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EDITORIAL COMMENT

Robotic Percutaneous Coronary Intervention

Time to Focus on the Patient*

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Percutaneous coronary intervention (PCI) is the dominant mode of revascularization for ischemic heart disease with >2 million procedures performed annually worldwide. Technological advancements in interventional equipment and adjunctive antithrombotic therapy combined with high-fidelity angiography and intravascular imaging (i.e., intravascular ultrasound, optical coherence tomography [OCT]) have optimized clinical outcomes resulting in procedural and clinical success rates exceeding 97% with very low complication rates. Perhaps influenced by the development of robotic approaches for minimally invasive surgery, biomedical engineers working closely with interventional cardiologists and electrophysiologists have developed robotic systems for coronary intervention (e.g., CorPath, Corindus Vascular Robotics, Waltham, Massachusetts) and for the treatment of arrhythmias (e.g., Niobe magnetic navigation system, Stereotaxis, St. Louis, Missouri). Robotic-assisted technologies for cardiovascular application offer the promise of reduced radiation exposure to the operator and enhanced catheter precision.

The PRECISE (Percutaneous Robotically Enhanced Coronary Intervention) trial demonstrated the safety and feasibility of robotic-assisted PCI in a multicenter registry study of 163 patients without an increase in patient radiation or contrast use (1). However, in this registry, the majority of lesions treated were simple and not reflective of real-world clinical practice. The applicability of robotic technology for PCI in a wider, "all-comer" cohort and, in particular, for complex coronary lesions is unknown. In this issue of *JACC: Cardiovascular Interventions*, Mahmud et al. (2) report on the results of the CORA-PCI (Complex Robotically Assisted Percutaneous Coronary Intervention) study, which was designed to evaluate the feasibility and technical success of robotic-assisted PCI (Corindus CorPath 200) for the treatment of coronary artery

SEE PAGE 1320

disease in a real-world cohort, and to determine the safety and clinical success of robotic-assisted PCI as compared with manual PCI. A total of 315 patients underwent 334 PCI procedures (108 robotic PCI, 157 lesions, 78.3% type B2/C; 226 manual PCI, 336 lesions, 68.8% type B2/C). Technical success with robotic PCI was 91.7%, requiring manual assistance in 11.1% of cases and manual conversion in 7.4%. Clinical success, stent utilization, and fluoroscopy time were similar between both groups, whereas in propensity-matched analysis, procedure time was longer in the robotic PCI group by about 9 min.

The authors should be commended for focusing on a near "all-comer" population with complex disease. The results with this first-generation robotic system are more than acceptable given the ability for only passive manipulation of the guide catheter via wire and balloon interactions, which itself requires a new set of skills. The second-generation CorPath GRX system is now Food and Drug Administration approved and has a third joystick with the ability to

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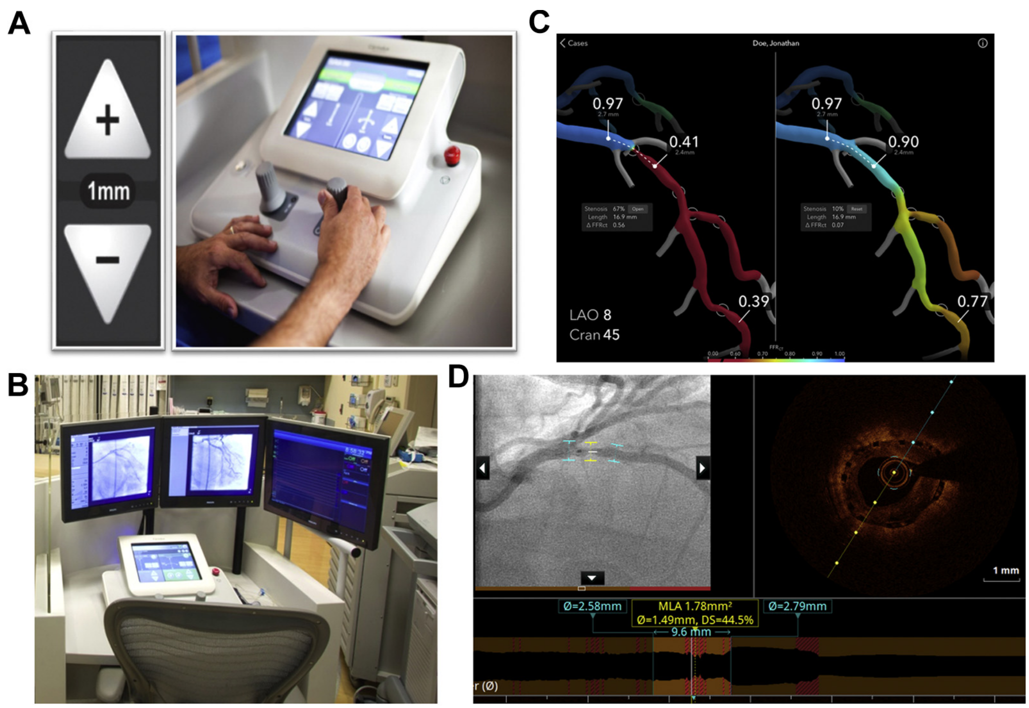
FIGURE 1 Robotic-Assisted Cockpit of the Future



(A) The robotic system allows for precise control with millimeter movements of wire and devices. **(B)** Cockpit design permits easy visualization on multiple monitors for integration and manipulation of multimodality imaging. **(C)** Example of HeartFlow FFR-CT PCI planner with visualization of coronary arteries and potential for determining precise lesion length **(left-hand panel, dotted line)** and then modeling restoration of normal coronary flow and FFR following imputed coronary artery stent deployment **(right-hand panel)**. **(D)** OCT and angiography coregistration enable precise positioning of the stent by projecting OCT-based landing zones into the angiographic image. CT = computed tomography; FFR = fractional flow reserve; OCT = optical coherence tomography; PCI = percutaneous coronary intervention.

robotically control the guide catheter. This system should help improve robotic guide catheter support and decrease the number of procedures requiring manual assistance or conversion, but has not been studied clinically. Furthermore, it is important to emphasize that robotic PCI systems do not permit the use of atherectomy devices, guide extenders, or microcatheters—necessary tools for the interventional cardiologist tackling complex disease.

The central motivation, as discussed by the authors, for “first-generation” robotic PCI is reducing occupational hazards for the operator—namely, radiation exposure and chronic orthopedic conditions. It is important to highlight that one positive downstream effect of robotic PCI is heightened awareness of radiation exposure overall in the cardiac catheterization laboratory. Unfortunately, the intervention cardiology community has largely neglected to prioritize efforts that can significantly reduce patient and operator radiation exposure. All commercial angiography systems have dose-saving solutions, either on the front end by special filters or at the detector level or image post-processing level, that improve the quality of low-energy images (3). Shielding can also reduce radiation exposure by more than 90% (4). Most importantly, the simple adoption of low-frame pulsatile fluoroscopy coupled with storing fluoroscopy sequences rather than cine image acquisition can reduce radiation exposure dramatically to both patient and operator (4). Other maneuvers to reduce radiation dose include the avoidance of high magnification as well as limiting steep angulations. All the these should be considered and implemented independently of the availability of robotic PCI, because patient radiation exposure is not directly impacted by robotic PCI. Finally, operator apron technology has also evolved with 2-piece design, lighter materials, better belt support, and the inclusion of head and hand protection solutions (4,5). Other approaches such as Zero-Gravity (Biotronik, Berlin, Germany) virtually eliminate any radiation or orthopedic issues for the operator (6).