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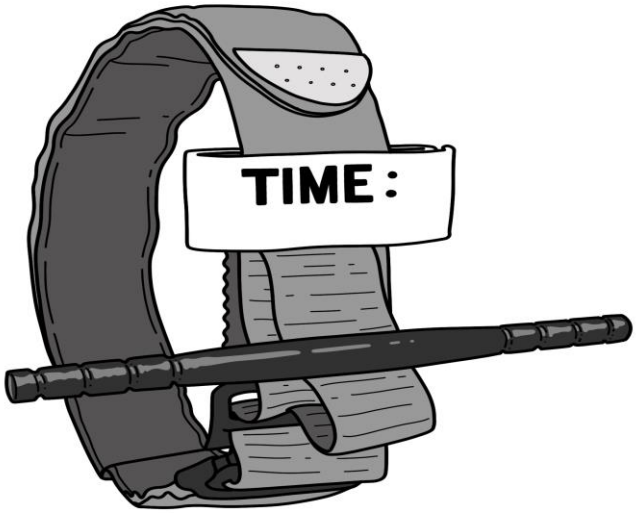

Tourniquets on Swedish merchant vessels

A review on the introduction of tourniquets onboard and the possible consequences

Bachelor thesis for Master Mariner Program

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
Image of a windlass type tourniquet. (Baedr-9439, 2020), CC0 1.0 In the public domain.

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Göteborg, Sweden 2022

PREFACE

Medicine and shipping are areas which are constantly under scrutiny by the scientist. Unfortunately, few scientists have taken on the task of researching the science of medicine onboard ships.

We want to thank Dan Edman, registered nurse and medical instructor at Chalmers University of Technology. It was Mr. Edman who recommended the topic of tourniquets and he was our supervisor throughout the project.

We would also like to extend our gratitude to you who have helped us in the progression of the thesis:

- Elisabeth Aecherli M.D. of the Swedish Armed Forces
- Björn Agnetun R.N.
- Dr. med. Jörg Abel of the Maritime Medical Service at Deutsche Flagge
- Lukas Arkestål CRNA at The Center for Disaster Medicine and Traumatology, national coordinator of TCCC, TECC and Stop the bleed in Sweden.

Thank you.

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SAMMANDRAG (in Swedish)

Tourniquet infördes som krav i fartygsapoteken på svenska handelsfartyg i december 2021. I remissvar till den nya författningen ifrågasattes det att tourniqueten skulle läggas till. Detta väckte frågan om det nya kravet är baserat på vetenskap. Syftet med studien var att undersöka om framgångsrik blödningskontroll genom användning av tourniqueter är möjlig ombord, med avseende på material, läkemedel och kompetens. Faktorer för framgångsrik användning av tourniqueter har identifierats och jämförts med de läkemedel, material och den kompetens som finns tillgänglig ombord. De möjliga utbildningsmässiga och medicinska konsekvenserna har utvärderats. Det har visat sig att material, och i vissa fall, smärtstillande läkemedel som är relevanta för användning av tourniqueter ombord kan optimeras. Kompetens i användning av tourniqueter krävs inte enligt nuvarande regelverk, som nu kan behöva ses över. Flera riktlinjer för tourquetens användning finns, det är inte känt vilken som är mest korrekt för användning till sjöss. Endast två av de studerade dokumenten innehåller procedurer för konvertering av tourniqueten till andra metoder för blödningskontroll, dessa var ej eniga i genomförandet. Tourniqueten kan rädda liv, men risken för komplikationer ombord kan vara onödigt stor på grund av bristen på kompetens i att konvertera tourniqueter till andra metoder för blödningskontroll. Det finns behov för riktlinjer som är särskilt utformade för användning till sjöss, efter vilka sjömäns utbildning och fartygsapoteken bör anpassas till.

Nyckelord: Tourniquet, blödningskontroll, fartygsapotek, skeppsapotek, sjukvård ombord, medical care, basic safety, grundläggande säkerhet, TMAS

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ABSTRACT

Tourniquets were introduced as a requirement in the medicine chest of Swedish merchant vessels in December of 2021. Responses to the proposition for the new medicine chest requirements questioned the tourniquet being added. This raised the question if the new requirement is based on science. The aim of the review was to investigate if bleeding control with tourniquets is possible onboard with regards to materials, drugs, and training. Factors for successful tourniquet use have been identified and compared to materials and competence available onboard. The possible educational and medical consequences have been evaluated. It has been found that materials, and in some cases, drugs relevant to tourniquet use are lacking. Competence in tourniquet use is not required in current regulation, which may now need to be revised. Several guidelines for tourniquet use exist, it is not known which is the most correct for use at sea. Two documents studied contained procedures for converting tourniquets, these were not consistent. The tourniquet may save lives, but the risk of complications may be unnecessarily great due to the lack of training in converting tourniquets to other means of bleeding control. There is a need for guidelines that are specifically designed for use at sea, according to which both the ship's medicine chest and seafarer's training should be adapted to.

Keywords: Tourniquet, haemorrhage, bleeding control, medicine chest, basic safety, medical care, TMAS

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ACRONYMS AND TERMINOLOGY

CAT	Combat Application Tourniquet
CoTCCC	Committee on TCCC, see also TCCC
CPR	Cardiopulmonary resuscitation
EMT	Emergency and Military Tourniquet (product)
ERC	European Resuscitation Council
ILCOR	International Liaison Committee on Resuscitation
KMC	The Center for Disaster Medicine and Traumatology (Katastrofmedicinskt centrum)
OTFC	Oral Transmucosal Fentanyl Citrate
PHTLS	Prehospital Trauma Life Support
SBEC	Stop the Bleed Education Consortium
SFS	Svensk författningssamling (Swedish code of statutes)
STB	Stop The Bleed
STCW	International Convention on Standards of Training, Certification and Watchkeeping
TCCC	Tactical Combat Casualty Care
TCCC-ASM	TCCC for All Service Members
TCCC-CLS	TCCC for Combat Lifesaver
TCCC-MP	TCCC for Medical Personnel
TECC	Tactical Emergency Casualty Care
TSFS	Transportstyrelsens Författningssamling (Swedish Transport Agency's code of statutes)

Analgesia	Pain relief
Fentanyl	Powerful synthetic opioid. Can be administered with patch, oral lozenge or by injection.
Haemostatic dressing	Dressing covered with an agent that promotes blood coagulation.
Indication	Reason for use, e.g., a drug or medical procedure.
Ischemia	Oxygen deprivation in tissues, often due to restriction in blood supply
Ketamine	Non opioid anaesthetic with analgesic properties
Naloxone	Drug to counteract the effects of opioids. Often if opioid use has induced respiratory depression.
Opioid	Substance with effect similar to morphine. Can be synthetic or derived from opium.
Skeppsapoteket	Branch of Apoteket AB which supplies ships with drugs and medical supplies.
Transmucosal	Drug administration by mucous membranes.
Vårdhandboken	The Handbook for Healthcare (Sweden)

1. INTRODUCTION

The tourniquet is a method of mechanically applying pressure around an extremity to stop blood loss, and in the end prevent a potential loss of life. The use of the tourniquet is recorded as far back as the sixth century BC, though its use was not to prevent blood loss, but to prevent poison to spread from a snake bite. The first recorded application on the battlefield to prevent blood loss occurred in 1678. The tourniquet has today found prevalence in the military (Kragh et al., 2012), but historically it has been regarded with doubt (Mabry, 2006). Major Blackwood, of the Royal Army Medical Corps during the First World War was quoted in the study of Kragh et al saying he was "inclined to think that tourniquets are an invention of the Evil One, and it is no exaggeration to say that many limbs have been lost during this campaign by the indiscriminate use of them" (Kragh et al., 2012). The discourse regarding its place on the battlefield was generally negative. Adversaries for its usefulness continued the debate (Kragh et al., 2012) until the mid-twenties when the United States Military fielded the modern tourniquet with the United States troops (Eastridge et al., 2012). From this time forth the tourniquet has seen further success in the battlefield (Örtenwall, 2013). And initiatives to implement it for the use in the civilian sector, with data now being collected for determining its advantages and disadvantages when used by first responders (Wellme et al., 2020).

