Evaluation the venous pathology of the lower extremities with triggered angiography non-contrast-enhanced sequence magnetic resonance imaging (TRANCE-MRI)

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Research article

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Abstract

Background To explore the diagnostic performance of non-contrast-enhanced magnetic resonance imaging using triggered angiography non-contrast-enhanced sequence (TRANCE-MRI) in evaluation of venous pathology of the lower extremity. Methods This is a single-center prospective cohort study of 25 patients with suspected venous disease in their lower extremities. Each patient received a Doppler ultrasound exam before the scheduled TRANCE-MRI on a 1.5T MR scanner (Philips Ingenia, Philips Healthcare, Best, The Netherlands). The following lymphography and CTA were arranged according to the diagnostic indications. Results The venous scenarios of the 25 patient were divided as follows: 11 had deep venous thrombosis (DVT), seven had a static ulcer, three had symptomatic varicose veins (VV), two had recurrent VV after surgery, and two had lymphedema. TRANCE-MRI unexpectedly found that 4 patients (16%) had occult peripheral arterial occlusive disease. Of the 11 patients with scenario of DVT, 4 patients (36.4%) did not actually have DVT on TRANCE-MRI, and the symptoms were due to malignancy, external compression, and congenital anomalies. One patient (4%) with radiation-related lymphedema was falsely diagnosed as external iliac vein compression. Interrater agreement for DVT in the thigh between the ultrasonography and TRANCE-MRI was substantial agreement (Cohen's kappa κ, 0.72). The sensitivity, specificity and accuracy of TRANCE-MRI were 85.7%, 88.9% and 88%, respectively. Venous thrombi and collateral veins could be clearly outlined by TRANCE-MRI, including in middle femoral veins that might be difficult to detect by ultrasound. Conclusion TRANCE-MRI provided not only vascular image of the lower extremity but also information about the pelvis and abdomen. However, false positive results may occur in iliac vessels. TRANCE-MRI could outline venous thrombi and collateral veins from the abdomen to both calves, and thus, could be a powerful tool in the treatment of venous pathology in the lower extremities.

Background

Venous pathology in the lower extremities is a critical public health problem with economic and social consequences. It includes scenarios from minor varicose veins (VV) and annoying venous static ulcers (SU) to potentially deadly deep vein thrombosis (DVT).[1-3] Ultrasonography (US) is used for routine initial evaluation of the venous system in the lower extremities. Previously, conventional venography had been considered the gold standard for detection of DVT in patients with VV.[4, 5] However, this procedure is time-consuming, invasive, and requires the use of ionizing radiation. Although computed tomographic (CT) venography is less invasive than conventional venography, it still requires contrast media plus radiation exposure, and the quality of the image is not as high as CT arteriography.[5, 6]

Magnetic resonance venography (MRV) with use of contrast media has been revealed as highly sensitive for detecting pathology in a variety of blood vessels when compared with conventional angiography. Magnetic resonance imaging (MRI) does not involve radiation exposure but the magnetic resonance contrast agents still have undesirable effects. Nephrogenic systemic fibrosis (NSF) is a common complication of using gadolinium-based contrast agents in patients with pre-existing impairment of kidney function.[7-9] TRiggered Angiography Non-Contrast Enhanced (TRANCE) is a
technique, which exploits differences of vascular signal intensity during the cardiac cycle for subsequent image subtraction, providing not only venogram but also arteriogram without use of contrast agents. TRANCE-MRI has been used in patients with renal insufficiency and vascular diseases; however, few applications of this technique in the venous pathology of the lower extremities can be found. [10-12]

