REVIEW ARTICLE

Clinical Update: Suspension Trauma

Mathieu Pasquier, MD; Bertrand Yersin, MD; Laurent Vallotton, MD; Pierre-Nicolas Carron, MD

From the Emergency Service, University Hospital of Lausanne, University Hospital Center (CHUV), Lausanne, Switzerland.

Objective.—Suspension trauma refers to the pathophysiologic syndrome that occurs when a victim is suspended motionless in a vertical position for an extended period of time. This can occur in sports that use a harness system as well as in various occupational activities including work on high wires or helicopter rescue operations. We reviewed the scientific evidence published to date in order to improve the prevention and treatment of suspension trauma.

Methods.—Medline, PreMedline, the Cochrane Library, and Google Scholar were searched for relevant information about suspension trauma.

Results.—Published data describing the pathophysiology of and the therapeutic approach to suspension trauma are sparse and consist mainly of case reports and a limited number of human experimental prospective studies. The pathophysiology of suspension trauma is related to hypovolemia induced by reduced venous return and by vagal stimulation. It is also influenced by the type of harness used. Chest harnesses may induce severe cardiorespiratory repercussions and have the lowest motionless suspension tolerance. Symptoms of suspension trauma include presyncope and can lead to a loss of consciousness.

Conclusions.—Sports enthusiasts and workers who use a body harness system should never act alone and should not use a simple chest harness. If a victim shows symptoms of presyncope or is unconscious, he should be released from suspension as soon as is safely possible. There is no clear evidence to support the idea that the return to the horizontal position may contribute to the potential risk of rescue death.

Key words: suspension trauma, orthostatic syndrome, harness, orthostatic intolerance

Introduction

Suspension trauma is the pathophysiologic response of the human body being suspended motionless in a vertical position for an extended period of time.¹ Symptoms include presyncope and can lead to a loss of consciousness.² Certain sports enthusiasts, as well as various medical and rescue professionals, have a keen interest in this subject.³ Since the early 1970s, disagreements about the mechanism and management of suspension trauma have sparked debate and controversy among laypersons, as well as professionals in rescue organizations, and elicited a variety of recommendations from experts based mainly upon personal experience and case reports. The medical risks run by suspension victims were outlined in a presentation of case reviews at the Second International Conference of Mountain Rescue Doctors in Innsbruck in 1972. The concept of “rescue death” surfaced, and some specialists advocated against

placing the victim in a horizontal position immediately following rescue due to the potential risk of cardiac arrest. This theoretical risk is thought to be tied to a rapid increase in venous return as the body returns to a horizontal position, which can cause a massive volume overload of the right heart chamber or a recirculation of toxic metabolites leading to cardiac arrest.⁴

The aim of our review was to present the most pertinent studies in this area and to synthesize the best scientific data currently available in order to improve the identification and treatment of suspension trauma. Traumatic injuries from the fall itself, as well as the potential delayed complications of crush syndrome from prolonged suspension, will not be discussed here.^{5,6}

Methods and Results

We conducted a literature search using Medline, Pre-Medline, the Cochrane Library, and Google Scholar, with the following keywords: “suspension trauma,” “or-

Corresponding author: Mathieu Pasquier, MD, Service des Urgences, 1011 Lausanne-CHUV, Switzerland (e-mail: Mathieu.Pasquier@chuv.ch).

Figure 1. Motionless suspension in a harness is an emergency, as it can quickly lead to loss of consciousness.

thostatic syndrome,” “harness,” and “orthostatic intolerance.” Over 10,000 articles surfaced and were filtered based on their abstracts. After eliminating irrelevant articles, 39 remained and were read in their entirety. We also checked their respective bibliographies for additional articles of interest.

