European Heart Journal Supplements (2022) **24** (Supplement J), J11–J16
The Heart of the Matter
https://doi.org/10.1093/eurheartjsupp/suac061

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Standardized pre-procedural clinical workup for protected percutaneous coronary intervention

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KEYWORDS
Protected PCI;
Femoral access;
Mechanical circulatory support;
Left ventricular function;
Comorbidities

In addition to appropriate patient screening, pre-procedural preparation is essential to optimize both technical success and patient outcome for protected percutaneous coronary intervention (PCI). A critical component of optimization is the identification and preparation of a suitable femoral access site. Here, we describe several options for both imaging and image-guided access to optimize the approach.

Pre-procedural clinical workup for protected percutaneous coronary intervention

Whenever possible, a careful pre-procedural assessment of indication, patient profile, and access should be integrated into the local protected percutaneous coronary intervention (PCI) algorithm to ensure procedural safety and efficacy. Clinical presentation of acute/chronic coronary syndromes or decompensated/chronic heart failure as well as non-cardiac comorbidities may impact the interventional timing and strategy, and therefore must be verified first. In addition, frailty, concomitant chronic kidney disease, oxygen-dependent chronic obstructive pulmonary disease, carotid artery disease, severe pulmonary hypertension, obstructive peripheral artery disease, recent stroke, active infection/sepsis, or cancer with concurrent cancer therapy may influence interventional strategies and increase procedural risk.[1] It is recommended to check availability in the intensive care unit prior to performing high-risk PCI, in the event of procedural complications (e.g. deteriorating haemodynamics and bleeding), or if the patient cannot be weaned off mechanical circulatory support (MCS). The anaesthesiology or intensive medical care team that will be conducting the procedure should also be determined early (*Figure 1*). Conscious sedation should be considered, particularly for vulnerable patients undergoing complex PCI with longer procedural times.

When navigation across the aortic valve is required, details regarding left-ventricular ejection fraction (LVEF) and pre-existing valvular disease such as severe aortic stenosis/regurgitation are critical for procedural planning. Given that PCI patients with reduced LVEF are typically older, have more comorbidities such as renal failure and diabetes, and have more complex and extensive disease than those with preserved LVEF, echocardiography is an important pre-procedural step. Impaired LVEF is an important consideration in high-risk PCI and remains a key predictor of adverse outcomes.[2] Right heart catheterization (RHC) is not a routine practice in the diagnostic workup of protected PCI, but it

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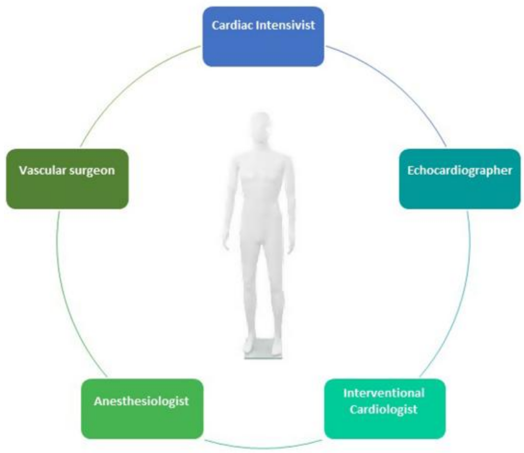

Professional figure	Role
Cardiologist/ Cardiac Intensivist	**Patient preparation** • Exclusion of clinical contraindication (e.g. active sepsis) • Co-morbidities management (e.g. anemia or chronic kidney disease) • Hemodynamic optimization (e.g. pulmonary congestion reduction) **Post procedure management** • Weaning protocol
Echo cardiographer	**Cardiac function assessment** • Left and right ventricle contractility • Intra-cardiac thrombotic mass • Aortic valve disease
Interventional cardiologist	**Procedure planning** • Access site selection • Revascularization strategy • Ventricular assistance duration
Anesthesiologist (especially in acute setting)	**Intra-procedural patient management** • Sedation • Oxygenation monitoring • Inotropic support (if required)
Vascular surgeon (if required)	**Complex access site management**

Figure 1 High-risk protected percutaneous coronary intervention medical practitioners. Potentially relevant members of the multidisciplinary team and their role during the workup for elective/urgent high-risk protected percutaneous coronary revascularization (percutaneous coronary intervention).