Methods

Subjects

The Institutional Review Board (IRB) of Chang Gung Memorial Hospital approved this study (IRB number: 201700389B0). We prospectively collected information on consecutive patients who had been evaluated by TRANCE-MRI for venous pathology in their lower extremities at a vascular wound care center of a tertiary hospital between April 2017 and March 2018. Patients were eligible for inclusion in the study if they had a clinical indication for computed tomography angiography (CTA) of the pelvic and leg vessels. Each patient was suspected to have venous pathology in their lower extremities. Exclusion criteria were non-MRI-compatible ferromagnetic devices and pregnancy. In addition, patients with poor compliance and patients with multiple comorbidities that prevented them from lying down for the 1-hour protocol of the TRANCE-MRI were excluded. There are 30 patients were evaluated initially. One patient was excluded due to possible pregnancy and the other was unable laydown owing to complicated spine disease. In 28 patients who scheduled of TRANCE-MRI examination, two patients were morbidly obese which could not go through the MRI scanner. One female patient failed to complete TRANCE-MRI owing to her restless legs. There were 16.7% patients (5/30) excluded from this TRANCE-MRI study. All patients received a non-invasive color Doppler exam for venous status of their lower extremities before the scheduled TRANCE-MRI. The Doppler exams performed in supine position. The femoral veins, great saphenous vein, popliteal veins and perforating vein in calves were checked. Pelvic veins were not included in the Doppler exams. Lymphoscintigraphy by Tc-99m phytate and CTA were arranged according to the diagnostic indications. We used ultrasonography and TRANCE-MRI to assess DVT in the thigh. Cohen's kappa coefficient was used to measure interrater agreement between ultrasonography and TRANCE-MRI. To evaluate the sensitivity, specificity, and accuracy of TRANCE-MRI, ultrasound was determined as true condition because it already exists in the gold standard.

MRI acquisition

MR imaging was acquired with a 1.5T MR scanner (Philips Ingenia, Philips Healthcare, Best, The Netherlands). Patients underwent imaging in a supine position and with Peripheral Pulse Unit (PPU) trigger. All images of the arterial systems were evaluated by three-dimensional (3D) turbo spin-echo (TSE) at systole and diastolic period. In the imaging with the TSE TRANCE, the following ranges of parameters were used: repetition time (TR), 1 beats; echo time (TE), shortest; flip angle, 90°; voxel size, 1.7 x 1.7 x 3mm field of view (FOV), 350 x 420. In systole, arterial blood is flowing fast. This causes dephasing of the signal and leads to flow voids; thus, the arteries were black with systolic triggering. In diastole, blood
flow in the arteries is slow. The signal does not dephase; thus, the arteries were bright on the diastolic
scans. Subtraction of the two phased scans will make up a 3D data set with only arteries. Another one
images of the venous systems were evaluated by 3D TSE Short tau inversion recovery (STIR) at systole
period. In the imaging with the TSE STIR TRANCE, the following ranges of parameters were used: TR, 1
beats; TE, 85; inversion recovery (IR) delay time, 160; voxel size, 1.7 x 1.7 x 4mm; FOV, 360 x 320. STIR
provides extra background suppression because fat and bones are also suppressed. With systolic
triggering, the arteries were black. The result was a dataset using TRANCE-MRI in the venous system in
which no subtraction was required. The Quantitative Flow (Q-Flow) scan was routinely performed to
determine the appropriate trigger delay times for systolic and diastolic triggering. The Figure 1
summarizes the principle of TRANCE-MRI technique. All the images were acquired without use of
gadolinium contrast medium (Figure 2). The TRANCE-MRI protocol requires 60 minutes for imaging
acquisition, 25 minutes for MRV, and 35 minutes for MRA.

