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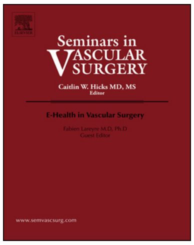

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Review article

# Computational surgery in the management of patients with abdominal aortic aneurysms: Opportunities, challenges, and future directions

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## ABSTRACT

Computational surgery (CS) is an interdisciplinary field that uses mathematical models and algorithms to focus specifically on operative planning, simulation, and outcomes analysis to improve surgical care provision. As the digital revolution transforms the surgical work environment through broader adoption of artificial intelligence and machine learning, close collaboration between surgeons and computational scientists is not only unavoidable, but will become essential. In this review, the authors summarize the main advances, as well as ongoing challenges and prospects, that surround the implementation of CS techniques in vascular surgery, with a particular focus on the care of patients affected by abdominal aortic aneurysms (AAAs). Several key areas of AAA care delivery, including patient-specific modelling, virtual surgery simulation, intraoperative imaging-guided surgery, and predictive analytics, as well as biomechanical analysis and machine learning, will be discussed. The overarching goals of these CS applications is to improve the precision and accuracy of AAA repair procedures, while enhancing safety and long-term outcomes. Accordingly, CS has the potential to significantly enhance patient care across the entire surgical journey, from preoperative planning and intraoperative decision making to postoperative surveillance. Moreover, CS-based approaches offer promising opportunities to augment AAA repair quality by enabling precise preoperative simulations, real-time intraoperative navigation, and robust postoperative monitoring. However, integrating these advanced computer-based tech-

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nologies into medical research and clinical practice presents new challenges. These include addressing technical limitations, ensuring accuracy and reliability, and managing unique ethical considerations associated with their use. Thorough evaluation of these aspects of advanced computation techniques in AAA management is crucial before widespread integration into health care systems can be achieved.

## 1. Introduction

Computational surgery (CS) is an emerging interdisciplinary field that leverages computational techniques and technologies, coupled with medical science, to improve the process of surgery [1]. The application of computational tools and techniques to the field of surgery may enable considerable advances in many aspects of care delivery, including disease modelling, outcome prediction, and development of new technologies that will deliver greater precision and predictability of care. As the digital revolution transforms the surgical work environment with broader incorporation of artificial intelligence (AI) and machine learning (ML), close collaboration between surgeons and computational scientists will become essential to harness the capabilities of both fields to optimize surgical care. We anticipate that novel investigations will greatly impact patient care far beyond the operating room. In this expert-based narrative review, we will summarize the main advances, as well as ongoing challenges and prospects related to the implementation of CS in vascular surgery, with a particular focus on the preoperative, intraoperative, and postoperative care of patients affected by abdominal aortic aneurysms (AAAs).

For most nonsurgeons, this description of surgery is often inaccurately reduced to the procedure performed in the operating room. Although it is true that many contemporary advances in surgery are driven by research in medical imaging, minimally invasive techniques, and medical robotics, these components are only part of the story. Research into the biological basis of surgical diseases, from genetic factors to integrative physiology, now greatly informs the understanding of pathophysiology and the expected results of surgical interventions. All of these research fields rely heavily on computational methods. For example, medical imaging and medical robotics are based on mathematical modeling, physics, (bio)engineering, and computing. Similarly, the field of biology has been completely transformed by computational methodologies, from DNA array techniques and analysis to computational multiscale modeling of biological networks. Consequently, computer science has revolutionized the work of surgeons; most new devices are computerized and the operating room is filled with digital equipment.

In this context, CS, particularly through the application of AI and ML, enhances modern surgical practices by leveraging computational science and technologies. CS integrates mathematics and algorithm design, offering practical applications, such as preoperative planning, simulation, augmented visualization, and manipulation of anatomic structures, and systematic analysis of large volumes of digital data [1]. Therefore, CS emerges as an interdisciplinary science that requires the integration of diverse skills and technologies, while remaining deeply rooted in surgical practice and ethical principles [2].

