if any; (3) thrombus distance from the saphenofemoral junction/saphenopopliteal junction; and (4) additional images (eg, length of thrombus), as required by the protocol.

INSTRUMENTATION, IMAGING TECHNIQUE, AND OPTIMIZATION

Lower extremity venous duplex examinations are performed with a linear array transducer using frequencies of 9 to 12 MHz. These exams require evaluation with

TABLE 2. DOCUMENTATION FOR REFLUX

Transverse Grayscale Image (With/Without Transducer Compression)	Spectral Doppler Waveform	Diameter Measurements (Transverse Grayscale Images)
• Common femoral vein • Saphenofemoral junction • Proximal femoral vein • Mid femoral vein • Distal femoral vein • Great saphenous vein • Popliteal vein • Small saphenous vein junction	• Common femoral vein • Saphenofemoral junction • Great saphenous vein: proximal thigh • Great saphenous vein: at knee • Femoral vein: mid-thigh • Popliteal vein • Anterior accessory saphenous vein (when identified) • Small saphenous vein: junction • Perforator vein waveforms in the setting of active or healed venous ulcer	• Saphenofemoral junction • Great saphenous vein: proximal thigh • Great saphenous vein: knee • Anterior accessory saphenous vein (when identified) • Small saphenous vein: junction
Note: Additional images needed to document areas of suspected reflux and as required by the protocol: (1) spectral Doppler waveforms with the extremity(s) in a dependent position, demonstrating baseline flow and response to distal augmentation; (2) if present, reflux duration of retrograde flow must be measured with calipers and documented as required by the protocol; and (3) transverse grayscale images of diameter measurement must be documented with the extremity(s) in a dependent position.		

grayscale, color flow, and pulsed-wave Doppler modalities. In the grayscale image mode, the ultrasound system settings should be optimized for the depth and location of the target anatomy (Figure 1). The overall gain should be optimized and adjusted to reflect a full range of signals in amplitude of low to high. If the gain is set too high, the signal image detail can be lost. If the gain is set too low and the image is dark, there is a high probability that disease will be missed. Time gain compensation should be used to define the vein walls, and the focal zone should be set at the area of interest.

The linear array transducer is used to compress the vein walls (Figure 2). This maneuver allows for identification of any acute or chronic intraluminal changes (eg, pathology). Vein diameter measurements are obtained in the transverse plane by placing calipers from the outer anterior wall to the outer posterior wall (Figure 2).[2]

The color flow Doppler mode increases the sensitivity of the exam by identifying luminal patency, flow direction, and areas of obstruction. Color flow is used to confirm patency when compression techniques are inadequate. Optimal color gain maximizes wall-to-wall filling, but excessive color gain can "bleed" into the surrounding tissues and obscure disease that is present. Color gain

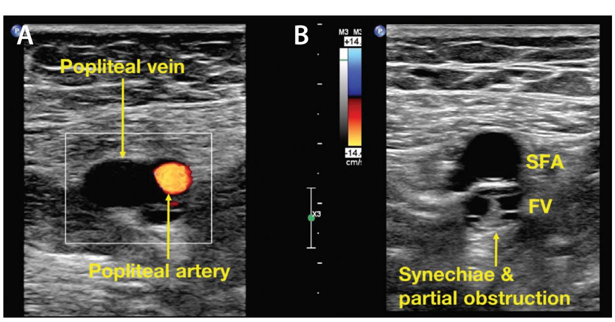

Figure 1. An acute deep vein thrombosis (DVT) that is virtually invisible on grayscale imaging (A) and chronic changes that occur with DVT (B).

