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Backcountry Lightning Risk Management

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This paper is for people who work or recreate in remote backcountry settings where there are no buildings or vehicles in which to seek protection from lightning. Using these practices where buildings and vehicles are available is a gross violation of conventional lightning protocols. Risk management does not ensure safety, but by understanding the hazards and risks, then responding with appropriate actions, we can reduce the chance for harm. It cannot be emphasized enough, that **being outdoors exposes people to random lightning hazard, no matter what actions are taken**. No place outside is safe when thunderstorms are in the area.

Contents

How Lightning Strikes (typically)

Lightning strikes fast: the whole process usually takes less than 1/10th of a second. Stepped leaders leave a cumulonimbus cloud and some leaders move toward the ground. They have many branches, but only 1-2 branches will reach the ground. Approximately every 50 meters (yards and meters can be used interchangeably) a new step leaves the previous step and heads in a fairly random direction. If a leader gets within about 100m from the ground, several positively-charged upward leaders (or streamers) start rising from the closest grounded objects towards the negatively-charged leader. This *strike distance* can vary tenfold (Uman, 1987). As soon as the downward leader is close enough to an upward leader, they attach to each other and "blaze a trail" for a significant electric current (a return stroke) to shoot from the ground to the cloud. . The return stroke heats the lightning channel to an extremely high temperature in a very short time, forming the visible lightning flash and causing thunder as the lightning channel expands rapidly. This step leader search distance concept is important to understand to avoid upward leaders and direct strikes.

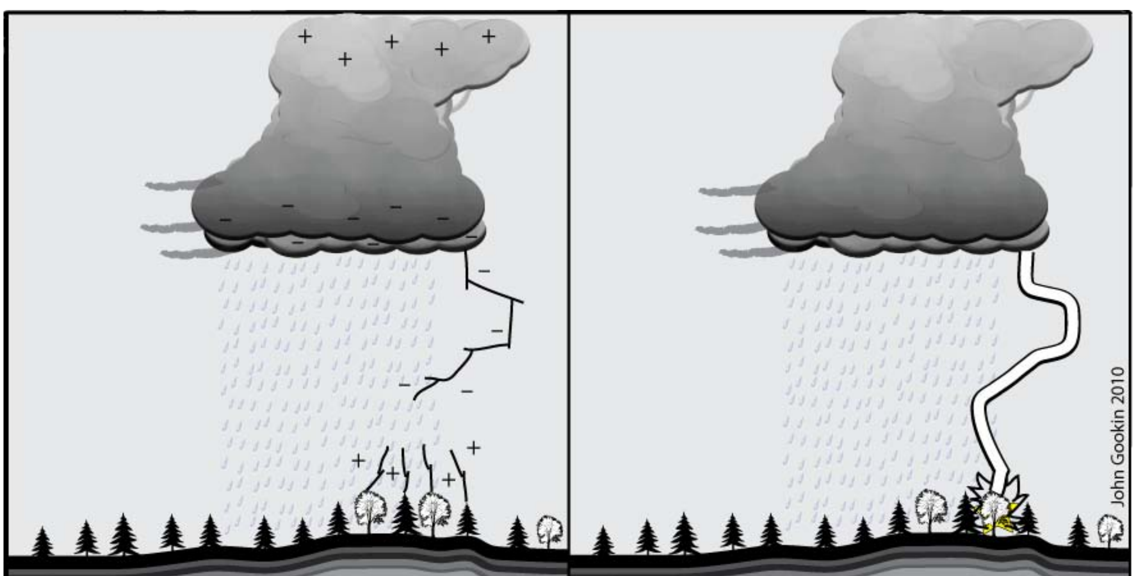

Fig. 1: A stepped leader moves down in 50m steps. Multiple streamers rise from tall objects near the leader. There are many more streamers than direct strikes.

Right: a single return stroke is the most obvious part we see. The downward leader connected with the upward streamer that was closest to it during the final step.

Most ground strikes occur below the cumulonimbus cloud, but many still strike beyond the shaft of rain or beyond the edge of the cloud. This is important for lighting safety since it doesn't need to be raining or even cloudy overhead for you to be in danger from lightning. Occasionally, a stroke of lightning can move horizontally and strike somewhere "out of the blue" (out of the blue sky) as far as 10 miles (16km) away or further. These horizontal strikes are uncommon and unpredictable, so they shouldn't affect our decisions with one exception: we should avoid the highest risk areas if anywhere near a thunderstorm.

Using the 50m search distance of stepped leaders (see above) lightning tends to hit the closest object within that range at the end of the last step. Lightning tends to hit elevated sharp terrain features like mountain tops. Lightning tends to hit tall trees in open areas, with objects twice as high receiving roughly 4X the strikes (Byerley, et al, 1999). Lightning tends to hit bushes in the desert if the bush is sticking up higher than the flat ground around it. Lightning hits people that are higher up than their immediate surroundings. Lightning tends to hit a boat on the water, especially if it has a tall mast. Lightning can still hit flat ground or water, but more randomly than it hits elevated objects.

On the macro scale, lightning strikes more often at higher elevations in a dry (continental) climate like in the Rocky Mountains. Lightning density maps show more lightning at lower elevations than on the ridges in the Appalachian Mountains, which are more humid (a more maritime climate). Lightning density maps can show local patterns, which give you more specific information. On the local scale, you still need to avoid higher terrain in either climate: that is, avoid high knobs at any altitude. The 50m leader search distance concept should help you understand why this is important.

Lightning often hits long electrical conductors and gets channeled along them. Metal fences, power lines, phone lines, handrails, measuring tapes, bridges and other long metallic objects can conduct currents. Long conductors that are insulated from the ground theoretically can carry more current further from the strike point (see fig.5).