## 2. Preoperative CS applications for patients with AAAs

Imaging plays a crucial role in the preoperative management of AAAs, facilitating diagnosis, disease characterization, and evaluation of vascular anatomy for surgical planning. Vascular segmentation poses several challenges due to vessel curvature, physiological variations among patients, and artefacts from surrounding structures. In recent decades, significant advances have led to commercialization of software capable of 3-dimensional (3D) reconstruction of AAAs and semiautomatic vessel measurements for endovascular aneurysm repair (EVAR) planning (Fig. 1). AI has revolutionized vascular imaging analysis, particularly in enhancing vascular segmentation [3,4]. Notably, multiple studies highlight AI's potential in automatically segmenting AAAs, intraluminal thrombus, and vascular calcifications. For instance, Lareyre et al [5,6] developed a hybrid method combining an expert system with a supervised deep learning (DL) algorithm, achieving accurate segmentation of AAA components with volume similarities of 0.8128 for luminal segmentation and 0.9404 for thrombus segmentation compared with human experts [5,6].

Furthermore, convolutional neural networks have shown promise in automating measurements of aortic diameters and volume of AAAs [7,8]. In one study, a convolutional neural network trained on computed tomography angiography (CTA) using a data set of 350 images from 216 patients achieved a median absolute diameter difference of 1.6 mm (95% CI, 1.5–1.7 mm) compared with ground truth measurements from human experts [9]. The median volume similarity errors ranged from 0.93 to 0.95 in the main trunk and 0.88 in the iliac arteries. Such AI applications promise to reduce intra- and interobserver variability, improve reproducibility, shorten computational time, and streamline preoperative surgical planning.

In addition, DL-based methods have also been proposed to improve AAA visualization from noncontrast CT scans. Chandrashekar et al [10] used generative adversarial networks (GANs) to generate CT angiograms from noncontrast images of 75 patients with AAAs and the models were subsequently validated in a separate cohort of 200 patients. In brief, GANs are a class of DL architecture whereby two neural networks (ie, a set of algorithms that attempt to recognize the underlying relationships in the provided data for a particular

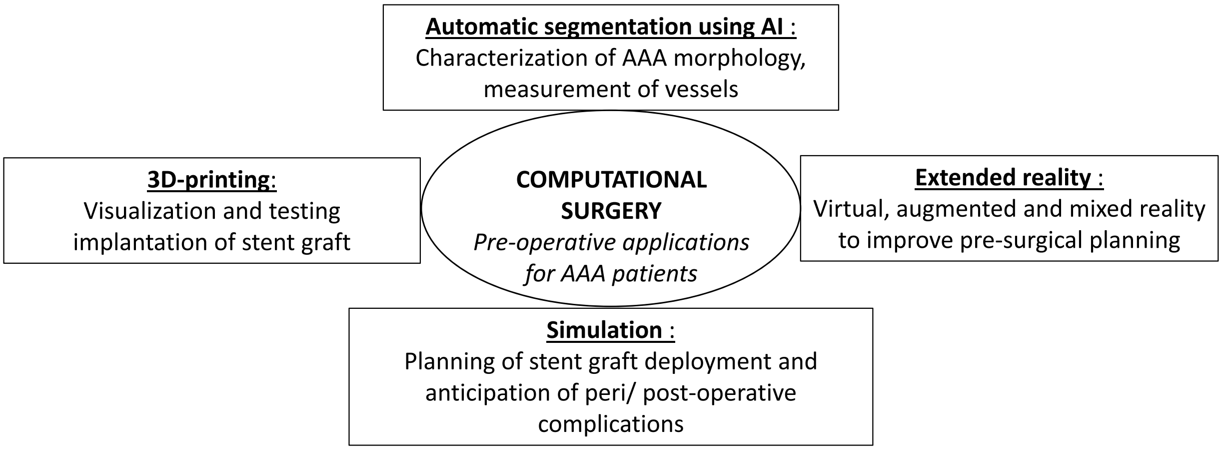

**Fig. 1 – Summary of pre-operative applications of computational methods for patients with abdominal aortic aneurysms. AAA, abdominal aortic aneurysm; 3D, 3-dimensional.**