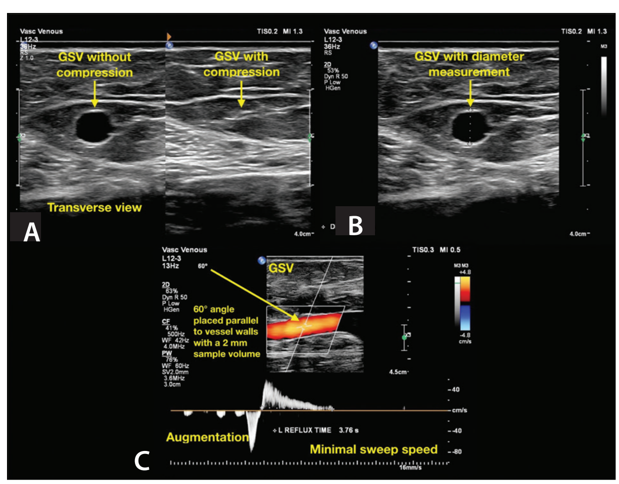

Figure 2. Compression maneuver to document lack of intraluminal thrombosis (A). Diameter measurement from outer wall to outer wall (B). Reflux curve with change in flow direction (above and below baseline) (C).

that is set too low can be misinterpreted as a potential intraluminal defect. The color scale, or pulse repetition frequency, is set from 4 to 14 cm/second with a low to medium wall filter and a medium-high color persistence, depending on the size and condition of the vein being evaluated.

The pulsed-wave Doppler mode quantifies information regarding patency, obstruction, and valvular reflux disease. The venous system typically displays variations in the normal appearance of pulsed Doppler waveforms. This is largely due to changes in respiration, right heart pressures, and the volume and depth of the vessels. Additionally, pulse Doppler waveforms will decrease in amplitude with increasing distance from the heart. When performing the exam, the veins are interrogated in the longitudinal axis plane using a 45° to 60° angle of insonation with a 2-mm sample volume.[3] Pulsed Doppler waveforms demonstrating reflux are measured with calipers on the screen (Figure 2).

In reflux examinations, a slower sweep speed helps delineate valve closure and differentiate it from spectral Doppler background artifact (noise), which could be misinterpreted as reflux. Aliasing artifacts (waveform "wrap-around" effects) related to waveform augmentation occur when the velocity surpasses the Nyquist limit and are eliminated by increasing the Doppler scale and baseline.

In obese patients, a curved array transducer with frequencies ranging from 1 to 5 MHz provides penetration to a depth of 30 cm. Figure 3 demonstrates improved imaging with proper technique and setting optimizations. Table 3 shows the general anatomic distribution of reflux disease.[4-6]

Of note, it is helpful to understand of the patient's clinical presentation. Iliac and other pelvic venous issues can result in venous hypertension and should also be considered in the evaluation.[7]

VALVULAR REFLUX PROTOCOL

The valvular reflux protocol has two distinct aspects: (1) technical performance of the exam and image acquisition and (2) communication of results, typically with a diagram and report to illustrate findings (eg, course of reflux) (Figure 4).

Deep Venous Component of the Reflux Exam

The reflux exam begins with the patient in a 10° to 20° reverse Trendelenburg (RT) position with the knee

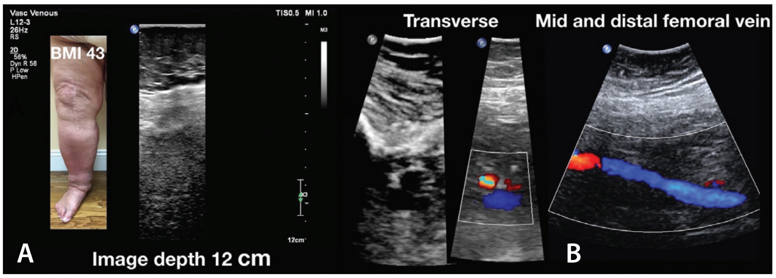

Figure 3. A 3- to 12-MHz linear transducer demonstrating inadequate image penetration and resolution within the thigh from a technically challenging patient (A). Longitudinal and transverse grayscale and color flow images obtained from the same patient using a curved array transducer demonstrating patency of the FV (B). BMI, body mass index.

