Lechner R[1], *Rauch S*[2,3]

Suspension Syndrome

Hängesyndrom

REVIEW

ACCEPTED: April 2020

PUBLISHED ONLINE: November 2020

Lechner R, Rauch S. Suspension syndrome. Dtsch Z Sportmed. 20202; 71: 275-279. doi:10.5960/dzsm.2020.434

1. ARMED FORCES HOSPITAL ULM, *Department of Anesthesiology, Intensive Care Medicine, Emergency Medicine and Pain Therapy, Ulm, Germany*
2. EURAC RESEARCH BOLZANO, *Institute of mountain emergency medicine, Bozen, Italy*
3. „F. TAPPEINER" HOSPITAL MERANO, *Department of Anesthesiology and Intensive Care Medicine, Merano, Italy*

Summary

- **Suspension syndrome** is a potentially fatal event of unknown incidence that can be caused by motionless hanging in the rope during rope-secured activities. During prolonged hanging, generalized hypoperfusion with reduced cerebral blood flow and consecutive loss of consciousness occurs.
- **Two mechanisms are discussed** as the cause leading to loss of consciousness: venous pooling in the legs and a sudden reduction of heart rate and blood pressure, similar to a neurocardiogenic syncope. The most important preventive measure is the activation of the muscle pump during hanging.
- **In principle,** the treatment follows standard <C>ABCDE care. The patient should be rescued from the hanging position as fast as possible and airway obstruction caused by hyperflexion of the head during unconscious hanging has to be reversed. There is an increased risk of hyperkalemia. Therefore, ECG monitoring should be established as soon as possible to recognize cardiac arrhythmias. Pulmonary embolism should be considered as a potentially reversible cause of cardiac arrest. Hypothermia prophylaxis and treatment have high priority. For suspension longer than two hours, a medical treatment facility able to provide continuous renal replacement therapy should be chosen.
- **There is no evidence** that laying a patient flat immediately after rescue is harmful.

KEY WORDS:
Neurocardiac Syncope, Venous Pooling, Rescue Death, Generalized Hypoperfusion, Standard <C>ABCDE Care

Zusammenfassung

- **Das Hängesyndrom** ist ein potenziell tödliches Krankheitsbild mit unklarer Inzidenz, das durch bewegungsloses Hängen im Seil verursacht werden kann. Bei längerem Hängen kommt es zu einer generalisierten Hypoperfusion mit verminderter Hirndurchblutung und konsekutivem Bewusstseinsverlust.
- **Zwei Mechanismen** werden als Ursache für den Bewusstseinsverlust diskutiert: Ein venöses Pooling in den abhängenden Körperpartien und ein plötzlicher Abfall der Herzfrequenz und des Blutdrucks, ähnlich einer neurokardiogenen Synkope. Die wichtigste präventive Maßnahme ist die Aktivierung der Muskelpumpe während des Hängens.
- **Im Grundprinzip** folgt die Behandlung dem Standard <C>ABCDE Algorithmus. Der Patient sollte so schnell wie möglich aus der hängenden Position gerettet werden. Eine mögliche Atemwegsverlegung durch Hyperflexion des Kopfes während des Hängens muss schnellstmöglich aufgehoben werden. Patienten mit Hängesyndrom haben ein erhöhtes Risiko für eine Hyperkaliämie. Daher muss ein EKG-Monitoring so schnell wie möglich erfolgen, um mögliche Herzrhythmusstörungen frühestmöglich zu erkennen und zu therapieren. Eine Lungenarterienembolie ist eine potentiell reversible Ursache für einen Herzkreislaufstillstand. Zudem ist die Prophylaxe und Behandlung einer Unterkühlung von großer Bedeutung. Ab einer Hängezeit von zwei Stunden sollte die Zielklinik die Möglichkeit eines Nierenersatzverfahrens haben.
- **Der momentane wissenschaftliche Kenntnisstand** sieht keine Hinweise dafür, dass eine initiale Flachlagerung nach Rettung gesundheitsschädlich ist.

SCHLÜSSELWÖRTER:
Neurokardiale Synkope, venöses Pooling, Bergetod, generalisierte Hypoperfusion, Standard <C>ABCDE Algorithmus

Scan QR Code and read article online.

