INTRODUCTION

The purpose of this study is to review the use of tourniquet that is a lifesaving procedure to stop bleeding of extremity wounds on the battlefield. And especially we aimed to present the findings of researches, aspects of literature and suggestions of training and reference books about releasing time and duration of a tourniquet if it is a correct application. Hemorrhage is the leading cause of preventable death on the battlefield. 90% of combat fatalities occur forward of medical care. Half of these casualties bleed to death, 1/5 from extremity trauma (10%–15% of all deaths) (1).

In the course of external hemorrhage from extremity wounds direct pressure is the most effective and preferred method of hemorrhage control. If direct pressure fails to stop the hemorrhage, it signifies deep, massive, or arterial injury, and will require surgery or advanced haemostatic agents (1).

A tourniquet is a constricting or compressing device that is used to control venous and arterial circulation to an extremity for a period of time. It should be applied if the techniques like direct pressure, elevation, point compression of the proximal artery signify the need. Although tourniquet is a reliable method it can cause complications such as nerve damage, compartment syndrome, and tissue loss (2).

The tourniquet has been recognized as effective at controlling hemorrhage since at least the time of the Greeks and it was described briefly in Roman literature but, perhaps because it lead to gangrene, it did not come into general clinical use until the mid-1500s with Ambrose Paré’ studies (2).

Tourniquet may be first choice in combat. If a wounded must remain under fire he or the medical personnel should stop external bleeding with use of a tourniquet. Despite tourniquets are effective on arresting life-threatening external hemorrhage from limb injury their use remains a subject of much debate, with many unanswered questions and significant concerns regarding the potential complications from their use.

Are tourniquets safe? We do not know. Application for shorter than two hours may be considered ‘safe’, but much of the evidence is based on experimental animal work.

Should tourniquets be intermittently released? This action was once thought to prevent prolonged ischemia. This is no longer recommended as a brisk hemorrhage can occur and results in death from ‘incremental exsanguination (removal of blood)’ (3). Some arguments about tourniquet time and removals are:

- Tourniquets should be removed as soon as possible under conditions where the hemorrhage can be directly controlled.
- Tourniquet time > 6 hours is associated with distal tissue loss (4).
- A tourniquet should not be loosened in any patient with obvious signs of shock, amputation, uncontrolled bleeding, recurrent hemorrhage upon release of the tourniquet, conversion of casualty can not be monitored regularly for rebleeding or any case where the hemorrhage associated with the wound would be expected to be uncontrollable by any other means. (5, 6).
- Any tourniquet that has been in place for more than six hours should be left in place until arrival at a facility capable of definitive care (5).

METHOD

To present the historical process of tourniquet application especially military usage in the battlefield and to collect information about tourniquet from the recent modern operations (wars) we searched the words “tourniquet”, “remove”, “release”, “time”, and “duration” at the published articles and we reviewed some of these items. And also some training sheets and reference books about medical support of military operations, first aid procedures and hemorrhage control are reviewed for the purpose of determining the correct procedure about removing or releasing a tourniquet.

RESULTS

“Handbook for the Medical Soldier” by Tuttle gives some good advice about the applications of tourniquets and at the end he says “Lastly, remember, if a tourniquet is left on a wound for six hours the limb will surely die.”

The lesson from World War I was that the benefit of a tourniquet was not without potential cost. Properly placed tourniquets left in place for long periods led to loss of the distal limb. Apparently, with the long time to final care that often occurred during that war, the surgeons thought that some limbs could have been saved if the tourniquet had not been used, leading to the caution to avoid long term use, to be sure the tourniquet was needed, but to avoid it if possible (7).

During World War II, MAJ Luther H. Wolff, MC, and Capt. Troglier F. Adkins, MC carried out a study on the use of tourniquets. The results of this study give the practicing procedures to the end of World War II (and which remained standard practice in our time):

Patients with tourniquets in situ should have the highest priority for transportation to the nearest hospital. An effective tourniquet should be placed on an actively bleeding extremity at the earliest possible moment. At the end of 2 hours, if the patient was not in shock and if all circumstances were favorable, the medical officer might cautiously loosen the tourniquet if facilities were available for immediate control of hemorrhage. If bleeding was negligible or did not recur, the tourniquet might be removed, but the patient was kept under continuous observations. On no account should a tourniquet on a patient in shock be removed within 4 to 6 hours of its application unless the blood volume had been at least partly replaced by plasma or whole blood. After this time, the removal or loosening of the tourniquet was a matter of individual judgment. In many instances, sufficient clotting and spasm had occurred by this time to prevent further bleeding (2).