High voltage tends to travel across the surface of many conductors. A ground strike typically hits a primary object and then disperses until it dissipates. How it disperses depends on many factors but the voltage stays higher along better conductors. These conductors may even include wet terrain. In the absence of long conductors and surface arcs (below), data from lightning striking crowds suggests that a lightning strike is hazardous out to roughly 10 meters from the strike point, with 1-2 fatalities and dozens of injuries. Some people occasionally get injured 50-100' from a strike. This is roughly equivalent to the kill radius and injury radius of a hand grenade.

Lightning Injury Mechanisms: How Can Lightning Hurt Us?

Lightning throws an ensemble of deadly and injurious threats our way. All of these effects happen in the same few milliseconds, but none of the threats linger after each strike. These mechanisms are arranged below by order of how often they contribute to fatalities. Presenting them in order supports teaching their relative importance.

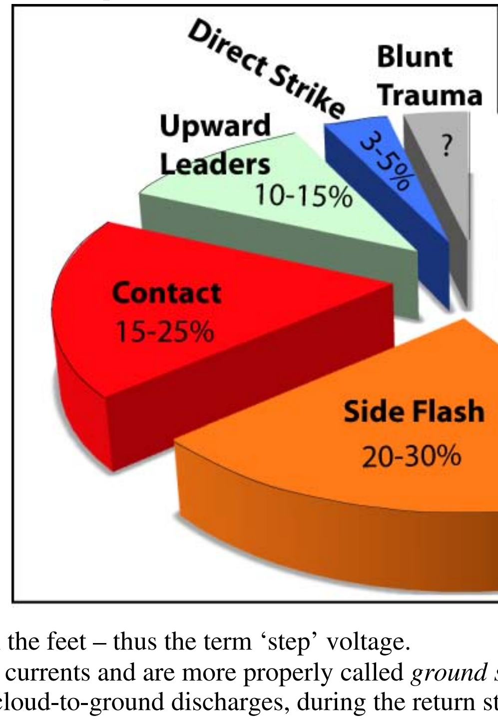

Fig. 2: This chart shows the frequencies of the primary lightning fatality mechanisms (Cooper & Holle, 2008).

Ground Current/ Step Voltage: ground current occurs with each strike and causes roughly half of all lightning injuries. Ground currents are driven by the enormous potential differences that appear in the earth near the ground strike point (fig.3). Ground current is also referred to as *earth potential rise* (EPR). EPR is a more technically precise term but ground current may be easier for non-experts to comprehend. High voltage isn't the main problem: what matters is if one part of your body contacts one voltage and another part of your body contacts a different voltage: the difference in voltage is what drives current through your body. Voltage is the potential for current to move through you, which is why it is also just called potential. The potential difference can drive an electric current up one leg and down the other of a person or animal, with the amount of current depending on the potential difference, the distance between the feet, and the orientation of the difference between the feet – thus the term 'step' voltage.

Surface arcs are associated with ground currents and are more properly called *ground surface arcs*. High current surface arcs appear to be associated with some fraction of all cloud-to-ground discharges, during the return stroke. They appear in photographs as bright arcs of light radiating from a strike point like spokes of a wheel, in the air just above the ground's surface (see fig. 4C.) These long, hot horizontal currents have been measured up to 20 meters in length and can be longer. If you are in the path of a surface arc you are likely to conduct some of the surface arc current through or over your body.

Typical lightning-to-ground strikes inject roughly 20,000 amps into the Earth: since the Earth resists electrical flow, large potential differences will appear in the ground all around the strike point. How far the current flows varies widely since strike current and ground conductance easily vary by orders of magnitude. But the closer you are to the direct strike, the stronger the ground current. If you are standing with your legs separated, if you are on all fours, if you are in a prone position on the ground, or if you are touching a long metallic object, you maximize your exposure to potential differences that arise from ground currents. The term used for the voltage difference one step (1m) apart is *step voltage*. The potential difference that appears between your legs or across your prone body can drive significant currents through and over your body. You can minimize your exposure to ground currents by keeping your feet close together, especially avoiding a prone position. These actions can help minimize the amount of ground current going through your body, but most experts think these efforts are moot compared to getting to a safer location. We need to be careful that we don't give people a false sense of security by getting in the lightning position. Ground current contributes to 40-50% of lightning fatalities (Cooper, 2008) so this is the primary mechanism we should be thinking of when reducing lightning risks.