Results

Between April 2017 and March 2018, 25 patients were enrolled in this study and evaluated using
TRANCE-MRI for venous pathology in their lower extremities at a vascular wound center in a tertiary
hospital. These 25 patients were classified into four different venous scenarios: deep vein thrombosis
(DVT), static ulcer (SU), symptomatic varicose veins (symptomatic VV) and recurrent varicose veins after
venous surgery (recurrent VV). For example, those patients present with typical clinical figures (sudden
swelling legs, history of recent trauma and surgery) and physical examination (dark skin color, pitting
edema, no cracking /flaking change on the skin) . Their venous scenarios were classified as DVT whilst
enrolled into this study. The descriptive characteristics of this population are listed in Table 1. The venous
scenarios from the vascular wound center were DVT in 11 patients (44%; Figure 3), static ulcers in seven
patients (28%), symptomatic VV in three patients (12%), recurrent VV after surgery in two patients (8%),
and possible lymphedema in two patients (8%). Nine patients had undergone relevant surgeries, such as
stripping of the great saphenous vein (GSV), truncal ablation of the GSV, axillo-femoral arterial bypass,
hip replacement, flap reconstruction for severe crushing injury, and hysterectomy for cervical cancer,
before coming to the vascular wound center. All 25 patients were evaluated by Doppler scan for leg veins
and TRANCE-MRI for both venous and arterial systems. Interrater agreement for DVT in the thigh between
the ultrasonography and TRANCE-MRI was substantial agreement (Cohen's kappa κ, 0.72). The
sensitivity, specificity and accuracy of TRANCE-MRI were 85.7%, 88/9% and 88%, respectively. A patient
was diagnosed partial occlusion of right femoral vein on ultrasonography, but negative finding on
TRANCE-MRI. Two patients had negative finding on ultrasonography, but were noticed small thrombi on
TRANCE-MRI. Three patients had a CT scan with contrast media injection. One patient had suspected
radiation-related lymphedema and received radionuclide lymphoscintigraphy and a venogram to confirm
the diagnosis. Notably, in four patients, occult peripheral arterial occlusive diseases were found
accidently by TRANCE-MRI of the arterial system.

Details of the age, sex, imaging findings of TNACE-MRI and other studies were summarized in
Table 2. The patients who presented with DVT were older and may have received warfarin at the referral
visit. The case 24 classified as having lymphedema had an asymmetric swollen thigh with hardened skin for years. Ten patients were proven to have DVT by TRANCE-MRI, including two cases of iliac vein thrombosis. Notably, TRANCE-MRI accidentally identified two cases of PAOD. In the remaining four patients, cases 8 through 11, venous congestions in the lower extremities were attributed to external compression and congenital anomaly. One patient, case 8, had external iliac veins that were compressed by enlarged lymph nodes and was then diagnosed with advanced prostate cancer. In cases 9 and 10, venous congestions were caused by external compression from hip prosthesis with osteomyelitis and joint effusion. The venous congestion of the lower extremities may have been caused by a double inferior vena cava in case 11 (Additional file 1).

Of the seven patients with SU, five of them, cases 12 through 16, were related to venous pathology, including severe VV and chronic DVT. SU were caused by poor lymph drainage after complicated reconstructed surgery in case 17. In case 18, the unhealed wound was attributed to subacute occlusion of the left axillo-femoral arterial bypass. Three patients with symptomatic VV, including claudication, repeat cellulitis, and bleeding, were evaluated by TRANCE-MRI, and two of them were treated by truncal ablation of the GSV plus sclerotherapy. Cases 22 and 23 had truncal ablation and stripping of varicose GSVs at other institutions and were evaluated by TRANCE-MRI for recurrent venous claudication. Both had diffuse collateral veins in both lower limbs with occluded GSVs. Two patients were evaluated by TRANCE-MRI for lymphedema in their lower extremities. One patient, case 24, had typical radiation-related lymphedema after treatment for cervical cancer and had a venous system evaluation by TRANCE-MRI for a scheduled lymph node transfer by the plastic surgeon. TRANCE-MRI of the venous system revealed equivocal interruption of the left common iliac vein. Conventional venography and testing balloon angioplasty was performed with a 14-mm balloon. High-grade lesions were not present over the left common iliac vein and the symptom of morbid limb did not improve after angioplasty. The left thigh and calf shrank significantly after laparoscopic lymph node harvest and lymph node transplantation in the ankle.

