Glacier Travel and Crevasse Rescue Course

Travelling over snow-covered glaciers could be considered a relatively straightforward mountain activity. New Zealand's high glaciers are an inspiring destination for ambitious trekkers or ski tourers and are considered the easy approach to more serious mountaineering objectives. With some understanding of the geography of glaciers, the worst areas of crevasses can usually be avoided and the risks minimised. There is however, the residual risk of an unexpected fall into a hidden or thinly bridged crevasse and this has the potential to result in a challenging rescue situation. All members of a team should be able to identify the factors that contribute to a heightened risk, have the skills to rope up when required and be familiar with and practised in emergency self and companion crevasse rescue techniques.

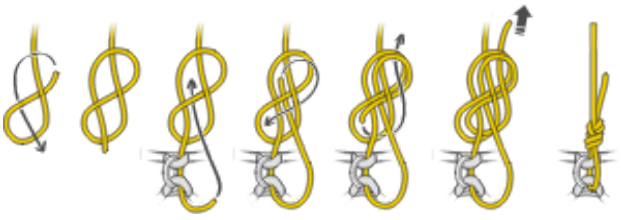
Knots and hitches

Below is a list of knots used by mountaineers and common uses. A hitch is a type of knot that is tied around an object, most commonly a carabiner. When the object is removed the hitch collapses.

Overhand knot is the simplest knot. Can be used to join two strands of rope and is typically used when abseiling on two ropes.

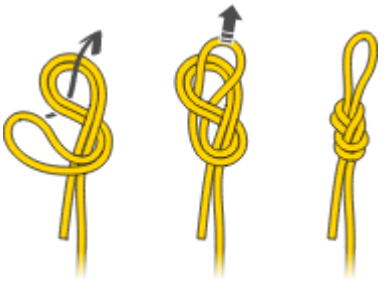
Overhand knot on a bight is a simple and easy knot that is an option whenever a loop of rope (or bight) is required along a length of rope.

Rethreaded Figure-8 is most commonly used to tie into a harness. Always make sure that there is at least 10-15 cm of the tail of the rope left hanging out of the back of the knot.



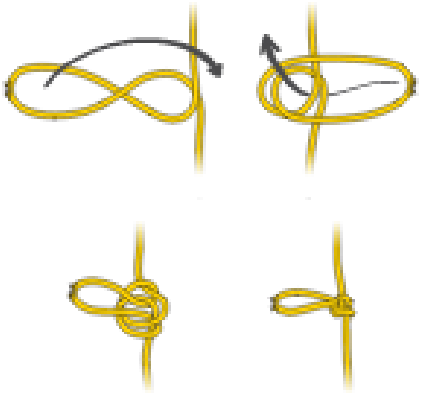
(*Petzl*)

Figure-8 on a bight is similar to an overhand on a bight with an extra twist. It Is not very stable if pulled laterally so not the best option when loops are required along a length of rope but is useful for tying loops at the end of ropes, for example at the end of abseil ropes.



(Petzl)

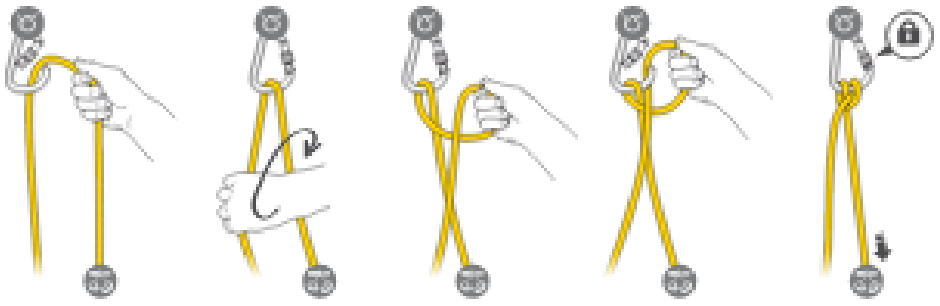
Alpine butterfly is a bight knot that can be used as an alternative to an overhand on a bight for creating loops along a length of rope. It has the advantage of being strong and stable when pulled laterally.



(Petzl)

Double fisherman's is used to create prusiks from loops of chord and can be used to join two ropes together - especially if of different diameters.

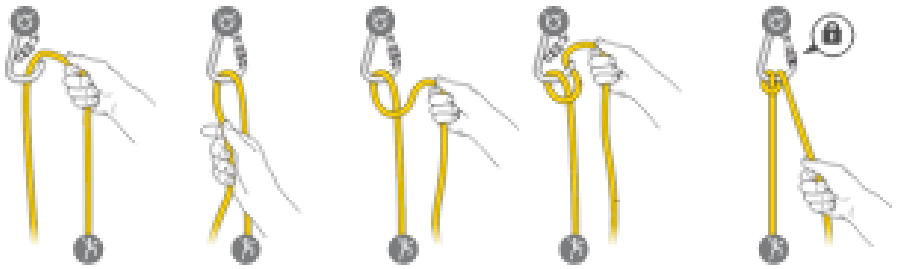
Clove hitch is used to attach the rope to a carabiner and typically used to attach a climber to an anchor. It has the advantage of being adjustable without taking it off the carabiner and is easy to undo once loaded.



(Petzl)

Italian hitch is a friction hitch (also known as Munter hitch) that can be used for rappelling and belaying.

Being able to lock off an Italian hitch with a *Munter mule* hitch is useful for rescue situations.



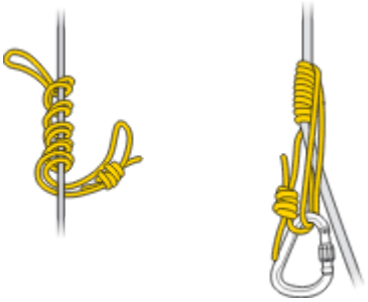
(*Petzl*)

Prusik hitches

Prusiks are loops of cord and are lightweight, inexpensive and can be useful in a variety of situations. It is usual that 2 or 3 prusiks or other mechanical ascending devices are carried when climbing or mountaineering. Prusiks are made from lengths of 6 or 7 mm diameter chords with the two ends together using a double fisherman's knot.

