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Proposal of an Effective Algorithm to Manage Suspension Trauma in the Field

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Abstract

Introduction: Suspension trauma describes a set of symptoms that occurs when a person is suspended motionless in a harness, which can evolve rapidly to unconsciousness and even death. Therefore, rapid initial care by first responders appears to be vital, even before the arrival of emergency healthcare. There is currently no consensual management algorithm.

Methods: The objective was to make an analysis of previously published data concerning this topic and to propose a specific algorithm for in such cases.

Results: The victim should be released quickly from motionless suspension by the first responders; if unconscious and/or presenting injuries, emergency assistance must be called. If a rapid descent is not possible and the subject is conscious, leg muscle activity must be maintained or a saddle may be placed under the thighs. In case of unconsciousness and/or trauma, and if access to the victim is possible, first responders, while waiting for an emergency team, will place the victim in a holding position, with straps or a net. On the ground, the recommendation is to follow international basic life support guidelines.

Conclusion: Nowadays, the existence of such dramatic situations is confirmed, but research studies still must be undertaken in order to support knowledge in this area.

Keywords: Harness; Suspension trauma; Orthostatic syndrome; Reflow syndrome; Rescue death

Introduction

Those who practice mountain activities such as rock or ice climbers, cavers and canyoning practitioners use the harness. Its use is also prevalent in many professional activities involving height or exposure to a danger of falling, like rope workers, pruners, stuntmen, theatre or circus technicians. This personal protective equipment provides a link between the subject and the belay (rope or cable) that holds it. When a fall occurs, the harness keeps the subject in suspension until the activity can be resumed or evacuated. If the suspension is prolonged, and the subject remains motionless, blood begins to pool in the lower parts of the body and several pathophysiological mechanisms are activated which may potentially result in a loss of consciousness and secondarily death, even though there are no traumatic and/or lethal injuries associated, for example within the context of an exhaustion [1].

This phenomenon, which is called suspension trauma, is defined as a natural reaction of the body being held motionless in an upright position [2]. In an experimental work on harness design, patients have been reported to develop pre-syncopal symptoms including faint, dizzy, palpitations, sweating, nausea and reduction in peripheral vision and/or the presence of a black veil [3]. Drowsiness, agitation and/or confusion may also be present, as well as partial paralysis of the extremities, with or without paresthesia. The clinical expression of suspension trauma is a functional hypovolemia with tachycardia and tachypnea that could by followed by a loss of consciousness.

This article is a narrative review of the current knowledge about suspension trauma. Although there is no convincing evidence found of a distinct clinical entity of suspension trauma, as mentioned by Adisesh [4] and a low level of evidence in literature, there is need for an efficient algorithm for the management, specifically designed for first responders.

Literature Search

A systematic literature search of the related articles published between January 1972 and July 2014 was performed using Medline, PubMed, the Cochrane library and Google scholar with the following key words: "suspension syndrome", "suspension trauma", "harness suspension", "harness hang syndrome", "orthostatic syndrome", "orthostatic intolerance", "reflow syndrome", "rescue death","harness suspension syncope" and "suspension stress". Using the criteria defined by the American College of Chest Physicians (ACCP), each form of intervention was attributed a recommendation grade where appropriate (Figure 1). The algorithm proposed was based on literature and elaborated with the collaboration of both actors of mountain rescue (GMSP, ENSA) and industrial partners (DPMC).

Grade of Recommendation/ Description	Benefit vs Risk and Burdens	Methodological Quality of Supporting Evidence	Implications
1A/strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1B/strong recommendation, moderate quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1C/strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	Observational studies or case series	Strong recommendation but may change when higher quality evidence becomes available
2A/weak recommendation, high-quality evidence	Benefits closely balanced with risks and burden	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

Figure 1: ACCP classification criteria for grading evidence in clinical guideline [5].

History of Suspension Trauma

In 1968 the research laboratory scientists of the United States Air Force performed the first tests on five healthy volunteers suspended in paratrooper harnesses. One lost consciousness after 27 minutes of suspension and then regained consciousness once placed on the floor. The origin of this unconsciousness was at that time attributed to a venous sequestration in the lower limbs ("venous pooling") and prior inadequate calorie intake. These results would be published some twenty years later [1]. In 1972, the issue of "harness syndrome" was the one of the topics at the Congress of Mountain Medicine in Innsbruck. Several climbers autopsies not traumatized but dead after prolonged suspension, were presented. The assumed hypothesis of their death was that of a circulatory collapse caused by an orthostatic shock [6].

