'Time critical' rapid amputation using fire service hydraulic cutting equipment


A R T I C L E   I N F O

Article history:
Accepted 3 May 2011

Keywords:
Amputation
Emergency amputation
Extrication
Hydraulic cutting equipment
Pre-hospital care

A B S T R A C T

Introduction: Entrapped trauma victims require extrication, which, on rare occasions, may involve amputation of a limb. Standard extrication techniques sometimes fail or may be impossible, leading to the death of the entrapped victim. We propose that the use of fire service hydraulic cutting equipment can be used effectively to urgently amputate a limb, where conventional techniques are unusable.

Method: The study aims to determine: (i) the potential use of this equipment to achieve expeditious life-saving amputations and (ii) the effect the fire service hydraulic cutting equipment has on the bony and surrounding soft tissues. Initially a porcine limb was used followed by fresh-frozen cadaveric lower limbs. We recorded the time, number of cuts, proximal fracture propagation and quality of bone cut when performing amputations at five levels.

Results: The experiment confirms that faster guillotine amputations in human cadaveric lower limb specimens can be achieved by using fire service hydraulic cutting equipment. Overall, the average time to complete an amputation in these ideal experimental circumstances at all five levels was quicker using the hydraulic cutting equipment. Either one or two cutting actions were required to achieve the amputation using fire service hydraulic cutting equipment. The degree and proximal extent of the comminution were greater using the fire service hydraulic cutting equipment.

Conclusion: If circumstances and time constrains allow, a conventional amputation technique carried out by a trained medical practitioner would be preferable to the use of the fire service hydraulic cutting equipment. However, we feel that this technique could be used to perform emergent amputation under trained medical supervision, if it is felt that a standard amputation technique would take too long or the environment is too restrictive to perform a standard amputation safely.

© 2011 Elsevier Ltd. All rights reserved.

Introduction

The Anaesthetic Trauma and Critical Care (ATACC) organisation is a multidisciplinary group of professionals involved in the management of trauma victims. The tragic scenario of the death of an entrapped victim of a road traffic accident who could not be extricated using hydraulic cutting and spreading equipment for ‘space creation’ was raised at an ATACC meeting. Although rare, failed extrication can occur if a vehicle is at risk of explosion, from a chemical spill, gross instability or the casualty deteriorates very rapidly. In all of the above cases, the entrapped occupant needs to be extricated as a matter of urgency and adopting an emergency ‘B’ plan, or performing a conventional amputation may not be possible.

Another case discussed involved a victim who was entrapped in rising floodwater in the United Kingdom in 2007. Standard extrication techniques failed, by which time standard surgical amputation of the limb to free the victim was deemed impossible and the victim died. The Coroners Court inquest summarised that “…this must never happen again…”. These events led us to try to consider how such loss of life could be avoided. Unfortunately, before publication of this research another death has occurred where a crane operator died whilst entrapped by his legs in icy water in Cambridge in 2010.

Materials and methods

The study aims to determine: (i) the potential use of this equipment to achieve expeditious life-saving amputations and (ii) the effect the fire service hydraulic cutting equipment has on the bony and surrounding soft tissues.

The hydraulic cutting equipment carried on Fire & Rescue Appliances in Cheshire, United Kingdom (UK), is a Holmatro Core
Technology™ type manufactured by Holmatro Ltd., Amsterdam, Holland.³ This intelligent hydraulic system uses carbon-steel-edged curved blades with feedback limiting power to achieve full closure. It is capable of delivering 7000 lbs psi and can cut through 41-mm round bar Boron steel, or the sub-frame of modern motor vehicles. It has a cutting capacity of 95 tonnes. It weighs 17.4 kg and is equipped with i-Bolt and CORE™ Technologies. We believe similar equipment to be carried on most fire and rescue appliances in the UK.