CORRESPONDING ADDRESS:
Dr. Raimund Lechner
Armed Forces Hospital Ulm, Department of Anesthesiology, Intensive Care Medicine, Emergency Medicine and Pain Therapy, Oberer Eselsberg 40, 89081 Ulm, Germany
✉: Raimundedgarlechner@bundeswehr.org

Introduction

There are many typical diseases in the mountains (5). However, apart from altitude illnesses, there are only a few conditions which occur predominantly in alpine areas or are associated with alpine sports. Suspension syndrome is a potentially fatal condition of unknown incidence that can be caused by motionless hanging in the rope during rope-secured activities (9). The incidence is unclear and difficult to determine. Clinically serious cases are likely to be rare. For example, in a survey by IRATA in the UK, not a single case was reported (13). In addition to (ice) climbers and mountaineers also speleologists, paragliders or industrial climbers can ›

Figure 1

Because the legs are below the attachment point of the harness, there is no backflow of blood from the legs to the brain while hanging suspended on a rope. (Picture: Peter Plattner, www.argonaut.pro).

Figure 2

Activation of the muscle pump with a foot sling. (Picture: Peter Plattner, www.argonaut.pro).

be affected. The expressions "harness hang syncope", "suspension trauma" or similar terms are often used synonymously. However, since there is no actual trauma in this clinical condition, this misleading terminology should be avoided. In recent years, some new findings on the pathophysiology of suspension syndrome have been published, some of which have a direct impact on initial treatment. Therefore, the aim of this article is to summarize the current state of knowledge on this condition.

Pathophysiology

The pathophysiology of suspension syndrome is complex. Via mechanisms that have not yet been fully understood, a generalized hypoperfusion with reduced cerebral blood flow and consecutive loss of consciousness occurs (4). This is usually accompanied by pre-syncopal symptoms (lightheadedness, paleness, cold sweating, warmth, blurred vision, nausea) (10). When these pre-syncopal signs and symptoms appear, fainting is to be expected within seconds to minutes. While hanging suspended on a rope after collapse, there is no backflow of blood from the legs to the brain because the legs are below the attachment point of the harness (Figure 1). The more vertical the hanging position, the more pronounced this effect is. This results in persistent unconsciousness and reduced organ perfusion, which can finally lead to death. In contrast, during a syncope on plane ground, consciousness is restored quickly due to the reestablished cerebral blood flow after the collapse (6).

Two mechanisms are discussed as the cause leading to loss of consciousness in suspension syndrome. Gravity and loss of the muscle pump lead to venous pooling in the legs. This was assumed to prompt a reduced cardiac output due to a reduced preload with a consecutive cerebral hypoperfusion and loss of consciousness (7). Venous pooling has been experimentally demonstrated (10). However, no difference in the extent of pooling was found between subjects with and without pre-syncopal symptoms. In addition, pooling did not lead to any of the expected hemodynamic changes such as tachycardia and reduced stroke volume. Therefore, it must be assumed, that venous pooling is not the main cause leading to loss of consciousness in suspension syndrome (10).

In several experiments, a sudden reduction in heart rate and blood pressure occurred in temporal relationship to the appearance of pre-syncopal symptoms, similar to a neurocardiogenic syncope (4, 11). The Bezold-Jarisch reflex, a loss of muscle sympathetic neural activity due to decreased afferent input from baroreceptors / defective baroreflex function, mechanisms of post-exercise syncope and pain as a contributing factor of the vagal event are discussed (4, 11). Although the precise, neurohumoral mechanism of neurocardiogenic syncope is not fully understood, a syncope generally is characterized by a close relationship of gravitational stress, vasomotor dysfunction and/or bradycardia, reduced venous return and reduced cardiac output (3). And it is often associated with prolonged orthostatic stress (10). Thus, venous pooling can be considered a trigger for neurocardiogenic syncope. Currently, a neurocardiogenic reflex leading to sudden bradycardia and hypotension is considered to be the main mechanism leading to loss of consciousness in suspension syndrome (10).

Preventive Measures

Each person potentially exposed to suspension syndrome should be aware of the risk, prevention and correct treatment. This requires appropriate training.

- A rope-secured work should never be carried out alone (9).
- Activation of the muscle pump leads temporarily to a better venous return flow (10). This can be achieved by "riding an aerial bicycle" or pushing up the legs against rock /crevasse / house walls. When hanging freely, this can be supported by attaching a foot sling, for example with friction hitches or carabiners (Figure 2) (9, 15).