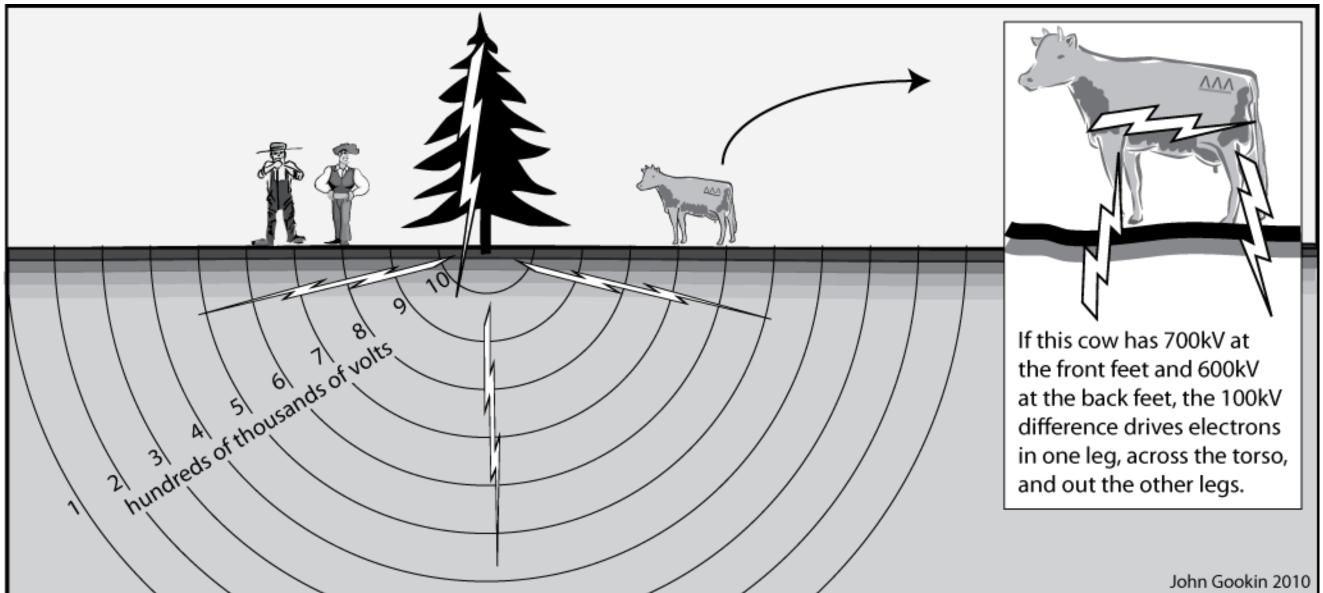

Fig. 3: **Ground current** causes roughly half of all lightning injuries to humans. The difference in voltage between one foot and the other drives current through us. In this simplified illustration the cow has a 100kV (100,000 volts) differential, one farmer has a 50kV differential, and the other farmer has her feet together so her voltage difference is close to zero.
See Uman's book (2008, ch.5) for a more precise representation of ground current distribution.

Side flash: (see fig. 4D) When lightning hits a tree or other tall object, the main current follows the tree trunk to the ground, but some current may arc across the air to a path of least resistance (like people) that can help conduct the current to the ground. This is similar to surface arcs, but off the ground. Side flash is more significant in tall objects with higher resistance than with low resistance (Uman, 2008, p.81) so it happens more significantly with trees than with towers. Since side flash emanates from trees or other tall objects struck by lightning, **never seek shelter near a tree, other tall object, or tall vertical surface.** Side flash contributes to 20-30% of lightning fatalities (Cooper, 2008). Side flash is one of the reasons that the "cone of protection" is a myth.

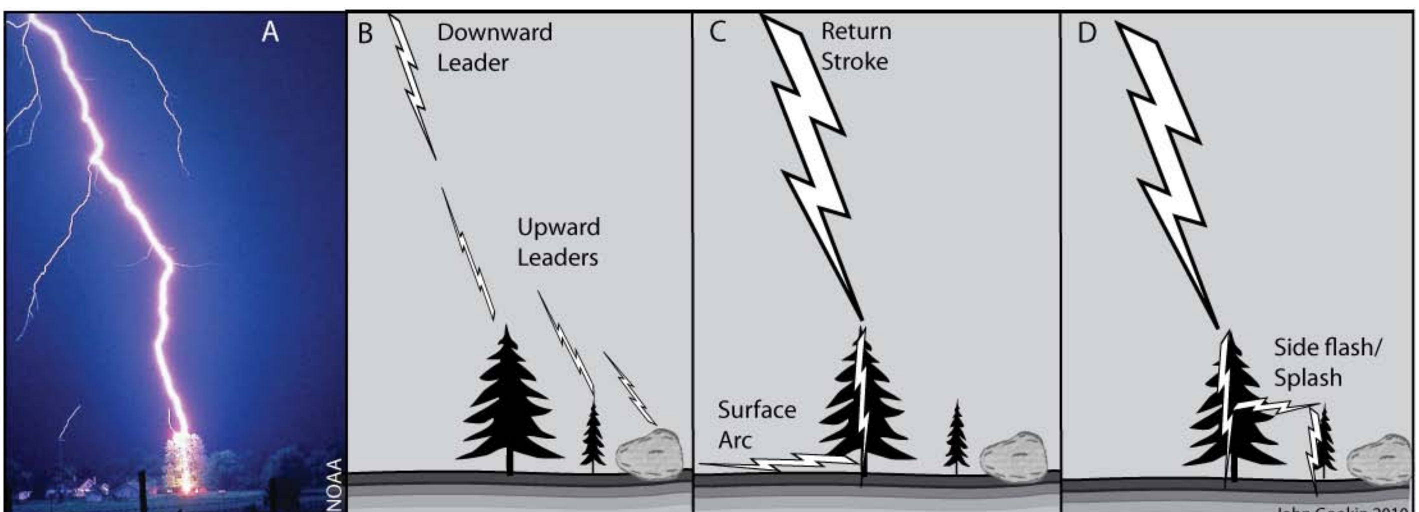

Fig. 4: A) A typical lightning strike to a tall tree. There are two upward leaders that did not attach to the downward leader.
B) Some **upward leaders** do not attach to the downward leader but still carry hundreds of amps and are quite dangerous.
C) A **surface arc** is associated with ground current and can go tens of meters from the strike point.
D) **Side flash** splashes some of the current onto a nearby object as an additional path to the ground.