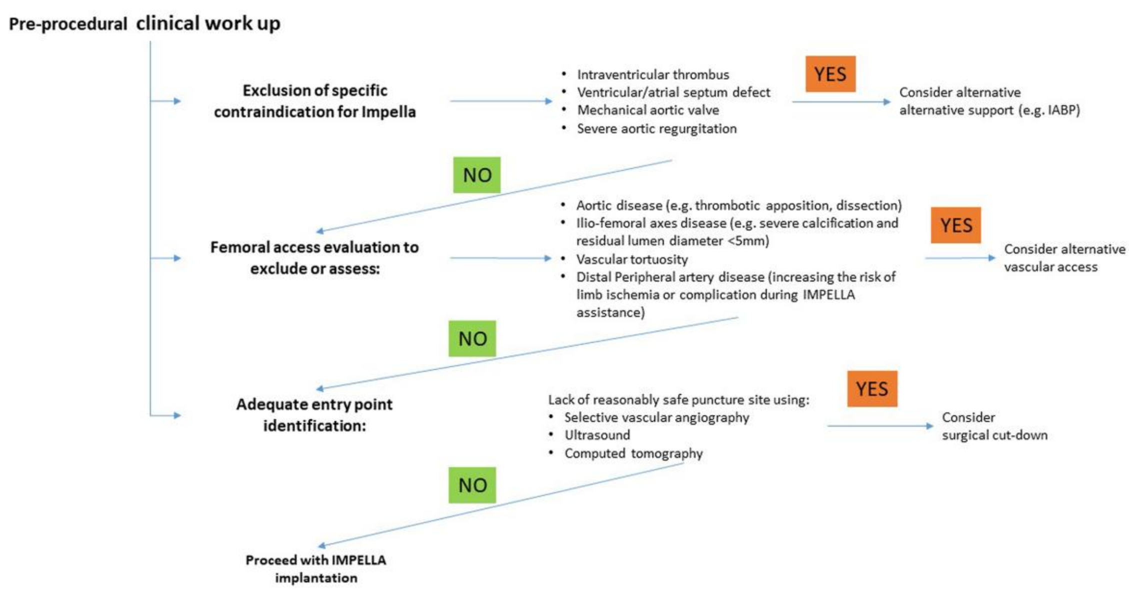

Figure 2 Screening algorithm for patients requiring protected percutaneous coronary revascularization (percutaneous coronary intervention).

can be helpful in patients with pulmonary hypertension or right ventricular dysfunction. Moreover, RHC is a reliable tool for evaluating the effects of MCS during PCI and for guiding post-procedural management such as weaning, or escalation of support (*Figure 2*).

Given the high burden of vascular complications following MCS, meticulous pre-procedural screening is paramount. Mural thrombus in the LV apex should specifically be sought in dilated left ventricles with reduced LVEF and may require contrast echocardiography in select cases. Use of transoesophageal echocardiography (TEE) will determine the presence of aortic valve disease. Severe aortic stenosis may require a complementary balloon valvuloplasty or transcatheter aortic valve implantation in tandem with the high-risk PCI. Additionally, multi-slice computed tomography (CT) and TEE may further complement the overall workup when severe aortic stenosis is suspected. Vascular access-site complications, particularly those due to the use of large-bore sheaths, may limit outcomes in protected PCI patients.[3] There are several options to determine eligibility for peripheral vascular access.