task) are trained simultaneously, with one network as generator and the other network as discriminator of data. In detail, two variations of the GAN architecture were used—cycle-GAN and conditional-GAN. Cycle-GAN can learn the modifications between two paired distributions without the need for direct pairings between samples, and conditional-GAN learns such transformations using a pixel-to-pixel approach. In this analysis, both deep learning generative models were able to perform this image transformation task with the cycle-GAN model outperforming the conditional-GAN model, as measured by aneurysm lumen segmentation accuracy (mean ± SD cycle-GAN: 86.1% ± 12.2% *v* conditional-GAN: 85.7% ± 10.4%) and thrombus spatial morphology classification accuracy (cycle-GAN: 93.5% *v* conditional-GAN: 85.7%). This application of CS has the potential to revolutionize clinical pathways that currently rely on contrast-based imaging methods.

In parallel to AI-based methods, several studies have focused on developing simulation techniques for stent-graft deployment to enhance EVAR planning. As an example, researchers have developed numerical simulations for sizing fenestrated stent grafts. This approach was tested in 51 consecutive patients who underwent successful fenestrated EVAR, encompassing 195 target arteries. The study found that simulation accurately planned fenestration positions compared with measurements obtained by the stent-graft manufacturer's planning team on preoperative CT scans and confirmed by postoperative imaging evaluations [11]. Further in vitro studies validated the method's accuracy for fenestration positioning, suggesting its potential to improve endovascular repair planning, as well as possibly anticipate and prevent postoperative complications [12].

Extended reality technology has also been proposed to improve visualization and preoperative assessment. Extended reality encompasses various sub-fields, including virtual reality (VR), augmented reality (AR), and mixed reality (MR). VR immerses users in artificial environments, AR projects virtual objects (holograms) into the real environment, and MR allows interaction with both virtual objects and the physical world. Several studies have highlighted VR's utility in preprocedural analysis of critical components of catheterization laboratory procedures, such as C-arm positioning, 3D measurements, and generating idealized roadmaps for vessel navigation [13,14]. Similarly, MR viewers have shown promise in assessing aortoiliac vascular anatomy of patients with AAAs. In a dataset of 50 preoperative CTAs, investigators reported the use of an MR viewer and demonstrated equal or better results compared with conventional DICOM viewers on 2D screens with multiplanar reconstructions for visualizing calcification, tortuosity, dilatation, and patency [15]. Future advancements should focus on improving hologram quality and ensuring accurate hologram registration with the patient's physical anatomy.

Furthermore, the introduction of 3D printing has opened new avenues for planning vascular interventions. 3D-printed models offer a more detailed understanding of complex vascular anatomies and pathologies. In the context of planning for complex EVAR procedures, 3D printing facilitates orientation and testing of stent-graft implantation to potentially reduce complications and improve outcomes [16]. Several case reports and series have documented successful use of 3D printing for planning aortic endovascular repairs, highlighting its potential benefits for both educational purposes and clinical application [17,18]. However, these methods require further validation in larger cohorts before widespread implementation in daily practice.

## 3. Intraoperative CS applications for patients with AAAs

Numerical modeling, especially in the field of mechanical interaction analysis, has the potential to improve the outcomes of AAA interventions. This can be achieved by predicting the behavior of aortic devices in personalized aortic anatomy [19]. Studies are exploring how to integrate numerical modeling into intraoperative guidance. A key aspect of this integration is creating a digital twin of the patient's anatomy that incorporates dynamic features essential for accounting of nonrigid anatomic deformations during surgery (Table 1).