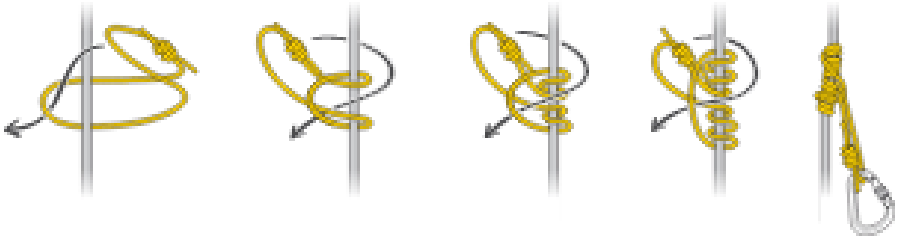
There are dedicated hitches that prusiks are used for and three types that are commonly used:

French prusik locks in both directions and is releasable under load and therefore commonly used as an abseil backup**.** It is tied by wrapping a prusik loop around the rope a number of times and clipping both ends into a carabiner. It is important that there is not too much slack to ensure it grips so the prusik loop may need to be shortened with an overhand knot if necessary.



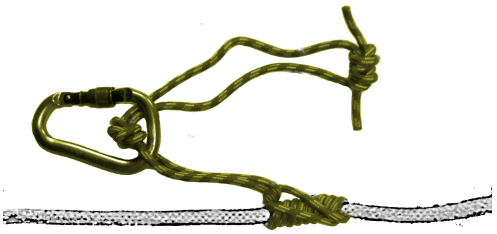
(*Petzl*)

Classic hitch works with pulls in either direction along the rope. It is tied starting with a larks girth hitch) around the rope, with successive wraps fed through in the inside. Once tightened unc it can be loosened by wiggling the *Breaking bar* so that it can be moved up the rope.



(Petzl)

Klemheist hitch is quick to tie and is useful as it is the only prusik hitch that can be tied with tape sling. The disadvantage is that it becomes very difficult to release under load. It also works best when pulled in the downwards direction.



The number of wraps around the rope for all prusik knots should be a minimum of 3 but can be as many as 5 depending upon the diameter of the rope being ascended. The diameter of the prusik cord should be less than 2/3 of the diameter of the rope it is being wrapped around. Too many wraps will introduce too much internal friction within the hitch. This may prevent the prusik from working correctly and tightening around the rope when loaded. All prusik hitches must be neatly dressed to ensure they work well and correctly and always check that they grip satisfactorily before committing weight to them.

Roping up for Glacier Travel

Mountaineers typically carry a rope between 30 and 60 meters long. The length depends on the objective. If pitching or abseiling is anticipated on their chosen route then a longer rope will be used. For straightforward glacier trekking or ski touring, a shorter rope may be carried.

It is not usual practice for ski tourers to rope up in good conditions. Route finding, visibility of any open crevasses, and the increased surface area provided by skis provide some mitigation against the risk of falling in a crevasse. In unfamiliar and/or broken terrain or when visibility is limited by weather, roping up provides further security against unexpected crevasses falls.

It is usual practice for glacier ski tourers to carry 30-60 m of dynamic or lightweight hyperstatic rope, primarily to be used in an emergency for crevasse rescue, but also to be used for roping up if required. Ski mountaineering objectives, especially those where some pitching or abseiling will be expected, may necessitate a longer dynamic rope.

There should always be at least two ropes in a party that are sufficiently separated in case the carrier of one of the ropes, ends up in a crevasse. The leader, heading out in front to find the route, must not be the only one carrying a rope so all group members are susceptible to being surprised by a hidden crevasse hazard.

When roping up, a similar spacing to summer mountaineering on foot can be used of 8 to 12 meters, depending on what is known about the size of the crevasses, the distance between them in the area, and the number of people on the rope. The aim is to avoid more than one person being exposed to the same crevasse at the same time and maximise the chance of holding a crevasse fall.

Teams of more than two

With more than two people on a rope, the chances of successfully holding a fall of any member of the party is increased. When roping up with three or more people, those not on the ends can clip their harness belay loop into a bight knot in the middle of the rope. To prevent potential *cross-loading* a secondary gated carabiner (eg Black Diamond Gridlock®) or two opposed carabiners are recommended when clipping into a bight knot. Alternatively, they could tie directly in with a rethreaded overhand knot but this is more difficult to escape. The distance between each person should still be between 8 to 12 meters but can be shortened due to the added security of more party members.

Brake knots

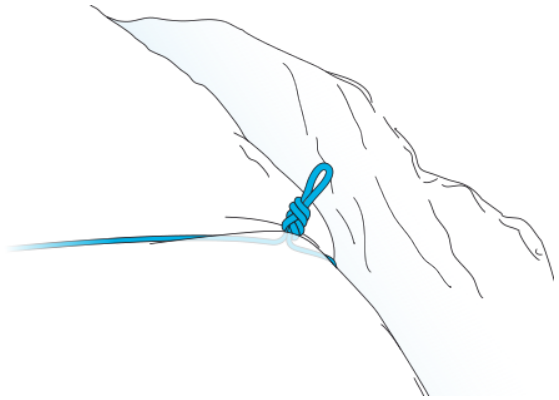


Figure 8 on a bight brake knot (Petzl)

Holding a crevasse fall when there are only two people on a rope is difficult, especially when the person falling into the crevasse is significantly heavier than the person holding the fall. One way to increase the chances of holding such a fall is to tie brake knots (figure 8 or overhand on a bight or an alpine butterfly) in the rope about 2-3 meters from each person. The knot will tend to drag through the snow or catch on the crevasse lip as the person falls into the crevasse and can significantly reduce the amount of effort needed for the person on the surface to hold the fall.

