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

Ian A. McKee
Jessica L. McKee, MSc
Brian E. Knudsen
Ryan Shelton
Tony LaPorta, MD
Juan Wachs, PhD
Andrew W. Kirkpatrick, MD, MHSc

Accepted Apr. 17, 2019

Correspondence to:

A.W. Kirkpatrick
EG23 Foothills Medical Centre
1403 29 St NW
Calgary AB T2N 2T9
Andrew.kirkpatrick@albertahealthservices.ca

SUMMARY

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.

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.¹ 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.²

Unfortunately, in mass shooting situations, many deaths that could have been prevented by first responders with simple life-saving measures are not prevented owing to the hostile nature of the scene making it unsafe for them to reach the victims. This recognition led the Hartford Consensus Group to recommend that fire and rescue, emergency medical services (EMS) personnel and law enforcement agencies work together and enter these scenes earlier. This collaborative action is suggested to give first responders early patient access so they can intervene promptly to stop ongoing external hemorrhage.³ It has been associated with a paradigm shift in EMS response to active shooter events. Previous policies of “no risk” entry have become “managed risk” entries using “warm zones” with threat containment and “safety corridors” for patient access.⁴ Despite the willingness of EMS personnel to accept increased risk in the service of providing hemorrhage control, there remain scenes in which the threat is active and where the victims are trapped and exsanguinate because no human response is possible. For example, the Stop the Bleed campaign recognizes that if a provider becomes injured, they will not be able to help the victim. The campaign recommends that if, at any time, a rescuer’s safety is threatened, they should remove themselves from danger and find a safe location.⁵

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 tissue⁷ 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.⁹ 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

Fig. 1. Overview of the Wolverine robot about to apply the wound clamp to the extremity exsanguination model. Video available at <https://www.youtube.com/watch?v=E1GDZM2oZjM>

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 Med 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.

References

1. Gun Violence Archive. Washington, DC.; 2018. Available: <https://www.gunviolencearchive.org/> (accessed 2018 Nov. 16).
2. Office of Homeland Security. Stop the Bleed 2016 [updated October 11, 2016. Available: <https://www.dhs.gov/stopthebleed> (accessed 2016 Oct. 18).
3. Jacobs LM, Wade D, McSwain NE, et al. Hartford Consensus: a call to action for THREAT, a medical disaster preparedness concept. *J Am Coll Surg* 2014;218:467-75.
4. Pons PT, Jerome J, McMullen J, et al. The Hartford Consensus on active shooters: implementing the continuum of prehospital trauma response. *J Emerg Med* 2015;49:878-85.
5. Committee on Trauma of the American College of Surgeons. Bleeding control. Chicago, IL: American College of Surgeons; 2018 Available: <https://www.bleedingcontrol.org/resources/how-to-stop-the-bleed> (accessed 2018 Nov. 16).
6. Weisberger M. Bomb robot' kills Dallas shooter: how police did it. *Live Science*; 2016 July 8. Available: <https://www.livescience.com/55331-dallas-shooting-bomb-robot.html> (accessed 2018 Dec. 12).
7. Kirkpatrick AW, McKee JL, McKee I, et al. A "human-proof pointy end" for a potential trauma pod effector: technical notes on robotically applied hemostatic applied clamp for care under fire: an update. *Can J Surg* 2018;61(Suppl):S14.
8. St John AE, Wang X, Lim EB, et al. Effects of rapid wound sealing on survival and blood loss in a swine model of lethal junctional arterial hemorrhage. *J Trauma Acute Care Surg* 2015;79:256-62.
9. Kirkpatrick AW, McKee JL, Tien CH, et al. Abbreviated closure for remote damage control laparotomy in extreme environments: a randomized trial of sutures versus wound clamps comparing terrestrial and weightless conditions. *Am J Surg* 2017;213:862-9.
10. LaPorta A, Kirkpatrick AW, McKee JL, et al. Randomised controlled trial comparing marksmanship following application of a tourniquet or haemostatic clamp in healthy volunteers. *J R Army Med Corps* 2017;163:177-83.
11. Jacobs LM. Strategies to enhance survival in active shooter and intentional mass casualty events. *Bull Am Coll Surg* 2015;100(Suppl):16-7.
12. Jacobs LM, Jr. Joint committee to create a national policy to enhance survivability from mass casualty shooting events: Hartford Consensus II. *J Am Coll Surg* 2014;218:476-8, 8 e1.
13. Jacobs LM, McSwain N, Rotondo M, et al. Improving survival from active shooter events: the Hartford Consensus. *Bull Am Coll Surg* 2013;98:14-6.