**Table 1 – Summary of intra-operative applications of computational methods for patients with abdominal aortic aneurysms.**

| Variable | Aims | Cons |
|---|---|---|
| Multimodal fusion technologies | Improvement of knowledge of patients' vascular anatomy during surgery by overlaying preoperative computed tomography angiography on conventional fluoroscopy | Continuous use of fluoroscopy |
| Virtual reality navigation | Intravascular navigation of endovascular catheters and guide wires | Costs<br>Limited data from humans |
| Fiber-Optic RealShape | Creation of real-time 3-dimensional renderings of guide wires and catheters without the support of fluoroscopy | Costs |
| Augmented reality | Virtual navigation integrated with the real-time surgical scenario, with the possibility to reduce the head-turning and the risk of inattentiveness compared with traditional navigation systems | No adaptability to body movements<br>Surgical instruments interaction |

In the past decade, multimodal fusion technologies have become increasingly important during endovascular procedures. These technologies provide a better understanding of patients' vascular anatomy during surgery by overlaying preoperative CTA data on conventional fluoroscopy. This offers 3D information about vascular anatomy and key landmarks, such as the target vessel origins and orientation. However, although these techniques excel at displaying underlying anatomy, the visualization of wires and catheters during navigation still relies on continuous x-ray fluoroscopy. This dependence on fluoroscopy exposes patients and health care providers to the risks of radiation and limits visualization to two dimensions (2D) [20].

To overcome these limitations, VR navigation tools are emerging. These tools use various tracking technologies, such as electromagnetic tracking [21,22], systems-based fiber Bragg grating-based tracking systems [20], or a combination of both [23]. This allows for navigation of endovascular catheters and guide wires, potentially reducing both x-ray exposure and contrast agent use. Interestingly, feasibility studies have shown promise for electromagnetic tracking in endovascular navigation; however, most results have been generated from in vitro phantom experiments, with some data derived from in vivo animal studies, but limited data from human patients thus far [24]. Proposed applications include, but are not limited to, navigation in EVAR [25], in situ fenestration of abdominal stent-grafts [26], branched endovascular thoracoabdominal aneurysm repair [3], and deployment of thoracic aortic endografts [27].

Another promising technology that is linked to computational framework is the Fiber Optic RealShape system that was recently developed by Philips to facilitate endovascular navigation. The software uses light refracted through optical fibers to create real-time 3D renderings of wires and catheters. The early results of clinical trials, which involved treating 45 patients with aortic aneurysms, indicate that the technology is both safe and effective. Early evidence appears to demonstrate that Fiber Optic RealShape helps to reduce procedural complexity and minimize radiation exposure. The current focus of research and development surrounding Fiber Optic RealShape technology is to improve the accuracy of the rendering and expand the range of endovascular devices that can interface with the image-guidance platform [28].

The use of x-ray–free localization systems has been proposed in the literature not only for developing VR navigation systems but also for AR systems. AR interfaces have the potential to revolutionize image-guided surgery by reducing cognitive load and improving information management. AR technology offers physicians virtual navigation aids that seamlessly integrate with the real-time surgical scenario, making it easier to use and understand 2D and 3D medical data in the operating room. This reduces the frequency of head-turning and risk of inattention compared with traditional navigation systems [29]. In addition, AR head-mounted displays, like the HoloLens (Microsoft Corp), can also be operated via voice commands and gestures, allowing for a hands-free experience and maintaining a sterile environment.

A common technical challenge in both VR and AR navigation systems is achieving and maintaining accurate registration (ie, spatial alignment) between the virtual anatomic models and the real patient's anatomy. Many computer-assisted systems rely on external artificial markers pinned on the body surface or anatomic landmarks for registration. This can limit registration accuracy due to the following two major factors: 1) inability to adapt to anatomic shifts from respiration and heartbeat and 2) soft-tissue deformation caused by surgical instrument interaction.

However, for procedures with minimal patient repositioning and targeting relatively fixed vascular structures, registration accuracy is less affected by anatomic shifts [29]. To correct the mismatch between the virtual construct and the real patient, several techniques have been proposed, including the use of computational models for image-to-patient registration.

