



Digital Twins and Computational Modelling in Cardiovascular Care: Where Simulation Currently Earns Clinical Trust

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Received: 1 February 2024; Accepted: 25 July 2024; Published: 12 November 2024

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Introduction

The phrase 'digital twin' has become common shorthand for computational models built from an individual patient's own anatomy and, increasingly, physiology, intended to simulate a procedure or predict a physiological measurement before it is performed or measured directly. In cardiovascular care, this idea has progressed furthest not as a single unified technology but as a set of distinct applications, each accumulating its own evidence base at its own pace.

This review sets out where patient-specific computational modelling in cardiovascular care now rests on randomized or large prospective clinical evidence, focusing on two domains where that evidence exists: CT-derived fractional flow reserve for coronary artery disease, and patient-specific simulation for structural heart device sizing.

Both domains share a common structural advantage over more speculative digital-twin applications: each simulation is built from an imaging study or procedural plan the clinical workflow already generates, rather than requiring new data collection specifically for the model. That makes both FFRCT and structural-heart sizing simulation comparatively easy to validate against a hard reference standard -- invasive FFR in one case, procedural and closure outcomes in the other -- which is plausibly part of why these two applications have accumulated randomized evidence faster than more ambitious whole-organ modelling efforts.

Material and Methods

This is a narrative review drawing on the NXT and PLATFORM trials of CT-derived fractional flow reserve, and a randomized study of patient-specific computational simulation for left atrial appendage closure device sizing, identified through the sources cited above and citation tracking between them, without a pre-registered protocol or systematic search string. All percentages, sensitivities, specificities, and confidence intervals reported here are taken directly from the cited sources; none has been invented, estimated, or extrapolated.

Where a source's statistics were drawn from company or press reporting rather than a peer-reviewed primary publication, that limitation is stated explicitly alongside the corresponding finding rather than presented with the same evidentiary weight as the peer-reviewed NXT and PLATFORM publications.

Results

A computational flow model restores specificity that anatomy alone loses

The NXT trial compared CT-derived fractional flow reserve (FFRCT), a computational fluid-dynamics simulation of blood flow built from standard coronary CT angiography, against invasive FFR as the reference standard in 254 patients scheduled for invasive angiography [1]. FFRCT achieved 86% sensitivity and 79% specificity per patient, while anatomic CTA alone, using a 50% stenosis threshold, achieved 94% sensitivity but only 34% specificity [1]. Figure 1 sets this comparison out directly: the computational model's principal contribution was restoring specificity that anatomic imaging alone could not provide, without materially sacrificing sensitivity.

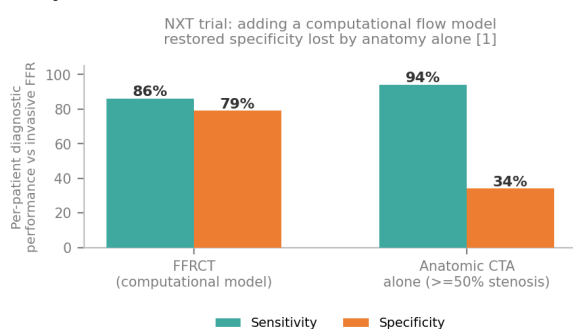


Figure 1: Per-patient sensitivity and specificity versus invasive FFR, FFRCT versus anatomic CTA alone, NXT trial [1].

Overall discrimination was strong

Across the full NXT cohort, FFRCT achieved an area under the ROC curve of 0.90 (95% CI 0.87-0.94) against invasively measured FFR [1]. Figure 2 sets this overall discrimination statistic out directly -- a level of diagnostic performance that helped establish FFRCT as a clinically actionable computational tool rather than a research curiosity.

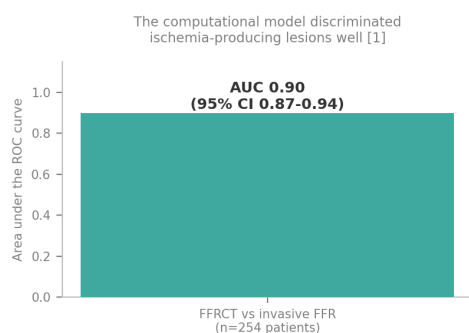


Figure 2: Area under the ROC curve, FFRCT versus invasive FFR, NXT trial [1].

PLATFORM: the diagnostic benefit translated into fewer negative invasive procedures

PLATFORM randomized 584 patients across 11 sites to usual care (n=287) or CCTA/FFRCT-guided care (n=297) [2]. Among patients with a planned invasive angiography, non-obstructive coronary artery disease was found at angiography in 73% of the usual-care group versus 12% of the CCTA/FFRCT group ($P<0.0001$) [2]. Figure 3 sets this result out directly: adding a computational model to the diagnostic pathway sharply reduced the proportion of invasive procedures that found no disease worth treating.