Upward streamer currents (upward leaders): fast high current pulses are launched from the tops of many elevated objects near each downward leader as it approaches the ground (see fig.1, 4A, & 4B.) These are launched in response to the tremendously high electric field that exists, momentarily, under each tip of the stepped leader. Since the tips of several or many leaders may approach the ground at about the same time, you do not have to be very near the actual ground strike point to be involved in a streamer current. Streamer currents, while much smaller than the return stroke current, are still large enough to cause injury or death to humans. You suppress the tendency to launch streamer currents from your person by crouching into a tight ball as close to the ground as possible. You avoid this possibility by avoiding high locations. Upward streamers contribute to 10-15% of lightning fatalities (Cooper, 2008).

Touch voltage: touch or contact voltage occurs when we touch an electrified object like a fence or a corded telephone. This doesn't have the current of a direct strike but can be fatal. An Internet search easily finds images of groups of dead animals (like fig.5) that were touching fences when lightning struck the wire. Contact injuries contribute to 15-25% of lightning fatalities (Cooper, 2008).

Fig. 5: Cows have a tendency to "pile up" against fences during storms, with many cows leaning against the wire. These 23 cows in Idaho were all near the fence when lightning probably struck the fence up on the hillside. Cows also have feet that are roughly 3x as far apart as human feet, so their step voltage is naturally higher.

A quick Internet search will show similar photos of dead livestock next to fences around the world. Note that these fences tend to have wooden fence posts, which is why some veterinarians recommend you use the occasional steel post to ground wire fences.

Direct strike: this means the stepped leader connected with a streamer coming out of your body, then the return stroke passed through you or over your body's surface. The return stroke is the most significant electrical event of a lightning strike and has a typical current of 20,000 amps. You greatly reduce the chances of receiving a direct strike by being inside a substantial building or a metal-topped vehicle. In the backcountry you should avoid high places and open ground to decrease risk of a direct strike. Direct strikes comprise about 3-5% of lightning fatalities (Cooper, 2008) so we should primarily focus our efforts on avoiding ground current, side flash, and other mechanisms of injury. Unfortunately past lightning education dwelled on direct strikes as the primary mechanism of injury, so people laid down to get lower, thereby increasing the chances of getting injured by the primary lightning injury mechanism which is ground current.

Reducing Lightning Risk In The Backcountry

The U.S. has had about 40 lightning fatalities and 400 lightning injuries per year over the past decade (per NOAA annual summaries). Here at NOLS we have had six lightning incidents (close calls) reported, with no injuries or fatalities, in our last 963,000 backcountry (away from buildings or vehicles) user days. Ranging from the Arctic to the Amazon, roughly 3/4ths of NOLS user days are exposed to a climate with lightning hazards. A typical NOLS expedition spends 30 days in the wilderness, many miles from the nearest road or building. This paper uses the term *backcountry* to mean away from civilization and *frontcountry* to mean near roads and buildings. A public campground is in the frontcountry because it is near roads and buildings.

Backcountry lightning safety data is sparse, so these suggestions are "best hunches," not objective scientific deductions. Random circumstance is a significant factor in determining where lightning strikes, meaning that these behaviors help reduce your "Las Vegas" odds of lightning injury, but can never make you safe. Bill Roeder (2009) says these "last minute" precautions lower your odds of injury to 47% of what your odds would be if you took no precautions at all. There are things you can do to reduce risk during a thunderstorm, but you can never get as safe as you could be in town. There are four actions that can reduce your risk. These behaviors are in order and each one is roughly twice as important as the next one:

- **time visits to high risk areas with weather patterns**
- **find safer terrain if you hear thunder**
- **avoid trees and long conductors once lightning gets close**
- **get in the lightning position if lightning is striking nearby.**

Timing activities with safe weather requires knowledge of typical and recent local weather patterns. There is no such thing as a surprise storm. You need to set turnaround times that will get you off of exposed terrain before storms hit. You need to observe the changing weather and discuss its status with your group. If you have logistical delays you may need to change your plan rather than summiting a peak or crossing open ground during a thunderstorm.

Begin your turnaround if you hear thunder (which means lightning is less than ten miles away.) In a flat quiet windless location you can hear thunder for about ten miles. In windy conditions you might be able to hear the thunder for about five miles or less. In hard rain you may only hear thunder out to one mile. Some parties in rain storms have been struck by lightning before they heard any thunder at all. (People wearing iPods or any other devices with earbuds can't be expected to hear the warning sounds of thunder.)

You can try to use the **flash-bang ranging system** to measure how far away a thunderstorm is. It is easy to make mistakes with this tool because sometimes you can't tell which flash is associated with which bang. The flash of light travels fast enough that it is virtually instantaneous. The sound travels a mile every 5 seconds (1km/3 sec) so ideally you just count the number of seconds between the obvious flash and the obvious bang, divide by 5, and see how many miles away the storm is. Do not stake your life on the reliability of this ranging system.

One safety system that utilizes this tool is the **30/30 rule**: if there is less than a 30 second delay from flash to bang, then you should be indoors. Be sure to allow time to get to safety before the time between lightning and its thunder reaches 30 seconds. Stay in the safe location for 30 minutes or more after the last thunder heard. Since backcountry travelers have no safe building to go, they need to be even more cautious than this and head to a safer location long before the storm gets close.

Safer terrain in the backcountry can decrease your chances of being struck. Lightning tends to hit high points and the terrain around it. Avoid peaks, ridges, and significantly higher ground during an electrical storm. If you have a choice, descend a mountain on the side that has no clouds over it, since strikes will be less frequent on that side until the clouds move over it. Once you get down to low rolling terrain, strikes are so random you shouldn't worry about terrain as much. Move to safer terrain as soon as you hear thunder, not when the storm is upon you. Be cautious of flash floods– NOLS has had more serious near misses with flash floods in dry camps (from distant storms) than we have had from lightning.