As of 1 December 2021 tourniquets were introduced to *Transportstyrelsens föreskrifter och allmäna råd om sjukvård och apotek på fartyg,* commonly known as *Transportsyrelsens föreskrifter* (TSFS) 2021:80. This document regulates the contents of the medicine chest onboard Swedish vessels used for shipping with employed seafarers onboard, though some vessels may not require conforming to this regulation or only partly conform according to the first chapter, paragraph 2 through 4. Contents of the vessels medicine chest may vary, depending on its area of operation, however it shall always contain one tourniquet (TSFS 2021:80).

Medical training for Swedish seafarers is regulated by four appendices, which complies with the International Convention on Standards of Training, Certification and Watchkeeping (STCW) requirements for medical education for seafarers (TSFS 2011:116). These four appendices currently mention, though vaguely, control of bleeding and similar phrasings which could imply the use of a tourniquet and other means of bleeding control. These few mentions of bleeding control are only a minimum requirement for the courses (TSFS 2011:116), which leave room for interpretation of the curriculum by educators. This may raise the question if the implementation of a tourniquet onboard has been made with the current regulation regarding education in mind.

There are several types of tourniquets commercially available, and in instances where none is available, an improvised tourniquet could be constructed by available materials; since the principal idea of the tourniquet is something that can apply pressure around a limb and keep that pressure. The principle of its use is simple, but its success rate is generally determined by the response time in its application, and that it is applied correctly. The tourniquet is a tool that can greatly increase the time available for first responders, to further evaluate and treat the patient (National Association Of Emergency Medical Technicians, 2020).

When encountering acute illness or accidents at sea, Tele Medical Assistance Service (TMAS) shall be contacted. TMAS at Sahlgrenska University Hospital documents all contacts. Out of 1765 contacts between 2017-01-01 and 2021-07-31, only two accidents regarded bleeding from

an extremity. Of these two, one could be stopped without the use of a tourniquet, the other one was lacking in documentation (J. Lindblad, personal communication, November 18 & 19, 2021).

1.1 Background

The success of the tourniquet can be linked to the amount of training someone receives in its use. This idea is supported by several articles surveying the layperson's success when applying a tourniquet without prior knowledge, they all show varying results in the success rate (Ross et al., 2018). Another study sought to find if the inclusion of an action-card supplied to the layperson, when applying the tourniquet, may improve the results (Goolsby et al., 2015). All studies concluded that training was paramount for a successful application.

Prior to regulation TSFS 2021:80 was in legal force, the proposition was responded to by several affected parties, as well as medical practitioners, documented in TSF 2020-18. One response to the implementation of the tourniquet was that studies have shown that only a few laypersons will succeed when applying a tourniquet. Though the mentioned study is not cited in the response, this claim has merit when reviewing studies surveying the laypersons success. Another point made in the response to the proposition was that only one tourniquet is required to be carried onboard to comply with the regulation, but that two should be applied if possible (TSF 2020-18).

This raises the question if the now implemented regulation is based on science and proven experience.

1.2 Aim of the study

The aim of this review is to investigate the conditions for successful bleeding control using tourniquets onboard Swedish merchant vessels with regards to the available materials, drugs, and competence.

1.3 Research questions

- Are equipment and analgesic drugs required in TSFS 2021:80 regarding tourniquet use consistent with current science and proven experience?
- Which are the possible educational consequences of the tourniquet being added to the ship's medicine chest?
- Which are the possible medical consequences of the tourniquet being added to the ship's medicine chest?

1.4 Delimitations

Delimitations have been made in order to find materials which will be most applicable to injuries and resources available at sea. The following has been excluded:

- Literature only intended for laypersons, since it generally focuses on early action by bystanders, and not quality of care.

- Recommended training time for the layperson tier of the Stop The Bleed courses due to this course not including hands-on training.

- Tactical Emergency Casualty Care (TECC), since TECC materials are not published. Lukas Arkestål states that TECC is based on the availability of ambulances in a short time and that Tactical Combat Casualty Care may be more applicable to the merchant navy (L. Arkestål, personal communication, December 7, 2021).

- The IMO model course for training in medical care from the year 2000, due to it being outdated.

Regulations for the contents the of medical chest only refers to the materials and drugs to be carried on Swedish ships. Crew has been assumed to be trained and certified according to Swedish regulations.

2. THEORY

This chapter will present basic overview of the circulatory system, organizations and their guidelines, the general function of different types of tourniquets as well as indications for when to apply a tourniquet.

Circulatory system and hypovolemic chock

The circulatory system consists of the heart, blood, and blood vessels. The heart is a muscle that pumps around the blood in all the blood vessels of the body. Normally the heart makes about 60 to 100 contractions per minute. The blood flows out of the heart through the arteries, which are the blood vessels that leave the heart. It then flows through the body's various tissues in small blood vessels called capillaries, where the nutrients, gas, and waste products are exchanged between the blood and the cells. The capillaries then become veins, which are the vessels that transport the blood back to the heart. The pressure that occurs when the heart pumps the blood through the blood vessels is called blood pressure (NHS, 2020). The blood of an adult weighing 70 kilograms constitutes a volume of about five litres (National Association Of Emergency Medical Technicians, 2020). The blood consists of blood cells and plasma. The red blood cells transport oxygen, the white blood cells are part of the body's immune system, and the platelets are part of the blood's ability to coagulate. The plasma consists mostly of water (Brydolf, 2020).

In order to supply all the body's tissues with oxygen and nutrients, as well as to be able to transport away carbon dioxide and harmful waste products, a functioning circulatory system is needed (NHS, 2020). Several factors can induce circulatory distress, one being bleeding. Bleeding if not controlled rapidly may lead to a state of shock (Briggs et al., 2019). Mokhtari and Dryver defines shock as a condition of acute circulatory distress which results in the supply of oxygen to the tissues falls below the demand, leading to tissue hypoxia (Mokhtari & Dryver, 2015). Both external and internal bleeding can cause loss of blood volume. Heavy bleeding can lead to a drop in blood pressure. If a person loses more than 30 percent of their blood volume, the result can be a condition called hypovolemic shock (Edman & Snöberg, 2018).

Bleeding control

External bleeding may be stopped by a pressure dressing, manual pressure, or tourniquets. Pressure dressings and manual pressure work by decreasing blood flow. Tourniquets work by completely cutting blood flow to the extremity. Dressings infused with haemostatic agents, a substance promoting blood clotting, are available on the market. These may cause blood to clot faster, when used in conjunction with manual pressure or a pressure dressing. These methods can be combined with elevation of the body part, this is however unlikely to stop arterial bleeds (Briggs et al., 2019). Bleeding may in some cases also be stopped by packing the wound with gauze or a haemostatic dressing (National Association Of Emergency Medical Technicians, 2020).

Ischemia

Restriction in blood flow in a limb causes ischemia. This problem occurs when applying a tourniquet, as its purpose is to restrict flow. Ischemic tissues will start supplying themselves with energy by anaerobic metabolism, the by-products of which are toxic if not properly treated for. The ischemia caused by tourniquets is painful, and requires powerful analgesics (Örtenwall, 2013).

Analgesia
Analgesia, or pain relief is often required in patients with traumatic injuries and with tourniquets. A few of very many types of drugs are included in the ship´s medicine chest. The non-narcotic drugs are ibuprofen and paracetamol these are available as tablets. Diclofenac is also available as a suppository. Narcotic drugs are paracetamol-codeine tables as well as morphine which may be given as an injection (TSFS 2021:80).