In 1973, Amphoux performed a short series of suspension tests, which ended rapidly due to all subjects almost reaching the point of unconsciousness with disturbing hemodynamic data [7]. In 1979, the medical commission of the French Federation of Speleology studied reports of 15 unexplained deaths among trained cavers during rope ascents. They first thought that the cause of the death was hypothermia, yet as they examined each case, they realized that the delay before loss of consciousness was too short to be compatible with hypothermia. These data where mentioned in 1992 in an article of Bariod who performed tests on healthy volunteers wearing a caving harness [8].

This study conducted under medical supervision and monitoring, was quickly stopped due to the occurrence of phases of severe bradycardia with loss of consciousness in two subjects after 7 minutes of suspension for the first and 30 minutes for the second. The experiment was repeated two years later in three healthy volunteers but was ended equally abruptly following the occurrence of severe malaises including a loss of consciousness. These two studies, although aborted, ruled out the possibility of hypothermia as the key role in the deaths, as had originally been thought.

Epidemiology

Within the few epidemiological data from the literature, it is estimated that deaths occurring after prolonged suspension of a victim remains sporadic, even in the absence of traumatic lesions [9,10]. Bowie et al reported a 6% death rate in mountain accidents; the causes were attributed to traumatic injuries or hypothermia [11]. The contribution from the industrial world to these statistics is also disappointing. In 2002, Seddon opened a registry for almost two years in the UK, reflecting on millions of man-hours of labour, but failed to collect a single case [12].

Pathophysiological Mechanisms

The pathophysiological mechanisms of suspension trauma remain to a large extent hypothetical (Figure 2). It is recognized that when a subject is in a standing position there is a transfer of blood volume, due to gravity, to the splanchnic system and the distal vascular system, in particular to the lower limbs, known as "venous pooling". Usually this phenomenon is counteracted by the activation of the muscular pump. In case of prolonged motionless suspension, it is rather accentuated: systemic blood pressure decrease, central venous pressure is reduced and therefore cardiac pre-load and stroke volume [13]. There is then an activation of arterial aortic and carotid baroreceptors, leading to sympathetic adrenergic stimulation. This is expressed by peripheral vasoconstriction and a positive inotropic response in order to maintain cardiac output and blood pressure [14].

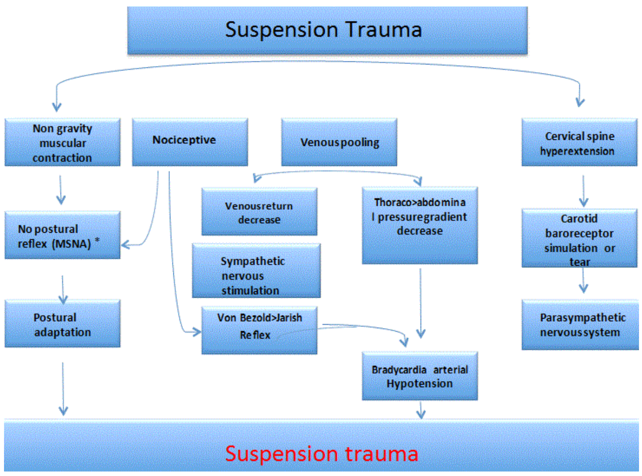

Figure 2: Suspension trauma pathophysiological hypothesis, Suspension syndrome: patholophysiological hypothesis (inspired from F. Bussienne).* MSNA: Muscle Sympathetic Nerve Activity.

However, pressure receptors in the wall of the under filled left ventricle may then sense stimuli, activating cardio inhibitory receptors, triggering the Von Bezold-Jarisch Reflex [15]. The result is a paradoxical bradycardia and decreased contractility, resulting in additional and relatively sudden arterial hypotension and a peripheral vasodilation. A vagal phenomenon could also be implicated in the pathophysiology of suspension trauma [16]. In neurocardiogenic syncope, the victim falls to the ground, which instantly restores sufficient preload to restore initial blood flow. In suspension trauma, the hypothesis would be that this flow could not be restored due to maintaining an orthostatic position. Increase of intra-thoracic pressure, as seen when a chest harness is used, reduces even more the venous return and lead to an impairment of hemodynamic and respiratory parameters [16]. This may also occur when the victim keeps the arms outstretched in the form of a cross [6].