**Discussion**

Venous pathology in the lower extremities may be suspected in patients with engorged calf veins, unhealed shadowing wounds, and asymmetrically swollen legs. [1, 3, 13] US is operator-dependent, time-consuming, and inadequate at providing information about the pelvic and abdominal areas. Conventional venography has been considered the gold standard for detection of DVT in patients with VV; however, it is invasive, time-consuming, and requires the use of radiation plus contrast media. [5, 14] Although CT venography is useful for exclusion of pulmonary embolism in patients with signs of thrombosis in the legs, it still cannot replace US as the first line image for detecting DVT. [15-18] MRI with contrast media, or time-of-flight (TOF) MRV, has been revealed as highly sensitive for detecting pathology in a variety of blood vessels when compared with conventional angiography. In TOF-MRV, blood flow is used as the intrinsic contrast agent and signal is based on an in-flow effect. The signal in the vessel depends on the flow up to a threshold speed, which is calculated by the slice thickness, in mm, divided by repetition time, in ms. However, the vessels can be observed most clearly when they are orthogonal to the two-dimensional plane, because in-plane vessels sometimes experience loss of signal. [19-21] In summary,
TOF-MRV is less invasive than conventional venography and CT venography, avoids the side effects of iodinated contrast material such as renal damage, and is less operator-dependent than US. The main disadvantage of TOF-MRV is that the FOV is small for each image acquisition and need much time to obtain a whole image of the lower extremity. MRI with gadolinium-based contrast media is an alternative and relatively rapid method for imaging lower extremity. Although MRI does not involve radiation exposure, the non-iodinated contrast agents involved still have undesirable effects. NSF is a common complication of gadolinium-based contrast agents in patients with pre-existing impairments of kidney function.[7, 8] The TRANCE technique in MRI, which exploits differences in vascular signal intensity during the cardiac cycle with subsequent image subtraction, was first described by Wedeen in 1985.[22] TRANCE-MRI has been applied in cranial neurologic diseases and arterial diseases; however, few applications of this technique in venous pathology in the lower extremities can be found. [19, 23-26]

The principle of TRANCE-MRI technique is that different blood flow velocities will have different signal intensities on TSE sequence. High signal intensity, as well as bright color, reflects slow velocity, such as venous blood flow and diastolic arterial blood flow. The high velocity of systolic arterial blood flow will result in a flow void effect and is dark, as well as low signal intensity. TRANCE MRI can present high resolution and isolated vascular structures, such as arteries or veins. Presenting only the venous structure without accompanying the arterial structure is difficult to be achieved on MRI or CT with use of contrast medium, because the proper acquisition time is short and variable. Therefore, TRANCE MRI is a useful tool for venous pathology of the lower extremities because it provides additional pelvic information, no contrast agents, and no radiation toxicity. This study highlight that TRANCE MRI may be a safe and useful tool for lower extremity imaging, especially venous pathology. TRANCE-MRI may be preferred in patients with chronic renal insucency, history of abdominal/pelvic/orthopedic surgery and allergy to contrast media.

In this study, we do not specifically describe how to distinguish between acute and chronic thrombosis. Distinguishing acute from chronic DVT is a potential advantage of MRI, with irregular wall thickening in the presence of collaterals and diminutive lumen suggestive of chronic DVT. Our MRI protocol provide coronal and axial images, as well as 3D MRA and MRV images. We will use the original unremoved background image to examine possible tumors or other causes of compression for all vascular lesions. (Figure 4). TRANCE-MRV showed that many subjects had equivocal interruption of the left common iliac vein, but no venous thrombosis, collateral vessels or related symptoms. This may be because the left is located between the right common iliac artery and the spine, which is an anatomically relatively narrow location (Figure 5).

Several advantages of TRANCE-MRI application in venous pathology in the lower extremities exist. First, TRANCE-MRI provides not only images of the arteries and veins in the lower extremities but also information on the pelvis and abdomen, which is valuable in patients with a venous scenario of DVT. DVT may be mistaken as external compression of the pelvic vessels. Moreover, it is notorious as a sign of occult malignancies. Among the 11 patients with a venous scenario of DVT, four of them (36.4%) had no DVT and the symptoms were attributed to malignancy, external compression by degenerated hip
prosthesis, external compression by knee effusion, and congenital anomaly. Second, the thrombi and collateral veins can be clearly outlined, including middle femoral veins that might be difficult to detect by US. This may be helpful in catheter-based thrombolytic therapy and rescue therapy in recurrent VV after truncal ablations of GSV. Finally, because TRANCE-MRI has no radiation and does not use contrast media, it is safe for patients with impaired renal function.