Brake knots for roped glacier travel (Petzl)

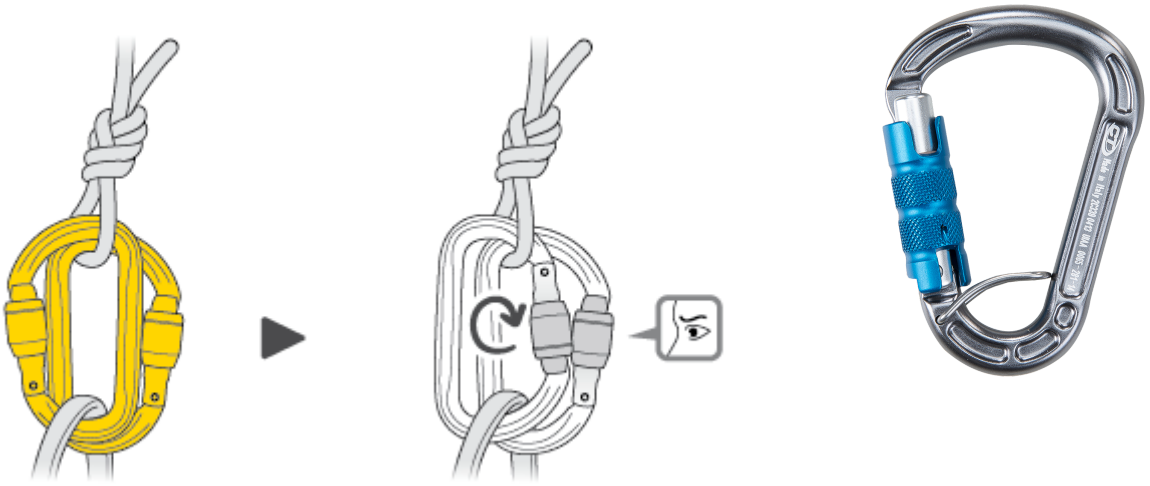
Shortening the rope

There are a number of methods for carrying the excess rope. All techniques start by finding the middle of the rope and measuring out 5-8 metres towards each end. At the chosen spacing a bight knot (such as an overhand knot on a bight is used to attach to the rope. More rope will be needed than the intended distances between members to account for tying brake knots.

Carrying the excess rope in a backpack is an option if it is not already too full and can be more comfortable than mountaineering coils where the weight is around the carrier's neck. If transitioning from glacier travel to pitching is anticipated during the day, it is important for each person to tie into the ends of the rope before stacking the rope in the pack.

To stack the rope, start by feeding the end of the rope or from the tie-in to the harness into the top of the pack or a stuff sack until the bight knot at the chosen spacing is reached. Stacking the rope into a stuff sack before putting it in the pack is useful as the sack can easily be taken out to access other items from the pack.

The bight knots can be clipped directly to the belay loop of the harness. In the event of a glacier fall, a bight knot is easier to escape from and therefore preferable to a clove hitch. To prevent potential Cross-loading a directional locking carabiner (eg Climbing Technology Concept HMS Triple Lock Carabiner®) or two opposed carabiners are recommended when clipping into a bight knot. The rope between the bight knot and the stuff sac in the backpack can be kept in place by clipping behind the backpack waist belt or sternum strap.



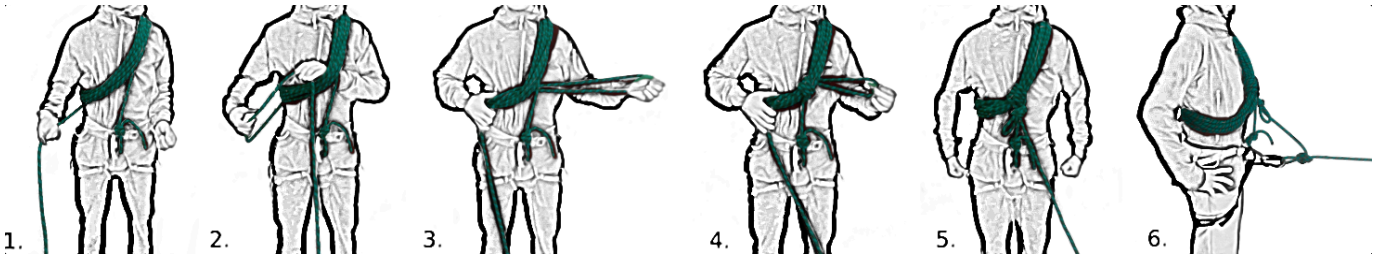
Opposing carabiners (Petzl) and directional carabiner (Climbing Technology)

Blocked 'Kiwi coils'

If backpacks are too full to stack the excess rope in, or the rope needs to be more easily accessible, the rope can be secured around the body in coils. Blocked 'Kiwi' coils are most commonly used for glacier travel. They take longer to adjust than unblocked coils but have the advantage of staying neat and reliable over time.

To tie Kiwi coils:

1. Find the middle of the rope and measure out the required distance between team members. Remember to account for the extra length required for tying brake knots. Tie into the end of the rope. This is especially important if it is anticipated that the rope may be lengthened for pitching during the day. From the knot, run the rope over your shoulder and start coiling the rope around your opposite hand, held statically at waist level (for example rope initially runs over the left shoulder so coils are taken around the right hand). Keeping your hand static at your belly button level will create uniform length and neat coils;
2. Pass your hand behind the coils and grab the loop of the rope.
3. Pull back through a long loop of rope. Hold the coiled end of this loop using the waist hand to ensure the strand of rope does not ride up;
4. Wrap the long loop around the coils a few times, this keeps the coils neat and secure;
5. With the remaining loop, tie an overhand knot around the rope coming from your figure-8 knot and the live rope (the rope connecting you to your partner);
6. An isolation knot is required to provide a low tie-off and ensure any loading comes directly onto the harness. A bright knot makes it easier to escape the system for companion crevasse rescue if the live rope is loaded. Whilst pitching or moving together, a clove hitch can also be used as it is easily adjustable, providing it is regularly checked to avoid loosening during movement.