Duménil et al [30] developed a system to improve pre- and intraoperative registration in EVAR interventions. The system relies on building a patient's anatomic model from preoperative CT, constructing and tuning a biomechanical model, simulating tool (guide wire)–tissue interactions via implicit finite-element analysis, and projecting the deformed model onto intraoperative imaging. The mechanical parameters (boundary conditions and pre-stress level) of the finite-element analysis were initially calibrated on a group of 10 patients by comparing them with intraoperative images. Based on the resulting data, laws that establish the relationship between patient-specific "imaging" data and "biomechanical" data were assessed using polynomial regression to obtain a unique patient-adaptive model.

In 2017, Gindre et al [31] reported the potential of using numerical simulation to predict substantial variations in the vascular geometry caused by the insertion of endovascular tools, even in severe aorto-iliac morphologies. However, their approach is not yet fully validated for improving fusion guidance. In 2018, Mohammadi et al [32] proposed precomputing the deformation of the vascular tree during EVAR by simulating the positioning and deployment of stent-grafts. More specifically, they developed a patient-specific biomechanical model of the aorto-iliac structure and its surrounding tissues, incorporating the support provided by perivascular tissues and organs. This model's predictive capability was evaluated on a group of 4 patients. The mean ± SD distance between the real and simulated endovascular tools was 2.99 ± 1.78 mm on the ipsilateral side and 4.59 ± 3.25 mm on the contralateral side. In addition, the distance between the deformed iliac ostia and their corresponding landmarks on intraoperative images was 2.99 ± 2.48 mm. This system could potentially help surgeons match preoperative data with intraoperative images, providing an accurate roadmap, while reducing the number of contrast exposures. However, the method relies on precalculating model deformations, requiring precise prediction of the surgical workflow. Any unexpected event or change in surgical tools during the procedure can render the model unusable.

A notable commercially available system is the Cydar EV (Cydar Medical). This cloud-based, AI-powered system fuses preoperative CT to create a detailed, patient-specific 3D map of the target vasculature, aiding surgical planning. It uses these maps to augment intraoperative live image guidance, updating them in real-time to account for anatomic deformations caused by instruments or guide wires. A multicenter observational study involving 109 patients conducted in 2014 to 2015 evaluated the safety, performance, usability, and efficacy of Cydar EV, ultimately leading to its CE marking. The study demonstrated significant patient benefits, including a 35% reduction in x-ray fluoroscopy screening time ($P = .013$), a 41% reduction in iodinated contrast used ($P = .008$), and a nearly 1-hour decrease in average operating time. In a more recent single-center study conducted over 7 years, a comparative analysis was performed on 53 fenestrated EVAR cases without, and 63 with, Cydar EV imaging guidance. The cohorts were similar in patient demographic characteristics, medical comorbidities, and aortic aneurysm characteristics. No significant differences were noted between the two groups for major adverse postoperative events, length of hospital stay, or length of intensive care unit stay. However, the use of Cydar EV resulted in nonsignificant decreases in mean ± SD fluoroscopy time (69.3 ± 28 minutes *v* 66.2 ± 33 minutes; $P = .598$) and operative time (204.4 ± 64 minutes *v* 186 ± 105 minutes; $P = .278$). A statistically significant decrease was found in iodinated contrast volume (105 ± 44 mL *v* 83 ± 32 mL; $P = .005$), patient radiation exposure using the dose area product (1,049,841 mGy/cm$^2$ *v* 630,990 mGy/cm$^2$; $P < .001$), and cumulative air kerma levels (4518 mGy *v* 3084 mGy; $P = .02$) for patients undergoing fenestrated EVAR with Cydar EV guidance [33]. Currently, an open-label, two-armed randomized controlled clinical trial called ARIA is underway. This multicenter study with 340 patients aims to assess the clinical, technical, and cost-effectiveness of the system compared with standard treatment for EVAR [34].

