

Usefulness of Direct Computed Tomography Venography in Predicting Inflow for Venous Reconstruction in Chronic Post-thrombotic Syndrome

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Abstract

Purpose The purpose of this paper is to assess the applicability of direct computed tomography venography (DCTV) in assessing dominant inflow vein in the femoral confluence in extensive chronic iliofemoral venous obstruction, using venography as the gold standard.

Methods All DCTVs performed in symptomatic patients with previous iliofemoral deep vein thrombosis subsequently submitted to venography in the period from January 2014 to August 2018 were retrospectively reviewed. Two groups were defined depending on whether the femoral vein (FV) or the deep femoral vein (DFV) was the dominant inflow on venography in order to identify predictors of DFV as dominant inflow in DCTV. Statistical analysis was performed with SPSS V25.

Results A total of 30 DCTVs and subsequent venographies were reviewed. Venography identified the FV as the dominant inflow in 18 (60%) and the DFV in 12 (40%) patients. Predictors for DFV as dominant inflow were identified as follows: larger DFV diameter 50 mm and 250 mm below lesser trochanter (8.73 ± 4.34 mm vs. 11.9 ± 3.52 mm; $p = 0.043$ and 5.4 ± 3.90 mm vs.

8.90 ± 2.70 mm; $p = 0.011$); lower FV/DFV ratio 150 mm below lesser trochanter (11.39 ± 20.01 mm vs. 1.05 ± 0.47 mm; $p = 0.043$); and presence of FV scarring/synechiae, collaterals and abnormal wall thickness ($p = 0.003$, $p = 0.003$ and $p < 0.0001$).

Conclusion In cases of extensive chronic iliofemoral venous obstruction, especially when stent deployment into the DFV is entertained, the key to success is thorough pre-procedure planning focusing on choosing the access site. This study suggests DCTV is valuable in defining the dominant iliac vein inflow, but additional findings are necessary to validate these preliminary data.

Keywords Computed tomography angiography · Post-thrombotic syndrome (MeSH) · Diagnosis, differential (MeSH)

Introduction

Chronic post-thrombotic (CPT) syndrome is a debilitating long-term complication following deep vein thrombosis (DVT) [1]. It is particularly common after iliac DVT with 70–80% of patients developing a variable degree of chronic obstruction [2].

When considering endovascular treatment for CPT with ilio caval stenting, a thorough clinical and imaging assessment is mandatory in order to appropriately plan the procedure [3].

The diagnosis of CPT is challenging, and currently there is no ideal imaging method. Phlebography is no longer

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used for routine examination of the venous network of the lower limbs, due to its invasiveness, but remains classified as the “gold standard” [4].

Duplex ultrasound (DUS) combines anatomical data and haemodynamic evaluation of the lower limb veins, but lacks accuracy in abdominopelvic veins [5]. On the other hand, intravascular ultrasound (IVUS) is most suitable for evaluation of large-sized suprainguinal vessels meaning that information about infrainguinal veins will be lacking if used as a sole investigative tool [6].

Regarding magnetic resonance venography (MRV), several studies have shown high-quality imaging of the venous system, from the calf up to the IVC. However, MRV remains an expensive, time-consuming and scarcely available examination that requires a level of expertise most centres have yet to reach [7].

There are two main techniques for performing lower limb computed tomography venography (CTV): indirect and direct. Indirect CTV (IDCTV) is performed as post-intravenous contrast-enhanced CT, with imaging results largely dependent on cardiac output, size of the intravenous line, rate of injection and degree of hydration [4].

Direct CTV (DCTV) involves intravenous injection of contrast in the foot with ascending acquisition of imaging, providing outstanding detail [8].

Venous stenting has several technical differences compared to arterial stenting, with the most important being the imperative need to ensure a sufficient in- and outflow of the stent for long-term patency by covering the entire obstructive lesion with stent [9]. In patients with extensive chronic iliofemoral venous obstruction, planning is exceptionally important, as stenting from “healthy to healthy” may mean having to choose an inflow—femoral vein (FV) or deep femoral vein (DFV)—as the caudal limit of the stent [9]. Pre-procedure definition of inflow facilitates pre-procedure planning with emphasis on optimal access site definition.

