What is suspension trauma?

Suspension trauma is a perfectly natural reaction caused by the body being held in an upright position. It will happen to everyone, and you do not need to be ill or injured - simply standing still and unable to fall over.

Our blood supply and heart cannot cope very well with standing up - gravity pulls blood into the tissues of our legs, and the heart cannot suck it back. Eventually, if enough blood pools in the legs, we will faint. This is fine, so long as we fall over - the blood all rushes back - but if we can't fall over, then we die.

Of course we can stand and walk about in normal life and not risk death, and this is because our leg muscles can pump the blood back upwards, provided you are able to move your legs. When we walk about, this works very well. Standing still it's less effective, and sometimes we faint. If we can't use our legs at all, such as if we're strapped into something or hanging in a harness, then we will faint. The problem comes after that - if you faint, you really need to fall over right away. Stay in the same position, and your brain has no oxygen supply.

Who does it affect?

Anyone who could faint and not fall over. People working in industrial harnesses (using abseiling or fall arrest systems or people in confined space shafts), people using harnesses for sport (caving, climbing, parachuting, parascending, bungee jumping) and people using harnesses for special tasks (stuntmen, theatrical flying, etc) are all exposing themselves to high risk, some more than others. Anyone who is secured to a vertical surface for any reason (a rescue litter or spine board, plank of wood, door, bondage equipment, etc) may also be at risk. The most famous, or infamous, example of deliberate suspension trauma is of course nailing someone to a cross.

In any of these situations if you are not using your legs for support, or are unable to move them, then you will eventually faint. If you live or die depends simply on how quickly you fall over - preventing that from happening will of course kill you.
What exactly happens?

First, let's look at blood, and where you can put it. Your body contains about ten pints of blood, most within your veins and arteries. Think of these like stockings - they will stretch a lot if you keep pushing more into them, so to fill them to the top you need to squeeze the outsides. Tiny muscles do that to our veins, a process called 'tone'. If these muscles relax a little, then all your blood pours down under gravity, and at the extreme it will all fit below your waist. Naturally this isn't a daily event, but keeping the blood from pooling in your legs is actually a difficult problem. Gravity is strong, and blood is dense, so to suck it back up the four or five feet from your legs to your head would be

very hard work - you certainly couldn't do it yourself with a length of tube! Your heart is the pump, and it can't suck that hard. In fact it can't suck at all - it needs blood to be pumped IN under pressure or it just beats on empty.

Now to get that blood back up from our feet, we could increase the pressure - forcing it round like a blockage in a U-bend - but that would need such high pressure our hips would burst. No, instead of turning up the power, we have evolved a much better solution - hearts in our legs. Yes, you read that right. The veins in our legs already have one-way valves in them, so all we need is to squeeze them and we've got ourselves a pump! Since we started walking upright, these leg veins have moved so they are buried in between the muscles, so as we move our legs and walk about, the veins are squashed and released over and over - pumping the blood back up into your abdomen. It's an amazingly good system - when you're running, there's hardly any blood pressure in your feet at all!

Of course you can see the error with this perfect plan - if you don't use those muscles the pumping effect stops and your brain, right at the top of the pile, runs dangerously low on blood very quickly! This can happen if you're standing very still, or hanging in mid-air, or strapped to something. If you're standing still then the brain can fix the problem...

Firstly, when blood to the brain reduces, your brain decides to put you in shock. You must be bleeding somewhere, right? So, it increases your pulse and breathing rates, you feel a little sick, shivery, cold, sweaty and anxious. This doesn't really help much, as what you SHOULD be feeling is a craving for exercise - but never mind, evolution is never perfect. That higher pulse rate shunts blood up to the brain and away from the skin, which helps for a few minutes - but of course it's still pumping blood down into those legs as well. Eventually, your brain realizes its mistake and goes for plan B - the Central Ischaemic Response. You faint.

Why? Because of course if you faint, you must fall over. Your brain has learnt that from millions of years of... falling over. When you hit the floor, the blood trapped in your legs returns, and all is well. You wake up, feel sick, and if you're a soldier on the parade ground you prepare for the punishment of your life. The problem is when you don't fall over. Your brain has no comprehension of that idea - so if you are physcially held upright after you've fainted - by a harness, litter or cross - your brain is in deep trouble. It's turned off its own blood supply to get you to faint, and it still needs the blood in your legs. So, it waits. You're unconscious of course, so you aren't aware of all this.. but you wait. You do not 'wake up and try something else' - you wait. You die waiting.