Surgery of Modern Warfare edited by Hamilton Bailey and published in 1941. For the purposes of his book, tourniquets are only used for arterial bleeding. Bailey was not totally in favor of the use of tourniquets. Bailey’s belief in the value of the tourniquet was balanced by caution and respect (8).

Another book appeared also in 1941, Medical Department Soldier’s Handbook, as the US Army troops were preparing for World War II. It warns that: Applying a tourniquet may be a dangerous procedure and should not be used if bleeding can be stopped by other means. The dangers of a tourniquet are that if
applied tightly enough to control arterial hemorrhage it will cause pain and swelling of the part below the constricting band. It should therefore be watched and released at about half-hour intervals (7).

The United States Army Medical Department in a review of the medical services of World War II stated that soldiers frequently misused tourniquets, and contributed to negative outcomes stemming from the use of tourniquets. This was such a widespread problem that their use was restricted by the senior surgeon. He ordered that the only reason for the use of such a device was for the control of “active spurting hemorrhage from a major artery”. The early advice to loosen the tourniquet every 30 minutes to allow perfusion of the limb which has a risk of bleeding to death also replaced with orders that a tourniquet that should only be removed by a medical officer. This opinion continues to be common practice today (5).

Wolff and Adkins wrote an article about a series of over 200 wounded servicemen who had tourniquets applied during World War II. They described occlusive times of up to six hours with no clinically significant damage depending on the environmental conditions; anecdotal reports from cases occurring during the wintertime indicated that cold temperatures and resultant cooling of the affected limb might lead to minimal negative effect on the limb despite prolonged ischemic times (5).

The lesson from World War II was that misuse or inadequate observation of tourniquets could outweigh their benefit; they should be used for only obvious arterial bleeding. (7).

Dr Carl W Hughes was a prominent military surgeon during the Korean Conflict says that “I had a number of vascular injuries sent to me with tourniquets applied. I do not recall ever seeing limb loss as a result of a tourniquet. They were important, even life-saving, in Korea”. (CW Hughes, personal communication, July 19, 2005) (7).

A study during the Korean war of 79 major extremity vascular injuries showed that 47% were admitted with a tourniquet in place for between 40 minutes and 14 ½ hours; the average time being 4 hours (2).

The lesson from Korea seems to be that tourniquets could be of benefit or of harm, depending on the circumstances.

Dr John E Hutton who served at Vietnam recalls his personal memories of the use of tourniquets: “The medics were careful not to over constrict the tourniquets, but would tighten them just to the point of hemorrhage control. Fasciotomies were sometimes used when tourniquets had been left in place in excess of 2 hours. We did not see the inappropriate use of tourniquets and we definitely did see some lives saved because of them (Dr John E Hutton, personal recollections) (7).

A review of the original TCCC (Tactical Combat Casualty Care) article found data from the Vietnam conflict that showed that the most common cause of preventable death on the battlefield was exsanguination (removal of blood) from extremity wounds. Uncontrolled bleeding from extremity hemorrhage was the cause of death for >2,500 fatalities in Vietnam and is still the leading cause of preventable deaths on the battlefield today (9).

A report describing the Israeli experience with tourniquets applied on the battlefield reported 91 uses on combat casualties. Seventy-eight percent of these tourniquets were successful in controlling bleeding. The authors reported infrequent complications from tourniquet use, with seven instances of peripheral neuropathies attributed to tourniquet use in five casualties, for a rate of 5.5% with an ischemic time between 109–187 min. The mean ischemic time for use of a tourniquet with no complications was 78 minutes. No cases of ischemic limb necrosis were reported. The authors described tourniquet use on the battlefield as fast, easy, and potentially lifesaving (9). Tarpey addressed the use of tourniquets in his experience with the Third Infantry Division in Operation Iraqi Freedom (OIF); “Tourniquets played a decisive role in quickly and effectively stopping hemorrhage under fire and keeping a number of soldiers with serious extremity wounds involving arterial bleeding alive until they could eventually undergo emergent surgery at the Forward Surgical Team.” The author also stated that: “Given the intense conditions under which our medics treated casualties, it would have been absolutely impossible for them to have attempted to hold pressure over wounds while continuing to fight and treat other wounded,” There were no known complications ensuing from tourniquet use in this report. (9).