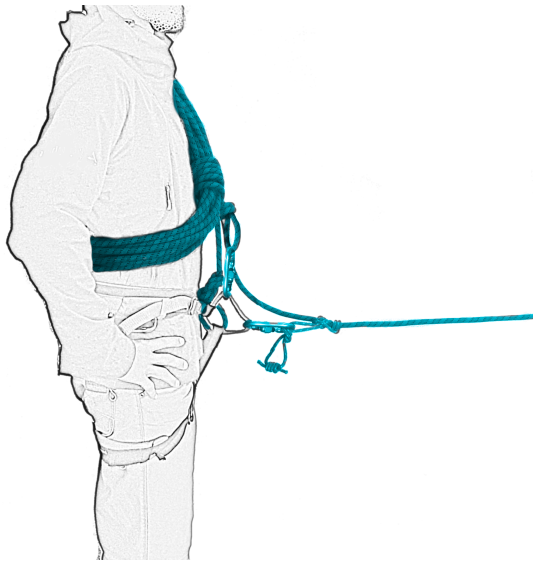


Kiwi coils

Hand-coils

Hand coils are often used to shorten the rope on easy and low-consequence terrain where leaving the rope run out can get in the way or snag. It is a quick alternative to temporarily untying from the rope for a short section of soloing terrain. It must be emphasised that this is not the same as the short roping technique often seen being used by professional mountain guides to safeguard their clients and should not be used when there is any chance of slipping or falling in which case the rope will intensify the seriousness of the situation.

Pre-rigging



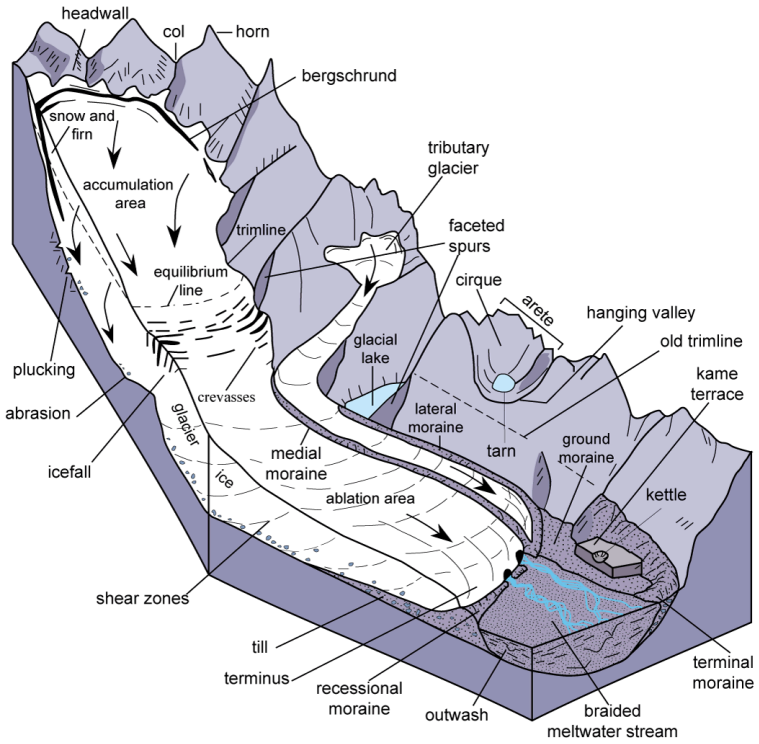
Pre-rigging of prusiks on the live rope allows them to be quickly and readily available for crevasse rescue if required. The decision to pre-rig depends on the nature of the crevasse hazard at the time including snow surface and travel conditions.

The short 'waist' prusik loop is put on the live rope and clipped into its own screwgate carabiner on the belay loop of your harness with some slack between it and the blocked coils. This can replace the bight knot providing the knot securing the blocked coils is also clipped into the belay loop with its own carabiner forming a chest harness. In the event of falling in the crevasse, the chest harness will provide more support, especially with a heavier pack.

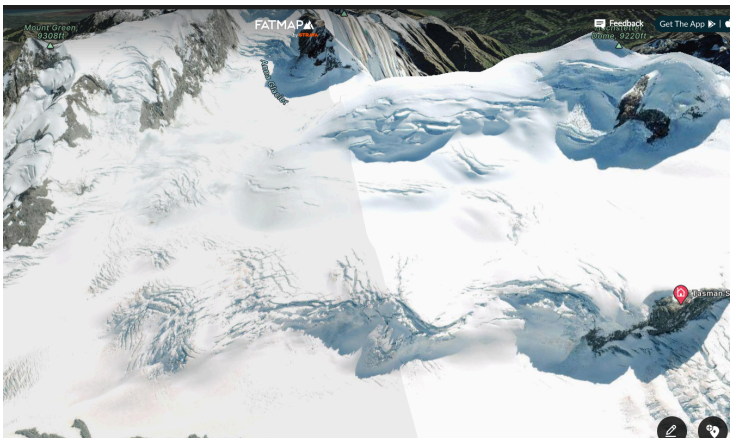
The optional long 'leg' prusik loop can be placed between the short prusik and the belay loop with the remainder tucked out of the way in your jacket or wrapped around coils.

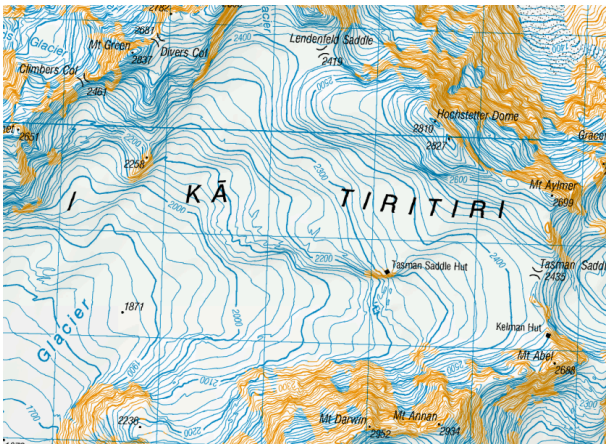
Glacier travel

Identifying crevasse hazards



Glaciers flow down the landscape like a slow-moving river. Crevasses will form in the top 50m of a glacier where the ice is brittle, particularly in areas of tension or friction or where ice is flowing at different speeds. This includes over convexities, over any steep terrain, or towards the edge of the glacier.