How long have you got?

If your legs are perfectly still, then you can start feeling the first signs of shock in as little as three minutes. The average is between five and twenty minutes. You will faint a few minutes after that, and if you are not allowed to lie down straight away then your brain can start to die a few minutes later.

So, worst case scenario you can be dead in ten minutes. Actually, less than that - because once you faint, you lose control of your airway and if your body is upright you can choke on your tongue and suffocate in a matter of seconds.

Not everyone will be pushing death inside of a quarter hour though - the time it takes is random. Some people will last ten, some sixty. Age, height, weight, fitness, sex, race - none make any difference. The same person will react differently from one day to the next. In short, it's unpredictable. Very old people suffer first, as their muscles are less able to control the blood flow, and very young children are immune as their bodies are just too short! Nobody's sure at what age you become 'at risk', but certainly anyone over about 5 feet tall is capable of feeling the effects.

Luckily, we're telling you all this because there are lots of simple ways to prevent it from happening.

Reflow sydrome in suspension trauma

Anyone who has developed suspension trauma is also at risk from reflow syndrome - caused when the pooled blood in their legs is allowed to flow back into their body. It is potentially fatal.

The exact details of what happens and why are dealt with in our medical treatment section, but the idea is simple enough to summarise. The blood that is pooled in the legs starts off perfectly normal, with oxygen and nutrients dissolved in it. Over time, the cells in the legs use up the oxygen and nutrients - even though they may not be moving much, they still need to stay alive. When all the oxygen is used up, the cells start to burn fats. This process, called anaerobic metabolism, is usually only seen in extreme exercise, and relies on a fast blood flow to keep the process safe. As the blood in the legs is not moving, toxic byproducts of fat burning start to build up in the blood. After quite a short time they can reach dangerous levels.

If the blood is allowed to rush back into the rest of the body then these toxins, and the lack of any oxygen, can cause very serious problems. The heart can stop, the liver, kidneys and brain can be damaged, and in many cases they will die. This will happen if the patient is allowed to lie flat on the floor. It's therefore very important that they stay in a safe position until they reach hospital, or until the blood has had time to gradually clear the toxins. A 'safe position' is the same as for the rest of suspension trauma - sitting upright with their legs bent at the waist. During a rescue, transport to hospital or even when they arrive, they have to be kept in this position and NEVER allowed to lie down. Our guideline is that they should stay sitting for 30 minutes after being released from suspension. It does not matter if they have fainted or not.

Preventing suspension trauma

Without being too obvious, the best way to prevent suspension trauma is never to get into a position where it can start! Working with harnesses is perfectly OK, provided you PLAN to prevent suspension trauma. The same goes for medics and rescuers using litters, and for those who enjoy tying each other up.

Assuming you've read the Introduction you'll know how and why the condition develops, and that it's all started by blood pooling in your legs. If you are going to be in an upright position for more than five or ten minutes, then you will be at risk. A rock climber is safe because he or she is using their legs all the time - but if they fall off, stop for lunch, or just get bored and 'dangle', then it's a different matter.

Preventing suspension trauma can take one of two approaches - either we stop the blood pooling in the first place, or we make sure it's pumped back out. Which you choose depends on what you're doing, and it is very important indeed that you pick the right method. Some sources of advice, even some government publications, get this bit very wrong and you could end up very dead if you follow their plans.

Plan 1 : Sitting up, chilling out

You're probably sitting in a chair reading this. You haven't moved your legs in a while, but you're not dead. It's all down to the fact your thighs are almost horizontal - they are where most of the blood pools, and so if they are kept elevated then suspension trauma is almost impossible. Think of how many times you've heard of someone fainting to death in an armchair.

For anyone suspended in a harness and who doesn't need to move about all the time, or who can't (for example someone who has fallen and is injured, tired or just lazy) then the best, most effective and easiest way to keep them safe is to lift them into a sitting position. Looping something under their knees, or sitting them on a swing-seat, is all you need to do - the person can often do that themselves if they've got something to hand. It's very important to do this as soon as possible - within a few minutes of suspension - so the blood has no time to begin pooling.

If you know you're going to be suspended for a while, like an abseiler cleaning windows on a skyscraper, then you can take a seat with you. If you're tying someone up, think carefully about the position of their legs. If you're about to winch someone down a lift shaft in a rescue litter, then don't!.