Fentanyl is a powerful opioid which may be administered as a lozenge (*Actiq® - Fass Allmänhet*, 2021). Fentanyl can be used as an analgesic in military applications. Ketamine is a narcotic drug primarily used for anaesthesia and sedation, but also provides analgesia with a favourable safety profile (JTS / CoTCCC, 2020). Opioids may suppress breathing at high doses. Overdose of opioids can be treated with an antidote called naloxone (*Nexodal - FASS Vårdpersonal*, 2019).

Frequency of incidents in the Swedish merchant navy
Statistics from the Swedish Transport Agency (requested in December 2021) lists 103 incidents judged to have caused, or to have the potential to cause life-threatening bleeding in an extremity. 4 passengers were injured, no passengers died. 96 crew were injured and out of these 3 died. The administrator providing the statistics states that these numbers should only be used as an indication for how many incidents have occurred. Inconsistencies in the statistics may be explained by a non-crewmember being injured, such as dockyard workers. Delimitations for the statistics are:

- Swedish flagged ships
- Years 2011 to 2020
- Injury or death in passengers and crew
- Injuries have caused absence from work for over 72 hours
- Suicide is not included

Tele Medical Assistance Service
When facing an accident or illness onboard a doctor shall be contacted to ensure proper care is administered. Should the illness or injury be of such nature that immediate treatment is required, the person in charge of medical care onboard may delay contact until a call to Tele Medical Assistance Service is possible (TSFS 2021:80).

Tele Medical Assistance Service (TMAS) is provided through the Joint Rescue Coordination Centre (JRCC) by the Swedish Maritime Administration. JRCC relays calls from ships to an on-call doctor at Sahlgrenska University Hospital 24-hours of the day. The doctor on call is specialized in internal medicine and if other specialities are required, other doctors can be consulted (Edman & Snöberg, 2018).

2.1 Organizations, guidelines, and training material

There are several organizations in the area of research and training in first aid. Some organizations focus only on research, whilst others publish recommendations for first responders, hospital staff, and educators.

2.1.1 European Resuscitation Council

The European Resuscitation Council (ERC) creates guidelines for medical care in areas regarding cardiopulmonary resuscitation (CPR), advanced life support and first aid, and therefore tourniquets. ERC revises their guidelines every five years. These guidelines are commonly accepted in Europe as the standard for clinical practice in the areas of ERC's expertise (*A History of the European Resuscitation Council*, n.d.). ERC bases their guidelines on publications by the the International Liaison Committee on Resuscitation (ILCOR). ILCOR reviews research and writes treatment recommendations with strong scientific evidence (*Mission & Constitution*, n.d.). These recommendations are published on a yearly basis since 2017 (*Publications*, n.d.). ERC states the following regarding the intended audience in their executive summary of the 2021 guidelines:

> The intended audience are laypersons, first aiders, first responders, community healthcare staff, ambulance staff, hospital staff, trainers, and instructors, and those responsible for healthcare policy and practice. The guidelines are relevant for use in both the community (out-of-hospital) and hospital (in-hospital) settings. (Perkins et al., 2021)

2.1.2 Tactical Combat Casualty Care

Tactical Combat Casualty Care (TCCC) is a training system, and a concept with guidelines developed by the U.S. Department of Defense Health Agency. The purpose of these guidelines is to be used by military organizations (*Tactical Combat Casualty Care*, n.d.). TCCC courses teaches bleed control with tourniquets. Routines for tourniquets used by the Swedish Armed Forces are based on TCCC (E. Aecherli, personal communication, November 8, 2021).

2.1.3. Stop the Bleed

The creation of the Stop the Bleed (STB) campaign was brought forth by a rise in mass casualty events affecting the United States of America and launched in 2015. The effort started as early as 2012 after the tragic mass shooting at Sandy Hook Elementary in Newtown, Connecticut. A panel of national experts convened to evaluate the public's response, when faced with mass casualty incidents. This panel's recommendations were later to be known as the Hartford Consensus, which sought to improve survivability of victims with life-threatening bleeding, following mass shootings and other intentional acts of mass violence. This was to be done through the empowerment of bystanders to take life-saving action. This initiated the launch of the STB campaign from the White House in 2015 (*Our Story*, n.d.).

An effect of this campaign was the emergence of educational programs for the public, teaching bleeding control practises. The STB campaign's goal is "to translate battlefield medicine successes to the civilian sector by empowering the general public to stop life-threatening bleeding." (Goolsby et al., 2018, p. 205). STB had a curriculum and a goal, but there was no unifying standard across the reach of the campaign (*Our Story*, n.d.). In 2017 the National Center for Disaster Medicine & Public Health formed the Stop the Bleed Education Consortium (SBEC), which is an informal group of medical professionals and educators with a goal to rectify this issue. The courses offered by STB are tiered, based on the participants former medical experience, three tiers were identified by SBEC. Laypersons (I), with no prior medical education and less likelihood of using the educational material in practice. Trained laypersons

(II), with a greater motivation to apply the education in practice on i.e., workplaces, and most likely have received first-aid training as part of their employment. Professional (III), professionally trained health care personnel (Goolsby et al., 2018).

2.1.4. Prehospital Trauma Life Support

Prehospital Trauma Life Support (PHTLS) is a course with an accompanying textbook. The course is intended for medical professionals working outside of hospitals, for example paramedics and nurses. PHTLS is recognized as a "global gold standard in prehospital trauma education" (*Prehospital Trauma Life Support*, n.d.). Swedish ambulance personnel are trained in PHTLS (Aléx & Gyllencreutz, 2018). The course includes training in tourniquets use as a part of bleed control (National Association Of Emergency Medical Technicians, 2020).

2.2 Different types of tourniquets

There are different types of commercially produced tourniquets available for purchase. Tourniquets designed for application to a limb is generally applied to the circumference of the limb, the difference between them usually is found in the closing method and the way it applies mechanical pressure around the limb.

Pneumatic type tourniquet

Increases the mechanically applied pressure by inflating the cuff with air (Figure 1).

Figure 1 Pneumatic type tourniquet model name EMT, (Delfi Medical Innovations, n.d.). *With permission from Delfi Medical Innovations Inc.*

Ratchet type tourniquet
Increases the mechanically applied pressure by utilizing a ratcheting mechanism (Figure 2, A).

Windlass type tourniquet
Increases the mechanically applied pressure by a windlass mechanism that increases the tension in the strap when twisting the attached rod (Figure 2, B).

Elastic type tourniquet
Made from an elastic material that is wrapped tightly around the limb, the loose end tucked underneath the wrapped part (Figure 2, C).

Figure 2 (A) Ratchet type tourniquet. (B) Windlass type tourniquet. (C) Elastic type tourniquet. Reprinted from The Journal of Emergency Medicine, (Ross et al., 2018). *With permission from Elsevier.*

Improvised tourniquet
Created on the scene of the incident by materials available, therefore it cannot be attributed to only one design. The design will differ from case to case, but the functionality will remain the same. Commonly illustrated is the windlass type, as illustrated below (Figure 3).

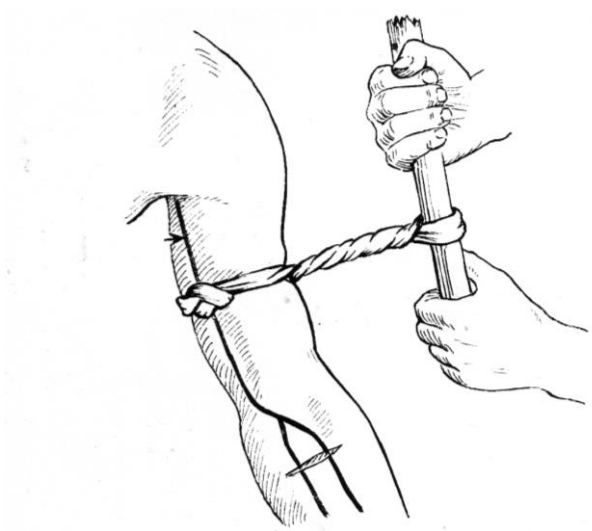

Figure 3 Improvised tourniquet, (Foresman, n.d.). *In the public domain.*

2.3 Indications for the application of a tourniquet

The Swedish website *Vårdhandboken* publishes standards for medical procedures. With the aim of ensuring equal quality care. *Vårdhandboken* is primarily intended for use by healthcare professionals (*About Us*, n.d.). *Vårdhandboken* mentions tourniquet once on their site. *Vårdhandboken* states in an article regarding assessment of the injured according to the ABCDE-concept: Stop catastrophic bleeds with compression or a tourniquet (Stenlund, 2021). No other support for decision making was found with *Vårdhandboken*.