## 4. Postoperative CS applications for patients with AAAs

Long-term follow-up is essential after AAA repair to detect postoperative complications. Innovative tools for risk stratification can help develop personalized follow-up strategies to improve outcomes. Traditionally, risk prediction has relied on statistical methods, but ML and DL offer new opportunities by analyzing large data sets and identifying hidden patterns in complex data. Various studies have highlighted the potential of these approaches to predict mortality outcomes after AAA repair [35]. For example, some investigators sought to predict mortality after either open or endovascular repair of AAA [36,37]. Other investigators have focused on other major cardiovascular events, such as a composite end point of myocardial infarction, stroke, and/or death. Using the Vascular Quality Initiative database, including 12,027 patients who underwent elective open AAA repair, the authors trained six ML models [38]. The best-performing model achieved an area under the receiver operating characteristic curve of 0.93 (95% CI, 0.92–0.94) and outperformed logistic regression, suggesting the utility of this computational application in guiding risk-mitigation strategy.

Although EVAR has become a well-established alternative to open surgery, it requires long-term follow-up to detect postoperative complications, such as endoleaks, stent-graft migration, or stent-graft iliac limb thrombosis or stenosis. In this context, ML models have been developed to assess the risk of endoleaks after EVAR and thoracic EVAR. For instance, a study by Masuda et al [39] used patient characteristics, stent-graft configuration details, and vessel anatomy measurements (ie, lengths, diameters, and angles) from preoperative CTA to train a ML algorithm. The model predicted the occurrence of Type I and II endoleaks after EVAR with an area under the curve (AUC) of 0.88, a sensitivity of 0.85, and a specificity of 0.91. This approach was extended to patients who underwent thoracic EVAR, confirming its effectiveness in predicting endoleaks [40].

Charalambous et al [41] used radiomic features from CTAs to differentiate aggressive from benign Type II endoleaks after EVAR. Their ML model used up to 58 radiomic features and was able to predict sac expansion at 1-year follow-up with an AUC of 89.3%, a specificity of 78.6%, and a sensitivity of 100%. Another ML approach was used to predict severe adverse events related to EVAR and, in a cohort of 493 patients, the best-performing model achieved an AUC of 0.93, with an accuracy of 0.86 [42].

In addition to better predicting the risk of endoleaks, AI-based methods offer new opportunities to improve the detection and diagnosis of this complication based on postoperative imaging [43]. Detecting endoleaks can sometimes be challenging, leading to delayed diagnosis. Some researchers have trained ML algorithms to automatically detect endoleaks on CTA, achieving accuracy, precision, and recall for endoleak diagnosis of 95%, 90%, and 100%, respectively, compared with subspecialist interpretation (AUC = 0.99) [44]. Although additional studies are required, this approach may help improve endoleak detection and guide timely referral of patients to vascular specialists.

Furthermore, AI may outperform traditional statistical methods, such as Kaplan-Meier analyses, for estimating long-term survival after treatment of AAA [45]. This approach has the potential to provide more precise patient-specific survival estimates and identify survival differences between patient subgroups that conventional statistical tools cannot detect, thereby improving longitudinal surveillance.

## 5. Ongoing challenges and future directions: Multidisciplinary collaboration, data integration, confidentiality, and equity

Computer-based technologies offer exciting new opportunities to optimize patient care; however, their incorporation into medical research and clinical practice introduces new challenges that need to be addressed. Although the future seems promising, several key issues must be considered carefully. First, cross-disciplinary research can be hampered by difficulties in efficiently delivering information using a shared language. Indeed, surgeons and computational scientists not only have different scientific backgrounds, but also different working cultures. Therefore, effective collaboration relies on close and mutually fruitful discussions between these two groups. Computational scientists must remember that a proof of concept for one case may not be scalable to clinical practice or economically viable. Significant effort and patience are required to achieve meaningful collaboration between surgeons and computational scientists to ultimately produce high-quality clinical and translational results.