Compared with TRANCE-MRI, ultrasonography played a relatively small role in assessing varicose veins of the lower extremities and deep veins of the pelvis and abdomen. We still consider that ultrasound should be used preferentially when assessing venous lesions in the lower extremities because it is non-invasive and cost-effective. TRANCE-MRI is a non-invasive examination without use of contrast medium, which provide not only images of the arteries and veins in the lower extremities but also information about the pelvis and abdomen. If a patient has a pelvic vein problem or complicated varicose veins before surgery, we recommend an MRI.

We did learn of some drawbacks to TRANCE-MRI from this study. First, TRANCE-MRI of the venous system may cause a false positive in the left iliac vessels, which could be attributed to the complex anatomy and overlapping of the vessels with different blood flow directions. Other observations, such as increasing diameter and number of collateral veins, constant filling defect, and application of intravascular ultrasound, may decrease the risk of incorrect diagnosis. Second, the TRANCE-MRI protocol requires 60 minutes for imaging acquisition, 25 minutes for MRV, and 35 minutes for MRA. Thus, it is not suitable for critical and irritable patients. We suggest that the MRI protocol should be determined according to the patient's condition, and it is not necessary to perform the whole TRANCE-MRI protocol. Lastly, TRANCE-MRI is expensive and not widely used at our institution yet.

The major limitation of this investigation was that it was a nonrandomized study with few patients. This study also limited with lacking in comparison of inter-observer variability and adequate validation with other image studies. However, we attempted to identify the values and pitfalls of TRANCE-MRI in venous pathology. This was the first prospective study to apply TRANCE-MRI for assessing venous pathology in the lower extremities. Further evaluation of pelvic/abdominal assessment and accuracy for TRANCE MRI is needed before versatile clinical applications. The TRANCE-MRI may provide more useful information regarding optimal therapeutic protocols in treating complicated vascular diseases.

Conclusions

TRANCE-MRI provided not only images of the arteries and veins in the lower extremities but also information about the pelvis and abdomen. However, false positive results may occur in iliac vessels. TRANCE-MRI could outline venous thrombi and collateral veins from the abdomen to both calves, and thus, could be a powerful tool in the treatment of venous pathology in the lower extremities.

Abbreviations
3D=three-dimensional, CT=computed tomography, CTA=computed tomography angiography, DVT=deep venous thrombosis, FOV=field of view, GSV=great saphenous vein, IR=inversion recovery, IRB=institutional review board, MRI=magnetic resonance imaging, MRV=magnetic resonance venography, NSF=nephrogenic systemic fibrosis, Q-Flow=quantitative flow scan, STIR=short tau inversion recovery, TE=echo time, TOF=time-of-flight, TR=repetition time, TRANCE-MRI=triggered angiography non-contrast Enhanced MRI, TSE=turbo spin-echo, US=ultrasonography, VV=varicose vein, SU=static ulcer,

Declarations

Ethics approval and consent to participate:

The study was approved by the Institutional Review Board (IRB) of Chang Gung Medical Foundation, in accordance with the ethical standards of the responsible committee on human experimentation (IRB Nos. 201700389B0).

Consent for publication:

This original study was approved by the Chang Gung Medical Foundation IRB. Written informed consent forms for publication from study participants were obtained for all patients.

Availability of data and materials:

The dataset(s) supporting the conclusions of this article is(are) included within the article (and its additional file(s)).

Competing interests:

The authors declare no competing financial interests.

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Authors’ contributions:

YKH, YHT, CHL and CWC designed the study. YKH, YHT, CHL, SCW, YCH and CWC are involved with methodology and data analysis. YKH, YHT, SCW, YCH and CWC are involved with writing the manuscript. YKH and CWC were responsible for the study conception, design, data analysis and drafting of the manuscript. All authors read and approved the final manuscript.