This position is similar to that of the position of a person being crucified, who eventually dies from respiratory failure. Simultaneously, the neuro-sympathetic reflex of the lower limbs, also called “muscle sympathetic nerve activity” (MSNA) allows postural adaptation by maintenance of systemic arterial pressure to provide minimal cerebral blood flow [17]. Baroreceptors are the prime regulators of this reflex during orthostatic stress, but skeletal muscles of lower limb may also provide some effects [18]. In the absence of the contraction of anti-gravity muscles, as in a motionless suspension, this postural reflex could be inhibited. If the cervical spine is in hyperextension, as may be the case following a loss of consciousness during the suspension (Figure 4), an extrinsic stimulation of carotid chemoreceptors or of the carotid glomus could occur [19,20]. The ensuing vasovagal response would be responsible for a hypotension and a bradycardia [4].

This hypothesis is plausible since a traumatic carotid artery dissection is a recognized complication following head injury and trauma to the neck [21]. According to Brinckley, one hypothesis would be that nociceptive mechanisms might also be implicated in the onset of suspension trauma, triggered by the pain due to compression of the harness straps, inhibiting the postural reflex mentioned above and triggering Von Bezold-Jarish Reflex [22]. We could speculate that this could explain the differences in the delay of tolerance to suspension between subjects, which could be due to a pain threshold variable as well as the type of harness used and/or an inadequate fitting of the harness to the morphology of the victim. The compression of the femoral vein in the groin by the harness straps was initially seen as the primum movens of suspension trauma. In 1991, two prospective studies undermine this hypothesis by demonstrating by ultrasound, the absence of a major decrease of flow in the iliac and femoral veins on subjects suspended in a harness [8,23]. Anatomically this is understandable because the superficial femoral artery, which may be compressed by the harness straps, is only responsible for 15-20% of the flow. The deep femoral artery that provides most of the flow is protected by its extreme internal situation. Finally, the onset of suspension trauma seems dependent on the interaction of several physiological mechanisms that are summarized in the following algorithm (Figure 2).

Contributing Factors

Type of harness

The onset of prodromal symptoms of suspension trauma varies from one individual to another and also appears to depend on the type of harness used. In the study by Brice [24], the suspension time with a body belt was 5 minutes and 30 seconds and unlimited for the pelvic harness. Average times of suspension of 1.63 minutes for a body belt, 6.08 minutes for the thoracic harness (front side) and 14.38 minutes for the full body harness are found in the study of Orzech [1]. For Brinckley [22], the average length of tolerance in a full body harness was 14 minutes (3,053 to 60 minutes).

Madsen compared 1 hour 50 degrees tilt in 79 volunteers: 87% were symptomatic at 60 minutes, and 9 volunteers with a leg strap system, from which one subject (11%) was symptomatic at 58 minutes and 9 seconds [25]. A study by Turner demonstrated that when a saddle was added to a back attachment harness, allowing to raise the upper legs to a horizontal position, the mean time before symptoms of suspension trauma was double, from 29 minutes to 58 minutes [26]. These studies suggest that the time to onset of prodromal symptoms of suspension trauma tends to increase with a pelvic or a full body harness and becomes significantly longer when the suspension mechanism is supplemented with a saddle or other device to further elevate the legs.

Position and angle of suspension

The angle of suspension, defined by the angle formed between the axis passing through the centre of the suspended subject and the vertical, is important. According to Hsiao, the onset of early syncopal symptoms is accelerated when this angle exceeds 35 degrees [27] and/or when the harness is not properly adjusted [28]. The attachment point of the harness will influence the position of the body during the fall. A ventral attachment will place the subject in hyperextension of the spine, particularly when he losses consciousness, which could have an adverse effect on evolution of the situation (recommendation grade 2A).