There is a paucity of scientific data about suspension trauma and what little is available consists of case reports and human experimental prospective studies of which only a few are controlled and randomized. Most of these studies did not measure the tolerance to passive suspension in a modern sports harness such as the sit harness (Figure 1), which is worn around the waist and also encircles the upper thighs. Rather, they used either a whole body industrial harness which encircles the chest and upper thighs, or a body belt which consists of only 1 belt around the waist. We found only 2 studies that used rigorous evidence-based review methods to develop guidelines and recommendations on this topic.^{7,8}

Etiology and Prevalence

Suspension trauma can occur in any activity that uses a body harness system. This includes sports such as mountaineering, rock climbing, parachuting, paragliding, via ferrata, canyoneering, BASE jumping, and spelunking. Occupational activities include work on high wires or rescue operations in hostile environments (mountainous

or other difficult terrain, helicopter winching in rescues at sea, etc). We were unable to find precise data on the prevalence of suspension trauma. A retrospective review of work on high wires reflecting millions of man-hours of labor did not reveal 1 suspected case of suspension trauma.⁹ The currently available literature describes only cases from sports accidents or healthy volunteer studies.

Mechanism

The human body’s response to the orthostatic position is pooling of blood in the lower extremities, resulting in functional hypovolemia. The absence of a muscle pump in an immobilized subject diminishes venous return, thereby accentuating this phenomenon. These factors can lead to symptoms of presyncope (nausea, light-headedness, hot flashes, numbness of the extremities) or unconsciousness if not treated in a timely manner. Different types of body harnesses can exacerbate this situation. When a sit harness is used, the leg straps compress the femoral veins, reducing venous return; this is the same mechanism that has also been implicated in the pathogenesis of thromboembolic events.¹⁰ When a simple chest harness is used, as in free suspension, intrathoracic pressure increases, which has been shown to lead to a dramatic impairment of hemodynamic and respiratory parameters.¹¹

In addition to hypovolemia due to reduced venous return, a vagal phenomenon (either reflexive or from a nociceptive stimulus) appears to be implicated in the pathophysiology of suspension trauma.¹¹ Experimental studies in presyncopal subjects have demonstrated that heart rate and mean arterial pressure increase at first but subsequently decrease as presyncopal symptoms develop.¹² In a study of motionless suspension in healthy volunteers, 1 subject experienced bradycardia of 30 bpm followed by syncope. These experimental findings can be explained by a vasovagal mechanism that results in a hypotensive-bradycardic response that, along with orthostasis, leads to syncope.¹³

Timing

In the case of passive orthostasis, the appearance of presyncopal symptoms is the rule and these can develop very quickly. Eight percent of volunteers subjected to a passive head-up tilt of 50° experienced such symptoms after only 5 minutes, and 50% were symptomatic after 27 minutes.¹² These time periods are even shorter when one is suspended in a harness, and depend on the type of harness used. The tolerance for motionless suspension was shown to be greater in a whole body harness (14.38

min) than in a body belt (1.63 min) or a simple chest harness (6.08 min).¹³

Under normal conditions, a return to the horizontal position typically allows restoration of adequate cerebral blood flow to prevent syncope. However, when a subject is suspended in a harness, the orthostatic position together with reduced leg movement can lead to a loss of consciousness. The time between the appearance of symptoms and syncope itself during suspension is not known, as the first symptoms of presyncope come exclusively from prospective human studies and also serve as a criteria to stop the experiment and return the subject to a recumbent position. However, 2 prospective studies have reported 3 cases of syncope while the subjects were being lowered from the suspension after complaining of symptoms. The lead time from symptoms to syncope can therefore be as short as a few seconds.^{13,14}

Mortality

Although a risk of death from suspension trauma does exist, it is likely very small.¹² Whereas there are reported cases of deaths involving suspension, the cause of death in these cases was inconclusive. These reports involved either prolonged suspension times of several hours¹⁵ or did not have sufficient data to unequivocally attribute the death to suspension trauma alone.¹⁶ Depending on the type of harness used, a reduction in cardiac output or a compromised respiratory system are the most likely mechanisms leading to nontraumatic death during motionless suspension.

Prevention and Management

A person who is suspended motionless in a harness is a medical emergency, and the primary goal during rescue/resuscitation should be the prevention of medical complications. Workers and sportsmen using a harness should never act alone, and the activity must be conducted in such a way as to allow for a prompt rescue or a quick release from suspension in an emergency situation.