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### Tables

**Table 1.** Summary statistics (n=25)

| Variables                                                                 | % (mean±SD) |
|---------------------------------------------------------------------------|-------------|
| Gender - Male                                                              | 19 (76%)    |
| Age (years)                                                               | 62±13.94    |
| Venous scenario for vascular wound center                                 |             |
| Deep vein thrombosis                                                      | 11 (44%)    |
| Venous static ulcer                                                       | 7 (28%)     |
| Symptomatic varicose vein                                                 | 3 (12%)     |
| Recurrent varicose vein                                                   | 2 (8%)      |
| Lymphedema                                                                | 2 (8%)      |
| History of venous, arterial reconstructed and other related procedure      |             |
| Stripping of GSV                                                          | 2 (8%)      |
| Truncal ablation of GSV                                                   | 3 (12%)     |
| Left axillo-femoral arterial bypass graft                                 | 1 (4%)      |
| Total hip replacement                                                     | 1 (4%)      |
| Free flap for left leg crushing injury                                     | 1 (4%)      |
| Hysterectomy plus radial therapy                                          | 1 (4%)      |
| Image survey in vascular wound center                                     |             |
| TRANCE MR in venous system                                                | 25 (100%)   |
| TRANCE MR in arterial system                                              | 25 (100%)   |
| Doppler scan in venous system                                             | 25 (100%)   |
| Computed tomography with contrast media                                   | 3 (12%)     |
| Radionuclide lymphoscintigraphy                                           | 1 (4%)      |
| Venogram (for angioplasty)                                                | 1 (4%)      |
| Coexisted leg arterial disease (by TRANCE MR)                             | 4 (16%)     |

GSV: greater saphenous vein; TRANCE MR: triggered angiography non-contrast-enhanced sequence magnetic resonance imaging
**Table 2. Finds of TRANCE MRI (artery and venous system) and other image studies**

| No | Age/Sex | TRANCE MRI                                      | Other image study                                                                 |
|----|---------|-------------------------------------------------|-----------------------------------------------------------------------------------|
| 1  | 69/M    | DVT in left FV                                   | Doppler: DVT in left thigh.                                                        |
| 2  | 55/M    | DVT in left EIV                                  | Doppler&CT: no thrombosis.                                                         |
| 3  | 59/M    | DVT in left PV                                   | Doppler: DVT in left PV.                                                           |
| 4  | 72/F    | DVT in the left FV                               | Doppler: DVT in the left FV.                                                       |
| 5  | 57/F    | Right EIV occlusion with collaterals             | Doppler&CT: no thrombosis.                                                         |
| 6  | 78/M    | DVT in left FV                                   | Doppler: DVT in left FV.                                                           |
| 7  | 74/F    | DVT in left CIV, EIV, PV, ATV and PTV; PAOD in left CFA and SFA | Doppler: DVT in left thigh and calf.                                                |
| 8  | 84/M    | Both EIVs compression by metastatic lymph nodes; PAOD in left ATA | Doppler: no DVT.                                                                  |
| 9  | 74/M    | Left FV compression by hip prosthesis with osteomyelitis | Doppler: no DVT.                                                                  |
| 10 | 72/F    | Left PV compression by knee effusion             | Doppler: no DVT.                                                                  |
| 11 | 78/M    | Double IVC                                       | Doppler: no DVT.                                                                  |
| 12 | 53/M    | Varicose veins of left SSV                       | Doppler: prominent calf perforating varicose veins.                                |
| 13 | 34/M    | Collateral veins from medial calf to medial thigh, with pelvic collateral vein | Doppler: no DVT.                                                                  |
| 14 | 68/M    | Small left PV and thrombosis in left PTV, subcutaneous swelling of left leg | Dopplex: venous insufficiency of both FVs.                                          |
| 15 | 60/M    | Right FV and PV occlusion; PAOD in right ATA and PTA | Dopplex: venous insufficiency of both FVs.                                          |
| 16 | 78/M    | DVT from EIV to PV in left leg                   | Doppler: DVT in left thigh.                                                        |
| 17 | 55/M    | no DVT; no PAOD                                  | Doppler: no DVT.                                                                  |
| 18 | 65/M    | Varicose vein of left calf; occluded left axillofemoral bypass graft | Doppler: no DVT.                                                                  |
| 19 | 38/M    | Varicose veins of both GSVs                     | Dopplex: both GSVs insufficiency.                                                   |
| 20 | 38/M    | Varicose veins of right GSV                      | Dopplex: right GSV insufficiency.                                                   |
| 21 | 54/F    | Varicose vein in left GSV                        | Doppler: left GSV insufficiency.                                                    |
| 22 | 50/F    | Varicose veins of both legs                     | Dopplex: DVT in left FV.                                                           |
| 23 | 45/M    | Varicose veins over right leg                    | Dopplex: no DVT.                                                                  |
| 24 | 65/M    | Equivocal interruption of left CIV, diffuse subcutaneous swelling | Dopplex&CT: no DVT.                  |
|    |         | Lymphoscintigraphy: lymphedema.                  |                                                                                   |
| 25 | 75/M    | Subcutaneous swelling of left leg, no DVT.       | Dopplex: no DVT.                                                                  |