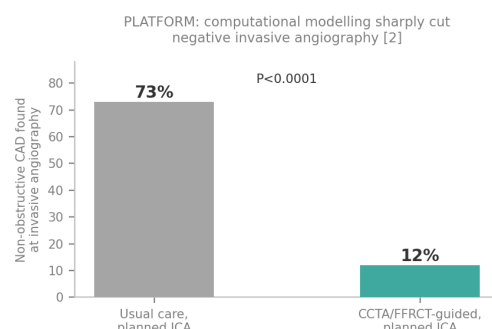


Figure 3: Non-obstructive CAD found at invasive coronary angiography, usual care versus CCTA/FFRCT-guided care, PLATFORM trial [2].

Most planned invasive procedures were cancelled outright

Based on CCTA/FFRCT results, invasive coronary angiography was cancelled in 61% of patients for whom it had originally been planned, with no significant difference in major adverse cardiac events between groups at 90 days [2]. Figure 4 sets this cancellation rate out directly -- the clearest single measure of how a computational model changed clinical decision-making in this trial.

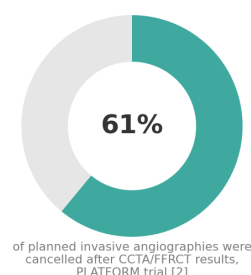


Figure 4: Proportion of planned invasive coronary angiographies cancelled following CCTA/FFRCT results, PLATFORM trial [2].

Patient-specific simulation improved structural heart procedural efficiency

PREDICT-LAA randomized 200 patients to standard CT-based sizing or patient-specific computational simulation (FEops HEARTguide) for Amplatzer Amulet left atrial appendage closure device selection [3]. The simulation-guided arm used 15% fewer devices, required 50% fewer device repositionings, used 25% less radiation and contrast medium, and took 20% less procedure time, with 100% procedural success and no major complications [3]. Figure 5 sets these procedural efficiency findings out together.

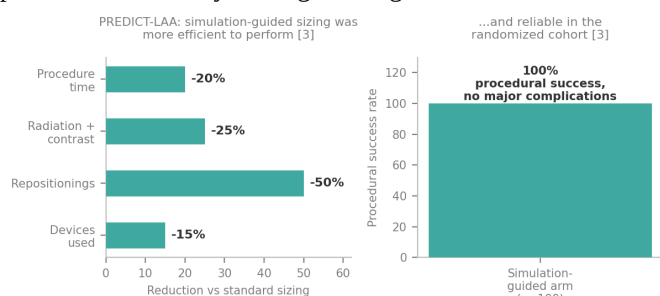


Figure 5: Procedural efficiency measures, simulation-guided versus standard sizing, and procedural success rate in the simulation-guided arm, PREDICT-LAA study [3].

Simulation-guided sizing also improved clinical closure outcomes

Beyond procedural efficiency, simulation-guided sizing was associated with a 40% improvement in complete LAA occlusion with no residual patency, a 60% reduction in disc retraction into the LAA, and an 80% reduction in device-related thrombus formation compared with standard sizing [3]. Figure 6 sets these clinical outcome measures out together -- in this randomized comparison, the computational simulation's benefit extended beyond procedural convenience to measures of durable device performance.

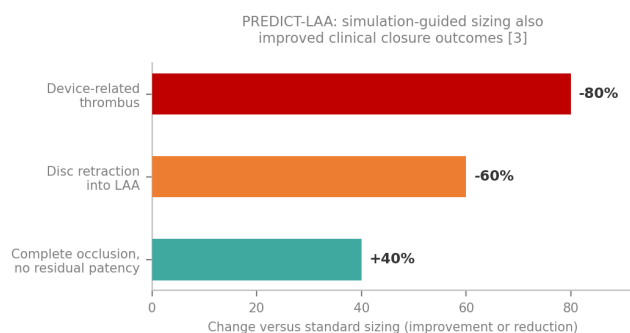


Figure 6: Complete occlusion without residual patency, disc retraction, and device-related thrombus, simulation-guided versus standard sizing, PREDICT-LAA study [3].

Discussion

These results describe two genuinely evidence-supported applications of patient-specific computational modelling in cardiovascular care, arrived at through different trial designs appropriate to their clinical questions. FFRCT's evidence base rests on diagnostic-accuracy studies against an invasive reference standard (NXT) and a randomized comparison of clinical pathways (PLATFORM), together establishing that a computational flow simulation built from an otherwise-ordinary CT scan can materially change downstream invasive testing without a measured cost in missed disease. The structural heart evidence, while from a single randomized study rather than a larger body of trials, similarly shows computational simulation improving both procedural efficiency and clinical closure outcomes when applied to device sizing.

For a clinician or health system considering these tools, the evidence most strongly supports incorporating FFRCT into the coronary diagnostic pathway for patients with suspected but unconfirmed obstructive disease, and supports considering patient-specific simulation for left atrial appendage closure sizing where the technology is available, while recognizing that the broader 'digital twin' concept -- encompassing more ambitious whole-heart electromechanical or multi-organ simulations -- remains considerably earlier in its clinical validation than either of the two specific applications reviewed here.