The purpose of this paper is to evaluate whether imaging of the iliofemoral veins with DCTV can provide hemodynamic information on main inflow to the common femoral vein (CFV) in patients with extensive chronic iliofemoral venous obstruction, using venography as the gold standard.

Methods

All DCTVs of lower limbs including the ilio caval segment performed in the period from January 2014 to August 2018 in Galway University Hospitals were retrospectively identified.

Inclusion criteria included symptomatic patients with previous iliofemoral DVT. Clinical Etiology Anatomy Pathophysiology (CEAP) classification was used to stratify

the disease. Only patients considered candidates for venous recanalization, who also underwent both pre-procedure DCTV and venography, were considered.

Patients with underlying neoplasia were excluded.

DCTV is performed as follows: first, a thigh-high compression stocking is placed on the affected limb, and a 21-gauge needle is inserted into any vein in the foot after rolling the stocking up a few centimetres. The stocking is then rolled back over the cannula and 100 mL of iodinated contrast is injected at 3 mL/s with a 30 mL saline chaser, and scans are acquired from mid-calf up to the diaphragm in a bolus chasing method (Fig. 4).

Multiphase venography is performed with antero-posterior, right anterior oblique and left anterior oblique views. Venogram findings are classified as compatible with significant chronic iliofemoral venous outflow obstruction when they presented the following features: absent flow in the iliac vein; narrowed iliac vein lumen (> 50%); slow flow in the iliac vein; and extensive collaterals on ascending venography.

Both DCTV and venography were reviewed by an experienced physician. Whenever in doubt, a second blinded opinion was obtained from a similarly experienced vascular specialist. Femoral vein (FV) and deep femoral vein (DFV) were evaluated for axial maximum diameter in three different locations: 50, 150 and 250 mm below the lesser trochanter of the femur (Fig. 1). FV scarring/synechiae, abnormal wall thickness, duplication, absence and collateralization were evaluated on a binary present/not present basis.

Venogram findings were compared with DCTV as gold standard for chronic iliofemoral venous outflow obstruction. The dominant inflow vein (FV vs. DFV) was defined in the venogram as the vein with the greater maximum calibre juxta-femoral confluence.

Data were collected regarding patient's age, gender and risk factors for deep venous thrombosis (DVT), disease severity (CEAP classification), presence of iliac vein compression syndrome (IVCS), presence of the obturator hook sign, presence of contralateral iliac occlusion (when contralateral iliac vein was imaged) and presence of engorged pelvic veins. Obturator hook sign is characterized by an engorged angled vein, similar to a hook. It is identified mainly in DCTV, evidencing obturator vein engorgement as a marker of hemodynamically significant collateralization and representing an indirect sign for chronic iliac vein outflow obstruction [10].

Two groups were defined depending on whether FV or DFV was the dominant inflow on venography, in order to identify predictors for the dominant inflow in DCTV. Several variables were compared between groups, including DFV and FV diameters (in mm) at the three defined points of analysis (50, 150 and 250 mm below the lesser

