Control of junctional hemorrhages in the civilian arena : what physician assistants should know

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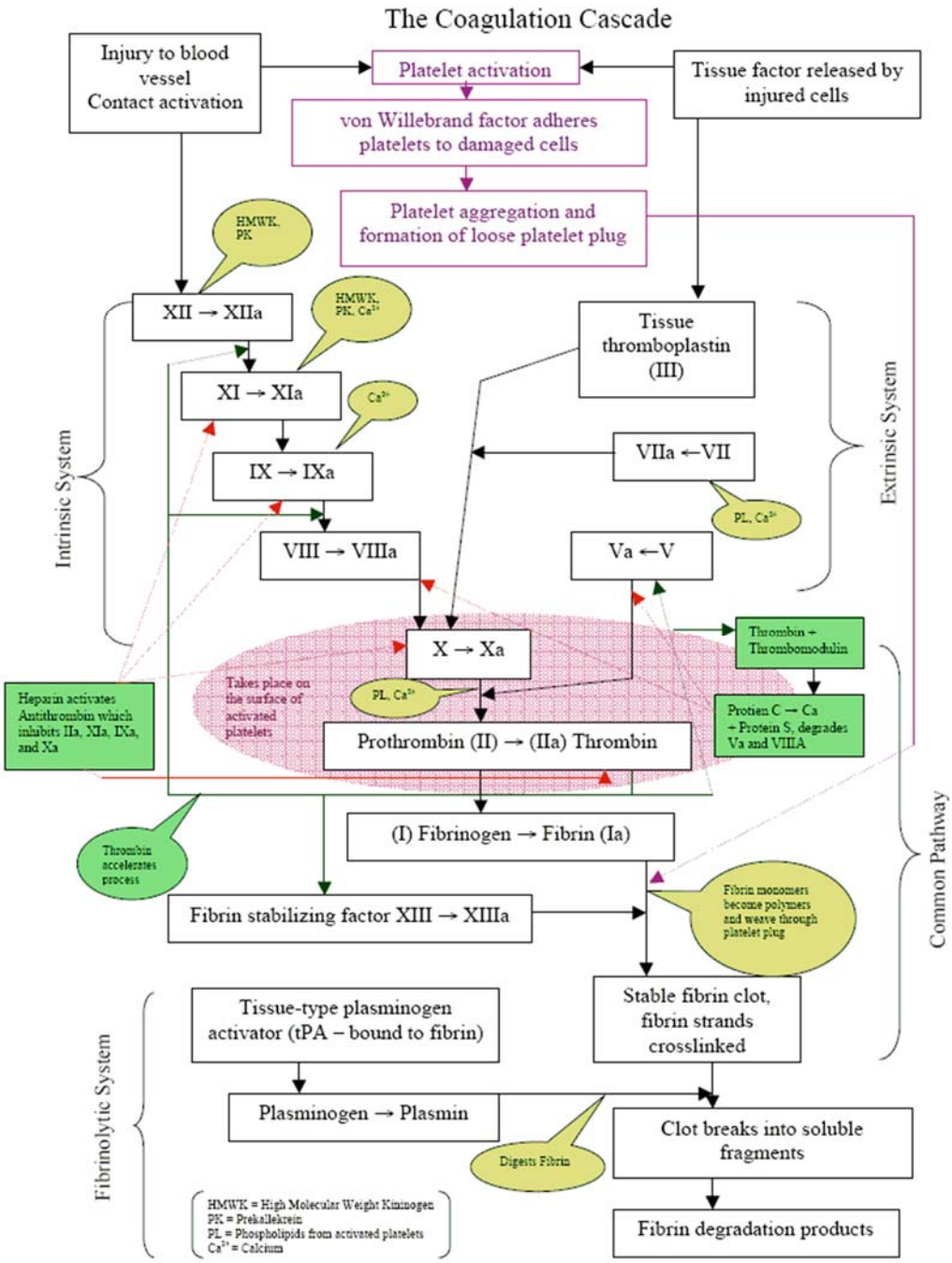
Introduction

