

SUSPENSION TRAUMA AND RESCUE HARNESS SAFETY

BY DR. WILLIAM WEEMS AND DR. PHILLIP BISHOP

TO EVERYONE'S SURPRISE, THE CITY FIRE CHIEF HAD agreed to send one team to the regional technical rescue team competition, and the specially assembled competitive team wasn't going to blow its chance. At every opportunity, the members trained until they were white-eyed. Today, for the first time, they were practicing an evolution in which they hoisted a team member strapped in a stokes stretcher (without anyone serving as a stretcher tender) 30 feet vertically. They had rappelled quickly down the side of the smoke tower; had strapped the lightest team member, Sarah, extra securely into the stretcher; and were performing a fast-haul to the top. She was barely off the ground when the uphaul block at the top of the tripod jammed. When it became apparent that this wasn't going to be fixed quickly, the team members argued about how such a thing could happen and how they were going to make sure it didn't happen again. The argument and the uphaul block repair took only 15 minutes but seemed even shorter to the team. In another minute, Sarah was at the top.

When the team rolled the stretcher over the edge, they noticed that Sarah had her eyes closed. Thinking she was just playing, they laughed a few seconds and then realized it was no joke. They forgot their training drill and started a real rescue. Between checking her pulse and strapping on a blood pressure cuff, her eyes fluttered open. What happened?

HARNESS TRAUMA

Sarah had suffered harness (suspension) trauma. During the time she was suspended head-up, vertically strapped to the stokes, her blood was pooling in her legs. She was strapped tightly into the stretcher, and her legs were totally relaxed. The muscle pumps that normally aid the return of blood to the right atrium of her heart were, because of the circumstances, not functioning. As the filling pressure to her right atrium declined, her cardiac output fell. Her left ventricle couldn't pump blood if it wasn't coming into the heart. In response,

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her heart rate increased, trying to maintain cerebral blood flow. After a few more minutes, when even more blood was sequestered in her legs, Sarah's body gave its normal palliative response and slowed her heart rate to induce fainting. In most cases, fainting causes the victim to fall to the ground, putting the legs, heart, and brain on the same level and restoring blood flow. But since she was strapped in a stokes, when Sarah fainted, her posture hardly changed. Had the argument gone longer, or had something else gone wrong, Sarah could have died as the result of prolonged cerebral hypoxia, which may have been primary or secondary to a heart attack because of the low myocardial oxygen levels.

Suspension trauma is unknown to most of us. It is a variation of orthostatic intolerance, which is hypotension resulting from quiet standing. When we are sitting or lying, our heart is able to pump enough to keep our brain perfused. If we are standing and moving, our muscles compress our leg veins, causing blood to move. One-way valves in our leg veins keep blood from flowing backward, so the muscle pump assists in returning blood to the right atrium. Even when we are standing quietly, we are constantly swaying and contracting our muscles; before too long, we move, fully activating the muscle pump. However, if our legs are fully relaxed, blood will start to accumulate in our leg veins, which have a very large capacity. If we are quiet long enough and we are upright so that blood must be pumped from our feet vertically to the right atrium of our heart, the venous return may fall so low that our cardiac output to our brain is compromised, resulting in syncope and, after a few minutes, brain damage.

This doesn't happen when we sit quietly because our upper legs are nearly horizontal and the total vertical pumping distance is fairly short. It doesn't happen when babies sit in a seat swing because the distance is again quite short. It doesn't happen to a parachutist because the suspension time is usually very short. And it doesn't happen if we contract our leg muscles because the muscle pump is effective.

MAKING THINGS WORSE

On the other hand, it happens more quickly if our circulatory system is compromised in any way. Sarah's situation would have been even more likely to result in tragedy if she had been dehydrated, had suffered substantial blood loss, was in shock, or had been overheated. Since many rescued victims experience these conditions, they are at a substantial risk for suspension trauma.

Patients in stretchers aren't the only ones subject to suspension

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trauma. Rescuers using harnesses to access or evacuate victims also must be alert to the possibility of suspension-induced circulatory incompetence. In a harness, as in a stretcher, difficulties can occur while the body is in an upright position, when the legs are relaxed and dangling straight beneath the person, and when the suspension is prolonged. The harness can add to physical problems because the compression of the large leg veins by the harness straps can further restrict blood return to the right atrium of the heart. Most work harnesses have a seat that elevates the upper leg sufficiently to prevent suspension trauma. As we mentioned earlier, this upper-leg elevation is what keeps us from having problems when we sit quietly in a chair. Also, workers in work-positioning harnesses are generally

active and don't tolerate a poorly fitting harness; they won't work in a harness that compromises leg blood flow. But regardless of the harness type, if the victim can slide into a full vertical posture with his legs relaxed, the danger of suspension trauma exists.