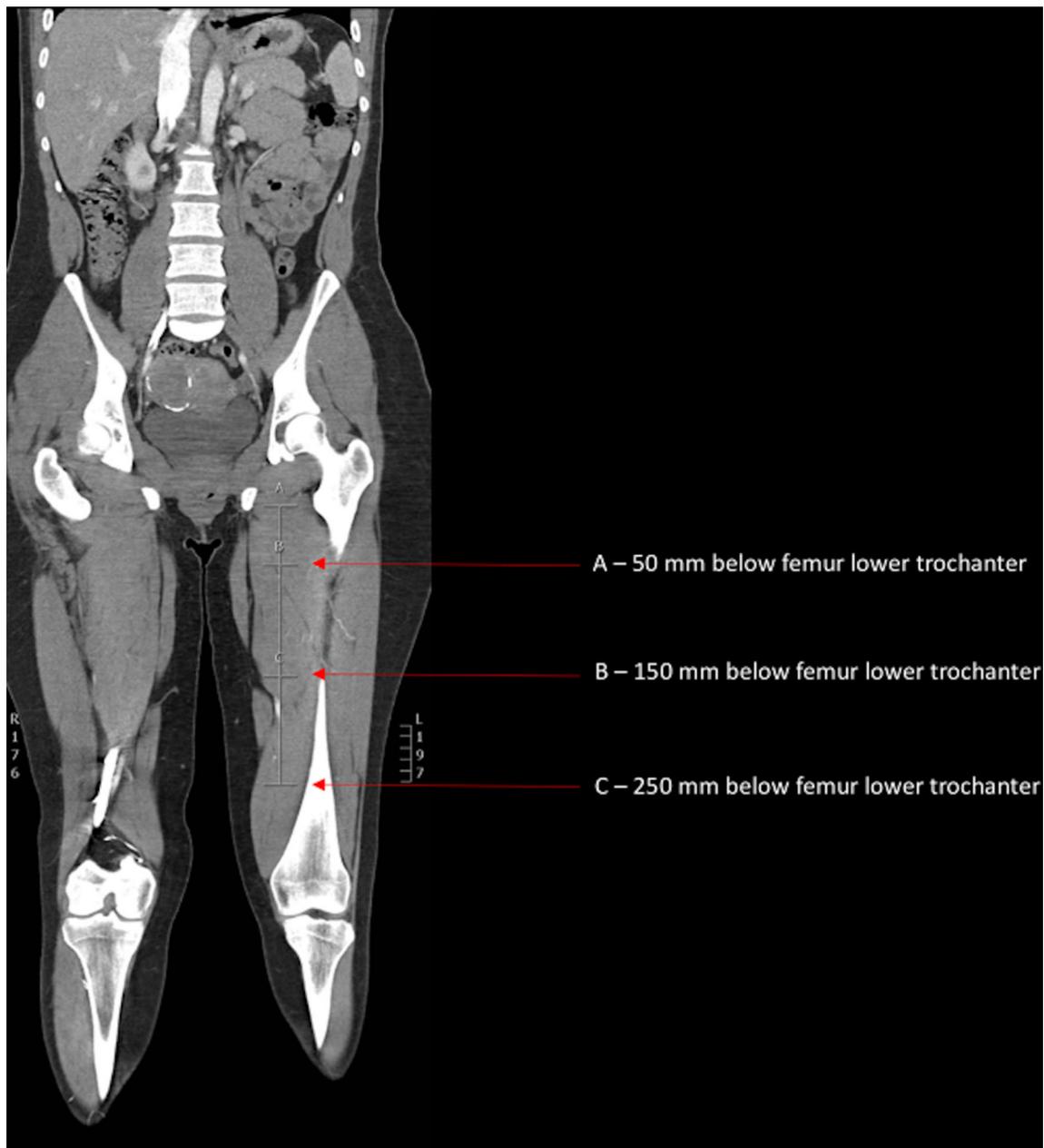


Fig. 1 Imagiologic demonstration on FV and DFV data collection in 3 different points (50, 150 and 250 mm below the lesser trochanter of the femur). DFV: Deep femoral vein; FV: Femoral vein

trochanter) as well as the diameter ratio between FV and DFV (FV/DFV ratio).

Categorical variables are presented as frequencies and percentages, and continuous variables as means and standard deviations, or medians and interquartile ranges for variables with skewed distributions. All reported p values are two-tailed, with a p value of 0.05 indicating statistical significance. Analyses were performed with the use of SPSS, version 25.0. Statistical analysis was performed to determine the association between relevant risk factors and mortality with Pearson χ^2 test in categorical variables and independent sample T test for continuous variables.

Results

A total of 72 DCTVs were identified in the designated time frame, of which 60 demonstrated chronic occlusion of the iliofemoral outflow. A total of 42 patients were excluded due to underlying neoplasia ($n = 2$), absence of venography ($n = 28$) or because DCTV was performed for follow-up of patients already submitted to stenting ($n = 10$).