A simple chest harness is rarely used today and should be discouraged because it significantly compromises the cardiorespiratory system, especially during free suspension.¹¹ As to the other harness styles (sit harness, whole body harness, or body belt), whereas the harness type has not been shown to influence the pattern and severity of injuries from a fall, the whole body harness is the only system that guarantees upright suspension, especially in an unconscious victim.⁵

Since motionless suspension is a chief risk factor for syncope, a victim of suspension should: (1) move his

legs in an attempt to increase venous return to prevent or at least delay the onset of syncope; and (2) elevate the legs to a semi-recumbent position if at all possible. Two experimental studies support this notion, as it has been shown to double the tolerable and symptom-free suspension time.^{12,17} Since it is difficult to achieve these tasks during a real-life suspension situation, people participating in activities that require a harness should be prepared for such emergency situations and should have specially designed foot slings (which alleviate stress on the body) within easy reach at all times. Such devices have recently been developed mainly for professional use, including "leg up suspension trauma straps" and "suspension trauma relief straps."^{18,19} If a victim has symptoms of presyncope or is unconscious, he should be released from suspension as soon as is safely possible. This can be achieved using various rescue techniques such as helicopter winching, human cargo sling evacuation, or rappelling the victim to a flat area. The best choice of evacuation strategy will depend on the expertise of the rescue team and the materials available as well as meteorological conditions and the topography of the rescue site. If the victim is conscious and shows no symptoms of presyncope, the evacuation strategy should take into account potential traumatic injuries, suspension trauma, and other medical or environmental insults.

Rescue Death

Until recently, there was no consensus on the initial management of suspension trauma casualties.¹ Most recommendations advised against laying a casualty down after being rescued from suspension because of the perceived risk of death from moving a victim to a horizontal position too rapidly.^{9,20} These recommendations were based on expert opinions and case reports presented at the 1972 Innsbruck conference on mountain medicine.¹⁵ The hypothetical cause of death was thought to be due to an acute volume overload of the right heart from blood returning from the legs upon horizontal positioning, or due to recirculation of blood resulting in reperfusion injuries.

A recent critical review of the potential cases of rescue death presented at the 1972 Innsbruck conference examined the circumstances and timing of the deaths associated with suspension.⁷ The data review found nothing to suggest that placing a victim in a horizontal position following suspension trauma increases the risk of rescue death. The authors therefore suggested that initial management of these patients should follow the international prehospital and advanced life support guidelines without modifications.^{7,21,22} The same conclusion was drawn by what is probably the most rigorous and extensive review

of the literature on this topic to date, namely, the UK Health and Safety Executive that offers evidence-based first aid measures for suspension trauma casualties.⁸ Whereas the concept of rescue death was widely debated in both medical and lay literature up to the early 2000s, opinions about this topic are more convergent today, and no scientific evidence suggests that the management guidelines for the care of these patients should differ from that of other trauma victims.³

Conclusion

Suspension trauma is the result of the normal response of the human body to motionless suspension in an orthostatic position. Its identification is crucial for those participating in certain sports, and occupations, as well as in rescue organizations, because of the possible medical risks and complications associated with suspension trauma. Typically, the natural course of immobilized suspension will lead to syncope, which can occur within minutes. A symptomatic victim should therefore be released from suspension as soon as possible. If a victim is conscious, moving the legs and placing them in a horizontal position will delay the onset of presyncopal symptoms. There is currently insufficient scientific evidence to support the concept of immediate rescue death or to therefore justify changing the current treatment recommendations for these victims once they have been released from suspension. Therefore, once a victim has been brought to the ground, rescue professionals should follow the current international prehospital and advanced life support guidelines without modifications.^{21,22}

Acknowledgments

The authors acknowledge: Danielle Wyss for proof-reading and final translation; and François Mathey, IFMGA mountain guide and paramedic, for the illustration (www.fm-guide.ch).

Supplementary Data

Supplementary data, including a short film on a suspension rescue, associated with this article can be found, in the online version (available at www.wemjournal.org).