There have been many tourniquets used in Iraq. One surgeon’s recollections are as follows: “We saw dozens of tourniquets used. For the most part, they were appropriately placed—however some were not, with the obvious outcomes. We did not see vascular ischemia from prolonged usage (due to relatively short aerovac and transport times). Overall, tourniquets were extremely valuable—lifesaving and priceless! (7).

In a recent animal study of pneumatic tourniquet times and the effect of periodic episodes of reperfusion on muscle injury, Pedowitz demonstrated that 2 hours was a time threshold for tourniquet compression injury. Physiologic and morphologic
nerve abnormalities were caused by a 2-hour tourniquet time and necrosis was observed. (2).

Interestingly, this study found that if the tourniquet time was longer than 2 hours, episodes of reperfusion tended to exacerbate, not reduce, muscle injury. It is generally taught that muscles are more sensitive than nerves to long tourniquet time and that tourniquet times > 2 hours and the use of high pressure increases the risk of nerve damage. It is also generally taught that if > 2 hours is required, the tourniquet should be deflated for 5 minutes during every 30 minutes of inflation time. Contradicting this recommendation is a 1999 study by Mohler et al. that demonstrated that intermittent reperfusion does not reduce neurological injury. This study also showed that although tourniquet-induced muscle damage may resolve, nerve damage, if it occurs, does not (2).

Navein and Coupland, in their 2003 Journal of Trauma article, noted that a limb occluded for less than 2 hours is almost always salvageable while a limb occluded for more than 6 hours is almost certainly not salvageable (2).

There are only a few significant datasets containing clinical information regarding the field use of military tourniquets. One of them describes the Norwegian military experience in Iraq in 1991. 109 patients were treated in a Norwegian United Nations (UN) hospital in the demilitarized zone between Iraq and Kuwait. 68 of these patients had suffered major traumatic amputations during UN de-mining operations. There were two observation periods in the study: 31st July to 27th September and 28th September to 14th October. In the first period, tourniquets were liberally used and continuous bleeding distal to the wounds was frequently seen. Field protocols were then changed to a policy of “remove any tourniquets and dress the wound with a tight elastic bandage”. 3/18 (17%) died in the first period and 1/50 (2%) in the second (p<0.05) (10).

A prospective survey of injured who required tourniquets was performed over 7 months, at a combat support hospital in Baghdad, in 2006. Among 2,838 injured civilian and military casualties with major limb trauma, 232 (8%) had 428 tourniquets applied on 309 injured limbs. There were 31 deaths (13%). Tourniquet use when shock was absent was strongly associated with survival (90% vs. 10%; p < 0.001). Prehospital tourniquets were applied in 194 patients of which 23 died (11% mortality), whereas 38 patients had emergency department application of which 9 died (24% mortality; p = 0.05). The 5 casualties indicated for tourniquets but had none used had a survival rate of 0% versus 87% for those casualties with tourniquets used (p < 0.001). Four patients (1.7%) sustained transient nerve palsy at the level of the tourniquet. No amputations resulted solely from tourniquet use (11).

The same authors had a second study at same combat support hospital in Iraq, and they reported the major lifesaving benefits of emergency tourniquets to stop bleeding in major limb trauma. Morbidity associated with tourniquet use was minor. This report is a continuation of their previous study. After verifying comparable methodologies for the first study and the current study, they compared patient results for these two time periods and then pooled data to analyze outcomes with a larger sample size. The total study population was 499 (232 in the previous study and 267 in the current study). In all, 862 tourniquets were applied on 651 limbs. Survival was 87% for both study periods. Morbidity rates for palsies at the level of the tourniquet were 1.7% for previous study and 1.5% for second study. Survival was associated with prehospital application (89% vs. 78% hospital, p < 0.01) and application before the onset of shock (96% vs. 4% after). This study shows consistent lifesaving benefits and low risk of emergency tourniquets to stop bleeding in major limb trauma (12).

