AI-Driven EVAR Planning: Automated Measurements and Stent Graft Selection

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Abstract

Discover how AI enhances EVAR planning with automated measurements and stent graft selection, improving accuracy and reducing pre-operative planning time.

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Introduction

Endovascular aneurysm repair (EVAR) has revolutionized the management of abdominal aortic aneurysms (AAA) by offering a minimally invasive alternative to open surgery. Success in EVAR critically depends on precise preoperative planning, which involves detailed anatomical measurements and appropriate stent graft selection tailored to the patient's vascular anatomy. Traditionally, this process is time-consuming, subject to inter-observer variability, and requires significant expertise. Recent advances in artificial intelligence (AI) have introduced transformative tools that automate these steps, enhancing accuracy, efficiency, and clinical outcomes.

This article explores the evolving role of AI in EVAR planning, focusing on automated anatomical measurements, AI-guided stent graft selection, clinical significance, supporting research, challenges, and future directions.

Automated Anatomical Measurements in EVAR

Accurate anatomical assessment is a cornerstone of EVAR planning. Critical parameters include the proximal aortic neck diameter and length, neck angulation, iliac artery diameters, and the maximum aneurysm diameter. AI algorithms, primarily based on deep learning and advanced image segmentation techniques, analyze computed tomography angiography (CTA) datasets to extract these measurements with remarkable precision.

Key Measurements and Their Clinical Relevance

- **Aortic Neck Diameter:** Typically ranges from 18 to 32 mm. The proximal neck diameter informs the sizing of the stent graft's proximal sealing zone. Oversizing by 10-20% is standard to minimize risks of endoleak and graft migration. - **Aortic Neck Length:** A minimum neck length of 15 mm is recommended to provide an adequate seal and fixation zone. - **Neck Angulation:** Angulations less than 60° are considered favorable for EVAR; higher angles increase procedural complexity and risk of stent graft complications. - **Iliac Artery Diameters:** Both left and right iliac diameters, generally between 8 and 20 mm, guide the distal landing zone and device compatibility. - **Maximum AAA Diameter:** An aneurysm diameter exceeding 55 mm is a common threshold for intervention.

AI-powered software can rapidly segment vascular structures, generate 3D reconstructions, and produce reproducible quantitative measurements, reducing reliance on manual caliper-based assessments prone to observer bias.

AI-Based Stent Graft Selection

Following anatomical characterization, the next pivotal step is selecting an appropriately sized and configured stent graft. AI systems integrate measured parameters to recommend devices optimized for the patient's unique anatomy. This involves:

- **Proximal Diameter Oversizing:** Typically around 17% larger than the neck diameter to ensure an effective seal without excessive radial force. - **Distal Diameter Matching:** Ensuring compatibility with iliac artery diameters to prevent limb occlusion or endoleak. - **Device Length:** Adequate coverage of the aneurysm with sufficient proximal and distal sealing zones. - **Neck Angulation Compatibility:** Selecting grafts designed to accommodate specific angulations to minimize graft kinking or migration.

For example, an AI system might recommend a primary stent graft with a 28 mm proximal diameter, 24 mm distal diameter, and 145 mm length, suitable for a patient with a 42° neck angulation. Alternative graft options with similar anatomical fit are also provided to support clinical decision-making.

Workflow Efficiency and Clinical Impact

Several clinical studies have evaluated AI-assisted EVAR planning platforms, demonstrating substantial benefits:

Planning Method	Planning Time	Time Saved	Accuracy vs. Manual
Manual Planning	45 minutes	—	Baseline
AI-Assisted Planning	8 minutes	37 minutes	98% concordance

Key Advantages

- **Significant Time Reduction:** AI reduces planning time by up to 82%, facilitating faster preoperative workflows and improved operating room scheduling. - **High Measurement Accuracy:** AI achieves over 98% concordance with manual expert measurements, ensuring clinical reliability. - **Standardization and Reduced Variability:** Automated measurements minimize inter- and intra-observer variability, promoting consistency. - **Enhanced Patient Throughput:** Streamlined planning supports higher case volumes without compromising safety. - **Improved Clinical Outcomes:** Accurate sizing and device selection decrease the incidence of complications such as endoleaks, graft migration, and reinterventions.