Internetmedicin.se is a database intended for physicians and nurses which is managed by physicians and Swedish experts in their field (*Om Internetmedicin.Se*, n.d.). *Internetmedicin.se* has one article specifically regarding bleeds and bleeding control. This article states that most bleeds can be stopped using a pressure bandage, and that a tourniquet should be used if a pressure bandage does not seem to be sufficient (Riddez, 2021).

TCCC states that a tourniquet shall be applied if a life-threatening bleeding is identified. Haemostatic and pressure dressings can also be used to control the bleeding, if a tourniquet cannot be effectively applied (Joint Trauma System, 2019a).

SBEC states that discussions of which wounds would be appropriate for bleeding control, especially those requiring a tourniquet should be included in their education. Though it can pose a challenge to distinguish if a bleeding is life-threatening or non-life-threatening. When faced with bleeding this shall result in the responder acting to stem the bleeding, by using an appropriate method that will stop the bleed, this being the premise of the concept (Goolsby et al., 2018).

PHTLS lists tourniquet application as indicated if direct pressure fails to provide sufficient effects in stopping bleeding. (National Association Of Emergency Medical Technicians, 2020)

2.3.1 Classifications of bleeding

According to the prior guidelines, a bleeding identified as life-threatening is the common denominator for when to apply a tourniquet, therefore a definition and classification is of importance. Several phrasings exist, dependent on the intended reader. For sources aimed towards laypersons, terminology revolving around the word bleeding is the most prominent. For medical personnel, more well versed in the medical terminology, haemorrhage or variations of this term is commonplace.

Visually estimating an amount of blood lost is a difficult task, as found in a study performed by Phillips et al. Participants (medical laypersons) were asked to estimate blood loss visually by viewing recordings of actors portraying different stages of blood loss. Only 17% classified a blood loss of 150 ml as potentially life-threatening. The study concluded that the estimated volume of blood lost were greater than the actual volume, when displaying a small amount. The participants underestimated if the amount portrayed were of a greater volume (Phillips et al., 2020).

This section will explore the term “bleeding” from different system and guidelines, and what these may classify as “life-threatening bleeding.”

European Resuscitation Council
The ERC guidelines do not list any classification on bleeding.

Tactical Casualty Combat Care
TCCC defines the signs of a life-threatening bleed in their TCCC-All Service Members (TCCC-ASM) speaker notes as:

1. There is pulsing or steady bleeding from the wound.
2. Blood is pooling on the ground.
3. The overlying clothes are soaked with blood.
4. Bandages or makeshift bandages used to cover the wound are ineffective and steadily becoming soaked with blood.
5. There is an amputation of an arm or a leg.
6. There was prior bleeding, and the patient is now in shock (i.e., unconscious, confused, pale). (Joint Trauma System, 2019a)

The speaker notes also list that a patient with severe injuries can bleed to death in a short as three minutes (Joint Trauma System, 2019a).

Stop The Bleed Education Consortium
SBEC is divided into tiers, based on the prior medical knowledge of the participant: layperson, trained layperson, and professional.

SBEC recommends that only flow and volume shall be discussed in the layperson tier, with a note that volume can be difficult to estimate. Therefore, as a visual aid half a standard soda can (330 ml) can be used for reference, which would equal approximately 165 ml. Flow is another indicator, when continuous and steady, that shall prompt the participant to act immediately. SBEC also suggest against teaching other concepts, such as colour of blood and specific injury patterns. As it may be "confusing to learners and dilute the primary intent of delineating life-threatening from non life-threatening bleeding" (Goolsby et al., 2018, p. 207). For the trained layperson tier SBEC recommends that all above points shall be discussed, but no additional indications are added to this tier. The same is true for the professional tier, though basic concepts of haemorrhagic shock, professional responsibility and more nuanced discussions shall be included (Goolsby et al., 2018).

Prehospital Trauma Life support

PHTLS 9th edition defines haemorrhage as an acute loss of circulating blood volume. A normal adult of 70 kg would have approximately 5 litres of blood. The material contains information on haemorrhagic shock and sorts shock in four classes according to the volume lost; classification is based on clinical symptoms, not the estimated volume lost.

Classification of haemorrhagic shock according to PHTLS 9th edition:

- Class 1: <15% blood volume loss.
    - Patient shows minimal clinical signs, if the cause is not of a complicated nature. The blood pressure remains on a steady level, as does the pulse pressure and respiratory rate should be unaffected
- Class 2: 15% to 30% blood volume loss.
    - Patient starts to show signs of an affected state of mind. Increased pulse and respiratory rate.
- Class 3: 30% to 40% blood volume loss.
    - Patient shows marked signs of an affected mind. A significant increase in pulse and respiratory rate and the blood pressure will fall markedly.
- Class 4: >40% blood volume loss.
    - The amount of lost blood is deemed to be immediately life-threatening to the patient according to PHTLS. Symptoms include a significant increase in pulse and a significant fall in blood pressure (National Association Of Emergency Medical Technicians, 2020).

3. METHODS

The method of working has been based on finding current recommendations, for example materials and drugs needed, protocols and times for training. The results were compared to the materials required to be carried onboard and the training requirements for crew.

Unstructured interviews and lectures
Elisabeth Aecherli of the Swedish Armed Forces served the as initial source to TCCC. Aecherli stated that routines regarding tourniquet use, used by the Swedish Armed Forces are based on TCCC. This led to snowball sampling (Denscombe, 2016) to other experts in the field. A short lecture was held by Björn Agnetun, an educator in the Swedish Armed Forces, which served for basis of much of the initial research. An unstructured interview was conducted with Dr. med. Jörg Abel, with the intention of finding the reason for why tourniquets were introduced. Lukas Arkestål, national coordinator of TCCC and TECC in Sweden working at the Center for Disaster Medicine and Traumatology (KMC) has assisted in answering questions relating to tourniquet use and TCCC which may not have been obvious.

Snowball sampling of guidelines and recommendations
National recommendations for tourniquet use were searched for. *Vårdhandboken* was searched with "tourniquet" and "avsnörande förband". One relevant article was found, it was however not focused on bleeding control, but rather on examining patients according to the ABCDE-concept. *Internetmedicin.se* was searched with "tourniquet", "avsnörande förband" and "livshotande blödning". One article had advice on tourniquet use.

TCCC was initially the only source for guidelines as it was recommended by Aecherli. Snowball sampling (Denscombe, 2016) was used to find other documents regarding training in tourniquet use. Searching databases for "tourniquet AND civilian" resulted in the discovery of Stop The Bleed and SBEC. It was known that the European Resuscitation Council publishes guidelines in CPR and it was later realized that ERC might have published guidelines in first aid. This turned out to be the case.

Edman, supervisor, recommended Advanced Trauma Life Support which is used in trauma care. Prehospital Trauma Life Support was studied instead, due to it being based on ATLS, but adopted for prehospital care.

The following information was extracted to the extent it was possible: indications for the application of a tourniquet, positioning of tourniquets, tourniquet tightness, analgesia protocols, conversion protocols, materials needed and training time.

Medical handbooks for ships
Convenience selection (Denscombe, 2016) was used when choosing medical handbooks. This is a result of many countries having their own handbook, often not printed in English.