A total of 30 DCTVs and subsequent venographies were reviewed in 30 different patients. Patient's mean age was 39.9 ± 12.7 years and 24 (80%) were female. Disease

severity was classified using CEAP: CEAP 3 ($n = 2$; 6.7%); CEAP 4 ($n = 21$; 70%); CEAP 5 ($n = 5$; 16.7%); and CEAP 6 ($n = 1$; 3.3%). In one patient, no data on CEAP classification were available ($n = 1$; 3.3%).

Regarding risk factors for iliofemoral DVT, 28 patients presented with common iliac vein compression (93.3%) and one (3.3%) patient was diagnosed with antiphospholipid syndrome.

Venography analysis identified the FV as the dominant inflow vein in 18 patients (60%) and the DFV in 12 (40%) patients. Several parameters were compared between the two groups (dominant FV vs. dominant DFV) (Table 1).

There was no significant difference between both groups regarding age and gender ($p > 0.05$). However, DFV diameter was significantly larger 50 mm below lesser trochanter when the DFV was dominant (8.73 ± 4.34 mm vs. 11.9 ± 3.52 mm; $p = 0.043$), even though FV/DFV ratio did not reach statistical significance at this level ($p = 0.14$).

At 150 mm below femur's lesser trochanter, FV/DFV ratio was significantly lower when DFV was dominant (11.39 ± 20.01 vs. 1.05 ± 0.47 ; $p = 0.043$) (Table 1).

At 250 mm below femur's lesser trochanter, DFV diameter was significantly larger when DFV was dominant (5.4 ± 3.90 mm vs. 8.90 ± 2.70 mm; $p = 0.011$), but FV/DFV ratio did not reach statistical significance (Table 1).

The presence of femoral vein scarring/synechiae, collaterals and abnormal wall thickness were all predictors for DFV dominance ($p = 0.003$, $p = 0.003$ and $p < 0.0001$, respectively). Femoral vein absence and duplication as well

as presence of obturator hook sign or pelvic collaterals did not reach statistical significance as predictor for DFV dominance ($p > 0.05$) (Table 1).

In Fig. 2, we showcase a venogram and corresponding DCTV of a patient with DFV dominance, who was submitted to stenting having DFV as the main inflow (Fig. 3). In Fig. 4, a venogram and corresponding DCTV of a patient with FV dominance are available.

Discussion

In the setting of chronic iliac vein outflow obstruction, ascending phlebography is still considered gold standard for assessment of chronic venous obstruction before treatment and should include oblique projections to properly visualize eccentric stenosis [3].

IVUS appears to be the most accurate method in estimating the morphological degree and extent of iliac vein stenosis and visualizing details of intraluminal lesions, such as intraluminal trabeculation in post-thrombotic vessels, but does not demonstrate flow dynamics nor contrast clearance following injection [6]. Also, it is usually performed as an intraprocedural adjunct being an invaluable assistance in the accurate placement of venous stents after venoplasty, but with limited value in planning vascular access site pre-procedure.

Computed tomography venography (CTV) or magnetic resonance venography (MRV) imaging is increasingly used to assess the extent of disease in the ilio caval segment as a

Table 1 Comparison between patients with dominant FV or DFV

	Dominant FV	Dominant DFV	<i>p</i>
Age (μ , SD)	42.79 \pm 14.2	35.5 \pm 8.8	0.095
Female gender (<i>n</i> , %)	15 (83.3)	9 (75)	0.576
FV diameter at 50 mm (μ , SD)	10.84 \pm 2.9	9.38 \pm 4.2	0.275
DFV diameter at 50 mm (μ , SD)	8.73 \pm 4.3	11.90 \pm 3.5	0.043
FV/DFV at 50 mm (μ , SD)	2.96 \pm 5.6	0.89 \pm 0.5	0.140
FV diameter at 150 mm(μ , SD)	20.4 \pm 30.7	17.3 \pm 22.0	0.768
DFV at 150 mm (μ , SD)	6.14 \pm 4.3	17.9 \pm 24.3	0.052
FV/DFV at 150 mm (μ , SD)	11.39 \pm 20	1.05 \pm 0.47	0.043
FV diameter at 250 mm(μ , SD)	12.69 \pm 3.3	21.72 \pm 30.79	0.330
DFV at 250 mm (μ , SD)	5.4 \pm 3.90	8.9 \pm 2.70	0.011
FV/DFV at 250 mm (μ , SD)	8.04 \pm 12.6	2.70 \pm 3.9	0.104
FV scarring/synechiae (<i>n</i> , %)	9 (50)	12 (100)	0.003
FV abnormal wall thickness (<i>n</i> , %)	2 (11.1)	12 (100)	< 0.0001
FV absent (<i>n</i> , %)	0 (0)	1 (8.3)	0.213
FV duplicated (<i>n</i> , %)	2 (11.1)	0 (0)	0.232
FV collaterals (<i>n</i> , %)	9 (50)	12 (100)	0.003
Obturator hook sign (<i>n</i> , %)	12 (66.7)	10 (83.3)	0.312
Pelvic vein collaterals (<i>n</i> , %)	10 (55.6)	6 (50)	0.765
Total	18	12	