Areas of likely crevassing can be identified by analysing the terrain using Topomaps and satellite images. Steep terrain and irregular contour spacing and shape indicated crevassing.

Good planning and route finding on snow-covered glaciers will reduce exposure to falling in a crevasse.

Crevasses may be indicated by visible cracks or slumps in the surface of the snow. These clues may however be masked by fresh snow, blowing snow, or crust layers on or close to the surface.

The time of year and prevailing snow conditions will influence the supportive strength of any bridge. New snow, or snow that has had its strength weakened by cold temperatures[1] commonly encountered mid-winter, will be weak. Older snow has consolidated through a number of melt-freeze cycles (more typical of the warmer spring season) and will be stronger when frozen but may be weakened during the warmth of the day.

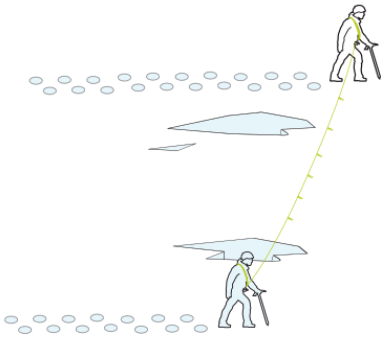
Crossing crevasses

When travelling near visible crevasses, determining the characteristics and shape of the shape of the crevasses will assist with route finding. Bell-shaped crevasses get wider as they get deeper and should be given a wide berth. Narrow parallel or constricting crevasses can often be stepped over.

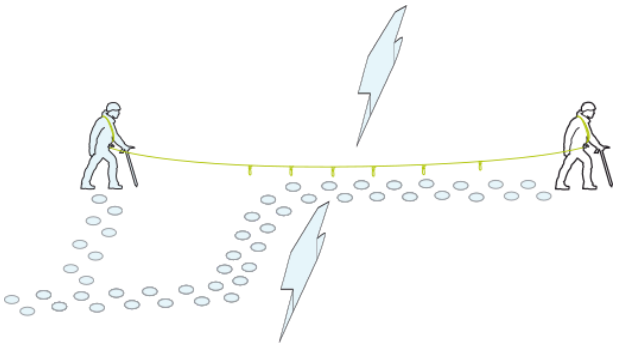
When crossing visible or potentially hidden crevasses it is important to try to keep the rope between members of the team tight and as close to 90° to the crevasses as possible. This may require different team members to take different lines.

If travelling parallel to the crevasses, it can be advantageous to travel in echelon formation with the rope perpendicular to the direction of travel. This is to avoid more than one person standing over the same crevasse at the same time and avoid pendulum falls that can be difficult to arrest.

[1] Snowpack metamorphosis also has implications on avalanche problem formation.

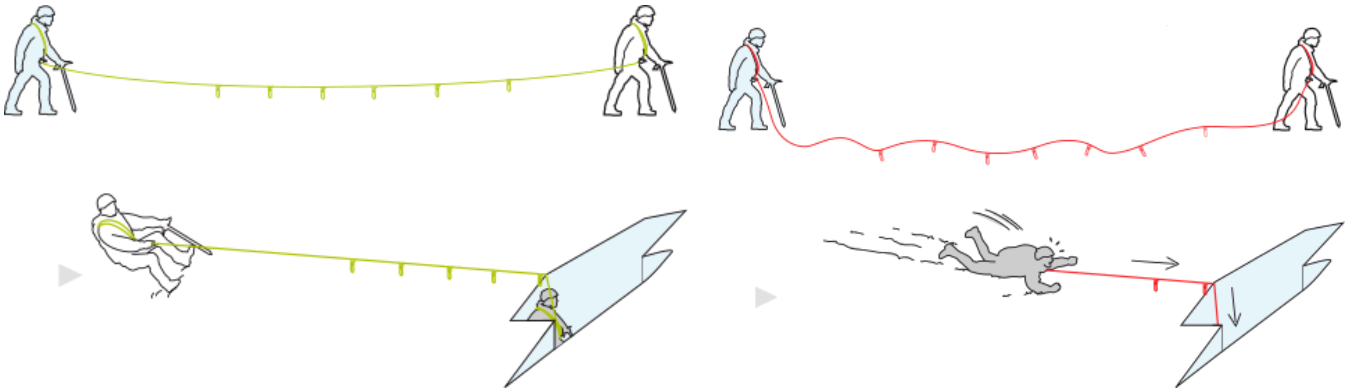


Echelon formation



Crossing crevasses at 90 degrees

The rope between team members should not be too slack. A loose rope compromises the safety of the party as it increases the shock loading when a fall occurs and can dramatically reduce the chances of successfully holding a crevasse fall. Excessively loose rope can also pose a trip hazard. Too tight however can make it difficult for all members to maintain an efficient pace. A good tension is achieved when the rope is dancing along the snow surface at the bottom of its arc.



Glacier travel (Petzl)

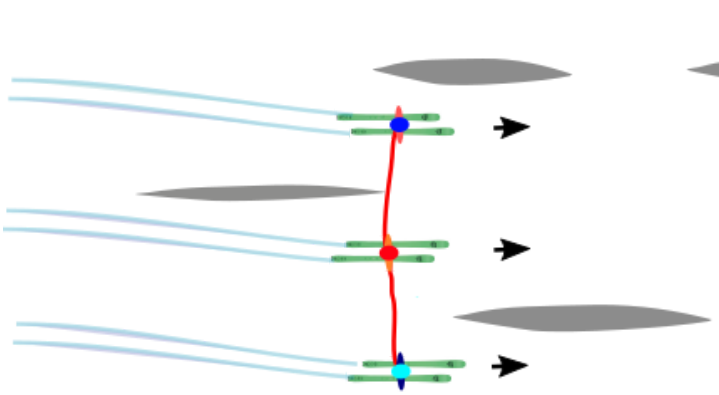
On approaching the edge of a crevasse or any suspect areas the leader can probe using their feet, ice axe or ski pole whilst the other team members are braced. Whenever in doubt. Put in a snow anchor and belay across.