Tents may sometimes increase the likelihood of lightning hitting that spot if they are higher than nearby objects. Tent poles conduct ground current and may generate upward leaders. Use your understanding of terrain and lightning to select tent sites that may reduce your chances of being struck or affected by ground current. If you are in a tent in "safer terrain" and you hear thunder, you at least need to be in the lightning position to possibly reduce ground current effects. But if your tent is in an exposed location, such as on a ridge, in a broad open area, or near a tall tree, you need to get out of the tent and get to safer terrain before the storm starts, and stay out until it has passed. It would be wise to anticipate additional hazards of getting out of tents in the dark of night during a storm. Determine a meeting spot, have rain gear and flashlights accessible, and have a plan for managing the group during this time.

In **gently rolling hills** the lower flat areas are probably not safer than the higher flat areas because none of the gentle terrain attracts leaders. Strikes are random in this terrain. Look for a dry ravine or other significant depression to reduce risk.

Wide open ground offers high exposure during an electrical storm. Avoid trees and bushes that rise above the others, since the highest objects around tend to generate streamers. Your best bet is to look for an obvious ravine or depression before the storm hits. When the storm is over you, spread out your group at 50' intervals to reduce multiple injuries and assume the lightning position.

Naturally wet ground, like damp ground next to a stream, isn't any more dangerous than dry ground. It used to be said that wet ground was more dangerous, because it conducted more ground current, but wet ground actually dissipates ground current faster. Neither wet nor dry is considered more dangerous than the other. Standing *in* water is very dangerous during a thunderstorm.

Cavers should avoid cave entrances during thunderstorms. Small overhangs (rock shelters, as in fig.6) can allow arcs to cross the gap. Natural caves that go well into the ground can be struck, either via the entrance or through the ground. People who have been shocked standing in water deep inside caves cite weak charges, indicating that deep within a cave is safer than being on the surface (Gookin, 2002). If you are caving near an entrance during electrical activity, don't stand in water, avoid metal conductors, and avoid bridging the gap between ceiling and floor. Move quickly through the entrance (in or out) to minimize the time of your exposure. If you are stopped waiting for others near a cave entrance area, rest in the lightning position, but stay far from the entrance.

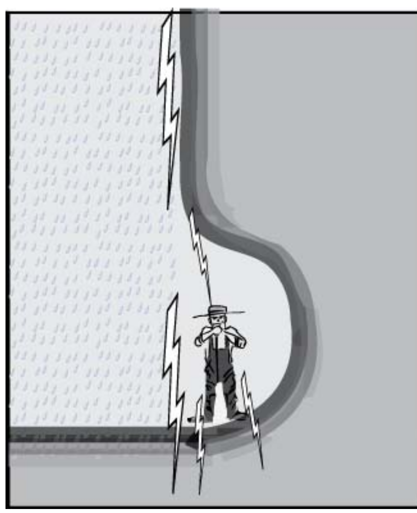

Fig.6: Rock shelters, cave entrances, and overhangs are especially hazardous because lightning travels along vertical surfaces to seek the ground. When lightning needs to jump a gap, any object bridging that gap can help conduct the current. Standing near the edge of an overhang is extremely dangerous during a thunderstorm. This even includes standing on the porch of a building where you could help conduct current across the open gap.

Boaters should monitor the weather forecast (if available) and schedule their activities to avoid thunderstorms. While on the water, boaters need to watch the skies diligently for approaching or locally developing clouds threatening thunderstorms and get off the water before the storm arrives. If you wait until you hear thunder, you may have inadequate time to get to safety. There are fewer incidents of lightning accidents on rivers in canyons, probably because the higher terrain above the canyon attracts the leaders. But there is ample lightning injury data for boaters on rivers in flat terrain, on lakes, and on the ocean. When you get to shore, look for protective terrain to wait out the storm. Be especially cautious of trees at the edge of the water because they might be the tallest objects around the body of water. Boats that can't get off the water in lightning-prone areas should have lightning protection: see this website for information: http://nasdonline.org/document/209/d000007/boating-lightning-protection.html. The bottom line is that boaters need to start getting off the water long before a storm arrives and they need to be especially cautious of tall trees at the edge of the water (Gookin, 2007).

Avoid trees because they are taller than their surroundings. Tall trees are especially adept at generating streamers that attract strikes. If you need to move through a forest while seeking safer terrain, stay away from the tree trunks as you move. You should also avoid open areas that are 100 m wide or wider. Lone trees are especially dangerous: the laws of probability say you are hundreds of times safer in a forest with hundreds of trees than you are near a lone tree in an open space.

“Cone of protection” from trees and cliffs is a myth and has no place in lightning safety education anymore. It is still used in lightning protection systems built with low resistance materials specifically engineered for conducting lightning strikes into the ground (Uman, 2008, p.58). The cone of protection is the area under a 45° cone drawn downward from the tip of a lightning rod. But trees and cliffs have high resistance so rather than channeling the pulse into the ground like a good lightning rod, they splash electricity all over the place. People that try to use trees as a cone of protection inadvertently place themselves near some of the most common strike injury mechanisms which are ground current and side flash (see fig.7). Lightning has been photographed striking 100 m from 200 m towers, and surface arcs have been photographed exactly where “cones of protection” inferred we were all safe. Instead we need to teach the 50 m leader search distance concept (fig.1) and avoid tall trees.

Fig. 7: These dozen elk were killed by a lightning strike to the 30’ tall lodgepole pine tree they were under in the Wind River Range. The tree was on a slight ridge and was only slightly taller than the trees near it. This tree had both a new lightning scar (circle on left) and another scar that was 10-15 years old.