Google search for "medical guide for ships" only showed the English publication *The Ship Captain's Medical Guide* as an advertisement on page two. *International Medical Guide for Ships* was consulted since it is recommended in TSFS 2021:80.

Dr. Abel recommended the *Maritime Medical Handbook* which is intended for use by ships with a German medicine chest.

The following information was extracted to the extent it was possible: indications for the application of a tourniquet, positioning of tourniquets, tourniquet tightness, analgesia protocols, conversion protocols and materials needed.

Comparison to materials, drugs, and competence available onboard

The above-mentioned research was compared to the current regulations regarding Swedish flagged ships, i.e., the ship's medical chest and the contents of courses and their minimum time.

Effectiveness of tourniquets and layperson success rates

For the effectiveness of tourniquets, Scopus was searched with "tourniquet AND trauma"; Out of 70 results, four were systematic reviews, two were in English and one was accessible at Chalmers. This was the peer reviewed systematic review *Control of severe, life-threatening external bleeding in the out-of-hospital setting: a systematic review* by Charlton et al., (2020).

To investigate layperson success rates in tourniquet use, Pubmed was searched with "tourniquet AND layperson"; Out of 23 results, only one was a randomized controlled trial which determined success rate without prior training or instructions, this was *The Tourniquet Gap: A Pilot Study of the Intuitive Placement of Three Tourniquet Types by Laypersons* (Ross et al., 2018).

4. RESULTS

This chapter will present current science on tourniquet use and the relevant conditions on merchant vessels. Relevant information from four different organizations was collected and presented below. Recommendations from medical handbooks are also included.

4.1 Tactical Combat Casualty Care

TCCC recommends a Committee on TCCC (CoTCCC) recommended tourniquet to be applied 2–3 inches (5-8 cm) above the injury. The tourniquet is to be tightened until bleeding stops and pulse in extremity is eliminated. A second tourniquet should be used if the bleed is not stopped with one (Joint Trauma System, 2018b). These instructions are from 2018, but do not seem to conflict with TCCC guidelines from 2020 (JTS / CoTCCC, 2020). A tourniquet should be converted to a haemostatic dressing within two hours of application using a CoTCCC recommended haemostatic dressing. This is provided if the following criteria are met:

- The patient is not in shock
- It is possible to monitor the wound closely for bleeding
- The tourniquet is not controlling bleeding from an amputated extremity

A tourniquet should not be removed if it has been in place more than six hours unless laboratory capabilities are available. The haemostatic dressing should initially be applied with three minutes of manual pressure. Loosen the tourniquet but leave it in place. If a haemostatic dressing fails to control bleeding, re-tighten the tourniquet, and try converting again six hours after initial tourniquet placement (Joint Trauma System, 2018b). CoTCCC recommends the EMT (pneumatic tourniquet) in medical treatment facilities, but not to be carried by soldiers (Joint Trauma System, 2018a).

According to TCCC-Medical Personnel (TCCC-MP) training material from 2018 analgesia is provided with fentanyl through the mucus membranes of the mouth. Protocols also exists for intravenous morphine and ketamine. Naloxone is an antidote to opioids and should be available when using opioid drugs (Joint Trauma System, 2018c). TCCC guidelines from 2020 do not mention morphine. 2020 guidelines instead recommend fentanyl in other ways of administration. Ketamine is listed as an alternative when shock or respiratory distress is current or there is a risk for these conditions (JTS / CoTCCC, 2020).

Lukas Arkestål, national coordinator (Sweden) for TCCC at The Center for Disaster Medicine and Traumatology (KMC) lists ketamine as more potent, quicker acting and with a wider therapeutic interval than opioids when used to manage pain associated with tourniquet use (L. Arkestål, personal communication, December 7, 2021).

4.2 European Resuscitation Council

The European Resuscitation Council guidelines in first aid from 2021 recommend tourniquets for all life-threatening bleeds that are amenable to treatment with a tourniquet. The tourniquet should be placed 5 to 7 centimetres above the wound, but not over a joint. The tourniquet should be tightened until bleeding stops. Should one tourniquet be insufficient in stopping the bleed, a second one should be placed beside the first one. Note the time of application. An improvised tourniquet should only be used if a commercial tourniquet is not available and if manual pressure and pressure dressings fail to control the bleed. The first aid provider should in this case be trained in the use of improvised tourniquets (Zideman et al., 2021).

4.3 Stop The Bleed

Stop The Bleed Education Consortium (SBEC) states that a tourniquet should be placed above the wound, but not on top of the wound. No distance between the wound and the tourniquet is specified. The tourniquet is to be tightened until the bleeding stops. Anticipate pain and leave the tourniquet until the patient is evaluated by medical personnel. If the first tourniquet is not sufficient, another tourniquet should be applied above the first one. If a second tourniquet is not available, direct pressure should be used. Gloves should be used if manual pressure is necessary. SBEC also states: "Wear gloves or other types of physical barriers when they are readily present. However, absence of gloves should NOT equal absence of action" (Goolsby et al., 2018, p. 207). SBEC states that there is weak evidence for improvised tourniquets to be effective and that they may not be more effective than no tourniquet at all. It is also stated that improvised tourniquets might be an option if manual pressure is impracticable due to the need for the person providing manual pressure to do other tasks (Goolsby et al., 2018).

4.4 Prehospital Trauma Life Support

The Prehospital Trauma Life Support textbook states a tourniquet should only be used if manual pressure and pressure dressings fail to control the bleeding. The tourniquet should be applied as close to the core of body as possible and tightened until bleeding stops. The time of application should be noted in 24-hour format. Monitor for bleeding and add a second tourniquet above the first one in case the first tourniquet fails to stop the bleed. Pulse in the extremity should be eliminated. PHTLS states in a chapter regarding wilderness trauma care that the tourniquet should be placed above the wound, but as close to it as possible (National Association Of Emergency Medical Technicians, 2020).

4.5 Literature intended for use on merchant vessels

The International Medical Guide for Ships advice against the use of tourniquets (World Health Organization, 2007). *The Ship Captain's Medical Guide* and *Maritime Medical Handbook* both recommend using a tourniquet. Both are similar in intended use to *The International Medical Guide for Ships*.

The Ship Captain's Medical Guide

The Ship Captain's Medical Guide does not provide a step-by-step instruction for how a tourniquet should be applied. The medical guide lists it as a tool for controlling bleeding if other means have failed to do so. It is a last resort if direct pressure, combined with pressure dressings or haemostatic dressings is not effectively controlling the bleeding. The removal of the applied tourniquet shall be discussed with Tele Medical Assistance Service (Briggs et al., 2019).

Maritime Medical Handbook
The *Maritime Medical Handbook* recommends the application of a tourniquet as a last means of stopping bleeds. The tourniquet should be placed above the wound, but as close to it as possible, the steps of application are:

- Remove clothing with scissors.
- Place the tourniquet around the limb.
- Tighten until bleeding stops.
- Document time of application.

The tourniquet should be loosened after 30 minutes. If the bleeding has stopped – continue monitoring to ensure the wound does not start bleeding again. The tourniquet should be tightened if the wound starts to bleed after loosening. Try loosening again after 30 minutes.

The patient should be given intravenous fluid resuscitation and TMAS contacted as soon as possible. Pulse and blood pressure should be measured and documented (Langenbuch et al., 2020).

4.6 Effectiveness of tourniquets

One comprehensive systematic review was conducted in 2020 and published in *Prehospital Emergency Care* on behalf on ILCOR. 49 of these studies were regarding tourniquet use. It was found that robust studies are lacking. Many studies were of low quality. It was however concluded that "commercial tourniquets are superior to the application of direct manual pressure or hemostatic dressings for the treatment of life-threatening limb bleeding" (Charlton et al., 2020, p. 17).

4.7 Complications of tourniquet application

It is difficult to determine the complications of tourniquet application. One example is compartment syndrome, which is a collection of blood in the muscles causing a restriction in blood circulation (NHS, 2019). Compartment syndrome can be caused by the initial injury calling for a tourniquet, but also from the tourniquet itself especially if it is not properly tightened (L. Arkestål, personal communication, January 4, 2022).