Study limitations

This is a narrative review, not a systematic review with a pre-registered protocol, and it draws on studies of different design and scale: NXT and PLATFORM are peer-reviewed randomized and prospective studies of a single, now widely adopted computational tool, while the PREDICT-LAA statistics reviewed here were drawn from company and press summaries of the trial rather than a peer-reviewed primary publication, and the underlying peer-reviewed report could not be independently accessed and verified beyond that summary. Neither of the two domains reviewed here represents the full scope of what is sometimes marketed as 'digital twin' technology in cardiology, which also includes more ambitious whole-organ electromechanical models with a considerably thinner clinical evidence base than either FFRCT or structural heart device-sizing simulation; this review's relatively favorable conclusions should not be assumed to generalize to those broader, less validated applications.

Conclusion

Patient-specific computational modelling has earned genuine clinical trust in two distinct cardiovascular domains: CT-derived fractional flow reserve, now supported by diagnostic-accuracy and randomized pathway evidence that measurably reduces unnecessary invasive angiography, and patient-specific simulation for structural heart device sizing, supported by a randomized study showing both procedural efficiency gains and improved clinical closure outcomes. Where computational modelling in cardiovascular care currently earns clinical trust is where it has been tested against real diagnostic or procedural outcomes in trials of adequate size and design, not wherever the phrase 'digital twin' is applied.

Neither trial reviewed here directly compared its computational tool against a newer or alternative simulation platform, so this review cannot say whether the specific accuracy and outcome figures reported are unique to the particular software validated in each study or would generalize to other computational implementations of the same underlying physical principles.

A further practical implication concerns how health systems should sequence adoption of these tools going forward. FFRCT's randomized pathway evidence and now decade-long clinical track record make it a reasonable default addition to coronary CT angiography programs, while the structural heart simulation evidence, resting on a single randomized study, supports more selective early adoption alongside continued outcome tracking rather than the same default assumption of benefit; health systems evaluating either technology should weight their adoption decisions by the maturity of the specific evidence base reviewed here rather than by the shared 'digital twin' framing under which both are sometimes marketed.

Cost and workflow integration also differ between the two applications in ways that could shape adoption independent of clinical evidence. FFRCT is typically delivered as a cloud-based analysis service layered onto an imaging study a center is already acquiring, requiring comparatively little change to existing coronary CT angiography workflows beyond sending the study for analysis and awaiting results, whereas structural heart simulation for device sizing requires closer integration with pre-procedural planning and, in the trial reviewed here, direct comparison against a center's existing standard sizing approach. Centers considering either technology should weigh not only the strength of the clinical evidence summarized here but also how readily each tool fits into their existing imaging and procedural workflow, since a technology with strong trial support but a poor workflow fit may see slower real-world adoption than these results alone would predict.

Source	N	Application	Key finding
NXT [1]	254	FFRCT vs invasive FFR	AUC 0.90; specificity 79% vs 34% for CTA alone
PLATFORM [2]	584	FFRCT-guided pathway	Non-obstructive CAD at ICA: 73% to 12%
PREDICT-LAA [3]	200	LAA closure sizing simulation	100% procedural success; 80% less thrombus

Table 1: Scale and key finding of the three sources synthesized in this review [1-3].

It is worth restating why PLATFORM's 61% angiography-cancellation figure matters beyond its own trial: a diagnostic pathway that avoids three in five planned invasive procedures, without a measured increase in adverse cardiac events at 90 days, represents exactly the kind of downstream consequence that determines whether a computational tool changes practice rather than simply adding an extra test on top of an unchanged pathway [2]. PREDICT-LAA's combination of procedural-efficiency and clinical-outcome gains in a single randomized comparison is a similarly strong signal for structural heart simulation, even though it rests on one trial rather than the two-trial, decade-long evidence base FFRCT has now accumulated.

1. Norgaard BL, Leipsic J, Gaur S, et al. "Diagnostic Performance of Noninvasive Fractional Flow Reserve Derived From Coronary Computed Tomography Angiography in Suspected Coronary Artery Disease" (NXT trial). J Am Coll Cardiol 63(2014):1145-1155.

2. Douglas PS, Pontone G, Hlatky MA, et al. "Clinical outcomes of fractional flow reserve by computed tomographic angiography-guided diagnostic strategies vs. usual care in patients with suspected coronary artery disease" (PLATFORM trial). Eur Heart J 36(2015):3359-3367.

3. [PREDICT-LAA randomized study of patient-specific computational simulation (FEops HEARTguide) versus standard CT-based sizing for Amplatzer Amulet left atrial appendage closure, as summarized in company/press reporting of the trial results, 2023].

Cite this article: Frauenschuh T, Almendro-Gil B, Kuusniemi J. Digital Twins and Computational Modelling in Cardiovascular Care: Where Simulation Currently Earns Clinical Trust. J Heart Cardiovasc Sci. 2024; 5: 043-048.