ATA=anterior tibial artery; ATV=anterior tibial vein; CFA=common femoral artery; CFV=common femoral vein; CIV=common iliac vein; DVT=deep venous thrombosis; EIV=external iliac vein; FV=femoral vein; GSV=greater saphenous vein; IVC=inferior vena cava; PAOD=peripheral arterial occlusive disease; PV=popliteal vein; PTV=posterior tibial vein; SFA=superficial femoral artery; SSV=small saphenous vein.

**Figures**
Summarized principle of TRANCE-MRI technique All images of the arterial systems were evaluated by 3D TSE sequences at systole and diastolic period. In systole, arterial blood is flowing fast and leading to flow voids. Subtraction of the two phased scans will make up a 3D data set with only arteries. Another one images of the venous systems were evaluated by 3D TSE STIR at systole period. STIR provides extra background suppression because fat and bones are also suppressed.
Figure 2

TRANCE MRA and MRV images TRANCE-MRI was performed on an elder patient. MRA showing arterial patency of bilateral lower extremities. MRV showing a large varicose vein along the right greater saphenous vein.
Figure 3

Deep vein thrombosis (DVT). Coronal (A) and axial (B) images showed poor opacification of left femoral vein (FV), consistent with DVT. Doppler ultrasound also showed the same result (C).
Figure 4

Multiplanar MRI was helpful for comprehensive diagnosis. Our MRI protocol provide coronal and axial images, as well as 3D MRA and MRV images. (A) High signal intensity reflects slow venous (v) blood flow in TSE sequence. In contrast, the flow void effect reflects a very high velocity of systolic arterial (a) blood flow. (B) 3D TSE STIR sequence triggered in diastole shows both venous and arterial structures with background subtraction. A retroperitoneal tumor (t) was observed in the left iliopsoas region, causing venous compression but still maintaining arterial patency. Coronal (C) and axial (D) images were then be examined for comprehensive diagnosis.
Figure 5

TRANCE-MRV showing interruption of the left common iliac vein and May-Thurner syndrome (A) TRANCE-MRV showed that many subjects had equivocal interruption of the left common iliac vein (CIV), but no venous thrombosis, collateral vessels or related symptoms. This may be because the left CIV is located between the right common iliac artery (CIA) and the spine, which is an anatomically relatively narrow location. (B-D) May-Thurner syndrome in a patient with recurrent DVT in the left leg. (B) MRV shows interruption of the left CIV and DVT of left femoral vein. (C, D) MRV and MRA show compression of the left CIV against the lumbar vertebrae by the overlying right CIA.

Supplementary Files

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- supplement1.mp4