References

1. Roggla G, Moser B, Roggla M. Suspension trauma. *Emerg Med J*. 2008;25:59.
2. Lee C, Porter KM. Suspension trauma. *Emerg Med J*. 2007;24:237–238.
3. Werntz CL 3rd. Workers at height are required to use fall prevention systems. What are the health risks from being suspended in a harness? *J Occup Environ Med*. 2008;50:858–859.
4. Flora G, Margreiter R, Dittrich P, Stuhlinger W. Hanging tests—conclusions for the mountaineer. In: Second International Conference of Mountain Rescue Doctors; 1972; Innsbruck, Austria.
5. Hohlrieder M, Lutz M, Schubert H, Eschertzhuber S, Mair P. Pattern of injury after rock-climbing falls is not determined by harness type. *Wilderness Environ Med*. 2007;18:30–35.
6. Schöffl V, Küpper T. Rope tangling injuries—how should a climber fall? *Wilderness Environ Med*. 2008;19:146–149.
7. Thomassen O, Skaiaa SC, Brattebo G, et al. Does the horizontal position increase risk of rescue death following suspension trauma? *Emerg Med J*. 2009;6:896–898.
8. Adisesh A, Robinson L, Codling A, et al. Evidence-based review of the current guidance on first aid measures for suspension trauma. Health and Safety Executive Research Report RR 708, UK Health and Safety Executive, Birmingham, 2009. Available at: <http://news.hse.gov.uk/2009/05/27/rr708-evidence-based-review-of-the-current-guidance-on-first-aid-measures-for-suspension-trauma/>. Accessed June 1, 2010.
9. Seddon P. Harness suspension: review and evaluation of existing information. Health and Safety Executive Research Report 451, UK Health and Safety Executive, London, 2002. Available at: http://www.hse.gov.uk/research/crr_pdf/2002/crr02451.pdf. Accessed June 1, 2010.
10. Pisati G, Cerri S, Achille G, Rossi G, Lorenzi G. Vascular thrombosis and pulmonary thrombo-embolism due to harness suspension. *Med Lav*. 2007;98:415–421.
11. Roeggla M, Brunner M, Michalek A, et al. Cardiorespiratory response to free suspension simulating the situation between fall and rescue in a rock climbing accident. *Wilderness Environ Med*. 1996;2:109–114.
12. Madsen P, Svendsen LB, Jorgensen LG, et al. Tolerance to head-up tilt and suspension with elevated legs. *Aviat Space Environ Med*. 1998;69:781–784.
13. Orzech MA, Goodwin MD, Brickley JW, Salerno MD, Seaworth J. *Test Program To Evaluate Human Response to Prolonged Motionless Suspension in Three Types of Fall Protection Harnesses*. Wright-Patterson Air Force Base, OH: Harry G Armstrong Aerospace Medical Research Laboratory; 1987:1–36.
14. Nelson B. Climbing harnesses: how long can you safely hang in your harness? *Off Belay Mag*. August 1979;46:10–12.
15. Flora G, Holzl H. Fatal and non-fatal accidents involving falls into the rope. In: Second International Conference of Mountain Rescue Doctors; 1972; Innsbruck, Austria.
16. Dobson J. Put suspension trauma in proper perspective. *Occup Health Safety*. 2004;73:10.
17. Turner NL, Wassell JT, Whisler R, Zwiener J. Suspension tolerance in a full-body safety harness, and a prototype harness accessory. *J Occup Environ Hyg*. 2008;5:227–231.

18. Guardian Fall Protection. Guardian Fall Protection's leg up suspension trauma straps. Available at: <http://www.guardianfall.com/product.php?id=4>. Accessed October 8, 2010.
19. Wolner JT, Betcher TP. Suspension trauma relief strap assembly for use with a full body harness. Available at: <http://www.faqs.org/patents/app/20090032333>. Accessed October 8, 2010.
20. Weems B, Bishop P. Will your safety harness kill you? *Occup Health Safety*. 2003;72:86–90.
21. National Association of Emergency Medical Technicians. *Prehospital Trauma Life Support (PHTLS)*. 6th ed. Clinton, MS: NAEMT; 2006.
22. American College of Surgeons Committee on Trauma. *ATLS Student Course Manual*. 8th ed. Chicago: ACS; 2008.