Conventional angiography

All protected PCI patients undergo a coronary angiography during their pre-procedural evaluation, regardless

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of the access route (radial or femoral). A pigtail is placed in the abdominal aorta just above the aortic bifurcation, and both iliac and femoral arteries can be visualized with injection of 20–30 mL of contrast medium. A selective injection in one or both iliofemoral axis can be used to limit contrast medium volume. At this time, the common femoral artery and the level of the femoral bifurcation in relation to the femoral head should be assessed.[4] Localized femoral disease, extensive calcification, or a high femoral bifurcation may impact the puncture site and the reliability of closure. As such, angiography offers only a limited evaluation of atherosclerotic disease burden and the degree of vessel tortuosity (*Figure 3*). However, it is readily available and precisely identifies key anatomical landmarks, such as the femoral bifurcation and the inferior epigastric artery. Due to its superior spatial resolution, digital subtraction angiography (DSA) remains the gold standard.[5,6] Digital subtraction and selective imaging may further enhance image quality and minimize use of contrast dye.

Computed tomography

The benefits of pre-procedural CT include accurate appraisal of vessel dimensions, tortuosity, calcifications, and plaque burden. Multidetector CT offers high spatial resolution in three dimensions and rapid image acquisition, which overcomes some of the limitations of conventional angiography and DSA[4] (*Figure 4*). Thus, CT can be especially useful in patients with peripheral vascular disease or an aortic aneurysm. Using a centreline approach to elongate the vessel image, multiple luminal measurements should be made in a plane orthogonal to the vessel rather than in the transverse axial plane. Approximately, 80–120 mL of intravenous contrast medium are typically injected to visualize the iliofemoral arteries.[7]

Vascular ultrasound

Vascular ultrasound is especially useful in patients who are at high risk of difficult access or complications, providing a real-time landscape to obtain vascular access with greater accuracy and fewer complications (*Figure 5*). Use of ultrasound allows the interventional team to identify certain arterial anatomic features, such as the exact location of the femoral bifurcation and the epigastric artery, and navigate around obstructive or calcified atherosclerotic disease at the time of procedure.[8,9] Moreover, ultrasound is readily available and precludes the patient to unnecessary exposure to

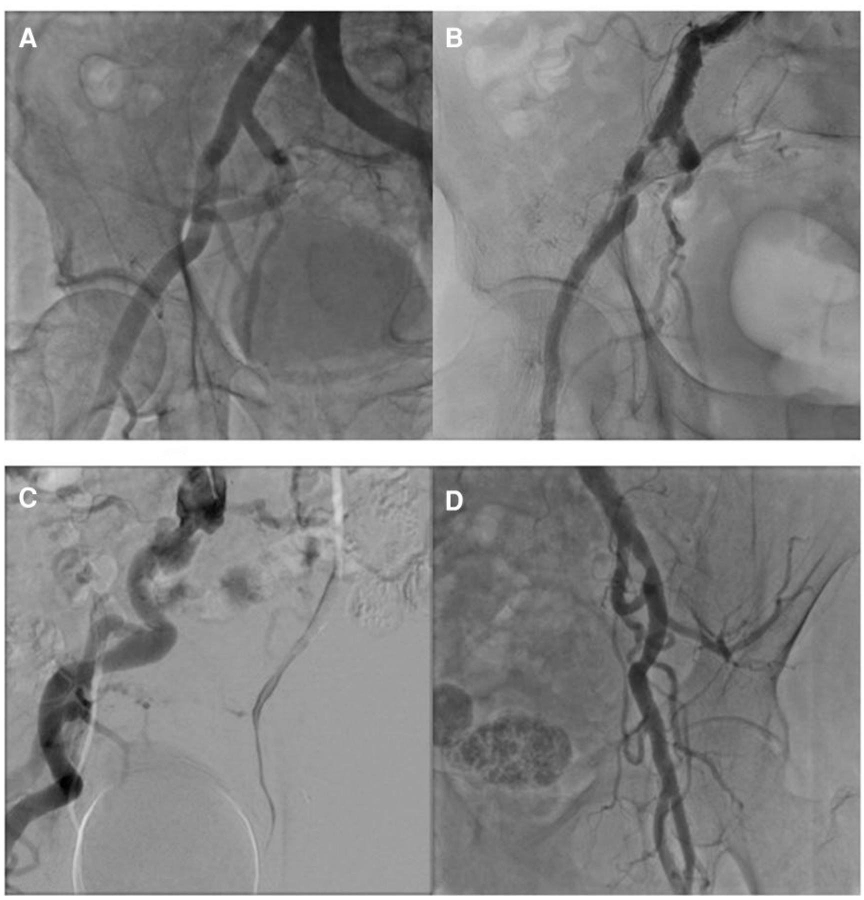

Figure 3 Conventional angiography. (*A*) Selective cannulation of an optimal iliac-femoral axis. (*B*) Diffusely calcified and stenotic iliac-femoral axis. (*C*) Tortuous iliac-femoral axis. (*D*) Femoral bifurcation proximal to inguinal ligament.