Roped travel on skis

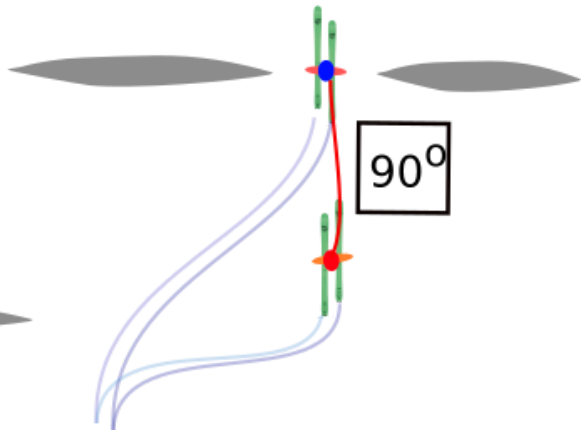
Roped glacier travel on skis should be a consideration in unfamiliar terrain or when visibility is poor. In downhill mode this is very difficult to manage so being roped up is most likely used when touring uphill.

As the slope angle increases, consideration must be given to the avalanche and slide hazards relative to any crevasse hazard. More so than on foot, ski tourers will have to zigzag which introduces issues with slack forming in the rope, and coming out of perpendicular with the crevassing.

When crossing obvious crevasses it is important to keep the rope between the members of the team tight and as close to 90° to the crevasses as possible.



Echelon formation



Crossing crevasses at 90 degrees

If travelling parallel to the crevasses, it can be advantageous to travel in echelon formation with the rope perpendicular to the direction of travel. This is to avoid more than one person standing over the same crevasse at the same time and avoids pendulum falls that can be difficult to arrest. Skis travelling parallel to crevasses however can increase the risk of punching through hidden snowbridges.

The rope between team members should not be too slack. A loose rope compromises the safety of the party as it increases the shock loading when a fall occurs and can dramatically reduce the chances of successfully holding a crevasse fall. Excessively loose rope can also pose a trip hazard. Too tight however can make it difficult for all members to maintain an efficient pace. A good tension is achieved when the rope is dancing along the snow surface at the bottom of its arc.

Crevasse rescue

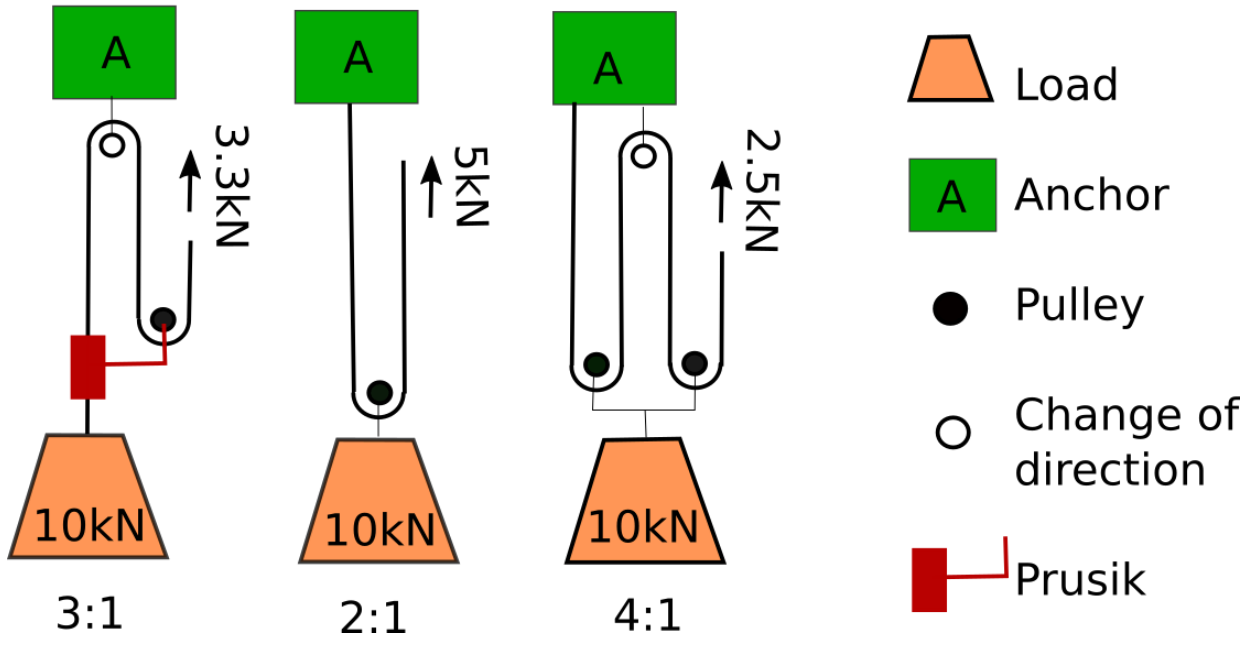
For any crevasse fall where the victim is injured and unable to extract themselves, the team members on the surface will have to execute a companion rescue.

Pulley systems

The aim of pulley systems is to use mechanical advantage to multiply the force of the pulling. The force required to pull decreases it but increases the amount of rope that has to be pulled through the system.

This is the theoretical value and in reality, the effect of stretch and friction reduces the effective advantage significantly. Friction is introduced at any point where the rope is running through a carabiner along the surface of the snow. Friction can be avoided by making sure the strands of rope are running neatly, using pulleys on carabiners if they are available and excavating snow from under all the moving parts of the system. If pulley devices are available, they should be used in priority on any moving pulleys (those moving towards the anchor). If only one pulley device is available, this should be placed as close as possible to the haul end of the rope so its benefit will be multiplied through the system to the load.

Pulley systems can be simple or compound. Simple systems use one continuous flow of rope.