TABLE 3. DISTRIBUTION OF SAPHENOUS INCOMPETENCE PATTERNS			
	Labropoulos et al[4]	Pittaluga et al[5]	Carrison et al[6]
Great saphenous vein	65%	82.7%	53%
Small saphenous vein	19%	10.9%	28%
Nonsaphenous	9%	6.4%	19%

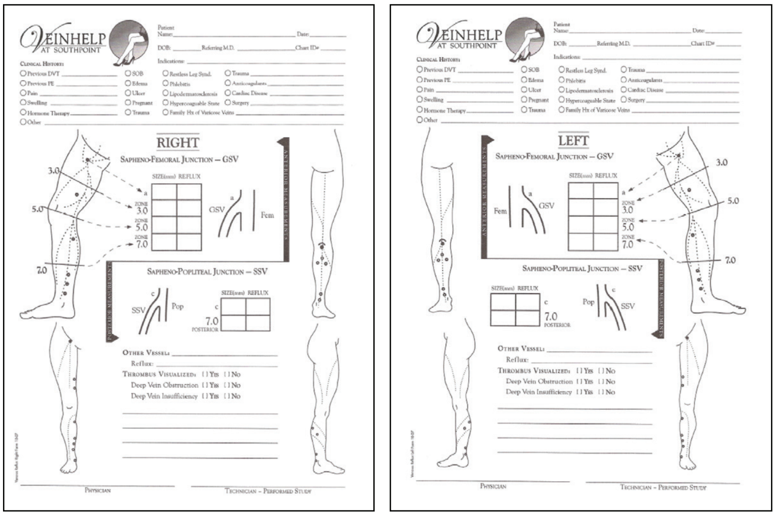

Figure 4. An example of a technical worksheet for chronic venous insufficiency reflux studies.

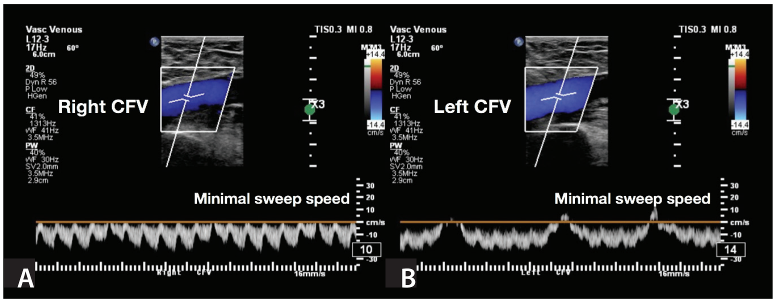

Figure 5. A 62-year-old woman presented with bilateral advanced venous disease. Asymmetric CFV pulse Doppler waveforms acquired during routine chronic venous insufficiency exam noted phasic flow bilaterally; however, the waveform contour was completely different between the right (A) and left (B) sides. Iliocaval duplex evaluation demonstrated significant bilateral compression by the overlying artery.

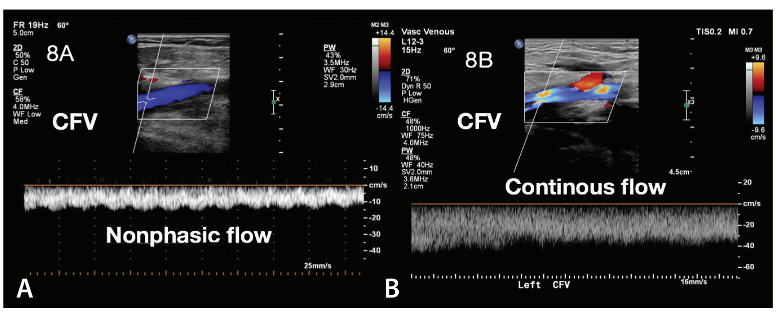

Figure 6. CFV nonphasic pulse Doppler waveform obtained from a 53-year-old woman with hyperpigmentation at both ankles (A). Duplex ultrasound revealed a 14- X 12- X 21-cm uterine tumor causing vein compression. A continuous pulse Doppler flow pattern was identified at the CFV level in a patient with significant left-sided postthrombotic disease (B).