Active shooter and bombing events have become an increasing problem in the United States. An active shooter incident is defined by the FBI as an individual who is actively attempting to kill people in a confined environment. According to the FBI there have been 160 active shooter incidents between 2000 and 2013 (Blair & Schweit, 2014). Between 2014 and 2015, 40 incidents have taken place in 26 states. There have been 231 casualties, 94 of those were fatal (Schweit, 2016). It is important to implement efforts to increase survival outcomes of victims. A conference was held which is known as the Hartford Consensus, the conference addressed the issue of hemorrhage control. The current system that is in place involves stopping the shooter first and dealing with hemorrhage control second. A system must be in place which addresses both containing the shooter and controlling hemorrhage in a synchronized manner. Military experience has shown the leading cause of death in a penetrating trauma is exsanguination (Jacobs et al., 2013).

The physiology of hemostasis must be addressed in order to understand the potential problems in hemorrhage control. The normal hemostatic process involves a series of steps. After injury to a vessel, the vessels contract. The injured vessels allow subendothelial collagen to be exposed activating platelet aggregation to the endothelial surface. The four responses of activated platelets include adhesion, aggregation, secretion and procoagulant activity. Platelets first adhere to the exposed endothelium which causes platelet aggregation or platelet-platelet cohesion. Secretion of ADP stimulate and recruit additional platelets. Platelets activate the clotting cascade. Ultimately prothrombin is activated and forms a fibrin mesh, causing hemostasis (Leung, 2015).


The Coagulation Cascade
Injury to blood vessel Contact activation
Platelet activation
Tissue factor released by injured cells
von Willebrand factor adheres platelets to damaged cells
Platelet aggregation and formation of loose platelet plug
HMWK, PK
XII → XIIa
HMWK, PK, Ca2+
XI → XIa
Ca2+
IX → IXa
VIII → VIIIa
Intrinsic System
Tissue thromboplastin (III)
VIIa ←VII
PL, Ca2+
Va ←V
Extrinsic System
X → Xa
PL, Ca2+
Takes place on the surface of activated platelets
Heparin activates Antithrombin which inhibits IIa, XIa, IXa, and Xa
Thrombin + Thrombomodulin
Protien C → Ca + Protein S, degrades Va and VIIIA
Prothrombin (II) → (IIa) Thrombin
(I) Fibrinogen → Fibrin (Ia)
Thrombin accelerates process
Fibrin stabilizing factor XIII → XIIIa
Fibrin monomers become polymers and weave through platelet plug
Stable fibrin clot, fibrin strands crosslinked
Common Pathway
Tissue-type plasminogen activator (tPA – bound to fibrin)
Plasminogen → Plasmin
Digests Fibrin
Clot breaks into soluble fragments
Fibrin degradation products
Fibrinolytic System
HMWK = High Molecular Weight Kininogen
PK = Prekallekrein
PL = Phospholipids from activated platelets
Ca2+ = Calcium

(Leung, 2015)

Literature Review

Traditional Tourniquets

A systematic review of mechanical and chemical hemostatic agents is important to decide the best methods of hemorrhage control and increasing survival outcomes. An increasing number of physician assistants may have to deal with the acute consequences of an active shooter or bombing due to their increasing role in healthcare. This paper will review the different methods in controlling hemorrhage by efficacy of the agent and training. While this paper will focus mainly on junctional hemorrhage control, "classic" hemorrhage control will be discussed briefly. Most of the research will come from military medicine. Hemostatic agents have been used in the setting of the battlefield more often than in the civilian setting. Historically, tourniquets have been used to control bleeding however when considering junctional hemorrhage, a tourniquet designed for extremity use may not be adequate in controlling hemorrhage.

Research Question: What is the easiest method of junctional hemorrhage control for physician assistants to understand and implement if providing care during an active shooter or IED event?