Mechanical advantage of simple pulley systems

The mechanical advantage of simple pulley systems can be determined by:

- Measuring the distance the load moves relative to the rope being pulled through the pulley system.
- Counting the strands of rope in the pulley
- If the rope is fixed at the load end then the advantage of the pulley system will be odd (eg 1:3,5...). If the rope is fixed at the anchor end, the advantage will be even (eg 1:2,4,6..).
- Pulleys moving towards the anchor add advantage. If the rope runs through a carabiner or pulley and it doesn't move, it is referred to as a change of direction.

Progress capture

All pulley systems work best with a form of progress capture. This is a system that takes the load as progress is made, which means that the rescuer can take a break and the weight of the victim is taken directly on the anchor. Using an efficient progress capture will make the hauling easier and quicker.

For all pulley systems, it is useful to create a focal point with a bight knot for the progress capture about 3.5 meters away from the crevasse edge on the anchor rope. This provides an efficient space for hauling. If a brake knot on the live rope is in a suitable position, these can also be used.

There are a number of different options for progress capture;

Progress Capture Device - These small devices (eg Petzl Micro Traxion®) are the most efficient autoblock and are highly recommended. A Petzl Tibloc® is a mechanical prusik that can be used for ascending a rope and can be used as an efficient and simple progress capture.

Prusik - This is a simple but effective autoblock. A classic prusik hitch tends to work best. Using a Prusik Minding Pulley (PMP) instead of the belay device reduces friction.

Plaquette - Using a guide plate (eg Petzl Reverso® or Black Diamond ATC® Guide) as a progress capture introduces a lot of friction into the system and should only be used for smaller diameter ropes.

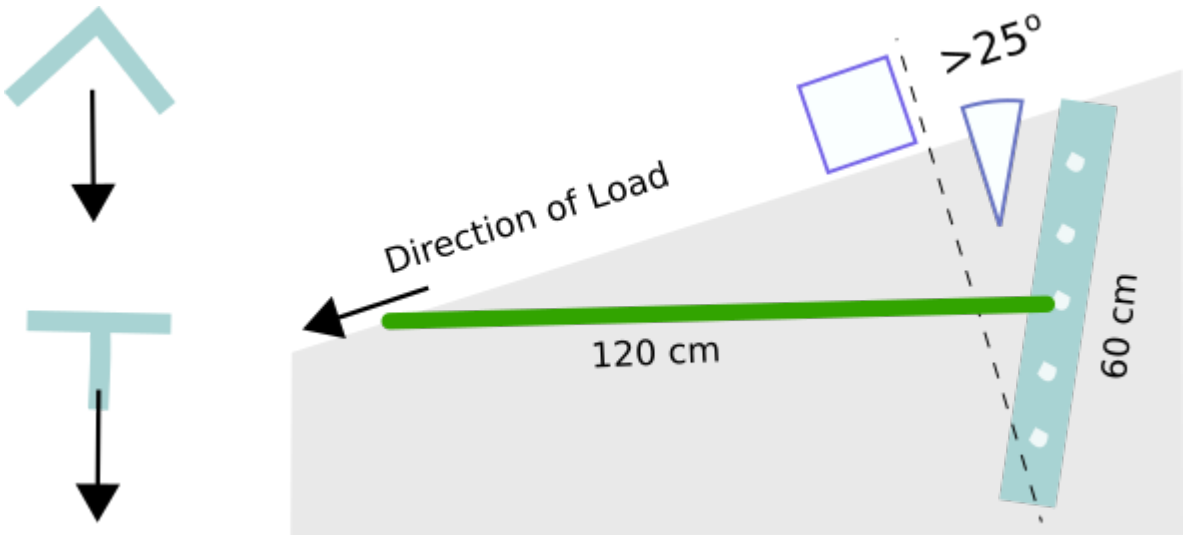
Snow anchors

In most situations, an anchor will need to be built, initially so that the rescuer can safely approach the edge of the crevasse to assess the situation. During the winter and spring seasons, ski tourers are likely to encounter soft snow on the surface of the glacier. In mid-winter and immediately after fresh snowfall, it may be dry snow. Later in the spring season, particularly after rain or a number of melt-freeze cycles, the snow will likely be wet.

Vertical mid-clip

If firm conditions are expected, usually encountered early in the morning during an established spring diurnal or melt-freeze cycle before the snow surface has released, snow stakes may be carried for snow anchors. The strongest possible orientation of snow stake anchors is the vertical mid-clip requiring a sling or cable attached to the middle of the stake.

The stake should be placed at least 25° back from perpendicular to the surface. For a V-shaped snow stake, the open part of the V points in the direction of the load and for a T shape, the spine points in the direction of the load. The channel for the attachment should be cut as narrow as possible with an ice axe pick or a snow saw and deep enough so it doesn't inadvertently pull upwards on the stake. Also, try not to disrupt the snow in front of the stake unless the snow in front of the stake can be compacted to increase strength.

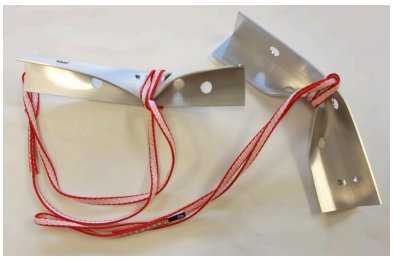


Vertical mid-clip

The wire cables and double-length slings are both 120cm long, twice the length of a typical snow stake. This is useful because if the top of the snow stake and the end of the wire/sling is

flush with the surface of the snow and the wire/sling is not kinked, the stake will be positioned at the correct angle back from perpendicular.