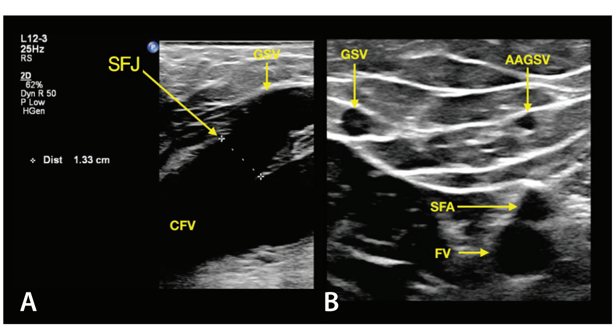

Figure 7. SFJ with a diameter measurement (A). The "alignment sign" of the AAGSV lies within its own compartment and aligns with the SFA and FV (B).

of the leg being examined slightly bent and externally rotated. In the transverse axis plane, the deep veins are identified below the inguinal ligament at the common femoral/saphenofemoral junction (SFJ) level. The transducer is advanced caudally with compression maneuvers every 1 to 2 cm; documentation includes a transverse grayscale image of the common femoral vein (CFV), the mid femoral vein (FV), and popliteal vein (PV) with and without coaptation (compression). In the longitudinal plane, pulsed Doppler waveforms are required for the bilateral CFVs, mid-FV, and PV; these same pulsed Doppler locations are also interrogated in a dependent position for deep vein reflux. In the presence of acute DVT or chronic intraluminal changes, additional images are required to document the exact location, extent, and severity of the disease. Of note, FV and PV duplications occur at a rate of 26% and 37%, respectively.[8]

When examining the right and left CFVs, pulsed Doppler waveforms are obtained to observe the symmetry of venous flow between sides (Figure 5). Asymmetric phasic CFV waveforms suggest proximal obstruction; however, symmetric phasic waveform patterns do not rule out proximal obstruction. Nonphasic or continuous CFV pulsed Doppler waveforms are indicative of obstructive disease or mass compression (Figure 6).

Patients with advanced disease (CEAP [clinical, etiology, anatomy, pathophysiology] clinical class 3–6) should be evaluated for iliocaval obstruction. Sloves and Almeida described the use of venous duplex ultrasound to evaluate iliocaval disease based on image optimization.[9]

The evaluation of the superficial venous system is performed in the standing position.[10] If testing is limited by the patient's physical ability, it may be performed in a steep RT position (at least 60°).[11] With the patient standing, the majority (approximately 70%) of the patient's weight should be on the contralateral leg, which allows for relaxation of the musculature and venous reservoir of the limb being examined.

REFLUX STUDY STEP BY STEP

Step 1: Above-Knee GSV and AAGSV Evaluation

The great saphenous vein (GSV) reflux evaluation begins at the above-knee segment. Starting at the SFJ level, the terminal and preterminal valves are evaluated for reflux and the SFJ diameter is measured. The transducer is then advanced caudally through the GSV while obtaining diameter measurements and reflux times at the proximal, mid, and knee levels. In addition, the GSV is evaluated for areas of tortuosity, aneurysm, and post-thrombotic changes. An abrupt change in diameter of the GSV within the compartment usually indicates where reflux begins or ends.[12] The incidence of GSV duplication is 2%,[13] and aplasia of the GSV is noted in approximately 16% of cases.[14] Diameter and reflux determinations for the SFJ are described in Table 2 and illustrated in Figure 7A.