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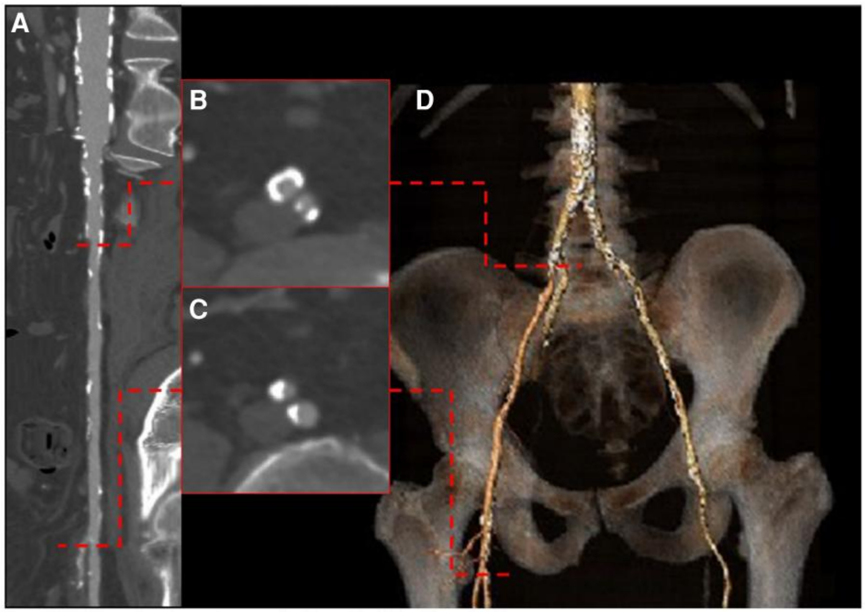

Figure 4 Computed tomography. (*A*) Bidimensional long axis reconstruction of right iliac–femoral axis. (*B*, *C*) Cross-sectional visualization of the minimum lumen area. (*D*) 3D iliac–femoral axis reconstruction.

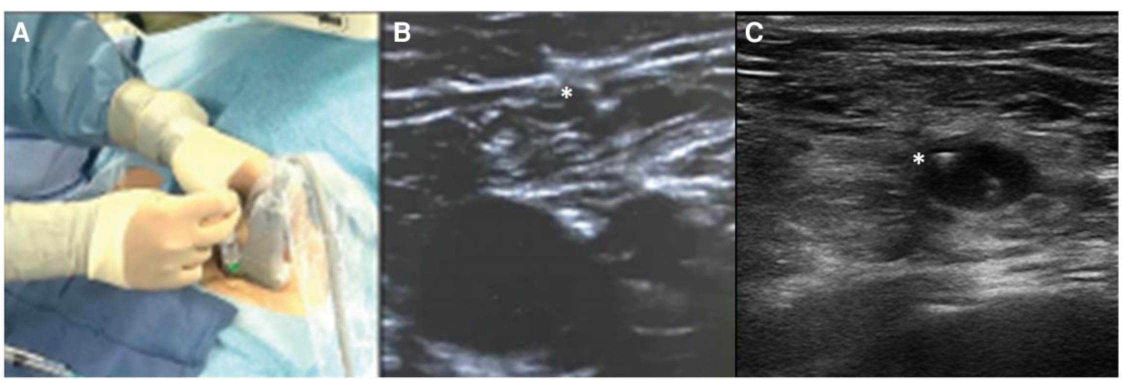

Figure 5 Vascular ultrasound. (*A*) Example of an echo-guided puncture. (*B*) Needle visualization (*) during entry point selection. (*C*) Accurate visualization of vessel wall to avoid calcified location.

radiation or contrast agents. For vascular access procedures, use of a linear probe with an adjustable depth of field view (ranging from 1.5 to 6 cm) is recommended to produce high-quality images.