Hemorrhage from penetrating injuries to extremities has been a leading cause of death in incidences throughout the United States. The initial step to control bleeding is pressure directly to the wound. Incidences where multiple casualties are encountered, this measure may not be practical. The next step would be the use of tourniquets to control bleeding. The use of tourniquets has long been implemented in battle, used by both medical and non-medical personnel. A tourniquet is defined as a limb constricting device used to control bleeding (Kragh et al., 2009). The use of tourniquets in civilian settings has remained controversial because without proper training, tissue injury can occur. A tourniquet placed on an extremity too tightly can cause limb ischemia due to restricting arterial blood flow to the distal extremity (Drew,

Bennett, & Littlejohn, 2015). There is also a risk of reperfusion injury to the tissues after removing the tourniquet; however, there are times in which tourniquets can save lives. The mean ischemic time for use of limb tourniquet was 78 minutes without complications. However, the physician assistant must be trained in order to properly use tourniquets to decrease the risk of ischemic injury. The tourniquet must be applied 2-5 cm proximal to the wound and applied with enough pressure to stop arterial blood flow (Lee, Porter, & Hodgetts, 2007). These include penetrating trauma from firearms and stabbings, or during terrorist incidents with penetrating or blast trauma. During an active attack, the traditional airway, breathing, circulation (ABC) of advanced life support does not apply. The most important step is hemorrhage control followed by ABC. The United States military uses the acronym MARCH (massive hemorrhage, airway, respiration, circulation, head trauma/ hypothermia) to treat injuries that provide the threat of exsanguination (Drew et al., 2015). The teaching of this acronym to hospital personal responding to a mass causality event could prove beneficial. As civilian clinicians the main goal is to preserve the circulation, but if the patient is in danger of bleeding to death, hemorrhage control must be the first priority. The principles of tourniquet use include placing the tourniquet as distal as possible but 5 cm proximal to the injury and applying as enough pressure to occlude arterial flow (Kue et al., 2015).

A prospective observational study was performed by Kragh et al. to determine if emergency tourniquet use saved lives. A tourniquet was defined as any limb constrictive device used on an extremity to control bleeding. The study period was from March 19 to October 4, 2006, 232 patients at the combat support hospital in Baghdad, Iraq who had tourniquets applied were included in the study. Five people in the study were identified as amenable to tourniquet use who did not receive tourniquets in the field either due to lack of supplies or because the

commanding office believed the person to be stable enough to transport. All five of the patients died either before reaching the hospital or shortly thereafter (2015). Mechanical pressure should be the first line when considering control of bleeding. When certain means are not amendable, one should consider other options such as chemical agents.

Chemical Hemostatic Agents

The next step to control hemorrhage would be chemical agents. There are many different options available. This article will briefly discuss options which are available including tranexamic acid as well as packing material impregnated with chemical hemostatic agents. There are several options that have been used, among these include QuickClot Combat Gauze (QCG), and tranexamic acid (TXA). QCG is a commercially available, nonwoven surgical gauze coated in kaolin. Kaolin activates factors XII and XI in the clotting cascade, thereby controlling bleeding (Leonard et al., 2016). A study comparing other hemostatic gauzes was performed. The other gauzes included Celox Gauze, Celox Trauma Gauze and ChitoGauze. The study used healthy male swines, two research surgeons performed all study injuries and were double blinded as to which gauze was used. The femoral artery was exposed and a 6.0mm punch lesion was made. Uninterrupted bleeding for 45 seconds was allowed before applying the gauze. Each gauze was then packed rapidly into the site while maintaining pressure and contact with the injury site. The overall time to pack the wound was 38.8 seconds. QCG was the second fastest packing agent. 60% of the swine survived the entire 150 minutes during the experiment using QCG (Rall, Cox, Songer, Cestero, & Ross, 2013). QCG may prove effective for fast packing of a junctional hemorrhage during an event when action must be taken quickly.

