Dangerous Suspension: Understanding suspension syndrome & prehospital treatment for those at risk

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JEMS Clinical Review Features

This clinical review feature article is presented in conjunction with the Department of Emergency Medicine Education at the University of Texas Southwestern Medical Center, Dallas.

Learning Objectives

>>Describe the pathophysiology and complications of suspension trauma syndrome (i.e., suspension trauma).

>>List the warning signs and symptoms of pre-syncope in suspension trauma victims.

>>Describe interventions used to minimize blood pooling,,when rescue is delayed for victims of suspension trauma.

>>Discuss prehospital treatment for suspension trauma.

>>List those at risk of death from suspension trauma.

Glossary Terms
Fall Arrest Systems: A series of equipment components designed to stop the fall of individuals elevated in the air. They're an OSHA requirement when workers are exposed to vertical drops of 6 feet or more.

Orthostatic Hypotension: In suspension trauma, this refers to the pooling of blood in leg veins that occurs when individuals caught in harnesses, confined spaces, ropes, etc., are forced to hang vertically with legs relaxed.

Reflow Syndrome: The return of pooled, hypoxic blood and its metabolic byproducts from the extremities to the heart.

Rescue Death: When related to suspension trauma, this type of death occurs in patients who appear physiologically stable during the rescue and extrication but suddenly die after being freed.

Suspension Trauma: Injuries sustained from being immobilized in a vertical position when the legs are relaxed. Injuries include hypoxia; syncope; hypoxemia; acidosis; ventricular fibrillation; myocardial infarction; damage to the liver, kidneys and brain; and possibly death.

Suspension Syndrome: The condition in which a suspended person becomes unconscious due to orthostasis without traumatic injury.

Suspension Trauma Syndrome: Previous terminology for suspension syndrome.

Syncope: A sudden loss of consciousness due to a rapid drop in blood pressure.

Introduction

A 40-year-old man is washing windows on a scaffold outside of an office building about 28 feet above the sidewalk when a support rope fails and one side of the platform drops. His safety harness works as designed and prevents him from falling more than a few feet. The straps around his legs pull tight, and he's a little sore from the sudden jerking halt of his fall, but he's not seriously injured. A pedestrian on the street hears the falling scaffold and the man's fearful yell and immediately calls 9-1-1.

Rescue units arrive at street-level in six minutes to find the worker dangling above the sidewalk. They immediately set out to rescue him through the office windows, thinking it will take only about 10 minutes to bring him in safely.

Those who work at heights on scaffolds and other structures higher than six feet often wear safety harnesses. The technology of safety harnesses has progressed in recent years, and state-of-the-art safety gear for workers is now designed as **fall arrest systems.** Even with the best designs in safety gear, however, those who fall in an upright position are at risk of death, even after a relatively short and effective rescue, especially if the rescuers are unaware of the risks of **suspension trauma.**

Several types of deaths occur after upright suspension in a harness and are categorized as **rescue deaths.**These include **suspension syndrome, suspension trauma syndrome, orthostatic hypotension** and reflow syndrome.In these closely related syndromes, patients may appear stable and uninjured while suspended and before being freed. Sometimes, the patient will feel faint or have already fainted prior to the release but will not have suffered any physical injuries. These patients, including those with no injuries at all and no feeling of faintness, are at risk of death upon rescue if the responders are not aware of appropriate care.

Two ancient forms of death by suspension are hanging and crucifixion. Death by hanging is a form of execution, lynching or suicide that most commonly causes death by fracturing several cervical vertebrae and causing rapid strangulation asphyxiation. Execution by crucifixion was commonly practiced for several thousand years.

Crucifixion was once thought to be a very slow and agonizing death, taking place over several days. However, observations of several recent suspension catastrophes and rescues led researchers to question how long suspension deaths took to occur. Research now shows that patients suspended in a motionless position, such as in motor vehicle collisions, in snow or ice, or during vertical rescues, are at a high risk of rapid death, sometimes within just a few minutes.