An Internet search can easily find similar photos of horses, cows, and other animals that sought shelter from the rain under a tree, then the tree was struck by lightning. Most of the trees in these photos are solitary trees in open ground.

Many human lightning fatalties are also from seeking refuge from the rain under trees.

Avoid long conductors. Lightning discharges and electrostatic fields tend to pass in long electrical conductors — particularly ones that are on or near the surface of the Earth. Metal fences, power lines, phone lines, railway tracks, handrails, measuring tapes, bridges, and other metal objects can carry significant lightning current even if these objects are at some distance from the lightning ground strike point. Near the ground strike point of a lightning discharge, wet ropes can conduct lethal currents. During a thunderstorm, wet, extended ropes should be regarded as equivalent in risk and danger to metal wires.

The lightning position (fig.8) is for waiting out a storm in stationary situations when it is impossible to move to a safer location. It may do more harm than good if you stop your movement to a less risky location to get in this position. In a stationary situation, keeping your feet together definitely reduces step voltage. If you are stuck in a tent on a dark rainy night, balling up is much better than being prone. Many people sit Indian style because it is more comfortable. Some other considerations are to wrap your arms around your legs, close your eyes, and/or cover your ears to help reduce the effects of both the lightning’s current and the thunder’s blast trauma.

Fig. 8: **the lightning position** is for waiting out storms in stationary situations when it is impractical to move to a safer location.
1) **Put your feet together** to *significantly* reduce the effects of ground current which causes about half of lightning fatalities.
2) **Crouch** to *slightly* reduce the effects of side flash and upward leaders which together cause ~40% of lightning fatalities.
3) **Don’t touch** long conductors to avoid contact voltage which causes ~20% of lightning fatalities.

The lightning position reduces the chances of lightning injuring you as badly as if you had your feet further apart, but is no substitute for getting to safer terrain or a structure if it is immediately available. But in wide-open country, or gentle rolling terrain, there are no simple terrain advantages, so use this position to reduce exposure (slightly). If you are concerned enough to get in the lightning position, disperse your group spaced several body lengths apart (~20’) to reduce the chances of multiple injuries, and so survivors can do first aid on lightning victims.

Corona: During any stage of a thunderstorm, the electrostatic field can be enhanced enough around grounded objects to cause brush or point discharge (corona). At night, you may be able to see corona as a faint glow from sharp rock outcrops or the tops of bushes or trees — sometimes even from the fingers of your outstretched hand. You may hear corona as a sizzling or buzzing sound. Even if you can't see or hear corona, you might smell ozone, one of the chemical products of point discharge in air. Ozone has an irritating, acrid "swimming pool" smell.

On land it is unusual to have optimum conditions for sensing corona. If you feel hairs on your head, leg, or arms tingling and standing on end, you are in an extremely high electric field. If you or any member of your group experiences any of these signs, it should be taken as an indication of immediate and severe danger. The response to any of these signs should be to instantly (seconds matter) move away from long conductors, tall trees, or high points, spread out, and adopt the lightning position. Do not ignore these signs and do not try to run to safety, unless safety is literally seconds away. If any of these signs are detected, the probability of a close discharge is high and every effort should be made to minimize injuries and the number of injured.

One possible strategy if you are trying to cross to safer ground and you experience corona is to stop and drop into the lightning position. If there is a nearby strike you often have a little time before the electrical field rebuilds itself. Rise up slowly. If you can rise without seeing any new corona, continue rushing to the safest location available.

Pathophysiology: The Effects Of Lightning Strikes On Humans

There are three ways lightning hurts us:

Electrical shock
Secondary heat production
Explosive force (Cooper, 2007).

Neuro-electrical Damage: Current through the torso or brain can stop the heart or stop breathing. Hearts often restart themselves quickly, but it can take the breathing control center longer to recover. Cardiac or respiratory arrest, that isn't restarted quickly, will eventually cause anaerobic conditions that make recovery problematic. Current through the tissues can also lead to numbness, paralysis, or other nervous system dysfunction.

Burns: Lightning victims can get burned from the high current electricity that turns into heat in conductors that resist its flow. Strike victims can get linear burns from head to feet along the skin, punctate (spotted) burns, or feathering skin marks (not really burns) from the charge flowing over their skin. They can get secondary burns from metallic objects like belt buckles and jewelry that heat up from the current. Burns can also occur from lightning-ignited clothing.

Large entry and exit burn wounds from lightning strikes are rare. Most victims have a flashover effect (current travels over their skin) that saves them from the more severe wounds: these people can get linear or punctate burns or feathering patterns. But flashover can also travel into orifices, which may explain the many ear and eye problems that result from lightning strikes.

Wet people may carry more current over their skin, instead of through their bodies, reducing their injuries. It is not suggested that you intentionally get wet in case you are struck, but it does mean you shouldn't be scared that being wet would increase your risk.

Trauma: The explosive force of lightning can result in direct or indirect trauma resulting in fractures or soft tissue injuries. Watch for explosive injuries at the feet. The high current can also trigger significant muscle spasms that may lead to involuntary jumping (Turner, 2000, p.107), falling, or even fractured bones. These spasms sometimes result in falls from heights and other mechanisms of secondary trauma that may render the person unconscious or injure them in other ways.

Psychological Effects: Electrical injury can injure the brain. Immediate problems may include altered consciousness, confusion, disorientation, or amnesia. Long-term problems may include anything from headaches and distractibility to persistent psychiatric disorders and dementia (Primeau, et al, 1995).

