Robotic Vascular Surgery: Current Technologies and Challenges

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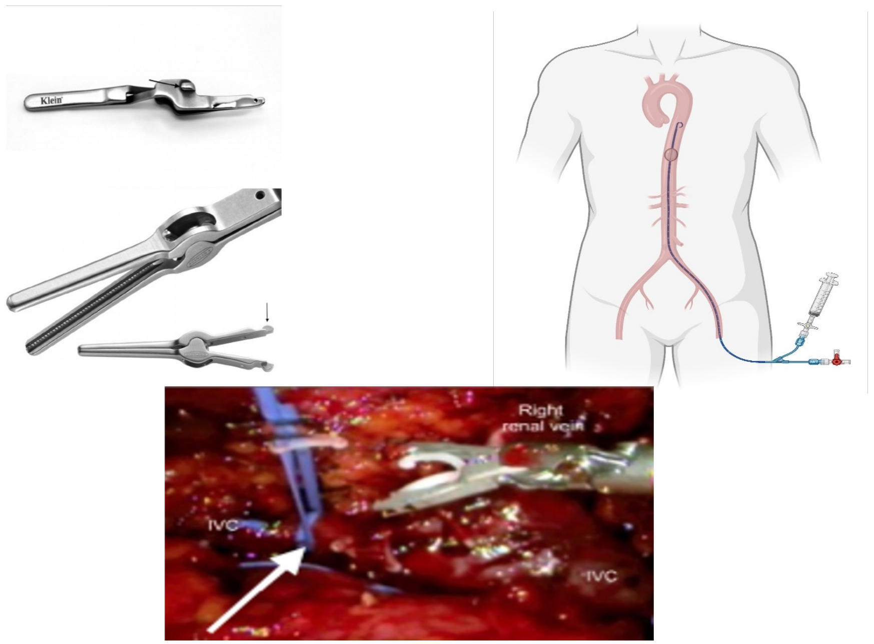
Background

Robotic vascular surgery has not been widely adopted due to the lack of dedicated training pathways, increased operative times, and the lack of suitable instruments for quick control in case of bleeding. This review identifies current robotic vascular technologies, technologies that can be translated to robotic vascular surgery, and upcoming devices showing promise in the field of robotic vascular surgery.

Methods

PubMed, Google Scholar, and Scopus were queried using various combinations of terms pertaining to robotic vascular surgery. Studies not published in full, editorials, and articles not written in English were excluded from consideration.

Figure 1



A. Klein Robotic Bulldog Clamp - Modified from [9]

B. REBOA catheter - Created with BioRender.com

C. Rummel Tourniquet (white arrow) - Modified from [10]

Results

Device	Product Status	Advantages	Disadvantages
Robotic Bulldog Clamp[1]	Current Robotic Vascular Technology	• Small • Reusable	• Partial occlusion due to lower clamping force • Clamping force is sensitive to positioning
Rummel Tourniquet[2]	Current Robotic Vascular Technology	• No reported complications in IVC-Thrombectomy	• Use is limited to small and noncalcified arteries
Chitwood Clamp[3]	Current Robotic Vascular Technology	• Unobstructed surgical field visualization • Minimizes the chance suture entanglement • Allows for adjustment of clamping force	• Risk of peripheral ischemia and reperfusion injury from aortic cross clamping
Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)[4-6]	Potential Robotic Adaptations	• Rapidly deployable • Causes less vessel damage than cross-clamping	• Risk of aortic perforation, rupture, and peripheral ischemia • Challenges associated with C-arm for fluoroscopic guidance
Flexible End Effector Surgical Devices[7]	Upcoming Technology	• Greater control via increased degrees of freedom	• Pending research and development • Has not been FDA cleared • Limited studies proving efficacy (due to its infancy)
Magnetically Actuated Endoscopic Devices[8]	Upcoming Technology	• Can interface with surgical robots to perform endovascular procedures robotically • Can be less invasive than laparoscopy	

Conclusion

Advancements in robotically deployed clamps, aortic occlusion devices, and end-effector robotic devices hold promise for enhancing surgical interventions. Intraoperative vascular injuries are rare; nevertheless, when they do happen, large vessel control is difficult with the currently available robotic instruments. Technologies that require undocking of the surgical robot present barriers to using them in robotic vascular procedures. Hence, addressing the limitations and potential complications of the use of these devices is essential for safe implementation and continued progress.

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