Because patients can deteriorate very quickly and the wrong intervention can mean the difference between a rescue and a recovery mission, first responders and EMS providers must know the current recommendations for suspension trauma rescues and the underlying theories and pathophysiology of suspension trauma syndrome.

Incident Prompts Research

Research on suspension trauma was triggered by several events in which a number of survivors later died of suspension trauma syndrome. In the early 1970s, researchers investigated the deaths of eight climbers who had not been seriously injured in a fall but were suspended for hours. Eight of 10 climbers had managed to survive hanging free, some for half an hour and others up to eight hours. They were rescued alive and survived for as short as 30 minutes and up to 11 days later; however, all eight eventually died as a result of having been suspended.

Reports of the deaths upon release from prolonged suspension, both immediate and in the following weeks, led to a series of medically monitored suspension tests. Many of the research subjects experienced critical circulatory collapse within 30 minutes of being suspended in a harness.

Five volunteers in one research study were suspended in various harnesses for up to 30 minutes. Three reported severe discomfort, and one lost consciousness at 28 minutes.

Sixty-five comparative tests of several sit-harness designs and one full-body harness showed that the mean times that suspension was tolerable were as little as 30 seconds and only up to 17 minutes. The test subjects experienced numerous symptoms, including narrowing pulse pressures.

Pathophysiology

When a person is suspended in a harness or held immobile in an upright position, gravity pools blood in the lower extremities. Depending on the underlying health of the patient's cardiovascular system and the ability of the patient to compensate for the pooling blood in the lower extremities, the patient may remain free of symptoms for several hours. Ultimately, however, a loss of consciousness will occur, soon followed by death. It's important to realize that even an individual who is symptom-free is at risk of sudden death due to myocardial rupture and infarct when moved rapidly to a horizontal position after being released from suspension and especially if they were motionless.

Reflow Syndrome: The lethal surge of blood return to the central circulation and the heart is known as reflow syndrome, in which the metabolism in the extremities with

pooled venous blood shifts to anaerobic metabolism as the blood becomes hypoxemic. When the patient is placed supine, the acidotic and hypoxic blood rapidly returns to central circulation and the heart. This can result in immediate ventricular fibrillation, a rupture and infarct of the heart, and lethal damage to the liver, kidneys and brain.

Orthostatic Hypotension: Orthostatic hypotension and syncope are quite common and are natural physiologic responses. Two conflicting theories describe orthostatic syncope. One says it_s a high-level homeostatic response that prevents permanent brain injury by causing us to rapidly move to a horizontal posture when blood flow to the brain is compromised. The other says it's the result of having a primitive cardiovascular system suited for walking on "all fours."

Either way, most adults are familiar with the unpleasant sensation of dizziness and nausea that occur with standing up too quickly. The signs and symptoms associated with orthostatic hypotension include "hot flashes," profuse sweating and syncope. Generally, these symptoms aren't serious, and we simply feel faint and ease back down to a supine or sitting position until our vascular system adjusts. However, if we're forced to remain motionless in an upright position, we risk serious consequences, including death.

Another example of orthostatic hypotension is that of the soldier or high school band musician who faints while standing for an extended period of time, especially in a hot environment and with their knees locked.

The fundamental cause of orthostatic hypotension is venous pooling, which is the accumulation of blood in the veins (typically in the legs) due to gravity. Some venous pooling is normal when a person remains in an upright position. Muscular activity in the legs, together with the one-way valves of the arteries and veins in the legs, normally assist in circulation and return blood to central circulation. However, when the legs are held completely immobile, the muscles of the legs provide insufficient circulation to prevent venous pooling. It's important to realize that the veins in the legs are capable of considerable expansion and a large volume of blood can pool in the lower extremities.

Metabolic byproducts in healthy and mobile individuals are continuously removed by the cardiovascular system. In an individual suspended upright and motionless in a harness, however, venous blood pools in the lower extremities and metabolic toxins, such as ketones and lactic acid, build up to dangerous levels.