REDUCING THE RISK

How do we minimize the risk? Awareness of the potential for problems is always the first step in prevention. Using sit-harnesses that raise the upper legs also greatly reduces risk. Anyone placed in a vertical posture with his legs relaxed must be constantly monitored and the time in this position must be minimized. Any time a conscious person is in a posture that could lead to suspension trauma, he should be instructed to

keep his legs active and as high as possible.

If there is anything to push against with his feet, he should do so. Unconscious persons hanging in a harness are in grave danger of suspension trauma and must be repositioned or rescued quickly.

Susceptibility to suspension trauma, like many physiological characteristics, is highly variable. What would not be a problem for one person may be a critical risk for another. As mentioned earlier, anything that compromises circulatory function will compromise tolerance to suspension.

TREATMENT

Emergency medical care for suspension victims seems to demand particular and somewhat counterintuitive techniques. Apparently, if a suspension trauma victim is quickly moved to a horizontal posture, the sudden return of sequestered blood along with its hypoxic-induced composition, can kill the victim (see Seddon, Paul. "Harness Suspension: review and evaluation of existing information." *Health and Safety Executive*. Research Report 451/2002, http://www.hse.gov.uk/research/crr_hnm/2002/crr02451.htm). MAST trousers would thus probably be counterproductive, in that the issue is to return blood *slowly* from the lower body.

The recommended procedure is to gradually recline the victim by placing that person in a kneeling, then sitting position before he is fully supine. If there is suspension trauma without additional injuries, it has been recommended that the process of going from recovery to kneeling to sitting to supine take between 30 and 40 minutes. This becomes tricky if other injuries are involved. Responders will have to weight the risks.

DOES SUSPENSION TRAUMA REALLY EXIST?

Some rescuers are skeptical that suspension trauma exists. Few cases are reported because it is often unrecognized. Because

Figure 1. Progression of Suspension Trauma

- 1 Fall arrested by harness
- 2 Legs suspended, blood flow is impeded by leg straps and by gravity
- 3 Blood collects in large leg muscles
- 4 Blood return to heart declines
- 5 Danger plus pain causes heart rate increase and hormone release
- 6 Heart pumping action reduced because of decreased blood return
- 7 More blood collects in legs
- 8 Body reflex reduces heart rate and blood pressure
- 9 Blood flow to brain falls
- 10 Victim loses consciousness
- 11 Blood flow to brain continues to fall
- 12 Brain damage
- 13 Eventual death



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the physiological mechanism isn't appreciated, other causes are assigned to the loss of consciousness while in vertical suspension. However, the physiology is seen in several research procedures.

Tilt tables are used in some medical research. One of the authors of this article experienced loss of consciousness as part of an experiment in which he lay quietly on a tilt table.

Likewise, in our Human Performance Laboratory, we have conducted a procedure known as lower body negative pressure. Participants lie quietly on their back with their legs relaxed. Vacuum is applied to the lower body, and blood is sequestered. Heart rate rises to maintain blood pressure. At some point, which varies among people, the heart rate and blood pressure suddenly fall. At this point we quickly release the vacuum, restoring blood flow, and the participant quickly recovers.

The most mundane example of orthostatic incompetence, which is the major causative factor in suspension trauma, involves soldiers standing at attention during a warm weather parade. Inexperienced soldiers will lock their

knees, supporting all their body weight with their leg bones. The muscles can relax, blood pools, and the soldier faints. Skilled soldiers will bend their knees slightly, requiring muscle action that aids in returning blood to the heart, which prevents the hypotensive syncope.

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Harness trauma is a threat to rescuers and victims. An even more likely suspension trauma risk than the scenario above involves the rescue of a victim with a leg injury from a narrow shaft, such as a manhole or well. Awareness of the potential for added complications from harness trauma goes a long way toward prevention and recognition of dangerous situations.

Make sure your rescue teams are aware of the potential dangers whenever anyone is in a situation in which their legs are relaxed and their body positioned straight and vertically with the head up. Make sure emergency medical responders realize that suspension trauma victims will require unusual post-rescue positioning and must be gradually lowered to the usual supine treatment positions. Keep your teams and your communities a little safer. ■



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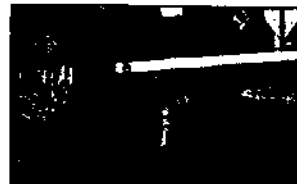
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