The trick is to lift the knees, and to use your legs as little as possible - the more you use them the more blood is sent down to the muscles. Sit down, relax, chill a little.

Plan 2: Invisible Bicycles

Just as with the rock climber, or you when walking to the kitchen, using your

legs keeps the blood flowing. Even hanging in a harness, if you are using your legs to climb about, you will be safe. The problem comes when you're in mid-air, or you're injured or tired, and that movement is a bit less forceful. Now, the pumping effect is reduced but your leg muscles are exercising, so they need blood! The arteries feeding your legs open wide, blood pours into your legs, and eventually... well you can see the result. The 'keep your legs active' plan works great if you have surfaces to kick against, like our rock climber. It's useless for anyone who physically cannot move (strapped into something, or injured), and once you start madly pedalling that invisible bicycle in mid-air, you know that you cannot stop. If you do, the blood rushing into your legs stays there, and the world goes dark around the edges.
In summary...

So, what have we learnt so far?

* Unless you're planning on moving about for some other reason, lifting your legs into a sitting position is the best plan, and the easiest.
* Try to avoid being 'upright and immobile' for more than a few minutes at a time, and if you feel ill, get out of the position straight away!
* Never leave anyone alone who may be at risk of suspension trauma

Of course if it does happen, you'll want to know how to treat the victim safely!

Suspension trauma treatment

Treating someone with suspension trauma is not standard First Aid. If you follow the normal advice for 'fainting' then you can easily kill your patient. If you haven't read our section on Reflow Syndrome then please do so now.

First Response

Anyone who has developed suspension trauma to any extent will have reduced blood flow to their brain. This initially causes symptoms of shock, and if untreated will lead to loss of consciousness. This in itself could kill by preventing the patient controlling their own airway, but eventually the reduced cerebral blood supply will lead to brain damage and death. The goal of the first responder is to return oxygen to the brain while preventing Reflow Syndrome. Never allow the patient to lie down, even for an instant Normally, suspension trauma makes the legs feel numb. If the patient has no other injuries and yet complains of severe pain in their legs, especially when you try to move them, then they may have developed a severe condition called compartment syndrome. You should place them in a sitting position and summon an ambulance with great urgency. The patient may deteriorate rapidly. There is nothing you can do for compartment syndrome as a first responder.

If the patient is conscious

Your first action should be to place the patient in a sitting position with their body upright and their legs flat. This will reduce the pooling effect of gravity, but will keep most of the pooled blood in the legs, preventing reflow. The patient must not be allowed to stand up, exercise, drink or eat. If possible keep them as calm and relaxed as you can, to reduce the effects of stress on the heart rate.

Obviously they need to be removed from suspension, and kept in the same sitting position at all times. They may feel faint, and so you will have to stay with them and prevent them collapsing onto the floor. If you have oxygen available, administer it at 100%. Do not give the patient any other medication or fluids. Summon medical help as soon as possible - a fully conscious and aware patient may be taken to hospital in a private vehicle, but remember that everyone suspended for more than a few minutes should be sent to hospital for routine blood tests, even if they are not injured.

If you cannot reposition the patient or remove them from suspension, then you must expect them to faint at some point. Providing oxygen will help a great deal, but your priority is maintaining their airway and arranging urgent rescue.

If the patient is unconscious

Loss of consciousness due to suspension trauma itself indicates that the pooled blood has had time to develop, and that laying the patient flat will probably be counterproductive - even leading to death. You will have to manage the airway while keeping the patient in a sitting position. Suspension trauma rarely leads to cardiorespiratory arrest in the short term, but if the patient requires CPR then this overrules the posture policy, and you must of course lay them flat. A patient who has been rendered unconscious by another event (such as impact in a fall or electrocution) and who is reached within the first 10 to 20 minutes of suspension may be allowed to lay flat. If you are trained in the use of artificial airways (such as the NPA) then these may assist in supporting the airway even in a sitting position
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EMT / Paramedical PHLS treatment

Note that suspension trauma (orthostatic incompetence) is not part of your standard training program. You should approach the incident as similar to a crush injury in terms of immediate management though there are critical differences in both pre-release and post-release therapy. If the condition is advanced or the patient has lost consciousness, urgent transport to a trauma center is required.