Pre-Syncope: The warning symptoms for **syncope** are palpitations, nausea, dizziness, sweating and confusion. When a patient experiences these symptoms just before fainting, the condition is known as "pre-syncope." In effect, by being quite unpleasant, pre-syncope is the body_s way of sending a warning signal that's so intolerable that it cannot be ignored, encouraging the individual to immediately move to a horizontal position to allow sufficient blood flow to the brain.

Motionless head-up suspension will often lead to pre-syncope in most normal subjects within one hour, and one in five will experience pre-syncope within 10 minutes.

Syncope: A common term for syncope is fainting. Syncope is a temporary loss of consciousness and postural muscle tone (balance and ability to stand) due to a decrease in the quantity and quality (oxygenation) of blood circulating to the brain.

Retention of blood in the legs due to venous pooling reduces the amount of circulating blood to the heart, lungs and brain. Cardiac output is reduced because of diminished right-heart return (preload). Subsequently, the arterial pressure falls below normal and leads to hypoxia. It's important to remember that the brain does not cope well with hypoxia or low blood glucose levels.

Further Effects: Loss of consciousness ensures that a suspended person will not be moving their limbs, so venous pooling will increase, which will in turn reduce the circulating blood volume even further. In addition, any restrictions of the femoral arteries and veins caused by harness straps would contribute to venous pooling. Thus, the detrimental effects are compounded.

Speed of Onset

If the legs of someone who's immobilized in a harness are relaxed, the first signs of discomfort and shock can begin in as little as three minutes, with an average onset between five to 20 minutes. Fainting generally soon follows the onset of pre-syncopal symptoms. When fainting occurs, the natural response is to move to a horizontal position with a return of circulation. If fainting occurs in a forced upright position, death can occur within minutes. Another complication that can hasten death is the loss of a patent airway when the head flexes forward.

The speed of onset is completely unpredictable. Some individuals survive longer, up to an hour, without losing consciousness or dying, and one person may react differently from one day to the next. Race, gender and body mass don't seem to predict tolerance, but age is a factor in the onset of suspension trauma. The very old are most at risk due to less responsive arteries and veins and a less robust heart; in contrast, young children seem to be immune, largely because their legs are shorter and have more resilient vasculature. Although it's unclear at what age the risk of dying from suspension trauma begins, it seems that when a person reaches five feet in height, the risk increases.

Rescue Prehospital Care

It's very important to realize that the emergency treatment for suspension trauma is not the standard and intuitive rescue response! If the rescuer follows the normal protocol for syncope, death is the likely outcome. It's critical that the rescuer avoids the natural and intuitive step of immediately moving the patient to a supine position but instead makes sure to keep the patient's upper torso upright at least at a 30-40 angle (i.e., a semi-Fowler's position) and then slowly moves the patient to a supine position over a period of approximately 30-45 minutes by adjusting the stretcher in increments.

Once rescuer and bystander safety has been ensured, the initial rescue response is to gain access to the patient as quickly as possible to begin moving the patient to safety. If access to a conscious patient is hampered due to structural instability or the patient is

inaccessible due to their elevation, rescuers should attempt to communicate with the patient to see if they're able to respond verbally. If so, then the rescuers can encourage the patient to position their legs as high as possible and keep the leg muscles working vigorously.

If the suspended patient is unconscious or has injuries that preclude movement of the legs, then the situation is life-threatening and the rescue must be completed as soon as possible. The patient needs to be released from the harness as quickly as possible, while the rescue maneuver is carried out carefully.

Every individual who has been suspended in a harness and motionless for more than 10 minutes should be evaluated in a medical facility, regardless of whether they have any other injuries or symptoms. It's equally important to realize that suspension syndrome is a risk only to those who are motionless. Therefore, an alarmed reaction to recreational climbers and others suspended from harnesses is an unnecessary overreaction.

