A “human-proof pointy-end”: a robotically applied hemostatic clamp for care-under-fire

Mass shootings are a frequent, unfortunate and potential threat to the life of every citizen. In 2017, the United States experienced 346 mass shootings that resulted in 437 people killed and 1803 injured. This equates to nearly 1 mass shooting a day with 1.3 people dead and 5.2 people injured. Following such an event, exsanguination is the pre-eminent cause of potentially preventable death, and it is now recognized that all members of society have both the responsibility and the potential capability to control hemorrhage and save lives. The Stop the Bleed campaign is an effort to widely train the lay public to prevent exsanguination, especially from extremity sites that are amenable to effective hemorrhage control. Providing the earliest hemorrhage control is now recognized as a shared responsibility of all members of society, including both the lay public and professionals, consistent with the Stop the Bleed campaign. However, providing early hemorrhage control in a hostile environment, such as the scene of a mass shooting, is extremely challenging. In such settings, the first access to a bleeding victim may be robotic. An all-purpose bomb robot was thus retrofitted with a commercial, off-the-shelf wound clamp and successfully applied to an extremity exsanguination simulator as a demonstration of remote robotic hemorrhage control. As this method can potentially control extremity hemorrhage, further development of the techniques, equipment and, most importantly, the guidelines and rules of engagement should continue. We suggest that in order to minimize the loss of life during an active shooter incident, the armamentarium of prehospital medical resources may be extended to include law-enforcement robots.

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Accepted Apr. 17, 2019

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DOI: 10.1503/cjs.002619
In such active shooter situations, the initial scene entry will likely be conducted by a robot, which routinely provides surveillance and communication and even may neutralize the threat.\(^6\) However, we are unaware of a robot ever being used to provide hemorrhage control.

We have previously described tests of concept in which a model robot made from a child’s toy was able to apply a wound clamp to a simulated tissue\(^7\) and in which a law-enforcement robot (Mini-Caliber SWAT robot, ICOR Technologies) was used to apply a wound clamp to a simulated skin laceration without hemorrhage.\(^7\)

Wound clamping involves the use of a mechanical device to physically seal the tissue between 2 locking jaws, can be augmented effectively with wound packing,\(^8\) and can be deployed quickly in the most extreme of environments, including weightlessness.\(^7\) Advancing on this previous work, we report a demonstration of robotic wound clamping with surrogate hemorrhage control using a bomb disposal robot (Wolverine, Northrop Grumman Remotec) equipped with a wound clamp (ITClamp, Innovative Trauma Care).

The Wolverine is an 810-lb, heavy-duty, outdoor, all-terrain workhorse robot with 6 wheels or removable tracks that has many features, including a manipulator arm with 7 degrees of freedom, a colour camera with low light switching capability, and a 2-way audio system with a weatherproof speaker and microphone. Pulsatile hemorrhage was simulated using an extremity hemorrhage simulator (Sawbones 1534 Arm Trainer, Pacific Research Laboratories Inc.). Using the robot, Arapahoe County Bomb Squad technicians were able to apply the wound clamp remotely using the bomb robot and completely control fluid loss from the simulator (Fig. 1; video available at https://www.youtube.com/watch?v=E1GDZM2oZjM). Although not all extremity wounds can be completely controlled with a wound clamp, many wounds can, and wound clamping will better preserve residual limb function if the limb is required for self-extrication or defence.\(^10\)

We suggest that when a victim is bleeding to death in any environment that is unsafe for human responders, robotic hemorrhage control should be considered. Further testing and refinement of techniques and technology will be required to determine which of the available variety of robots are optimal. We suspect these technical questions will be easily resolved; however, a larger task will be evolving the skill set of bomb disposal robotic operators to accept responsibility for robotic hemorrhage control as part of their core duties. Although this may seem out of scope, it does align with evolving concepts that clearly mandate hemorrhage control as a law-enforcement priority.\(^11–13\) Thus, we suggest that in order to minimize the loss of life during an active shooter/active assailant incident, the armamentarium of medical care should be extended to involve law-enforcement robots. This would entail dedicated development of the technology, techniques, and training to enhance this capability for some of the most vulnerable victims of our modern society.

**Affiliations:** From the City of Edmonton, Fire Rescue, Edmonton, AB (McKee); the Tele-Mentored Ultrasound Supported Medical Interventions (TMUSMI) Research Group Collaborators (add city) (McKee, LaPorta, Wachs, Kirkpatrick); the Regional Trauma Services Foothills Medical Centre, Calgary, AB (McKee, Kirkpatrick); the Canadian Forces Health Services (add city) (McKee); the Arapahoe County Sheriff’s Office, Denver, Colorado, USA (Knudsen); the Denver South Medic Fire Rescue, Denver, Colorado (Shelton); the Rocky Vista University, Rocky Vista, Colorado (LaPorta); the James Purdue University, West Lafayette, Indiana (Wachs); the Department of Surgery, University of Calgary, Calgary, AB (Kirkpatrick); and the Department of Critical Care Medicine, University of Calgary, Calgary, AB (Kirkpatrick).

**Funding:** This work was partially supported by a Near Earth Space Technologies Grant from the University of Calgary and the Office of the Assistant Secretary of Defense for Health Affairs under Award No. W81XWH-18-1-0769. Innovative Trauma Care is the manufacturer of the iTClamp. They provided the iTClamps for the study.

**Disclosure:** The opinions, interpretations, conclusions and recommendations are those of the authors only and are not specifically endorsed by the Department of Defense of the United States of America or the Department of National Defense of Canada, or any other public or governmental agencies.

**Competing interests:** I. McKee, J. McKee and A. Kirkpatrick declare consulting fees from Innovative Trauma Care, outside the submitted work. A. Kirkpatrick also declares consulting fees from Acelity Inc. No other authors declare competing interests.

**Contributors:** All authors contributed substantially to the conception, writing and revision of this article and approved the final version for publication.
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