FV Femoral vein, DFV Deep femoral vein

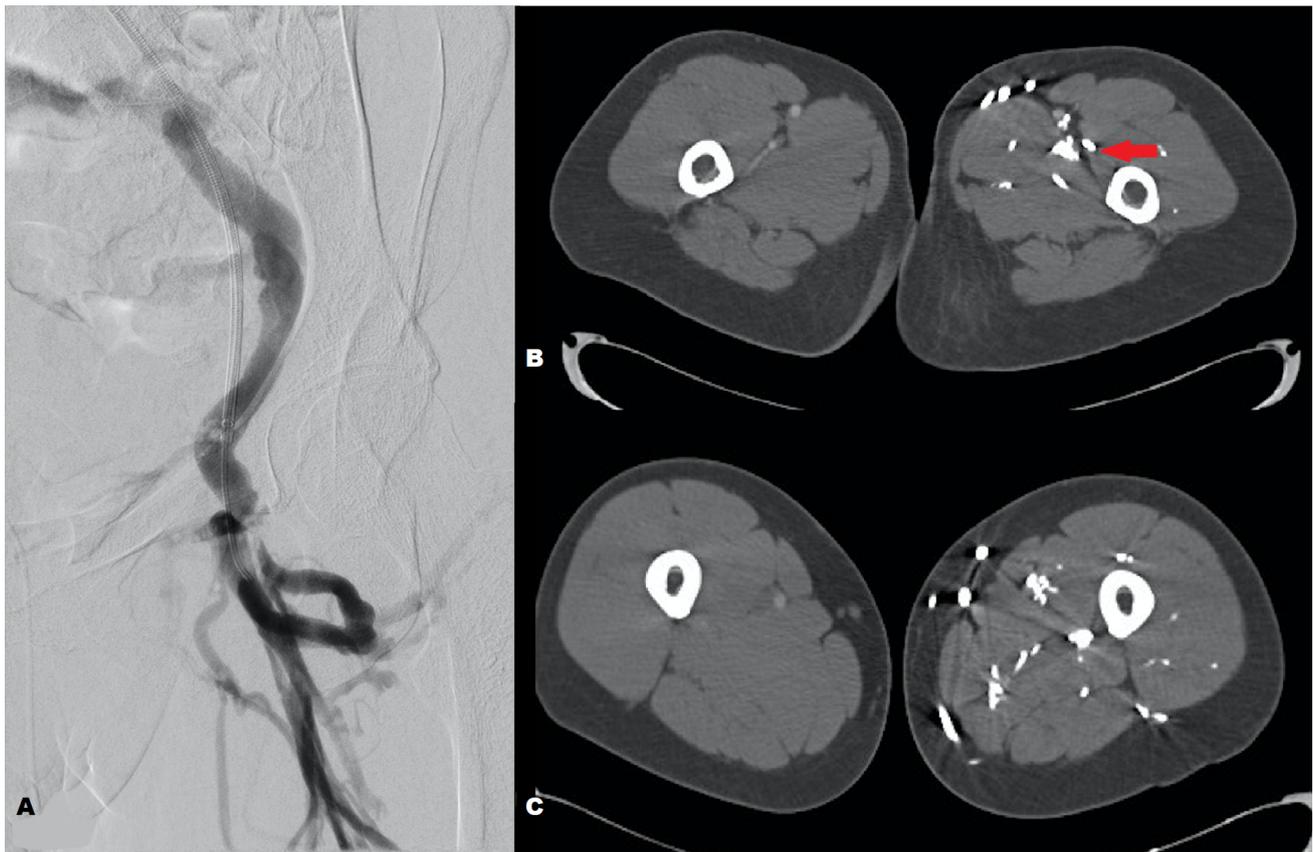


Fig. 2 **A** Angiographic image demonstrating DFV dominance. **B** DCTV image 50 mm below the lesser trochanter of the femur showing DFV dominance. **C** DCTV image 150 mm below the lesser

trochanter of the femur showing DFV dominance. DCTV: Direct Tomography venography; DFV: Deep femoral vein; FV: Femoral vein

non-invasive alternative to venography, having the additional advantage of excluding extravascular disease as a cause for obstruction, such as neoplasms or retroperitoneal fibrosis [3].

A meta-analysis of studies on the use of CTV between 1996 and 2004 showed a pooled estimated sensitivity and specificity of 96% and 95%, respectively, for detecting proximal DVT [11].

DCTV is akin to an arterial phase CT angiogram, imaging the venous system with a high level of contrast opacification. The contrast agent is injected in the dorsal vein of the affected foot, with a tourniquet applied to the ankle to allow preferential contrast flow into the deep veins. This allows superior visualization of the venous network and a more precise three-dimensional reconstruction [8]. It provides outstanding detail and is, in our view, essential for planning endovascular reconstruction, especially in post-thrombotic patients.

CTV is also the ideal imaging modality to examine the position and structure of a stent when ultrasound is equivocal or impossible, especially when the vena cava is involved [12].

An exceptionally challenging subset of lesions is post-thrombotic obstruction involving the femoral confluence, limiting inflow to the iliac vein. Venous inflow may be insufficient to support stent patency in such cases, and therefore, a hybrid procedure combining common femoral vein endophlebectomy, arteriovenous fistula and iliac stenting has been suggested. However, the rate of complications and reinterventions is not insignificant [13–16].

Stenting below the common femoral vein in extensive chronic iliofemoral venous obstruction with stent placement into the dominant inflow vein is a promising option, allowing coverage of the entire obstructive lesion with stent from “healthy to healthy” and choosing the vein with the best inflow volume in order to enhance patency rates [15]. In fact, a systematic review published in 2016 concluded any worse endovascular outcome with stents below the inguinal ligament reflected the severity of the post-thrombotic obstruction, rather than an inherent danger of caudal stent extension [17].

The question remains on how can we optimize the identification of the dominant inflow vein pre-procedure in order to properly plan the endovascular intervention.