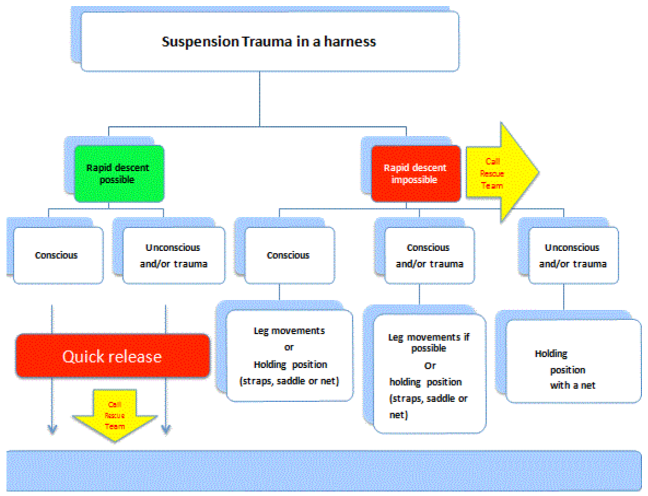

Figure 3: Suspension trauma management in the field

Management section

There is little consensus on the best way to manage properly suspension trauma. Recommendations set out by experts from industry and professionals in rescue, but also by unskilled persons, are frequently based upon personal experiences or anecdotal cases. As a result, there is few data which professionals working in the field can rely on to provide the best approach in this particular situation. First data have only been published from 2008 [2,4,29-31]. There is an agreement about the idea that a victim of inert suspension in a harness risks loss of consciousness in a relatively short delay and then possibly death if no action to stall is taken. According to Turner et al. [26] rescue would have to occur in 7 minutes for a chest attachment point and in 11 minutes for a back attachment point, in order to ensure that no more than 5% of subjects suspended motionless would experience symptoms (recommendation grade 2A). Once pre-syncopal symptoms appear, situation may evolve rapidly to a loss of consciousness. Nevertheless, the occurrence of pre-syncope symptoms is not going to influence the management of potential suspension trauma victims since the rapid descent is the only solution to prevent a suspension trauma. Whatever the gravity of injury, there is no argument to delay the descent as time lost in a complex management is going to decrease the risk-benefit balance.

There are mainly two types of situation (Figure 3)

If Rapid descent is possible: The victim must be released imperatively whatever its clinical condition (safe, unconscious, injured) to avoid occurrence of a suspension trauma. Once on the ground, if there are neither symptoms nor injuries, the subject may simply pursue his work. If the victim has minor injuries, it must be taken to the hospital for a medical advice. If the victim is unconscious and/or has serious injuries, rescue team must be called.

If rapid descent is impossible:

The victim is conscious and not injured: first responders, while waiting for reinforcements from an emergency team, have to stimulate him to maintain a muscular activity in the lower limbs, by moving legs, using rescue pedals or by lifting the feet against a wall.

The victim is conscious and injured: a sitting position is an interesting option, obtained with a saddle placed under the buttocks or upper thighs (Figure 4) [25] taking care to flex the thighs not more than the right angle, in order to avoid a plication of femoral vessels.

Figure 4: The victim is conscious and injured and is obtained with a saddle placed under the buttocks or upper thighs.

The victim is unconscious with/without injury: the first responder must try to access the victim in order to place him in a holding position, which would prevent from a posture in hyperextension of cervical spinal and allow placing the thighs in a horizontal position. The ideal scenario would be to have a rescue net able to maintain the victim in that posture, nearby a horizontal position.

While waiting for rescue team

Once the victim is placed on the ground, the modus operandi to adopt is still not clearly defined in the semi-professional or non-professional milieu that continues to debate this fact. There is indeed a current opinion among those persons that placing the victim in a reclining position on the ground after being rescued from suspension could potentiate the risk of death by a rapid increase in venous return, leading to cardiac arrest.

Nonetheless, there are no studies or even a single case report to support this argument. The survey from Thomassen et al. did not reveal any studies or personal observations among international medical colleagues, supporting the causal relation between the horizontal position and death [2]. Medical experts agree that the management once on ground should be as any other trauma victim; hence, until shown proof to the contrary, the usual processing procedures of basic life support (BLS) have to be strictly respected.

Discussion

Prolonged suspension in a harness is a normal situation in sporting activities such as rock climbing, mountaineering, canyoning, caving, etc. For professionals working at heights, the harness fulfils the functions of restraint in the event of falling. The main point is that vertical prolonged motionless suspension is enough to trigger the mechanisms that could lead quickly to a loss of consciousness and death, even without any traumatic injury. Given this risk, it is important not to waste time treating the injuries acrobatically while suspended and to consider this kind of situation as an emergency in which rescue procedures must be implemented as quickly as possible.

There is a need for efficiency to favour a better approach in the management of such dramatic situations. Further researches with prospective studies are necessary to focus on strengthening of the evidence regarding the occurrence of shock, and regarding the potential of death. It would be also of particular interest to improve the outcome in the field, particularly after removal from the suspended position. In the absence of any new arguments concerning initial management of the victim on the ground, the recommendation is to follow international basic life support guidelines without modification [2].

Conclusion

Interest in suspension trauma continues to grow. The future challenge will be to provide a rescue plan to be regularly used first of all by unskilled persons, in order to avoid the victim to wait for off-site rescuers. Ultimately, whatever the situation, a rapid removal must be initiated for any person hanging motionless in a harness. Concerning the type harness that should be used, full body harness with a saddle seems to be the best compromise in order to avoid or at least to reduce the risk of suspension trauma.

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