Evidence suggest gauze treated with chemical agents can be effective to control junctional hemorrhage. The gauze is lightweight, compact, and easily applied. The limitation for the use of gauze includes the amount of training necessary to use it effectively and safely. A study was performed by the Naval Medical Center in Virginia in order to determine if a fifteen-minute presentation on the application of QCG would be enough training to efficiently control junctional hemorrhage. 24 US Navy Corpsmen were selected for the study, 67% had no live tissue experience. Yorkshire swine were used as live subjects in the study. The results of the study had a 96% survival rate (Conley, Littlejohn, Henao, DeVito, & Zarow, 2015). Though this was a small study, the results provide evidence providers can effectively be trained in a short time frame.

TXA is an analog of the amino acid lysine, lysine blocks the binding site on plasminogen therefore inhibiting the conversion to plasmin. Plasmin degrades fibrin which if unavailable will act as a hemostatic agent. TXA has been used since the 1960s to prevent blood loss during surgical procedures as well as bleeding of the upper gastrointestinal tract. TXA is inexpensive, available and easy to use, which would make it ideal to use in an active shooting situation. The Clinical Randomization of an Antifibrinolytic in Significant Haemorrhage (CRASH-2) study assessed the effects of early administration of TXA on survival from traumatic injuries. There was found to be small absolute reduction in risk of death if TXA was administered within 3 hours of the trauma. If administered after 3 hours, TXA increased risk of mortality. TXA must be given IV to promote hemostasis (Watkins, Dribben, & Cohn, n.d.). During an active shooting event, physician assistants may not be in a situation where supplies for intravenous or intraosseous access are obtainable therefore making TXA less desirable.

Junctional Hemorrhage Control

The pelvis and lower limb are susceptible to penetrating trauma both on and off the battlefield. Bleeding in an emergency can be controlled by gauze impregnated with hemostatic agents such as silica or chitosan along with applied pressure, however in a mass casualty situation this method may not be ideal (Canadian Agency for Drugs and Technologies in Health [CADTH], 2014). Junctional hemorrhage is defined as bleeding from an area that is at the junction of the trunk, for example the axilla or groin. These areas are difficult to place a tourniquet because it is difficult to apply enough pressure to control arterial flow (Croushorn, McLester, Thomas, & McCord, 2013). Junctional tourniquets apply firm, direct pressure to the injured area. Research suggest approximated 54 kilograms of pressure is required to compress the iliac artery (one of the areas considered a junctional injury) (Theodoridis et al., 2016). The US military has become increasingly aware of the issues with controlling junctional hemorrhage, 19-21% of possible preventable deaths on the battlefield. Since 2009, junctional tourniquets have been approved by the FDA. Currently there are several different brands that may be used by military. Combat ready Clamp (CRoC), Junctional Emergency Treatment Tool (JETT), and SAM Junctional Tourniquet (SJT) are all FDA approved.

CRoC was specifically designed for such injuries. The CRoC is a collapsible, lightweight device which works by compressing the femoral artery in the inguinal area which controls distal blood flow to the lower extremity. The device can be used on three different surface types: hard and flat- such as a tile floor, soft and flat- such as a hospital bed, and soft and curved- evacuation devices. A study was conducted to evaluate user performance and the efficacy of CRoC on each type of surface. Six experienced medical researchers who were trained in CRoC were included in the research, five of the researchers were experienced medical professionals. The experiment was

(https://combatmedicalsystems.files.wordpress.com/2013/05/croc-combat-ready-clamp-with-carrier-bag-front-part-31_200-nsn-6515_01_589_91351.jpeg)

performed in a simulation lab on a manikin that was specifically designed for CRoC to simulate a gunshot wound to the groin. The primary outcome of the experiment was effectiveness, secondary outcomes included time to effectiveness, estimated blood volume loss, and safety of device. Effectiveness was measured by control of hemorrhage (yes or no). Time to effectiveness included time to assemble the device, time to position and target, and time to stop hemorrhage (measured in seconds). Safety of the device considered correct assembly, clip secured, slack in the strap, device breakage, vertical arm offset from the torso, and over-tightening. Hemorrhage control was achieved 100% of the time. The surface on which the manikin was on did affect time to achieve control. The fastest control was achieved on soft, flat surface. The time for the hard, flat surface was 58 +/- 9.5 seconds. Each stage- assembly, position of CRoC, and control of bleeding was all under 1 minute. (Mann-Salinas, Kragh Jr, Dubick, Baer, & lackbourne, 2013).