We postulated that this equipment could cut biological lower limb tissue. Initially, four cadaveric porcine hindquarter segments were studied to assess the effectiveness of the equipment's cutting of biological tissue, with its varied structural properties. Each limb underwent guillotine amputation at the following three levels: below knee, through knee and above knee. This porcine model pilot study was successful. There was no evidence of tissue tearing or 'choking' of the tool. A single cut was required for each porcine limb at all levels. There was minimal fracture propagation and the cut was made within a satisfactory time.

After the successful trial, access was provided to cadaveric lower limbs by the Laboratory of Human Anatomy, Glasgow University, Scotland, UK. Three bequeathed lower limb specimens, which had been initially amputated at proximal thigh level and stored in a fresh-frozen condition, were used for the study. Each limb underwent guillotine amputation at the following five levels: through ankle (Fig. 1), long below knee (a hands-breadth above the tibial plafond), standard below knee (a hands-breadth below the tibial plateau), through knee and above knee (a hands-breadth above the knee joint line).

These levels were chosen as they would facilitate rapid extrication from the likely levels of entrapment as directed by the instructors of the Cheshire Fire Service as well as being common levels of amputation of the lower limb. A scalpel and bone saw were used for the standard amputation technique.

The amputations were filmed with a Sony digital camera (DSC-T3™) using Mpeg 2 technology. This allowed image capture which could be studied later in order to define the following parameters: (i) number of cutting actions required to complete the amputations at the levels outlined above without the need for other cutting instruments, (ii) total time to achieve a completed amputation, (iii) quality of bone cut, i.e., degree of comminution and (iv) proximal extent of fracture propagation, if any. The degree of comminution was graded 1–4. Grade 1 was a clean, smooth bone cut as produced by a handsaw. Grade 2 was a moderately smooth bone cut. Grade 3 was a relatively poor-quality bone cut, with grade 4 being a ragged quality bone cut.

The soft-tissue cut achieved by the hydraulic equipment was then taken to be the distal extent of the flap for conventional amputation technique with medial and lateral longitudinal incisions to reflect the flaps and achieve the bone cut with an amputation saw. The quality of the soft-tissue cuts were satisfactory, similar in appearance to those made with the scalpels used for the conventional guillotine amputations (Fig. 2).

The data between the conventional and hydraulic cutting equipment methods of amputation were then compared. Due to the small sample size, only qualitative comparisons were made.

**Results**

The experiment confirms that faster guillotine amputations in human cadaveric lower limb specimens can be achieved by using fire service hydraulic cutting equipment. Overall, the average time to complete an amputation in these ideal experimental circumstances at all five levels was quicker using the hydraulic cutting equipment, varying from two to seven times faster. Either one or two cutting actions were required to achieve the completed amputation using fire service hydraulic cutting equipment. The degree of comminution was greater using the fire service hydraulic cutting equipment, as was the proximal extent of comminution (Table 1).

**Discussion**

The circumstances in which entrapped trauma victims’ lives are immediately at risk vary, but thankfully occur only rarely. Scenarios where this may occur include a risk of drowning, extreme low temperatures, confined space, chemical or biological leaks, industrial accidents and terrorist or natural disasters. On rare occasions when motor vehicle collisions result in severe lower limb entrapment, combined with major scene safety issues, or a rapidly deteriorating casualty with no hope of rapid release, an alternative extrication technique may be required. We feel the use of hydraulic cutting equipment is an alternative option.

We feel the amputation times of the conventional techniques at all five levels achieved in this study are unrealistically quick. The experimental set-up, with a cadaveric lower limb specimen amputated at proximal thigh level, allowed a 360° axial rotation of the specimen, perfect lighting conditions and completely free access to the specimen without restriction of the scalpel or saw stroke length. The conventional amputations were carried out by a consultant orthopaedic surgeon with specific training in amputation surgery. The circumstances in which life-saving amputation often occurs are never so ideal. The limb will often be difficult to access along with poor lighting and may be performed by a less experienced medical practitioner. We therefore postulate that the difference between the conventional amputation technique and