The patient will be cerebrally hypoxic due to gravitational pooling of venous blood in the legs, the majority being in the thighs. The initial presentation after 5 to 10 minutes of suspension will be of distributative shock leading to tachycardia and tachypnea. Local PP02 from fingertip sensors will be normal, but saturations from earlobe sensors will be reduced. There need be no other

injuries. The patient may complain of general symptoms of shock, heat or absence of sensation in the legs. Patients reporting severe pain in the legs with the absence of othopedic insult are of great concern as it suggests formation of compartment syndrome.

As soon as possible after suspension has begun, the patient should have been repositioned into a sitting posture with the thighs horizontal or elevated with respect to the pelvis, and the spinal column vertical. If this was done within a few minutes, then it is unlikely that a sufficient volume of blood has pooled to cause loss of consciousness, however it will still present a hazard if permitted to reflow. A patient who has not been repositioned in time is likely to have progressed beyond distributative shock and lost consciousness via the central ischaemic response. Barometric trigger pathways will produce enforced syncope via bradycardia, leading to decreased cerebral perfusion and instant LOC. If the patient falls into a prone position at LOC then blood returns to the brain and they recover without artifact, however in suspension the patient is usually unable to fall over, and remains held upright. In this position the LOC persists, as does bradycardia and almost negligable cerebral perfusion. This is in itself fatal within a matter of minutes, but of course the patient is also unable to maintain a patent airway and often will suffocate.

Stabilisation is possible on scene, but great care should be taken to monitor PP02 and HR during release and transport, as the patient will be electrocardially fragile.

* Do NOT allow the patient to lie flat or stand up
* Provide oxygen at 100% for all patients
* Manually stabilise the airway via all possible means, but do not lie the patient flat
* Minimise fluids to those required for unrelated trauma. The patient is not hypovolemic and adding IV will lead to hypervolemia when the patient is repositioned. You may start a keep-open line for future access but operate on minimal flow
* The patient may also be hypothermic if suspended outdoors, and external rewarming may be necessary. Do NOT give warmed IV fluids at this stage.
* Monitor ECG carefully - peaked T waves, prolonged QRS or HTN indicates hyperkalemia and the onset of crush syndrome. If detected, direct and agressive action is needed. This is beyond current PHTLS training but via direction will require IV bicarbonate, calcium chloride, albuterol or insulin via large-bore IVs running normal saline. This contradicts the earlier fluid restriction policy but is only to be initiated if ECG artifacts are identified.
* Transport the patient, in the sitting position, to the nearest hospital

Hospital ER treatment

If the patient has been in suspension for a prolonged period (variable, but between 5 and 40 minutes is normal) then venous pooling in the legs will have lead to cerebral hypoperfusion and hypoxia. This may have been treated on scene with O2 or by repositioning into a sitting posture. DO NOT

ALLOW THE PATIENT TO LAY FLAT for at least 30 minutes. Pooled blood has been static for some time, and will be entirely hypoxic. Anaerobic metabolism within the legs will result in toxic levels of metabolytes in the pooled volume, and on release into flow the pooled blood can result in cardiac arrest, dramatic ETCO2 and PP02 fluctuations and transient hypercarbia. Cytochrome-C release and transient renal hypoxia will result in renal artery spasm, tubular necrosis and potential acute renal failure within 60 to 80 hours of the incident. Increased serum certainine with reduced output, uremia and acidosis are diagnostic. Dialysis would be required to prevent mortality.

In most cases of suspension in a purpose-designed harness, confined space or litter then the patient will not have experienced insult sufficient to cause crush syndrome, however extended suspensions (in excess of 2 hours) or those with thin ropes or straps may initiate the syndrome. It manifests as release of potassium and myoglobin, and can contribute to renal insult. Serum K should be monitored, as hyperkalemia is diagnostic in these cases. Treatment of crush syndrome is based on volumetric support, renal protection and serum K management. Once local reflow has been corrected then IV support may be required to manage hypovolemia, bicarbonate and mannitol are indicated to control acidosis and hyperkalemia. Monitor ECG and regular urine myoglobin, CPK and full chem panel.

In severe cases of vertical immobile suspension where pooled blood has become cytotoxic, a split-form full blood transfusion is possible and effective, with surgical interruption of the femoral arteries and veins placing the lower limbs on bypass, enabling a localised transfusion and management regime for reflow and crush syndrome to be applied while the remainder of the body is managed in isolation. If successful this can remove the need for amputation, though the procedure is complex.