Tourniquet time (i.e., the total time during which arterial flow beyond the instrument can be safely interrupted) is an issue of controversy. Evidence from animal studies shows that even minutes of tourniquet use will lead to changes in muscle and nerve physiology as well as systemic effects. These studies demonstrated that after one hour, there was no evidence of muscle damage, while two hours of ischemia led to elevated levels of both lactic acid and CPK, suggesting muscle damage was occurring (13). Two hours of tourniquet time is a "useful guideline" for an upper limit. (14).

Recent military experience supports the safety of these short tourniquet times in prehospital patients. Chambers et al. reported limb salvage in 11 of 14 (79%) of patients with arterial injuries despite total tourniquet times averaging two hours. 24(13).

In the Gulf Conflict of 2003, it was a mean of 6 hours until patients reached hospital and 7 hours on Operation Herrick IV in 2006. Military tourniquets would currently be expected to be applied for at least this period of time. When this happens, amputation above the tourniquet is the only option (3).

Preventing arterial blood flow to a limb will result in ischemia. Continuous application for longer than 2 h can result in permanent nerve injury, muscle injury (including contractures, rhabdomyolysis and compartment syndrome), vascular injury and skin necrosis. Muscle damage is nearly complete by 6 hours, with likely required amputation. Numerous
studies have been performed to determine the maximum duration of tourniquet use before complications. The general conclusion is that a tourniquet can be left in place for 2 h with little risk of permanent ischemic injury. (15).

CONCLUSION

The new military trauma paradigm teaches that control of catastrophic hemorrhage takes priority over airway and breathing assessment. (16). Soldiers require a rapid system of hemorrhage control which can be self applied while under fire.

The U.S. Army and Marine Corps both now issue tourniquets to individual soldiers and marines in their Individual First Aid Kits (IFAK) and train them in their proper use. The Army prehospital trauma life support (PHTLS) mnemonic is now "MARCH" (Massive bleeding, Airway, Respirations, Circulation, and Head Injury) rather than "ABC" (Airway, Breathing, and Circulation) (13).

Forward healthcare providers should make every possible effort to evacuate, in less than 2 hours, all patients who require placement of a tourniquet to a facility where surgical control of hemorrhage can be provided (2).

Tourniquets should not be removed until the hemorrhage can be reliably controlled by advanced haemostatic agents or until arrival at surgery.

Application for more than 2 hours may increase limb loss. When we make a risk–benefit decision we should say: Don’t avoid a tourniquet in order to save a limb, and then lose a life! Use of tourniquet does not always lead to limb loss (1).

All known complications of tourniquets seem to worsen with prolonged tourniquet time. Unfortunately, tradition has held that tourniquets, once placed, should be left on until removed by a physician. This tenet likely arose from the recognition that repetitively loosening and retightening a tourniquet exacerbates blood loss. (13).

A policy of periodic loosening of a tourniquet in an attempt to reduce limb ischemia has often led to incremental exsanguination and death (15).

Contrary to common belief, the tourniquet is a lifesaving tool when it is used in necessary situations and appropriate time period. Although, most of the healthcare providers do not have a problem about determining the indication of tourniquet application they refrain from using a tourniquet because of concerns about complications. Tourniquet is still seen as a feared tool and as the last choice of stopping extremity arterial hemorrhage by the civilian medical community. Historically, the most of tourniquet complications have been ischemic complications related to prolonged applications. Because that reason, the time of loosing tourniquet is vitally important.

According to our review, it can be said that;
- Although some arguments about tourniquet application for six hour we strongly emphasize that using tourniquet within less than 2 hour is safe,
- Loosening a tourniquet in 15–20 minutes period is not enough to protect to extremity from ischemic complications and often this can lead to more blood loss and death,
- Unless the patient is transported to a facility or area where the bleeding can be treated surgically, the tourniquet should not be loosened.

Tourniquet should be added all the individual equipment of personnel especially working at hazardous environment. We recommended that the medical and non-medical staff should be trained on applying tourniquet especially “when should a tourniquet be released?”

REFERENCES