Ultrasound readily identifies patients with high common femoral artery (CFA) bifurcation. With knowledge of the CFA bifurcation location, the operator can proceed with a relatively high stick to ensure entry in the common femoral artery above the bifurcation. Ultrasound can provide visualization of the inguinal ligament as a triangular echodensity on the longitudinal view or linear density on axial views. Additionally, the longitudinal view provides an overview of the femoral trajectory, including its bifurcation, which may be helpful for following the needle course towards the artery. The probe should be rotated to obtain an axial view at the site of needle entry into the artery. In some cases, it may be beneficial to perform the femoral puncture using the axial short-axis view to ensure an anterior wall puncture in an area without anterior wall calcium, and thus avoid lateral entry into the vessel.[10]

The ultrasound-guided vascular access technique is an important asset in large-bore, catheter-based endovascular interventions and ensures successful closure. After a steep learning curve, the ultrasound-guided access technique is easy to adopt.[9] The Femoral Arterial Access with Ultrasound Trial (FAUST) demonstrated that the overall rate of CFA cannulation under ultrasound guidance was not significantly different compared with fluoroscopy (86.4 vs. 83.3%; $P = 0.17$) but was higher in the 31% of patients with high CFA bifurcations (82.6 vs. 69.8%; $P < 0.01$).[11] Ultrasound is essential in multimodality access evaluation, and complements angiography and CT.

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Table 1 Comparison of the used modalities

	Conventional angiography	Computed tomography (CT)	Vascular ultrasound
Key points	• Anterograde (ancillary radial or femoral access) or retrograde route • Nonselective using a pig tail in aorta (15–20 mL of contrast dye) or selective (6–8 mL of contrast dye) • Rough assessment of both iliac-femoral axis for significant stenosis, vessel calcification/tortuosity, and femoral bifurcation localization • Anatomical landmark identification (e.g. mid-femoral head, inguinal ligament) to select the target puncture zone	• A comprehensive view of the aorta and iliac–femoral axes (80-120 mL of contrast dye) • The most accurate appraisal of vessel dimensions tortuosity and disease, including plaque burden and calcification • 3D vessel reconstruction	• Local assessment of best puncture site without the need for additional radiation or contrast dye administration • Accurate assessment of plaque and vessel-wall calcification distribution to determine both entry zone and needle orientation during puncture
Limitations	• Potential to underestimate vessel plaque burden and calcification	• Availability of CT (time consuming) • Potential to overestimate vessel calcification	• Ultrasound machine availability in the catheterization laboratory • Limited femoral segment visualization (particularly in patients with obesity) • Need for anatomical landmark confirmation to understand femoral head/femoral bifurcation relationship

Conclusion

In selected cases, it may be important to combine several imaging techniques (*Table 1*) to achieve optimal femoral access. This is particularly true for patients with complex anatomy undergoing procedures requiring large femoral sheaths, alongside other simultaneous arterial accesses.[12]

Acknowledgement

This manuscript is one of eight manuscripts published as a Supplement to address best practices for Impella protected PCI. JetPub Scientific Communications, LLC, supported by funding from Abiomed Europe GmbH, provided editorial assistance to the authors during preparation of this manuscript.

Funding

This work has been supported by the Abiomed Europe GmbH to cover publication costs as well as professional language editing of each manuscript. No individual fees were paid to the authors in the generation of this publication. This paper was published as part of a supplement financially supported by Abiomed GmbH.

Conflict of interest: E.R. has received speakers fees at an educational event from Abiomed. F.A. has received payment or honoraria from Abiomed and Fresenius. N.V.M. has received research grants from Abbott Vascular, Boston Scientific, Biotronic, Edwards Lifesciences, Medtronic, Pulse Cath BV, and Abiomed.

Data availability

All research data is available through the corresponding author and can be used for future research.

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