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UCSB-designed soft robot intubation device could save lives

Maintaining an open airway is a critical priority in emergency medicine. Without the flow of oxygen, other emergency interventions can become ineffective at saving the patient's life. However, creating this airway through endotracheal intubation is a difficult task for highly trained individuals and under the best of circumstances. In the field and in the ER, where seconds matter, emergency medical personnel face many unknowns and wildly challenging conditions which lower their chances of success.

But what if successful endotracheal intubation could be less reliant on ideal conditions and years of specialized training? In a [paper published in the journal *Science Translational Medicine*](#), UC Santa Barbara researchers David Haggerty, [Elliot Hawkes](#) and collaborators demonstrate a non-electronic soft robotic device that quickly and autonomously guides a soft tube into the trachea. Initial device testing with highly trained users yielded a 100% success rate, and a 96% overall success rate with prehospital medical providers (EMTs and paramedics).

"Current intubation tools require extensive anatomical knowledge, training, skill and ideal conditions to be highly successful," said recent UC Santa Barbara Ph.D. graduate David Haggerty, a former researcher in the lab of mechanical engineering professor Elliot Hawkes. Current technology calls for the rescuer to first visualize the tracheal opening then manually direct a tube through the serpentine anatomy of the airway into the trachea. The challenge of this procedure increases in prehospital

settings due to various factors including inadequate light and nonideal body position in addition to potential injuries and fluid in the airway.

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From rigid tools to soft robotics

One of the main challenges to successful intubation is the body itself, and the mechanisms it has evolved to prevent food and foreign bodies from entering the lungs. The epiglottis is a small fleshy flap that closes over the trachea and guides food and liquid into the adjacent esophagus with each swallow. Conventional practice typically requires the rescuer to push a metal laryngoscope into the back of the mouth behind the tongue to lift the epiglottis out of the way in order to make room for the breathing tube.

But even with the epiglottis out of the way, the path the endotracheal tube must take is a twisted one, as it has to bend toward the front of the neck where the trachea is located, otherwise air could be delivered to the stomach via the esophagus, instead of to the lungs.

“Traditional tools, which you push from the base, are fundamentally limited in navigating delicate, tortuous anatomy,” Hawkes explained. “They must be relatively stiff so you can push them, and can only get around bends by deflecting off the sensitive tissue.”

The researchers’ device upends that paradigm with a soft, inflatable tube that everts from its tip. Called the soft robotic intubation system (SRIS), it consists of a curved “introducer” that slides into place at the back of the throat and stops at the esophagus. With that in place, a soft, pre-inflated tube is threaded through the introducer, emerging near its tip at the opening of the trachea. As the user advances the tube, it everts from its tip, carrying inside it a soft breathing tube as it enters the trachea. “So instead of trying to push this tube and bend it to get into this complex configuration, we can just mechanically create that complex configuration as we go,” Haggerty said. Once the endotracheal tube is at its destination, the user can inflate a cuff at its distal end to seal the opening and begin ventilation. The introducer can be removed, leaving the breathing tube in place.

Introducing a soft, growing tube eliminates friction with the surrounding tissue and minimizes injury due to excessive or misplaced force. It also automatically conforms to its environment, one of the major benefits of soft robotics. “This growing paradigm naturally accounts for minor variations in anatomical placement, size, shape or configuration,” Haggerty said, and because of this, users need not have extensive skill or a perfect understanding of the environment in order to navigate it.

In tests with mannequins and cadavers, the SRIS proved itself both effective, and, importantly, rapid, with a 100% success rate at a procedure duration of just seconds for expert users. For nonexpert users — the primary target of this technology — a five-minute training session was all that was needed to deliver an 87% success rate for first-pass attempts, translating into an 96% overall success rate, with a significantly lower procedure duration — 21 seconds versus 44 seconds — than state-of-the-art video laryngoscope intubation.

The next step for the researchers is to conduct clinical trials in order to get approvals from the Food and Drug Administration for clinical use. “We have good reason to believe it’s efficacious based on the data, but cadavers don’t say ‘ow’,” Haggerty said. They need to complete more testing to ascertain the device’s safety and effectiveness in a variety of airways and external conditions, he added. If successful, this device could benefit the millions of emergency intubations that occur each year in the US, and find application in military medical care. That's in addition to its potential to save lives in global populations that have poor or no access to essential health services.

Research on this project was also conducted by Linus Rydell at UCSB; James R. Cazzoli at Vine Medical, Inc.; Marvin A. Wayne at Whatcom County Emergency Medical Services in Washington; Christopher J. Winckler and David A. Wampler at University of Texas Health; Jeffrey L. Jarvis at the Fort Worth Office of the Medical Director; Aman Mahajan and Jose P. Zevallos at Stanford University; and David R. Drover at University of Pittsburgh Medical Center.

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