In rescuing an unconscious patient, the rescuer is faced with a serious dilemma. On one hand, the lack of oxygenated blood circulating to the brain is potentially lethal, but treating the patient by moving them to a horizontal position is also potentially lethal. A compromise position is recommended. Begin with the upper body (head and trunk) elevated approximately 30, while treatments (oxygenation and fluid hydration) are initiated and only gradually move the patient to a horizontal position. Constantly monitor the level of consciousness and vital signs. Paramedics should follow the appropriate treatment guidelines for co-morbid illnesses and injuries, including the administration of analgesics for pain.

Hospital Treatment
Because the clinical onset of serious consequences may be delayed for several hours, every patient freed from suspension should be transported to an emergency department (ED) for evaluation. Further, every patient who has been suspended upright and motionless in a harness and has even the most minor signs or symptoms, such as numb legs or transitory respiratory or circulatory problems, should be hospitalized.

Case Follow-Up
As the window washer hung in the safety harness, he was fully awake and able to move his arms and legs. The EMS crew knew to immediately make verbal contact with him and gain his cooperation in the rescue. They coached him into looping the safety line under his knees and over the ring above his head. They then had him pull his knees up to be level with his hips as a high-angle rescue response team quickly responded to the rooftop and rappelled down the side of the building. In just under 20 minutes, the rescuers were able to bring him to safety and transport him to the local ED to clear him for return to work the next morning. --**JEMS**

Summary
Suspension syndrome and suspension trauma have been largely overlooked and underappreciated in EMS and rescue training. The appropriate life-saving treatment of

patients who have been suspended in an upright and motionless position is counterintuitive; the intuitive and routine rescue procedures that would involve immediately placing patients supine are highly lethal due to reflow syndrome.

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High-Risk Populations

Anyone who's trapped in an upright motionless position or who becomes syncopal and unable to fall to a horizontal posture is at risk of suspension trauma death. Those who are at greatest risk of suspension trauma are those who work in safety harnesses (as opposed to work harnesses) or fall arrest systems, including:

>>Workers on scaffoldings and ledges (higher than 6 feet above ground)

>>Workers in confined spaces who have been lowered via a harness and winch

>>Spelunkers (cave explorers)

>>Recreational and occupational high-angle climbers

>>Parachutists

>>Paragliders

>>Bungee jumpers

>>Stuntmen

>>Theatrical wire flyers

>>Erotic bondage participants

Keys for Rescue & EMS Treatment
A patient who is experiencing pre-syncopal symptoms or who is unconscious while suspended in a harness should be rescued as soon as safely possible.

- If you cannot immediately release a conscious patient from a suspended position, instruct them to elevate their legs and contract their leg muscles periodically.
- Watch for signs and symptoms of pre-syncope: light-headedness, nausea, sensations of flushing, tingling or numbness of the arms or legs, anxiety, visual disturbance or a feeling they_re about to faint.,,
- After rescue, do NOT allow the patient to lie flat (unless CPR is required).
- Do NOT allow the patient to stand up. Risk of syncope and rapid weakness should be anticipated.
- For a semi-conscious or unconscious person who has already been placed in a horizontal position, follow standard first aid guidelines. Do not raise an unconscious or pre-syncopal patient back to a sitting or standing position.
- Maintain a patent airway and follow standard procedures for ABCs.
- Administer only minimal fluid via IV administration in the absence of blood loss. (After 20Ï40 minutes following the rescue and fluid administration, the rate of infusion can be increased to facilitate dieresis, as renal failure is a common complication.)
- Hypoglycemia should be corrected with an IV bolus of 25 g of 50% dextrose-in-water.
- Monitor the ECG for electrical abnormalities, such as hyperkalemia (peaked T waves, prolonged QT intervals, widened QRS complexes).

- Monitor the blood pressure. (Hypertension may indicate hyperkalemia and the onset of crush syndrome.)
- Consider additional drugs (IV bicarbonate, calcium chloride, albuterol,,or insulin).
- Transport in a sitting position for at least 30 minutes post-release from the vertical motionless position.

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