- An improvement in venous return can also be achieved by lifting the hanging legs by a rescuer or by attaching a sling below the knee (8).
- In addition, heavy equipment should be fixed centrally at the rope-in point during hanging to reduce the physical strain.
- A constriction of the femoral veins by a correctly fitted climbing harness is unlikely for anatomical reasons (9, 10). However, compression of groin vessels is imaginable when hanging in harnesses with an attachment point on the back, as it is used for industrial climbing. In addition, venous pooling is probably increased by the very vertical hanging position and reaching the rope-in point for self-rescue is considerably complicated (6).

Treatment

For the rescue and treatment of persons with suspension syndrome, the following principles of action apply:

- Fall protection for rescuers and protection from falling objects is paramount.
- First priority is to free the patient from the hanging position as quickly as possible (9). This may require mountain rescue or height rescue groups.
- The patient should be encouraged to take the preventive measures outlined above.
- The first rescuer who reaches the suspended patient must check patient safety and if necessary, prevent him from slipping out of the harness. Furthermore, any obstruction of the airway due to hyperflexion of the head should be reversed and, if possible, the legs should be lifted to achieve a more horizontal hanging position (2).
- After rescue from the rope, the treatment follows the standard priority-based <C>ABCDE algorithm (Critical bleeding, Airway, Breathing, Circulation, Disability, Environment). Patients can safely be put into a supine position (4, 6, 9, 11, 15).
- Patients with suspension trauma have an increased risk of rhabdomyolysis and thus of hyperkalemia and consecutive cardiac arrhythmia (12). Therefore, ECG monitoring should be performed promptly in order to detect signs of hyperkalemia and cardiac arrhythmias and to treat them according to current guidelines (6, 14, 16).
- The risk of acute kidney injury increases with the degree of muscle cell damage/rhabdomyolysis. For suspension longer than two hours, a medical treatment facility able to provide continuous renal replacement therapy should be chosen (6, 9).
- Pulmonary embolism should be considered as a potentially reversible cause of cardiac arrest after prolonged hanging and treated according to the current resuscitation guidelines (10, 14).
- Hypothermia prophylaxis and treatment have a high priority due to the increased risk of cooling during suspension (6, 9).
- Patients should be transported horizontally. If a vertical suspension of the stretcher is unavoidable for evacuation (e.g. caves), the patient should be able to support himself with his feet to activate the muscle pump (15).

Rescue death (i.e. death in a temporal relationship with rescue from the hanging position) is the subject of controversial debate. Although there are numerous case reports of people who died while hanging in a rope without any obvious medical or traumatological cause, there are very few case reports of victims who died during or shortly after rescue from hanging (9). A rescue death therefore seems to be a realistic but extremely rare event. After the initial description of this clinical picture in 1972 (1), for decades flat positioning directly after rescue from the hanging position was regarded as contraindicated because it was assumed that immediate supine positioning would lead to right ventricular volume overload with acute heart failure (15). However, there was no evidence of cardiac volume overload after long periods of hanging (11). It seems more likely that a possible rescue death is caused by cardiac arrhythmias or pulmonary artery embolism due to thrombi induced by lower limb blood stasis during hanging (9, 11).

Perspectives

The incidence and thus the relevance of the suspension syndrome is still unclear and partly the subject of intense debate. In order to determine the incidence of the suspension syndrome, an exact definition based on the clinical signs and symptoms, agreed upon by experts, is necessary in order to record and evaluate future cases in an international database. It is also currently unclear whether a history of syncope is a risk factor for suspension syndrome. Finally, basic research is still necessary regarding the pathophysiology of neurocardiogenic syncope. Further knowledge could provide additional information on the pathophysiology and thus prevention and treatment of suspension syndrome.

Conflict of Interest
The authors have no conflict of interest.

References

(1) **GERD F ED.** Fatal and non-fatal accidents involving falls into the rope. Werk-Verlag Dr. Edmund Banaschewski: München-Gräfelfing; 1972.

(2) **KOLB JJ, SMITH EL.** Suspension Shock. Redefining the diagnosis & treatment of suspension trauma. JEMS. 2015; 40: 48-51.