First Aid For Lightning Victims

Medical aspects of lightning injury are covered in the Wilderness Medicine Field Guide and NOLS Wilderness Medicine. This overview does not supersede those more comprehensive documents.

Treatment Principles

· **Scene Safety**: Avoid further injury to survivors, rescuers, and the patient. You may have to wait for the storm to pass to treat some patients if they are in extremely hazardous locations.

· **Basic Life Support**: Rescuers should be prepared to provide prolonged rescue breathing.

· **Triage**: Unlike normal triage protocols in multi-casualty situations, attend first to those who are in cardiac or respiratory arrest without obvious lethal injury.

· **Assessment**: All patients require a complete body survey and careful evaluation for head, spinal, long bone, or cardiac injuries. Peripheral pulses, and sensory and motor status, should be assessed. Check the skin for small hidden burns.

· **Monitor** closely for cardiovascular, respiratory and neurological collapse.

· **Evacuate** any patient obviously injured by lightning, and be alert for lingering physical or neurological issues from exposure to lightning that should be evacuated for further evaluation and treatment.

Teaching Backcountry Lightning Risk Management

Teaching backcountry lightning safety has the risk that our students will inappropriately defer to these techniques when civilization offers significantly better options. There are five things we can do to mitigate this possibility.

1) Be sure graphics and other abbreviated information includes urban choices for calibration of relative risks. This reduces the likelihood that people will use the information out of context, like choosing the "best" trees to be under instead of going inside of a building or car.

2) Explain the relative importance of the basic lightning heuristics. If people dwell on backcountry techniques when more urban techniques are available, tell them this is like asking whether to cover your face or not during a car crash in which you are not wearing your seatbelt: it is much, much, much more important that you learn to wear your seatbelt, than it is to learn what might be a little more helpful when you aren't wearing it. Educators need to emphasize the most *important* aspects of lightning safety, not the

most *interesting* aspects.

3) If lightning hazards present themselves in town, it is important that we model the reaction to seek safety in buildings or vehicles. Once inside, we need to avoid pipes, wires, computers, hard-wired video games, and other metal objects that could conduct a strike. If you aren't sure whether to "do the drill," err on the side of caution for the sake of having your students practice the routine. Just like CPR, emergency actions are best learned in the kinesthetic mode rather than an intellectual one, so they will be more memorable in times of stress. Remember to unplug the computer and other electronics BEFORE the storm gets overhead -- Not because the computer is valuable but because the hard drive contents and time setting a new one up are.

4) We can easily teach non-wilderness lightning safety techniques during a wilderness program, since the intown choices are so simple and so effective. Getting in a modern building or inside a car during an electrical storm are the only reasonable options when they are available. Indeed, we can use the relative ease of good choices while in town, and the comparatively high risk of backcountry options, to help our backcountry students default on the side of conservatism when it comes to getting up peaks by noon, getting off the water, choosing safe campsites, and generally avoiding exposed terrain when storms threaten us.

5) Be clear about objective and subjective aspects of lightning risk management (fig.10). A *hazard* is anything that has potential for harm. An *objective hazard* exists in a specific environment without regard to a person's presence. Severe weather happens. Lightning happens. We should have a reasonable amount of fear (deBecker, 1997) and respect for these hazards. A *subjective hazard* is the human behavior that puts people at greater risk of objective hazards. Wilderness risk managers sometimes refer to this as *the human factor*, and often use a Venn diagram to show the intersection of objective and subjective hazards that contribute to the typical accident. For instance, backcountry skiers often cross avalanche paths (objective hazard): skiers who don't recognize an avalanche path (subjective hazard) and stop to eat lunch in one greatly increase their risk by increasing their time of exposure to the hazard. Reinhold Niebuhr's serenity prayer says it well:

"Grant me the serenity to accept the things I cannot change (objective hazards),
The courage to change the things I can (subjective hazards),
And the wisdom to know the difference."

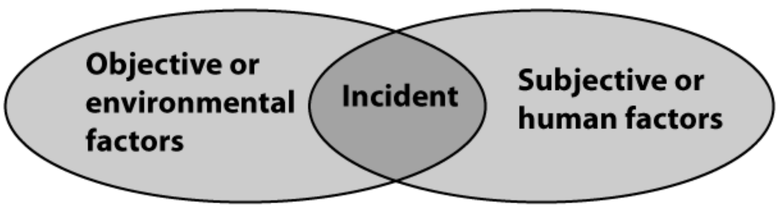

Fig.10: Accidents typically happen in the intersection of objective and subjective hazards. That is, accidents usually happen because of both natural environmental hazards and human behavior.

Record Keeping For Lightning Incidents

Normal near-miss forms used by camps and outdoor programs need to be completed quickly to accurately document any near miss. Near misses are used to inform others what hazards to be careful of, and to help predict accident types. Any lightning incident also needs a record of actions taken to avoid the hazard before the incident, i.e. weather observations, and thunder and lightning observations before the incident. You should sketch who was where relative to surrounding terrain and vegetation, with estimated distances, heights and elevations, a North arrow, and at least one definitive landmark. If you have time for a detailed sketch, measure using paces that you can convert to meters later. Be sure to record people who were and were not injured by the strike. A precise record of the time and location of the ground strike may help lightning scientists at Vaisala Lightning Strike Data www.vaisala.com give you some data about that actual strike. An easy way to do this is to take a photo of a GPS at the scene, so the coordinates are documented. Written documentation should include coordinates and map datum used.

Report any lightning strike that results in a fatality, injury and/or property and crop damage to your local National Weather Service office so they can enter it into the storm events database. This will enter it into the system that allows you to look up lightning events according to your US state at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms .

Thank you to Ron Holle, Mary Ann Cooper, MD, William Roeder, Martin Uman, and others for their tremendous contributions to the field and to this collection of information. Lightning scientists do not all agree on these adaptations of their careful scientific studies. Any misrepresentation of their material is my fault, not theirs. JTG

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Backcountry Lightning Risk Management

No place outdoors is safe from lightning when thunderstorms are in the area. Lightning is an *objective hazard*. Your behavior can reduce the *risk* of that hazard harming you. This diagram is specific to a continental (dry) climate. This diagram is part of the paper "Backcountry Lightning Risk Management" (Gookin, 2010): use of this diagram without the paper's context may increase the risk of lightning injury.

Terrain lightning safety factors

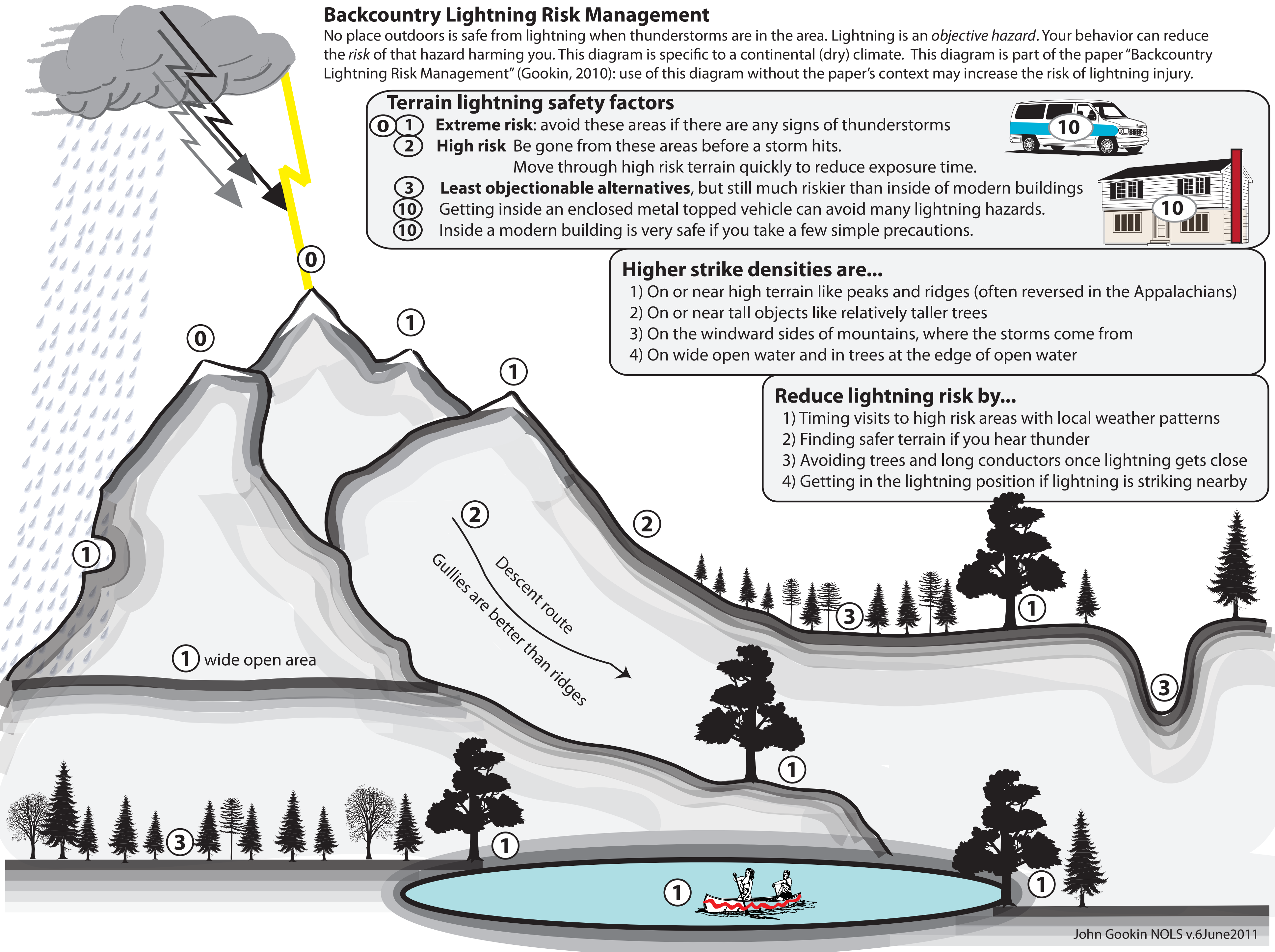
- (0) (1) **Extreme risk**: avoid these areas if there are any signs of thunderstorms
- (2) **High risk** Be gone from these areas before a storm hits. Move through high risk terrain quickly to reduce exposure time.
- (3) **Least objectionable alternatives**, but still much riskier than inside of modern buildings
- (10) Getting inside an enclosed metal topped vehicle can avoid many lightning hazards.
- (10) Inside a modern building is very safe if you take a few simple precautions.

Higher strike densities are...

1) On or near high terrain like peaks and ridges (often reversed in the Appalachians)
2) On or near tall objects like relatively taller trees
3) On the windward sides of mountains, where the storms come from
4) On wide open water and in trees at the edge of open water

Reduce lightning risk by...

1) Timing visits to high risk areas with local weather patterns
2) Finding safer terrain if you hear thunder
3) Avoiding trees and long conductors once lightning gets close
4) Getting in the lightning position if lightning is striking nearby



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