PHTLS mentions that the tourniquet carries a risk of causing injury to a limb but that this is negligible when compared to the benefits (National Association Of Emergency Medical Technicians, 2020).

4.8 Factors for successful tourniquet application

Below is a collection of training and materials used and recommended by different organizations. Current training of seafarers is also presented.

4.8.1 Tactical Combat Casualty Care

All Service Members (ASM) is the least extensive TCCC course (taking both time and target audience into account) (*Tactical Combat Casualty Care*, n.d.). The TCCC-ASM course includes the use of tourniquets but not the use of opioid analgesics (intravenous or transmucosal medications). TCCC-Combat Life Saver (CLS) has no significant difference in training of tourniquet use. CLS includes the administration of medications, these are however only oral, non-opioid drugs. TCCC training above Combat Life Saver such as TCCC-Medical Personnel includes the use of Oral Transmucosal Fentanyl Citrate (OTFC) and other intravenous drugs. OTFC is administered as a lozenge (*Tactical Combat Casualty Care Skill Sets by Responder Level*, 2019). The TCCC-ASM sample course recommends three hours for the skill station containing control of massive bleeding. This skill station also contains airway manoeuvres and rapid casualty assessment (Joint Trauma System, 2019b).

Arkestål emphasizes the need for training in converting tourniquets to other types of interventions for bleeding control (L. Arkestål, personal communication, December 7, 2021).

*Table 1 Non-instructor TCCC courses (*Tactical Combat Casualty Care*, n.d.)*

	Intended audience	*Time training [hours]*
TCCC-ASM	all service members	7
TCCC-CLS	non-medical military personnel	40
TCCC-MP	military medical personnel	16

4.8.2 Stop The Bleed Education Consortium

The SBEC recommended training for the tier trained layperson, takes a maximum of one hour. The skills dealt with in this level are as follows: identifying life-threatening bleeds, tourniquet application, improvised tourniquets as well as the use on one type of haemostatic dressing. The tier professional takes a maximum of two hours, includes all previously mentioned skills as well as: use of several types of haemostatic dressings, basics regarding haemorrhagic shock and how to communicate the type of injury to medical professionals. The professional care tier also contains scenario training and discussion regarding the removal of tourniquets.

Table 2 Summary of SBEC recommended training time (Goolsby et al., 2018)

	Intended audience	*Training time [min]*	*Education design*
Layperson	Non-medically oriented person, with low likelihood of using material	15	Web-based
Trained Layperson	Non-medically oriented person, with greater motivation or need to know the material i.e., industrial workers	60	Web-based In-person skill practice
Professional	Medical personnel	120	Web-based In-person didactics In-person skill practice

4.8.3 Prehospital Trauma Life Support

A PHTLS course takes 16 hours in a classroom (*Prehospital Trauma Life Support*, n.d.). Training time allocated to tourniquets and wound packing is typically around 20 minutes. 16 participants are divided in two stations, where everyone will be allowed to practice. This is in the PHTLS courses given at Sahlgrenska University hospital. The course contains practical exercises where tourniquets may be used, these are outside of the earlier mentioned 20 minutes. Holm emphasizes that PHTLS is not a course in tourniquet use, but one in general prehospital trauma care (B. Holm, personal communication, February 3, 2022).

4.8.4 Success rates of tourniquet application without training

A pilot study has been conducted investigating the likeliness of successful application of tourniquets in laypersons without prior training. The results were: ratchet- 23%, elastic- 11%, and windlass type 17%. The overall success rate was 16,9 %. Out of 236 volunteers, 195 were eligible and completed the study. After the testing phase, the participants received 20 minutes of instruction and a hands-on instruction, after which all participants were able to successfully apply the three types of tourniquets. The time used for hands-on instruction is not listed in the report (Ross et al., 2018).

4.8.5 Training according to existing maritime regulation

All the curriculums in the Swedish regulations are equal to the requirements stipulated by the STCW code, the following tables in STCW summarize the criteria required for certification:

- A -VI/1-3: Elementary first aid.
- A-VI/4-1: Medical first aid.
- A-VI/4-2: Medical care (IMO, 2011).

The master of a ship is responsible for all medical care onboard. The master shall have training in medical care in extent according to the vessel's medicine chest. The master may delegate the task of medical care to a person with the same qualification (SFS 2003:438, 4 kap. 9 §). Training in medical care shall be in accordance with appendix 37 of TSFS 2011:116. The regulation requires training in internal and external bleeds, but training time for these skills is not specified (TSFS 2011:116, appendix 37).

The medical first aid course, for the seafarers tasked with assisting the officer in charge of medical care onboard or the officer delegated with this task (SFS 2003:438, kap 4, 9 a §). No use of the wording to describe bleeding control, or similar phrasings is used. Training on the use of the emergency-kit is stated (TSFS 2011:116, appendix 33). The minimum time for the whole course is 30 hours, the time for the individual segments is not specified (TSFS 20111:116, appendix 33).

Seafarers who are signed on with a duty to the ship's safety shall have training in basic safety (SFS 2003:438, 4 kap. 4 §). Basic safety training in Sweden must contain nine hours of training in first aid. Bleeding control is one of six skills that shall be dealt with under these nine hours. Out of these nine hours, it is not specified how much time that should be dedicated to theory or practical exercises (TSFS 2011:116, appendix 12).

For Swedish ships carrying the medical chest D, the officer responsible for the medical care shall require a certification of competency, in accordance with TSFS 2011:116, 12 kap, 4 b §. The goals for the course states that the seafarer shall learn first aid according to the L-ABC concept, with sub-sections such as "immediate care" (TSFS 2011:116, appendix 36), "bleeding, wounds, crush injuries" (TSFS 2011:116, appendix 36), as well as techniques for dressing wounds (TSFS 2011:116, appendix 36).

Further on, the courses will use the commonly accepted names which comply with the STCW-code:

- Appendix 37 - Medical Care.
- Appendix 33 - Medical first aid.
- Appendix 12 - Elementary first aid (TSFS 2011:116).

4.8.6 Materials and drugs

This is a collection of materials recommended by previously mentioned guidelines and organizations. Note that these are materials mentioned in guidelines and training material, they are not from any list. Morphine is the only analgesic drug presented in Table 4 due to it being the only drug required to be carried which may be administered for severe pain (TSFS 2021:80).

Table 3 Materials recommended in guidelines and training material

	Tourniquet no 1	*Tourniquet no 2*	*Haemostatic dressing*	*Pressure dressing*	*Gauze dressing*
TCCC	X	X	X	X	
ERC	X	X	X		X
STB	X	X	X		

Table 4 Relevant contents and drugs of medicine chests according to TSFS 2021:80 depending on area of navigation and type of vessel

Medicine chest type	*Definition*	*Tourniquet no 1*	*Tourniquet no 2*	*Blood stopper*	*Sterile compress*	*Morphine*
A	< 12 hours to port	X		X	X	X
B	> 12 hours to port	X		X	X	X
D	< 2 hours to port	X		X	X	
E	Lifeboats and life rafts	X		X	X	

The term blood stopper (blodstoppare) is not defined in TSFS 2021:80, meaning it is not specified for this product to be infused with any haemostatic agent. The product provided by Skeppsapoteket AB is Cederoth 4-in-1 Bloodstopper. (Skeppsapoteket, personal communication, December 8, 2021) This product provides a "Pressure pad for heavy bleeding", but not is not infused with any haemostatic agent (Product Specification 4-in-1 Bloodstopper, n.d.).

The tourniquet that will be provided by Skeppsapoteket is the Combat Application Tourniquet (CAT) generation 7 (Skeppsapoteket, personal communication, December 8, 2021). The CAT generation 7 is a windlass type tourniquet, which is recommended by CoTCCC (JTS / CoTCCC, 2021).