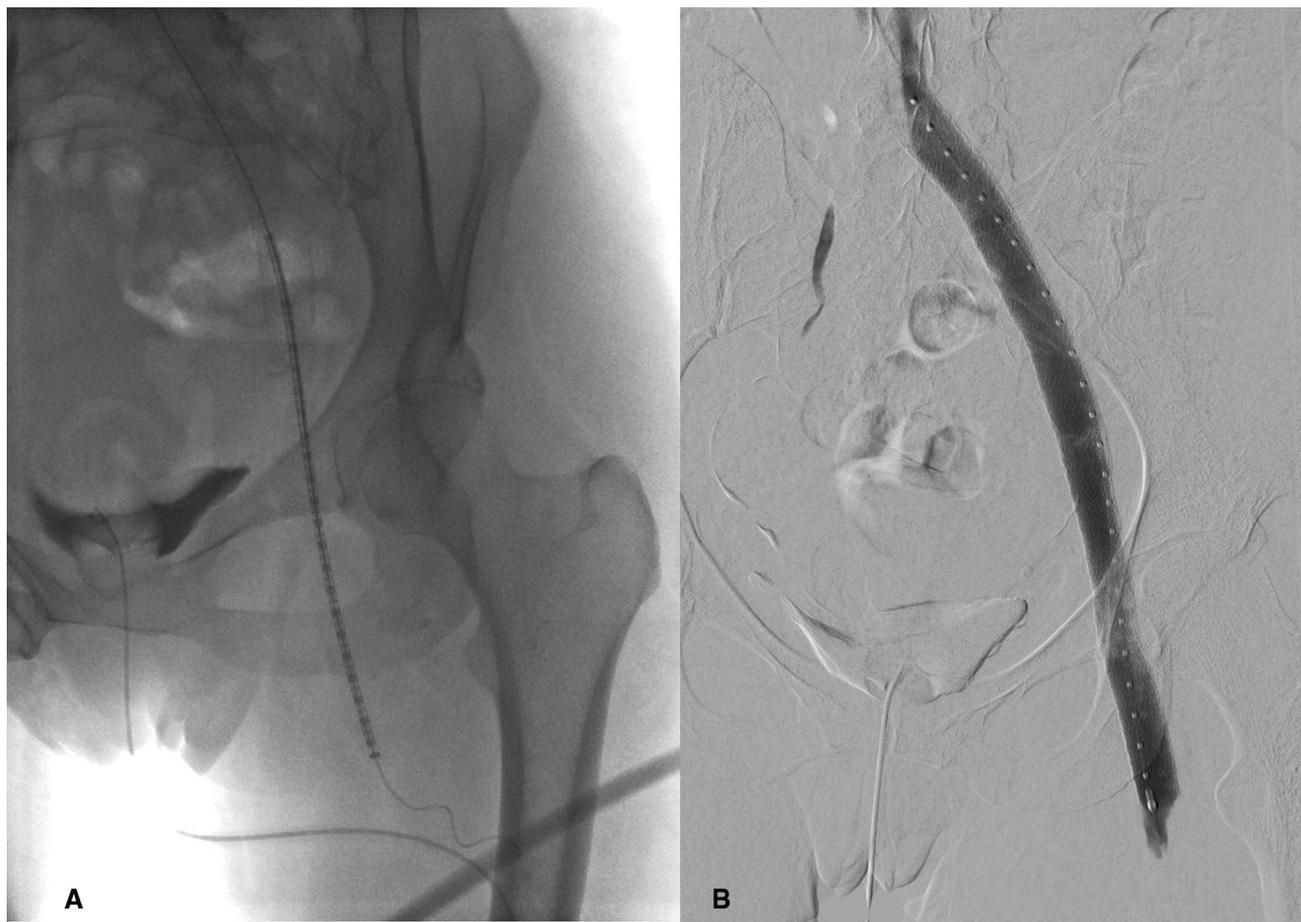


Fig. 3 Stent deployment into the origin of the DFV in a patient with DFV dominance

A variety of access sites can be used, each with specific advantages and disadvantages. In Galway University Hospitals, right jugular (remote) access has been increasingly used, having as its main advantage the possibility to choose the dominant inflow intraprocedure. Theoretically, using a mid-thigh FV puncture for stent deployment is far from ideal in DFV dominance and particularly if there are synechia obstructing the ostia of the DFV, as stenting will limit DFV inflow even further.

In this study, enlarged DFV maximum diameter (mm) and low FV/DFV ratio were consistently associated with DFV dominance, reaching statistical significance for the first criteria at 50 and 250 mm below lesser trochanter and for the second criteria at 150 mm below lesser trochanter. Possibly, the remaining studied parameters did not reach significance due to the small number of included patients ($n = 30$), and we admit the ideal level for evaluating DFV and FV diameters and DFV/FV ratio remains to be defined.

Probably the ideal level will lie nearest to the femoral confluence, in order to avoid interpatient variability depending on height and on number of DFV tributaries.

FV scarring/synechia, collaterals and abnormal wall thickness were also significant predictors for DFV dominance in this study.

It is noteworthy that pelvic vein collaterals and obturator hook sign (obturator vein engorgement), both markers of significant collateralization representing an indirect sign for chronic iliac vein outflow obstruction, were not different between groups ($p > 0.05$), suggesting both groups had similar outflow obstruction.

In conclusion, this study suggests DCTV is valuable in defining the dominant iliac vein inflow, but additional findings are necessary to validate these preliminary data. In addition, in centres with high volume and expertise in MRV probably similar results could be achieved.