JETT is a lightweight belt which is applied to the victim. The JETT has a two-pressure system which allows occlusion of bilateral lower extremities if there are two penetrating traumas,

the belt is equipped to allow for transportation of the victim without loosening of the device (*Junctional Emergency Tourniquet Tool*, n.d.).

A study comparing CRoC and JETT was performed by Theodoridis et al. in order to subjectively and objectively evaluate the efficacy of the two different tourniquets. There were 88 participants which were military and included soldiers, medics, and nurses. The objective data was measured by time to application to hemorrhage control, subjective data was measured via a questionnaire. Each participant went through a three-week course to standardize familiarity with

(https://www.quadmed.com/product/junctional-emercency-treatment-tool)

both devices. The study showed JETT is easier to use than CRoC and required less training. JETT was applied on average 15 seconds faster than CRoC. Overall the JETT received better ratings in safety, more effective in stopping bleeding, and smaller (2013).

SJT is like CRoC and JETT, SJT is another tourniquet which is designed to control hemorrhage in areas that aren't suitable for traditional tourniquets. SJT is compact and easy to use, the target compression device can be place proximal or on the penetrating trauma there by occluding blood flow to the injury. Two devices can be placed if there are bilateral injuries. This device also stabilizes the pelvis if a pelvic fracture is of concern. Another feature includes an

auto-tightening belt, which prevents over or under-tightening therefore providing optimum use of the tourniquet and prevention of ischemic injuries due to over-tightening (*Sam Junctional Tourniquet*, n.d.).

(http://r3.emsworld.com/files/base/image/EMSR/2014/04/16x9/1280x720/bound-tree-sam-junctional-tour_11365458.jpg)

A study performed by Kragh et al. looked at junctional tourniquets and how each performed regarding blood loss, time to hemostasis and user preference. The individuals in the study were trained one on one with instructional videos, hard copies, device handling and three uses of each model on the manikin. All tourniquets were applied by military medical professionals on non-human subjects. The three junctional tourniquets that were tested included CRoC, JETT, SJT; at the time of the study these 3 were the only FDA approved junctional tourniquets. The manikin allowed to assess hemorrhage control- efficacy was defined as the absence of bleeding from the gunshot wound in the groin. The time of application was also considered and the amount of blood loss. All tourniquets were placed approximately 3 cm proximal to the wound and over the inguinal fold which has the easiest palpable femoral pulse (2015).

Real time feedback was provided by the applicants for each tourniquet, including the instructions on use. Each instructional video had subtle features of best tourniquet techniques, which may not have been clear to the people watching the video. Some of the tourniquets took longer to apply but did provide partial hemorrhage control during application. The results provided showed all three tourniquets were 100% effective; however, results varied by user. CRoC and SJT performed best with least blood loss. CRoC had a shorter time to hemostasis when compared to SJT and JETT (Kragh et al., 2015). According to the Committee for Tactical Combat Casualty Care when the bleeding site is appropriate for use of a junctional tourniquet, this should be applied as quickly as possible. If there is not a junctional tourniquet available then a hemostatic gauze should be applied with pressure until a junctional tourniquet is available (CADTH, 2014).

Conclusion

As the incidents of active shooting and IED events increase, physician assistants should have some form of formal education on how to respond to such a manner. A short introductory course during didactic year of PA school would be ideal. The course should include introduction to the different measures of hemorrhage control. The training course would include traditional methods of hemorrhage control which are pressure control of the wound and proper use of tourniquets. Included in the course would be the teaching of the acronym MARCH- massive hemorrhage, airway, respiration, circulation, head trauma/ hypothermia, which was derived from battlefield casualties from military experience. PAs are traditionally taught to maintain airway, breathing, circulation before concerning oneself with hemorrhage control. In the setting of penetrating traumas, hemorrhage control is at utmost importance.