---

**Fig. 2.** Result of a through ankle amputation using hydraulic cutting equipment.

**Fig. 1.** Showing the hydraulic cutting equipment in preparation for a through ankle amputation.
the hydraulic cutting equipment would be greater in the real-life situation. It may also be possible to preserve greater stump length by using the fire service hydraulic cutting equipment. In addition, such equipment will operate underwater where a standard surgical amputation may be impossible.3

Amputations carried out in the field are not aseptic and the stump level will always need to be made more proximal in theatre to allow appropriate surgical debridement whether hydraulic cutting equipment or a standard amputation technique has been used. Mangled or crushed extremities in which the major vessels have been torn may bleed less than if the vessel is cut in a clean manner. If time and victim position allow, a military, pneumatic or suitable improvised tourniquet may be applied to the thigh to improve haemostasis. It may be necessary to perform the amputation and then extricate the victim before applying a tourniquet. Direct compression can be used whilst the victim and rescuer are being transferred to safety; however, it should be remembered that the time of tourniquet application should be written using a permanent marker upon the tourniquet or limb.5

Due to the rarity of the circumstances in which such amputations are required, there is scant literature on the subject. There are, however, case reports which illustrate clearly the need for first saving life then limb.6 This would not be the first application of unconventional equipment to achieve amputations in trauma victims.7−10

The decision to amputate a limb needs to be a carefully considered one, taken by a senior medical professional with experience of out of hospital amputation. A second opinion should preferably be sought. An onsite discussion would be ideal, but if this were impossible a discussion on a phone would suffice. Once a decision has been made to amputate, the most distal level should be chosen in discussion between the medical and fire service officer in charge. Whilst amputation is a surgical procedure, the fire service hydraulic cutting equipment should be used by a suitably trained member of the attending trauma team, be this the attending medic (there are suitably trained doctors in many parts of the UK) or most senior fire officer under suitable medical supervision. Even in experienced hands, there are cases of finger amputation reported from English and Irish fire service personnel using the hydraulic cutting equipment, hence great care should be exercised in its use.

The time saved by utilising the fire service hydraulic cutting equipment may be as little as 30 s, but in the rare circumstances in which we suggest the use of this technique, this could be the difference between life and death for an entrapped trauma victim. Typically, by the time that extrication commences a significant percentage of the ‘Platinum 10 min’ or even of the ‘golden hour’ has already passed and any further delay will potentially worsen outcome.11−13 Hydraulic cutting equipment amputation offers a viable, simple and effective alternative to avoid unnecessary delay on scene as a result of complex entrapment or injury. This supports the established ‘scoop and run’ concept to reach definitive care, in the shortest possible time.14,15

In conclusion, if circumstances and time constrains allow, amputation should rarely be necessary. However, if deemed essential, conventional amputation technique carried out by a trained medical practitioner would be preferable to the use of the fire service hydraulic cutting equipment. The bone cut is less comminuted and if a more proximal amputation is required there is less proximal propagation of the fracture. These problems, however, can be dealt with when the definitive amputation is fashioned in theatre after the emergent extrication has taken place. At least one and preferably two senior medical physicians, experienced in out-of-hospital amputation should make the decision with regard to the use of hydraulic cutting equipment. In at least one of the cases sited, many hours elapsed before amputation was required and such expert opinion could have been gained otherwise. We believe that this technique could be used to perform ‘time critical’ life-saving, emergent amputation under medical supervision, especially where a standard amputation technique would take too long or the environment is too restrictive or hazardous to perform a standard amputation safely.

Conflict of interest

There are no conflicts of interest from any of the authors, with regards to this publication.

References

1. Anaesthesia, Trauma and Critical Care (ATACC) the Organisation. Available at: http://www.atacc.net [accessed 03.11.10].
3. Holmatro Rescue Equipment Inc. Available at: http://holmatro.com/rescue [accessed 03.11.10].
13. Lerner EB, Moscati RM. The golden hour: scientific fact or medical “urban legend”? Acad Emerg Med 2001;8:758−60.