(3) **LANFRANCONI F, FERRI A, POLLASTRI L, BARTESAGHI M, NOVARINA M, DE VITO G, BERETTA E, TREMOLIZZO L.** Impact of Hanging Motionless in Harness on Respiratory and Blood Pressure Reflex Modulation in Mountain Climbers. High Alt Med Biol. 2019; 20: 122-132. doi:10.1089/ham.2018.0089

(4) **LANFRANCONI F, POLLASTRI L, CORNA G, BARTESAGHI M, NOVARINA M, FERRI A, MISEROCCHI GA.** The Elusive Path of Brain Tissue Oxygenation and Cerebral Perfusion in Harness Hang Syncope in Mountain Climbers. High Alt Med Biol. 2017; 18: 363-371. doi:10.1089/ham.2017.0028

(5) **LECHNER R, KÜPPER T, TANNHEIMER M.** Challenges of Military Health Service Support in Mountain Warfare. Wilderness Environ Med. 2018; 29: 266-274. doi:10.1016/j.wem.2018.01.006

(6) **LECHNER R, STAPS E, BRUGGER H, RAUCH S.** Notärztliche Strategie beim Hängetrauma. Notarzt. 2018; 34: 156-161. doi:10.1055/a-0632-3733

(7) **LEE C, PORTER KM.** Suspension trauma. Emerg Med J. 2007; 24: 237-238. doi:10.1136/emj.2007.046391

(8) **MADSEN P, SVENDSEN LB, JØRGENSEN LG, MATZEN S, JANSEN E, SECHER NH.** Tolerance to head-up tilt and suspension with elevated legs. Aviat Space Environ Med. 1998; 69: 781-784.

(9) **MORTIMER RB.** Risks and management of prolonged suspension in an Alpine harness. Wilderness Environ Med. 2011; 22: 77-86. doi:10.1016/j.wem.2010.10.008

(10) **RAUCH S, SCHENK K, GATTERER H, ERCKERT M, OBERHUBER L, BLIEMSRIEDER B, DAL CAPPELLO T, BRUGGER H, PAAL P, STRAPAZZON G.** Venous Pooling in Suspension Syndrome Assessed with Ultrasound. Wilderness Environ Med. 2020; 31: 204-208. doi:10.1016/j.wem.2019.08.012

(11) **RAUCH S, SCHENK K, STRAPAZZON G, DAL CAPPELLO T, GATTERER H, PALMA M, ERCKERT M, OBERHUBER L, BLIEMSRIEDER B, BRUGGER H, PAAL P.** Suspension syndrome: a potentially fatal vagally mediated circulatory collapse-an experimental randomized crossover trial. Eur J Appl Physiol. 2019; 119: 1353-1365. doi:10.1007/s00421-019-04126-5

(12) **REINERTSON R.** Suspension trauma and rhabdomyolysis. Wilderness Environ Med. 2011; 22: 286-287, author reply 287-288. doi:10.1016/j.wem.2011.05.005

(13) **SEDDON P.** Harness suspension: Review and evaluation of existing information. HSE Books: Sudbury; 2002.

(14) **SOAR J, NOLAN JP, BÖTTIGER BW, PERKINS GD, LOTT C, CARLI P, PELLIS T, SANDRONI C, SKRIFVARS MB, SMITH GB, SUNDE K, DEAKIN CD; ADULT ADVANCED LIFE SUPPORT SECTION COLLABORATORS.** European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult advanced life support. Resuscitation. 2015; 95: 100-147. doi:10.1016/j.resuscitation.2015.07.016

(15) **THOMASSEN O, SKAIAA SC, BRATTEBO G, HELTNE J-K, DAHLBERG T, SUNDE GA.** Does the horizontal position increase risk of rescue death following suspension trauma? Emerg Med J. 2009; 26: 896-898. doi:10.1136/emj.2008.064931

(16) **TRUHLÁR A, DEAKIN CD, SOAR J, KHALIFA GE, ALFONZO A, BIERENS JJ, BRATTEBØ G, BRUGGER H, DUNNING J, HUNYADI-ANTICEVIC S, KOSTER RW, LOCKEY DJ, LOTT C, PAAL P, PERKINS GD, SANDRONI C, THIES KC, ZIDEMAN DA, NOLAN JP; CARDIAC ARREST IN SPECIAL CIRCUMSTANCES SECTION COLLABORATORS.** European Resuscitation Council Guidelines for Resuscitation 2015: Section 4. Cardiac arrest in special circumstances. Resuscitation. 2015; 95: 148-201. doi:10.1016/j.resuscitation.2015.07.017