Chemical hemostasis should also be addressed as these products are readily available- since there are several forms of such agents the course should focus on one to two different options. For example, the use of TXA or chitosan impregnated gauze could be used or similar products that are available through a PA program. Indications for use of chemical agents as well as proper technique would be reviewed during the course.

Finally, junctional tourniquets should be addressed in the course. There is not substantial evidence of which tourniquet is best to control such junctional injuries. From the studies encountered during this literature review, it seems the JET is best to begin teaching students until further research is available. The studies that were reviewed for this paper seem to suggest JET is best due to ease of training and its light weight design. Ideally the course would include both a training video of JET as well hands on learning.

After the didactic portion of hemorrhage control has been completed, students would have the opportunity to train in a simulation lab. Different scenarios would be best, for example an incident where there are injuries to an extremity would allow hands on training of proper placement of tourniquets. Another scenario could include a junctional injury where proper technique of a junctional tourniquet could be applied. The scenarios should have multiple settings so the PA would be able to triage at different locations, such as at a marathon versus a hospital setting. An introductory class as described above would better prepare physician assistants to save lives in a high stress, mass casualty environment.

An example of a flow chart of controlling penetrating wounds could be as follows:

- Triage patients
    - MARCH (massive hemorrhage, airway, respiration, circulation, head trauma/ hypothermia)
- Apply pressure to actively bleeding wounds with gloved hands
- If the wound is to an extremity- apply tourniquet
    - 3-5 cm proximal to wound with enough pressure to occlude arterial blood flow
    - An additional tourniquet may be applied if needed
- If available pack wound with hemostatic gauze
    - E.g. QuikClot Combat Gauze. Note pressure must be applied to wound until hemostasis is achieved
- If junctional injury has occurred, a junctional tourniquet should be applied, even if all measures have been taken above
    - JETT has been proven superior in some studies due to ease of training, lightweight design and efficacy of hemostasis

Definitions

- hemostasis: the stopping of blood flow
- junctional hemorrhage: bleeding from the areas at the junction of the trunk and its appendages, is a difficult problem in trauma
- exsanguination: the action of draining a person, animal, or organ of blood. Severe loss of blood.
- mass casualty incident: The agreed-upon definition of an active shooter by U.S. government agencies—including the White House, U.S. Department of Justice/FBI, U.S. Department of Education, and U.S. Department of Homeland Security/Federal Emergency Management Agency—is “an individual actively engaged in killing or attempting to kill people in a confined and populated area.”3 Implicit in this definition is that the subject’s criminal actions involve the use of firearms
- kaolin- aluminosilicate clay that activates intrinsic coagulation pathway

Limitations

Torso injuries that caused bleeding from the aorta were not included in this paper. Bleeding from surgical procedures due to the nature of the paper was not included because this paper's focus was on non-surgical procedures. Procedures that required IV access to control hemorrhage were not included. There was not a large amount of studies on junctional hemorrhage control in the civilian setting. Most research was from military medicine, in the future research must be conducted in the civilian setting to understand which junctional tourniquet would be best used under mass shooting incidents.

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Abstract

Objective: To understand the importance of preparing physician assistants to control junctional hemorrhage during mass casualty incidents, specifically active shootings and bombing incidents.

Method: Literature review, search engine used was PubMed. Keywords include: mass shooter & hemorrhage, tourniquet & hemorrhage, JETT, SAM junctional tourniquet, CRoC, chemical hemostatic agents, and non-compressible hemorrhage.

Results: Three junctional tourniquets are FDA approved to control junctional hemorrhage which include Junctional Emergency Tool Tourniquet, Combat Ready clamp, and SAM Junctional Tourniquet. Other methods to control junctional hemorrhage include pressure applied to the wound, and chemical hemostatic agents such as tranexamic acid.

Conclusion: There are limited studies on which junctional tourniquet is best for use in the civilian arena. Most of the studies conducted were from military medicine journals and were from small sample groups. However, from the research obtained for this paper, Junctional Emergency Tool Tourniquet is recommended for training purposes in physician assistant programs.