After above-knee GSV thigh mapping, the anterior accessory GSV (AAGSV) is evaluated. The AAGSV is located within its own compartment just lateral to the GSV, with both veins often terminating at a common trunk of the SFJ. The AAGSV aligns and is parallel with the FV and superficial femoral artery (SFA), deep femoral artery, and profunda femoris vein. This "alignment sign" helps identify the AAGSV (Figure 7B).

The posterior accessory GSV (PAGSV) is evaluated throughout its course and is documented if it is abnormal. Once the saphenous system in the thigh is documented, investigation into any epifascial vessels may be carried out. Typically, any tributary with a diameter < 50% of the native saphenous vein can be disregarded in the absence of other suggestive pathology (ie, the "50% rule").[12] Other findings such as bulbous areas, large tributaries, and significant (> 3.5 mm) perforators are examined.

Step 2: Below-Knee GSV and PAGSV Evaluation

The next step is to evaluate the below-knee GSV. In the transverse orientation, the GSV can be followed within the sheath cranially to the knee level. At least one diameter measurement and reflux time should be obtained at the midcalf level. Another important part of this exam is assessment of the PAGSV. Previously called the "posterior arch" vein, this vein is the typical location where the ankle (Cockett) perforators connect to the posterior tibial veins. Of interest, this is the area where a majority of venous stasis ulcers occur. The paratibial (Boyd) perforators connect directly to the GSV as it courses slightly anterior just below the knee. Vein diameters and reflux times should be documented and added to the technical worksheet.

Step 3: SSV Evaluation

Interrogation of the small saphenous vein (SSV) begins in the transverse plane at the proximal calf with identification of the saphenopopliteal junction (SPJ), measuring vein diameter and reflux times with pulsed Doppler. The location of the junction varies from 11% to 25% in different studies and is usually 4 to 5 cm above the popliteal crease.[15,16] Similar diameter and reflux determinations

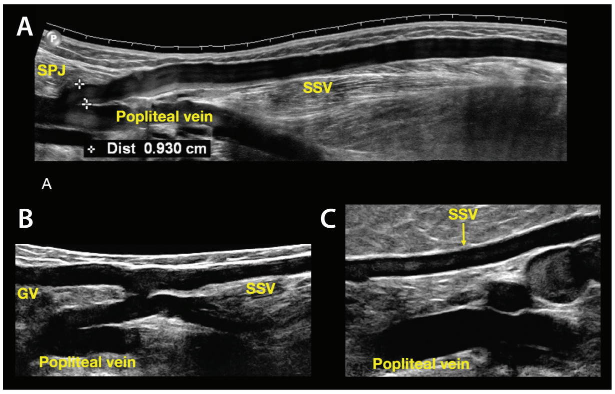

Figure 8. Saphenopopliteal (SPJ-SSV) variations. Panoramic view of the SPJ and SSV with diameter measurement (A). SSV with extension to the Giacomini vein (B). The SSV continues as the Giacomini vein, with no attachment to the PV (C).

are made at the midcalf level. The sonographer needs to be aware of crossover patterns between GSV and SSV networks, as described by Obermeyer and Garzon, especially when there is no SPJ reflux and reflux is found at midcalf or below.[17] The posterior thigh is examined for thigh extension, seeking to determine which of the four possible terminations exists, only one of which is the Giacomini vein, when present. Variations of SSV anatomy are shown in Figure 8.

Step 4: Perforator Vein Evaluation

For hemodynamic purposes, perforating veins are subdivided into above-knee and below-knee segments. In most cases, the above-knee perforator (eg, the SFJ) can be an "escape" perforator, where higher pressure from the deep system causes blood to exit into the superficial veins and cause reflux. Conversely, below-knee perforators can be either an escape perforator or a terminal perforator. A terminal or "reentry" perforator is simply a pathway for descending superficial reflux to reenter the deep system. Flow direction and diameter of the fascial defect, as well as outward flow > 0.5 seconds with a diameter of > 3.5 mm, can indicate incompetent perforators; perforators adjacent to ulcerated areas have been termed pathologic.[18] For documentation, measurement of a perforator should be done at the level of the deep fascia.