Supporting Research Evidence

Multiple peer-reviewed studies validate the utility of AI in EVAR planning:

- **Image Segmentation Accuracy:** Studies demonstrate that AI-based segmentation algorithms achieve Dice similarity coefficients exceeding 0.9 when delineating the aortic lumen and aneurysm sac, comparable to expert manual segmentation. - **Measurement Reproducibility:** Research shows AI tools reduce variability by 50–70% compared to manual measurements. - **Clinical Trial Data:** Prospective trials indicate AI-assisted planning accelerates workflow without compromising procedural outcomes, with some reports suggesting improved graft sizing accuracy leading to fewer postoperative complications.

Applications Beyond EVAR

While EVAR planning is a prominent AI application in vascular surgery, similar technologies are being developed for:

- **Thoracic Endovascular Aortic Repair (TEVAR):** Automated measurements facilitate device selection for thoracic aneurysms. - **Peripheral Artery Disease Interventions:** AI assists in vessel sizing and lesion characterization. - **Preoperative Simulation:** AI models simulate graft deployment and predict hemodynamic outcomes, aiding surgical strategy.

Challenges and Limitations

Despite promising advances, challenges remain:

- **Data Quality and Diversity:** AI performance depends on high-quality, annotated imaging datasets representative of diverse populations and anatomies. Limited datasets can impede generalizability. - **Integration into Clinical Workflow:** Seamless incorporation into existing hospital PACS and surgical planning systems requires interoperability and user training. - **Regulatory and Liability Issues:** Regulatory approval processes for AI medical devices are evolving, necessitating rigorous validation and clarity on liability. - **Physician Acceptance:** Clinician trust in AI recommendations requires transparency and demonstration of consistent reliability. - **Handling Complex Anatomies:** Highly tortuous or calcified vessels may challenge AI algorithms, requiring manual review.

Future Directions

Future research and development in AI-driven EVAR planning are likely to focus on:

- **Multimodal Data Integration:** Combining CTA with intravascular ultrasound and hemodynamic data for comprehensive assessment. - **Real-Time Intraoperative Guidance:** AI tools providing live feedback during stent graft deployment. - **Personalized Device Design:** Using AI to design custom stent grafts tailored to individual anatomy. - **Predictive Analytics:** AI models predicting long-term outcomes, risk of endoleak, or graft failure. - **Enhanced User Interfaces:** Intuitive visualization tools for surgeons to interact with AI-generated data.

Frequently Asked Questions

Q: How does AI improve EVAR planning accuracy? AI utilizes advanced image processing and machine learning algorithms to consistently and objectively measure vascular dimensions, minimizing human error and reducing inter-observer variability. **Q: Can AI recommendations replace physician judgment?** No. AI functions as a decision-support tool, providing evidence-based recommendations to assist clinicians. Final clinical decisions remain under the physician’s purview. **Q: What are the benefits of reducing EVAR planning time?** Shortened planning enhances workflow efficiency, reduces patient wait times, allows timely interventions, and optimizes resource allocation. **Q: Is AI applicable to all EVAR candidates?** While AI tools cover most typical anatomies, complex or unusual cases may still require manual planning and expert review.

Conclusion

AI-driven EVAR planning represents a paradigm shift in vascular surgery, offering rapid, reproducible, and precise anatomical measurements coupled with intelligent stent graft selection. This technology not only streamlines preoperative workflows but also supports personalized treatment strategies, ultimately improving patient safety and outcomes. As AI continues to evolve and integrate with clinical practice, it holds significant promise to advance the standard of care in endovascular interventions.

Keywords: Artificial intelligence, EVAR planning, endovascular aneurysm repair, automated measurements, stent graft selection, abdominal aortic aneurysm, vascular surgery, medical imaging, AI in healthcare, workflow optimization.