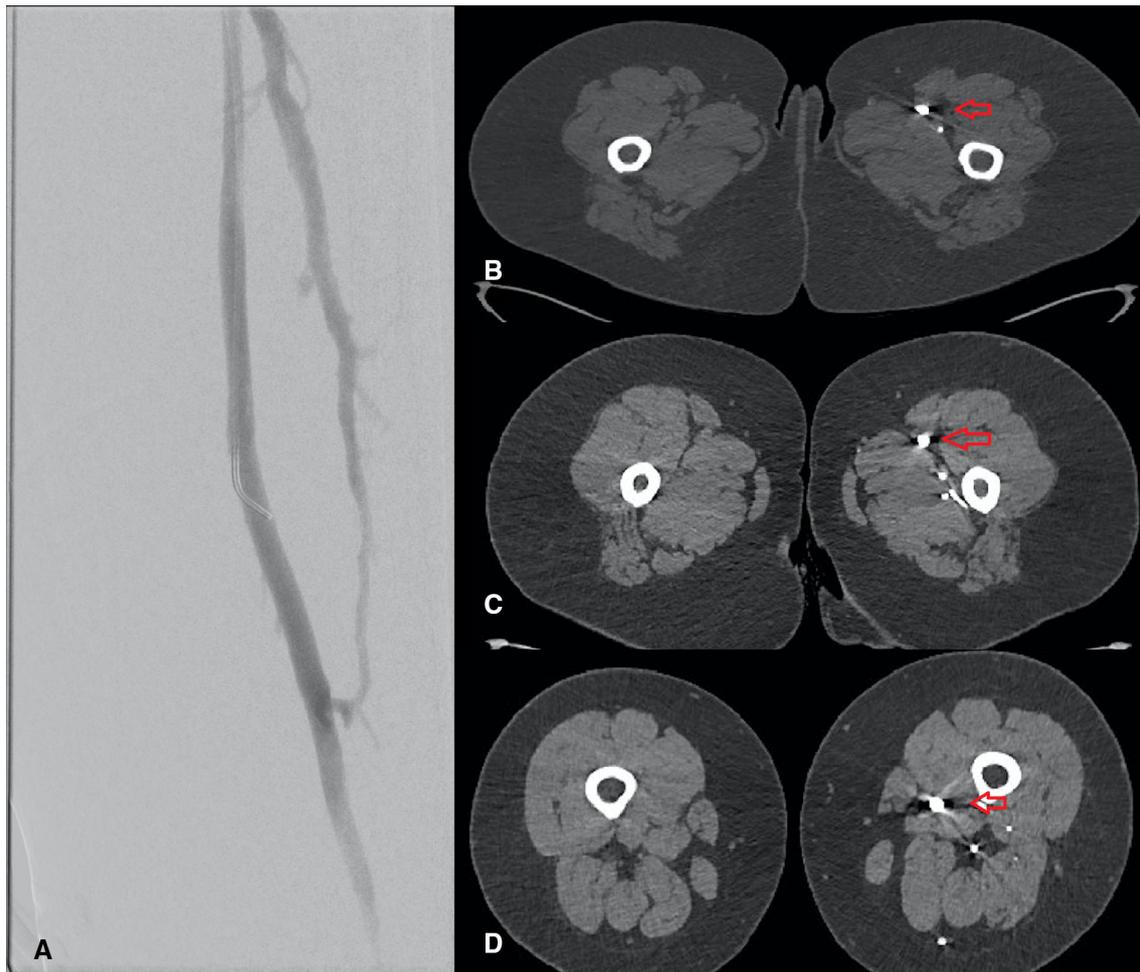


Fig. 4 **A** Angiographic image demonstrating FV dominance. **B** DCTV image 50 mm below the lesser trochanter of the femur showing FV dominance. **C** DCTV image 150 mm below the lesser trochanter of the femur showing DFV dominance. **D** DCTV image

250 mm below the lesser trochanter of the femur showing DFV dominance. DCTV: Direct Tomography venography; DFV: Deep femoral vein; FV: Femoral vein

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval Institutional review board (IRB) approved the submission.

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