Step 5: Evaluation for Other Varicosities

Nonsaphenous pathology can originate from multiple sources. Pelvic sources or "leaks" can result in varices of the upper posterior thigh or medial to the SFJ, including vulvar veins. Any other varicosities without an obvious source require direct interrogation, so it is important to scan directly over the varicosity with light probe pressure and trace the veins proximally and distally. Typically, the

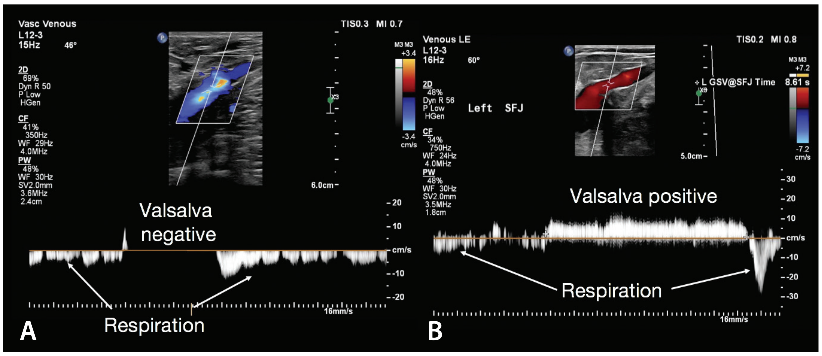

Figure 9. Normal (A) and abnormal (B) Valsalva maneuver results. Pulsed-wave Doppler: normal response to Valsalva, no flow with exertion (A) and abnormal response to Valsalva, reverse flow above baseline (B).

varices will increase in size as one is moving toward the source of reflux. It should be emphasized that ultrasound findings are operator dependent, and communication with the interpreting physician leads to the best results.

KEY FACTORS FOR CONSIDERATION

Definition of Venous Reflux and Importance of Patient Position

Venous reflux is commonly defined as retrograde flow > 0.5 seconds in the superficial system and > 1 second in the femoral or popliteal segment.[19] Spectral Doppler tracings allow for determination of "duration of time," and these "frozen" tracings allow for use of calculations in which the operator places calipers to determine duration. Accuracy in caliper placement, lack of noise, and understanding of the waveforms are necessary for accurate determinations of reflux.

In their pivotal 2013 work, Carty et al evaluated RT and standing positions for superficial venous reflux, noting that reflux duration in the RT position was longer (by a factor of > 2.8) compared with the standing position.[20]

Compression/Augmentation Maneuvers

Compression or augmentation maneuvers during a venous exam influence venous flow. There are two preferred methods of compression/augmentation; one is manual compression over the distal venous reservoir, and the other uses a rapid inflation/deflation cuff system. The rapid inflation system allows for standardization and improved ergonomics and is therefore recommended in standard practice. Compression proximal to the interrogating probe can produce false reflux over the length of the compression and is strongly discouraged, especially for superficial veins.

The Valsalva maneuver is often challenging for a patient to properly perform. There are three phases: normal flow, application of the force (or augmentation), and return to normal flow (Figure 9).

CONCLUSION

Our understanding of the venous system and its imaging by duplex ultrasound has grown in the past 2 decades. Diagnostic venous duplex protocols and documentation requirements are presented, as well as key concepts for considerations such as hemodynamics, anatomy, and other factors that influence clinical diagnosis and treatment. The step-by-step protocol is important, especially for standardization of process, awareness, and because educational gaps exist. Diagnostic sonography exam is operator-dependent. The technical and anatomic concepts presented herein address this knowledge gap and allow for better clinical correlation of the exam with patient pathology and salient findings. ■

To watch an accompanying video demonstrating these techniques, please view this article on our website at **www.evtoday.com**.

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