5. DISCUSSION

This chapter will discuss the relevancy of the different guidelines and how bleeding can be assessed. The findings of differences in the required materials, drugs and training are also discussed.

5.1 Relevancy of sources

It is not currently known which guidelines or which literature is the most applicable for use at sea. TCCC is intended for use in the battlefield, where distance and time to qualified medical care may be far away, but not impossible to reach. TCCC, with regards to the initial assessment of a patient focuses on stopping and controlling a life-threatening bleed. This is to buy time until a more thorough assessment can be performed, and injuries treated accordingly. One can assume that the average sailor never will experience a battlefield scenario; and that TCCC recommendations with regards to when a tourniquet should be applied would not apply. TCCC recommendations could however be deemed applicable in a scenario when a vessel would be sinking or tormented by a fire onboard.

SBEC and ERC do not contain procedures for removing or converting tourniquets. Their recommendations for how and when to apply a tourniquet could be relevant for use onboard, but the absence of procedures for converting make the guidelines incomplete for use onboard. ERC guidelines do not contain decision making support for when a tourniquet should be applied. ERC only states that a tourniquet should be applied during a life-threatening bleed if the wound location allows tourniquet application. SBEC however seem to state that a bleed larger than half of a standard soda can (half of 330 ml) should be considered as life-threatening. One could argue that it would be difficult to understand how much area this would cover when poured on asphalt, concrete, or a metal deck.

PHTLS is intended for use in prehospital care, which may make the information relevant for use onboard. However, PHTLS is intended for use on land, which could cause the treatment recommendations to be more aggressive then called for onboard. This has been found to be the case since the tourniquet should be applied high up on the limb if not in a wilderness situation. PHTLS does unfortunately not contain any information on removing or converting tourniquets.

The *Maritime Medical Handbook* was co-authored with physicians and intended for use by seafarers, on ships carrying a German medicine chest.

5.2 Assessment of bleeds

Bleeds are assessed in accordance with the system the first responder is trained within. As the information gathered may have different uses depending on who the first responder is, a trained professional may benefit from more information than a layperson responding to an incident.

SBEC states that flow and volume shall be discussed with the participants when determining if a bleed may be deemed life-threatening. Their key-point is that discussion shall be kept simple as to not distract from the intent of saving a patient's life. Especially for their lower tiers. This key-point could be regarded and incorporated in Swedish seafarer's first aid training, especially when training methods for bleeding control. During the training, presenting methods that conforms to what can be expected of the person partaking in said training. Someone with only the elementary first aid certificate may not be expected to have the same medical competence

as a person certified in medical care. Reasoning being to not deter from the goal of saving a life.

Determining the amount of blood lost is difficult, as proven in the study of Phillips et al, a discrepancy exists between the amount estimated and actual loss. As amount lost can be considered an indicator when to apply a tourniquet, methods and techniques for determining this should be used to minimize errors; or rather if other means than the tourniquet should be used to control bleeding.

The way of identifying life-threatening bleeding by comparing blood loss to a volume may not be optimal. One issue with this method is that it is difficult to study the area of a puddle and accurately estimate the volume lost. This may be an easy way of teaching but could also lead to applying tourniquets too often or too seldom. Using volume as an assessment tool could also possibly lead to a first aider delaying tourniquet application should the initial blood lost be too small. Focusing on flow instead of estimating volume, this problem could be avoided, since a high flow of blood is dangerous.The problem with flow is that it is difficult to estimate, another problem is that a lower flow but for a longer period of time is also dangerous. Assessing both volume and flow could be suitable to determine whether if a tourniquet is required or not. An alternative method of assessing bleeding could be looking at the characteristics of the bleed, such as if it is pulsating or pooling on the ground. This method is used in TCCC courses.

5.3 Comparing good practice

The guidelines and books studied have different recommendations in how to, and when to use tourniquets. This may not be a problem when a person is trained in only one system, and when the course was suitable for the conditions whom the person will be exposed to. No guidelines specifically designed for seafarers have been found, nor any guidelines that have been evaluated for use at sea. In an event when a tourniquet would be necessary, the delay and stress caused by differences in guidelines and training programs could determine the difference between life and death.

There are several different guidelines with indications for tourniquet application. None of the earlier mentioned organisations have guidelines which are specifically intended for use by merchant vessels. *The Ship Captain's Medical Guide* and the *Maritime Medical Handbook* did recommend tourniquet application, but the *International Medical Guide for Ships* did not. This may be a problem in case officers turn to the *International Medical Guide for Ships* for advice on tourniquet use, since this book is now outdated on the subject.

Some guidelines recommend trying pressure dressings and manual pressure before applying a tourniquet. TCCC recommends the tourniquet as a first measure against life-threatening bleeds. It is currently not known which of these would be most correct in ships. It is possible that the tourniquet would be a first choice if there are several casualties.

The position of where the tourniquet should be placed was not found to be consistent between recommendations, examples are 2 inches to 3 inches (5 cm to 8 cm) above the wound and 5 cm to 7 cm above the wound. PHTLS recommends placing the tourniquet as close to the core of the body as possible. Some recommendations however only specify that the tourniquet should be placed above the wound, but as close to it as possible.

TCCC and PHTLS state that pulse in the extremity should be eliminated when the tourniquet sufficiently tightened. ERC guidelines, *The Ship Captain's Medical Guide* and the *Maritime Medical Handbook* do not state that pulse in the extremity needs to be eliminated.

TCCC and the *Maritime Medical Handbook* were the only materials studied which contained advice on converting or removing tourniquets. They were not consistent in timing. The handbook instructs the reader to try removing the tourniquet after 30 minutes, and if that should fail, to try again after 30 minutes. TCCC recommends converting the tourniquet as soon as possible, but that the first attempt should be a maximum of two hours after the tourniquet was placed.

5.4 Materials, drugs, and training

Ketamine is not available onboard, the reason for this is unknown. Should ketamine be as user-friendly as morphine, it may be suitable to introduce onboard. TCCC was the only guideline studied with protocols for analgesia. ERC recognizes that tourniquets may be very painful but does not suggest any type of analgesic. TCCC requires naloxone to be available when using opioids, this is not required in medical chests following TSFS 2021:80. Ships with a type D medical chest lack powerful analgesics which may be necessary for the patient to accept the tourniquet as a treatment option, the same applies to lifeboats and life rafts (type E).

It is not required to carry two tourniquets by the ship's medical chest. This is not in line with current recommendations; since many guidelines recommend applying a second tourniquet in case the first one fails to provide sufficient effect. It may also be suitable to carry three tourniquets onboard, as to have one intended only for training. Preferably should the training-tourniquet be of a different colour from the other ones in order to decrease the risk of causing wear to the live tourniquets. A blood pressure cuff could on the other hand be used should a second tourniquet be unavailable, with the downside of having one less blood pressure cuff. CoTCCC recommends a pneumatic tourniquet for use in medical facilities, the reason for this has not been researched. This is however not the tourniquet supplied by Skeppsapoteket, it is not known if this will have any significant outcome on ships. When comparing successful application by laypersons without prior training, in the study by Ross et al (2018), it was discovered that ratchet type tourniquets had the best success rate, however this type will not be supplied by Skeppsapoteket. Implementing ratchet type tourniquets may be considered more logical in the early days of tourniquets onboard the Swedish merchant navy. As a better result was gained from using the ratchet type, therefore negating some of the consequences of not having seafarers previously trained in applying a tourniquet. The simplest to use tourniquet would also minimize points of failure from lack of training. These arguments are only based on one study, further studies should be performed where several points are analysed to determine the overall best type of tourniquet for a given situation.

Equipment and drugs required to be carried onboard should be stored inaccessible to non-authorized persons. This could result in a delay between injury and tourniquet application. It may be suitable to store tourniquets in first-aid stations. Should the tourniquet be regarded as a last option for bleed control, carrying haemostatic dressings onboard and using these could possibly decrease the risk of needing to apply a tourniquet. Haemostatic dressings could be placed in first-aid stations.