Patients are considered equally susceptible to suspension trauma in terms of gender, age, fitness, body mass or race. Those taking tricyclic antidepressants will have increased susceptibility as they contribute to orthostatic hypotension. There is no difference in treatment or medication required for patients on TcaDs.

Training for those at risk

Clearly everyone at risk of suspension trauma should be aware of what it is, how to prevent it and what to do in an emergency. Typical user groups include:-

* Industrial climbers, abseilers, rope access and fall arrest harness users
* Climbers, cavers, parachutists and parascenders
* Stunt professionals
* Theatrical and circus flying system operators and performers
* Professional and amateur performance artists and practitioners working with human suspension and bondage

* Mountain and cave rescue teams
* Military and special forces operatives using abseil or helicopter access systems

In addition, those who may be called in to handle a suspension incident need training in what medical and rescue procedures to use, and importantly what NOT to do. They should be aware of the information on our treatment pages and how to apply it safely. Normal First Aid, EMT and even paramedic training does not include suspension trauma, and what they know about 'fainting' can be dangerous as they will want to lie the patient flat. It is often up to the worker or his colleagues to advise medical staff as to what to do.

At-risk users should plan their work with suspension trauma in mind. Trying to avoid it in the first place is all-important, and so people planning jobs need to be mindful of the risks of accidents, how and when a worker could be placed in suspension, and how long it will take for them to be rescued. The critical things for workers to remember are:-

1. Hanging immobile in suspension is a life-threatening emergency
2. You must never work in suspension unless you are sitting on a workseat or actively using your legs
3. If someone falls into suspension and cannot be rescued, lifting their knees into a sitting position is very important and may save their life
4. When rescuing someone, avoid them laying flat on the ground. Keep them sitting up for 30 minutes
5. Explain all this to the emergency services, paramedics or hospital doctors - most will not know it

If you are working in the EU, then your national version of the EU Temporary Work at Height Directive makes it law that you plan for, and educate your workers in, the risks of suspension trauma. You also have to have effective and fully trained rescue plans and equipment in place for all work.

Useful links

Click here for literature references

Offical agencies and standards

* OSHA (USA)
* OSHA SHIB on Suspension Trauma
* ANSI (USA)
* ISO
* HSE (UK)
* The EurLex gateway (EU Standards)

Technical rescue resources

* Rescue training & resource guide

About the SuspensionTrauma.info Website

SuspensionTrauma.info is a non-profit organisation based in the USA and operated by a group of medical and rescue professionals from the USA, UK and elsewhere. Its aim is to provide the best advice and education about suspension trauma and associated conditions, without bias towards particular devices, training providers, protocols or national boundaries. Donations or sponsorship are not permitted to affect the content of this website in any way, and we will never display adverts. Links from our website are only granted to organisations who have no commercial bias.

The information on this website is based on agreed medical protocols and established research, by our staff and others. There has been relatively little recent research into 'suspension trauma' as a condition in itself, with the majority of work being conducted for aerospace medicine where the effects of posture and vertical G forces can cause similar effects. There have also been a number of studies into human suspension in harnesses as part of parachute system design, however the most relevent research is based on suspension in sports climbing harnesses conducted by various university groups and climbing societies - while a lot of this is unpublished in the refereed literature it remains valuable as many of the earlier studies now cannot be repeated with human volunteers for ethical and insurance reasons. Finally there are several published reviews of historical climbing and caving accidents that have shown the condition in action, with the most notable being the series of papers presented in the mid-1970s at the International Conference of Mountain Rescue Doctors.

Everything on the site is reviewed before release and is guaranteed to be an accurate reflection of the current consensus of opinion on suspension trauma and it's management. We take our work extremely seriously and try to provide the very best information for our visitors. If you have any queries or comments on our site, please let us know using the contact link above.

The SuspensionTrauma.info staff have varied backgrounds, but all are involved in either trauma medicine, anaesthesiology, military medicine, technical rescue or confined space rescue. They give their time freely to assist with this website and the enquiries we receive, and we are always interested to hear from medical staff who may wish to contribute to the group or comment on our published material.

We are not currently intending to provide on-site services such as lectures or training. All of our material may be used freely for education of medical students, ATLS/PHTLS/TacMed staff or those at risk of the condition, and many training providers are starting to offer courses based on our protocols. Current advice issued by the statutory workplace safety agencies for Europe and the USA is compatible with our guidance. We cannot guarantee

immediate response to enquiries and so are not able to offer patient-level diagnostic facilities.