Novel robotic training program reduces physician errors placing central lines

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Penn State researchers developed a robotic simulation training programing, pictured here, that allows medical residents to practice placing central lines under a variety of scenarios and receive immediate feedback. Credit: Michael Owen/Penn State

More than five million central lines are placed in patients who need

prolonged drug delivery, such as those undergoing cancer treatments, in the United States every year, yet the common procedure can lead to a bevy of complications in almost a million of those cases.

To help decrease the rate of infections, blood clots, and other complications associated with placing a central line catheter, Penn State researchers developed an online curriculum coupled with hands-on simulation training to provide trainee physicians with more practice.

Deployed in 2022 at the Penn State College of Medicine, the researchers recently assessed how the training impacted the prevalence of central line complications by comparing error rates from 2022-23, when the training had been fully implemented, to two prior years, 2016-17 and 2017-18, from before implementing the training. They found that all complication types—mechanical issues, infections, and blood clots—were significantly lower after the training was launched.

They published their results in the Journal of Surgical Education. The researchers hold patents on the technology used in this work. In addition to working to improve the central line placement training, the team is also applying the framework to other common procedures with high complication rates, such as colonoscopies and laparoscopic surgeries.

"Our approach is focused on reducing preventable errors—this paper is the first significant clinical evidence that we are moving the needle on the gap in clinical education and clinical practice," said Scarlett Miller, professor of industrial engineering and of mechanical engineering at Penn State and principal investigator on the project. "If we ensure physicians going through residency training are proficient in a skill, like placing central lines, we can minimize the risk on human life."

Traditional training for placing a central line and other routine surgical procedures starts with a resident watching a more senior doctor complete

the process. Then, the resident is expected to do the procedure themselves, and, finally, they teach someone else to do the procedure.

"The problem with that approach is that there are very few checks in the process, and the resident only improves by working with patients—who are at risk of complications," Miller said. "The simulation approach allows someone to try the procedure hundreds, thousands of times without putting anyone at risk."

The new approach—the result of interdisciplinary work between engineers and clinicians, Miller said—uses online- and simulation-based training to perform standardized ultrasound-guided internal jugular central venous catheterization (US-IJCVC), which is a central line placed into the internal jugular vein via the neck.

Residents first complete online training, which includes pre- and post-tests, to evaluate the knowledge gained. They then take that knowledge and apply it in a skills lab, where they practice placing the central line on a novel dynamic haptic robotic trainer that can simulate various conditions and reactions. Residents can use ultrasound to image the line placement, like they would on a real person, on the robotic trainer, which offers automated feedback.

"We started with 25 surgical residents at the Penn State Health Milton S. Hershey Medical Center, then expanded to all of the residents at Hershey and partnered with Cedars-Sinai Medical Center in Los Angeles to bring the training to their residents," Miller said. "In total, we have trained about 700 physicians to date, and we train about 200 a year with our current funding."

It seems practice may get physicians closer to perfection without the risk to human life, according to Miller. In this study, Miller and her team compared error rates from 2022, the first year the simulation training

was fully deployed, to error rates from 2016 and 2017, when the training was not yet established.

They did not use data from 2018-21, as the training was partially implemented but undergoing startup adjustments and challenges related to COVID that could not be controlled for a direct comparison. The researchers found that the range of reported error rates for mechanical complications—such as puncturing an artery or misplacing the catheter—increased from 10.4% in 2016 to 12.4% in 2017 but dropped to 7.3% in 2022.

The same trend continued for error rates related to infections, with the 6.6% rate in 2016 increasing to 7.6% in 2017 and dropping to 4.1% in 2022. For blood clots, the error rates decreased from 12.3% in 2016 to 11.4% in 2017 to 8.1% in 2022.

"We're very motivated by the results to improve the system and hopefully expand it to other hospitals," Miller said. "We're reducing the error rates in a significant way, but we want more. We want zero errors."

More information: Jessica M. Gonzalez-Vargas et al, Clinical Outcomes of Standardized Central Venous Catheterization Simulation Training: A Comparative Analysis, *Journal of Surgical Education* (2024). DOI: 10.1016/j.jsurg.2023.11.022

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