Elementary first aid, medical care, and training for ships with a type D medicine chest all require bleeding control as a part of the curriculum. Medical first aid is the only course without a specific requirement in bleeding control. For all courses, whether bleeding control is required or not, any medicine chest will always require a tourniquet to be carried onboard. Therefore, tourniquets inclusion or exclusion cannot precisely be determined if following the learning objectives literally. Its inclusion in the curriculum can therefore be assumed to be placed in the hands of whom interprets these learning objectives. The requirements of these courses should be specific in such a way that the contents cannot be significantly misinterpreted.

As for the feasibility of incorporating tourniquet training to the existing courses, the study of Ross et al (2018) showed that with first-hand training in application and 20 minutes instruction of haemorrhage control techniques, all participants of the study were able to demonstrate proper tourniquet use. SBEC's trained layperson tier recommends 60 minutes of training in tourniquet use and bleeding control techniques. Studies in support of conducting training in a limited amount of time and resulting in positive results could therefore be seen as feasible.

Converting the tourniquet to other means of bleeding control is not discussed in SBEC, though this could be relevant on ships as time to a hospital can be significant at some times, similar to TCCC where conversion is taught. Therefore, the inclusion of this technique could be of relevance, especially for ships with long time to a hospital. If conversion is to be included, this will increase time needed to fully train this skill. One could argue that only a basic understanding of the principal is enough, and the conversion can be performed in conjunction with TMAS, similar to how other medical interventions are performed.

When faced with life-threatening bleeding onboard, TMAS can provide a physician's view on the injuries. Though time is of the essence if the bleed is life-threatening, the injured can bleed to death in a noticeably short time. Time to contact TMAS will be limited. Therefore, the knowledge of when to, and how to apply a tourniquet needs to reside with the seafarer. After application, contact with TMAS can be established and care of the injured, or a possible conversion can be decided on.

5.5 Efficacy of carrying tourniquets onboard

Research on the possible complications of tourniquet is lacking. In studies on the efficacy of tourniquets, it is seldom possible to determine if injuries to the patient is a result of the initial injury or if it is a complication of the tourniquet. Tourniquet use is however strongly backed by science. Should competence in converting tourniquets to other means of bleed control be lacking, TMAS may be less likely to recommend converting. This could lead to an increased risk of complications.

5.6 Method Discussion

Investigating the suitability of equipment and drugs relevant to tourniquet use, as stated in the first research question is a difficult task. This is a result of an absence of a gold standard on how to use tourniquets and how to convert them to other means of bleed control. A standard for use at sea is even further away than one for use on land. This results in an impossibility to perform a perfect study on the question. Some injuries may require surgical intervention to provide a permanent solution for the patient, something that will never be possible onboard normal merchant vessels. The answer to the research question will always be "no" as long as vessels carry more cargo than surgeons, nurses, equipment, and drugs.

Snowball sampling was used to find guidelines and recommendations. This was to find a large number of documents which were used by medical personnel and also cited by studies regarding bleed control. This was deemed sufficient for the scope of the study. Other methods of research may be suitable if a guideline for tourniquet use at sea was to be created or if the entire contents of the ship's medicine chest was to be revised. Convenience selection was used for medical handbooks since some nations have books printed in languages other than Swedish or English. Convenience selection also gave the opportunity to exclude medical handbooks that were obviously outdated. There are few medical handbooks which are modern and provide realistic support for realistic situations.

The method of working may not have been the optimal way of finding the possible medical consequences of introducing tourniquets onboard. The optimal way could consist of comparing the number of deaths before and after the introduction. Since the cases of death by bleeding in extremities are rare in reports, it may not be possible to find statistically significant results proving the efficacy of tourniquet use onboard Swedish vessels. Purely studying the benefits and disadvantages of tourniquet use may be the only way of answering this research question. One other way to determine the efficacy of tourniquets onboard could be with a randomized trial, supplying some ships with tourniquets and some not. In this case, one could argue that it would be unethical to withhold tourniquets onboard, since their effect in stopping bleeding is well known.

Three training systems have been studied: TCCC, STB and PHTLS. They all contain varying time in training, but it can be assumed that all participants that finish the courses will be proficient in identifying a life-threatening bleed (as proficient as can be expected without experience in field) and applying a tourniquet if necessary. It is not always possible to find the exact course layout with time distribution since there is a commercial interest in selling courses and material. This is the reason why times for training have been listen for an entire segment of the training, rather than estimating the time allocated for tourniquet use. It must however be noted that training in bleed control should not only contain tourniquet use, but also other skills which have not been included in the study.

Only one study was cited for the effectiveness of tourniquets. The reason for this was that it would be impossible to perform a meta study of the same quality and extent as the one by Charlton et al., (2020) within the extent of the project.

It was determined that the extent of the project would not allow the study of each original article leading up to the guidelines used. It was instead decided that studying guidelines, medical handbooks, and training material would give sufficient depth for the scope of the project.

6. CONCLUSION

It has been found that ships which carry morphine have sufficient, but not optimal capabilities to treat pain related to tourniquet use. Antidote for an overdose of morphine is lacking. Lifeboats, life rafts and ships with a type D medicine chest lack powerful pain-relieving medications. All types of medicine chests studied have been found to lack materials necessary for treating bleeding in an optimal way. One tourniquet is required, but recommendations commonly describe a second tourniquet as something that may be necessary. Haemostatic dressings are not required in TSFS 2021:80 but are recommended in TCCC for use when converting tourniquets to other means of bleeding control.

The probability of successfully using a tourniquet for in bleeding control is low without prior training. This increases dramatically with even a short training session. For tourniquets to be able to fill their intended purpose, training in tourniquet use would have to be required in all courses pertaining to first aid, since the tourniquets are available both onboard, but also in lifeboats and life rafts. Courses in medical care would need to contain training in converting tourniquets to other forms of bleed control.

Consensus for how and where a tourniquet should be applied does not seem to exist. The same applies for how tourniquets should be converted to other means of bleed control. There is a need for first aid guidelines which are specifically designed for use at sea, after which the ship's medicine chests and the training requirements for seafarers should be designed.

The tourniquet should be viewed as a way of prolonging life until TMAS can be contacted, the patient evacuated, or the tourniquet converted. Properly used, the tourniquet can save lives who otherwise may have been lost. The possible consequences should not discourage tourniquet use onboard.

6.1 Recommendations for further research

- Investigating different routes of administration of analgesics when administered by nautical officers.
- Investigate the necessary time that should be spent training seafarers in bleeding control, considering the few cases reported to TMAS.
- Evaluating current competence in bleeding control in nautical officers.

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APPENDIX 1

Generic name	*Route of administration*	*Strength or concentration*	*Use according to TSFS 2021:80*	*Function according to TSFS 2021:80*	*Dosage according to TSFS 2021:80*
Paracetamol	Tablets	500 mg	Mild pain	Analgesic and antipyretic	1-2 tablets. 1-4 times per day.
Ibuprofen	Tablets	200 mg	Menstrual pain, joint, back or muscle pain	Analgesic and antipyretic	1-2 tablets. 1-3 times per day.
Diclofenac	Suppositories	50 mg	Gallstone- and kidney stone attacks	Anti-inflammatory, analgesic, and antipyretic	1-3 suppositories per day. *
Paracetamol-Codeine	Tablets	500 mg/30 mg	Moderate pain	Analgesic and antipyretic	1-2 tablets. 1-4 times per day. *
Morphine	Solution	10 mg/ml	Severe pain	Powerful analgesic	1-1,5 ml as an intramuscular or subcutaneous injection. *

** Only after consultation with a physician.*

The table shows all drugs with analgesic properties to be carried if a ship has a medicine chest type A or B according to TSFS 2021:80. The only analgesic drug of type D and E medicine chests is tablets with paracetamol, 500 mg. The contents of the table are translated from Swedish.

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