Another difficulty in establishing collaborations may be institutional in nature. The professional demands and financial models of surgeons and computation scientists often diverge. Nonetheless, the intellectual challenge and educational value of such collaborations are undoubtedly professionally rewarding. New models of education and funding may be considered in the future to facilitate building cultural and working bridges between these two communities [46].

Three important sources of digital information impact the development of CS in health care. The first is patient digital clinical information records maintained by several networks worldwide. The second source is the data generated in modern operating rooms, which include (but are not limited to) patients' vitals, procedural details (eg, type and number of devices, fluoroscopy duration and radiation exposure, blood loss, and intraoperative imaging), and medical charts, among others. The third source is electronic medical research databases, such as PubMed and Scopus. Together, these data produce a vast amount of digital data for patient data and clinical research. Data integration at the national and international level is also very challenging due to economic competition and the need for patient confidentiality.

Further challenges arise from the adoption of AI and ML, especially DL models, due to issues with interpretability. Although well-trained algorithms can achieve high levels of precision and accuracy, the methods by which an input generates a given output may be obscure, resembling a black-box model. Transparency and generalizability are essential in health care to improve decision making and integrate these technologies into clinical workflow [47].

As we enter an era of rapid change, evaluating the ethical concerns of AI is critical, particularly regarding patient safety and privacy. This is especially important in the early stages of adopting technology, as innovation often outpaces regulatory policies and ethical guidelines [48]. Key issues include patient privacy and confidentiality, risks of data breaches, protection of patient autonomy and informed consent, accuracy and applicability of the technology, and the propagation of health care disparities [49,50]. Accordingly, vascular surgeons should be equipped to work with these innovations and understand this technology to help design more accurate, robust, and widely applicable algorithms.

Examples of such leadership include conducting higher-quality studies that adhere to standard reporting tools, including all patients populations during the formative research period of AI in vascular surgery, conscientious and ethical data sharing to AI databases, and participating in institutional and national organizations overseeing data security for programs aimed at enhancing vascular surgery outcomes. AI has the potential to interfere with baseline ethical principles and the fundamental rights and freedoms of individuals; therefore, all stakeholders must ensure that newer technologies remain compatible with ethical considerations and moral values. As the field continues to evolve, being aware of the inherent biases and limitations related to black-box decision making, biased data sets agnostic to patient-level disparities, variation in present methodologies, and lack of common reporting standards will require ongoing research to provide transparency to AI and its applications.

## 6. Conclusions

Contemporary surgical practice can be significantly enhanced through the use of CS methods. This reality can occur through development of robust collaboration between surgeons and computational scientists that aims to leverage these tools to improve surgical care provision and outcomes. CS is an emerging discipline that integrates computational science and surgical processes. The scope of this discipline includes modeling and simulation of biological processes and procedural interventions to predict surgical outcomes; real-time augmented visualization to enhance surgical procedures and foster precision; multiscale modeling of surgical disease with integration of patient-specific data in procedural planning, and design of interventional and tracking devices to inform real-time assessment of surgeon performance.

Therefore, CS is central to the development of precision surgery. Computational science offers a unique ability to analyze health data more quickly and efficiently than humans alone. It can be used for clinical applications, such as diagnosis, risk stratification, and follow-up, as well as patient-centered applications to improve both patient and provider experiences, mitigate health care disparities, and individualize treatment. However, like all novel technologies, CS carries unique risks and ethical considerations that must be addressed before broad adoption and integration into health care systems. The assessment of new methods should consider the abilities of the surgeon and the entire health care team caring for the patient throughout a surgical intervention. We should develop new curricula and joint degree programs to provide opportunities for students in medicine and computational science to work synergistically in this evolving field.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

## CRediT authorship contribution statement

**Mario D'Oria:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Juliette Raffort:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Sara Condino:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Fabrizio Cutolo:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Giulia Bertagna:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Raffaella Berchiolli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Salvatore Scali:** Data curation, Methodology, Supervision, Validation, Visualization, Writing – review & editing. **Filippo Griselli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Nicola Troisi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Sandro Lepidi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Fabien Lareyre:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization.

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