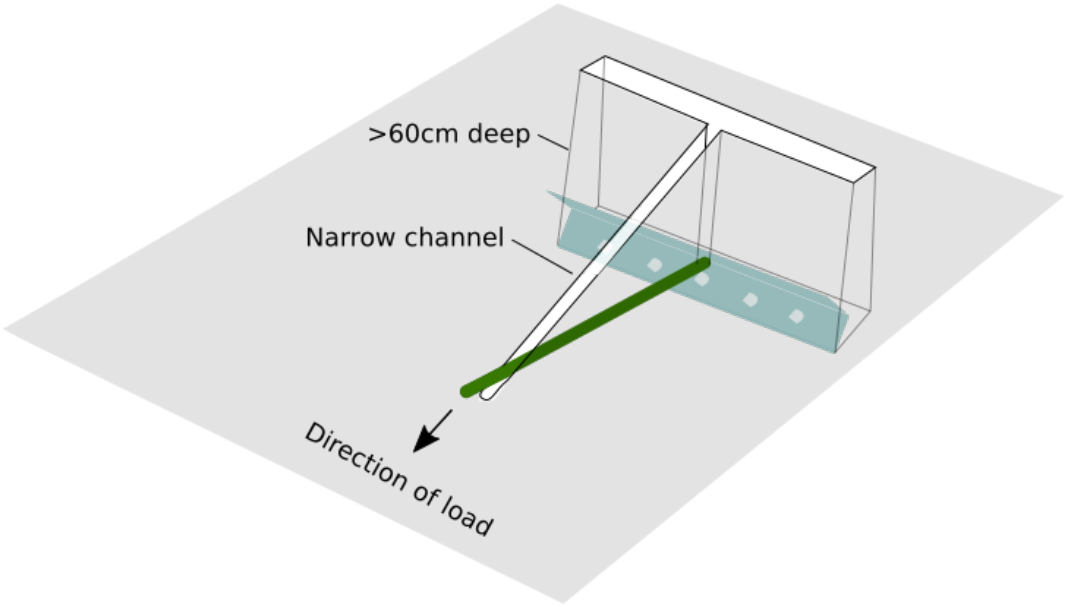
If a snow stake does not have a permanent mid-point attachment, the strongest possible improvised attachment is achieved by using a carabiner through the holes which is easier with a T stake. Improvising a mid-clip by larks footing a sling around a V stake should be avoided due to the potential for twisting and crushing the stake or sliding towards one end causing rotation of the stake. A clove hitch performs better.



Crushing of snow stakes by improvising a mid clip (Aspiring Safety)

Buried object

In soft snow, the strongest possible anchors are created by placing an object with the biggest surface area as possible, as deep as possible. This can be a snow stake, skis, backpacks or stuff sacks filled with snow. Skis should be placed with bases facing each other or using skins or some other padding to protect the sling from getting damaged on the edges if using one ski and with a sling hitched around the midpoint of the ski for an attachment.



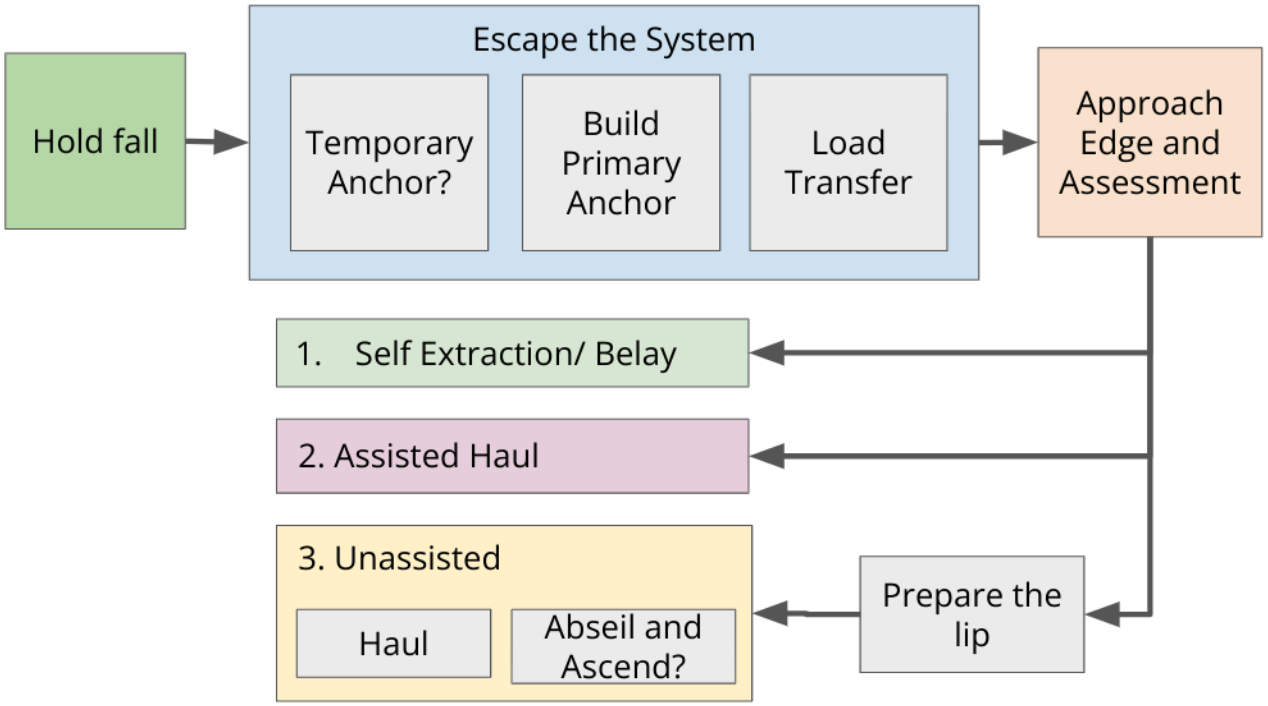
T-slot (or buried object)

Whilst digging the slot, observe the snow hardness and any weak layers that will affect the strength of the placement. The channel for the attachment must be as narrow as possible and the front face of the slot can also be undercut. The channel must be deep enough for the attachment sling to run straight and not inadvertently pull upwards on the skis.

If wet snow can be formed into a snowball, it can be made stronger through compacting with hands. Otherwise, or if the snow is dry, it is best not to disturb the snow in front of the anchor. Unless the snow is compatible, the snow in front of the T-slot should not be disturbed. Backfilling the slot does not increase the strength of the placement.

Companion rescue

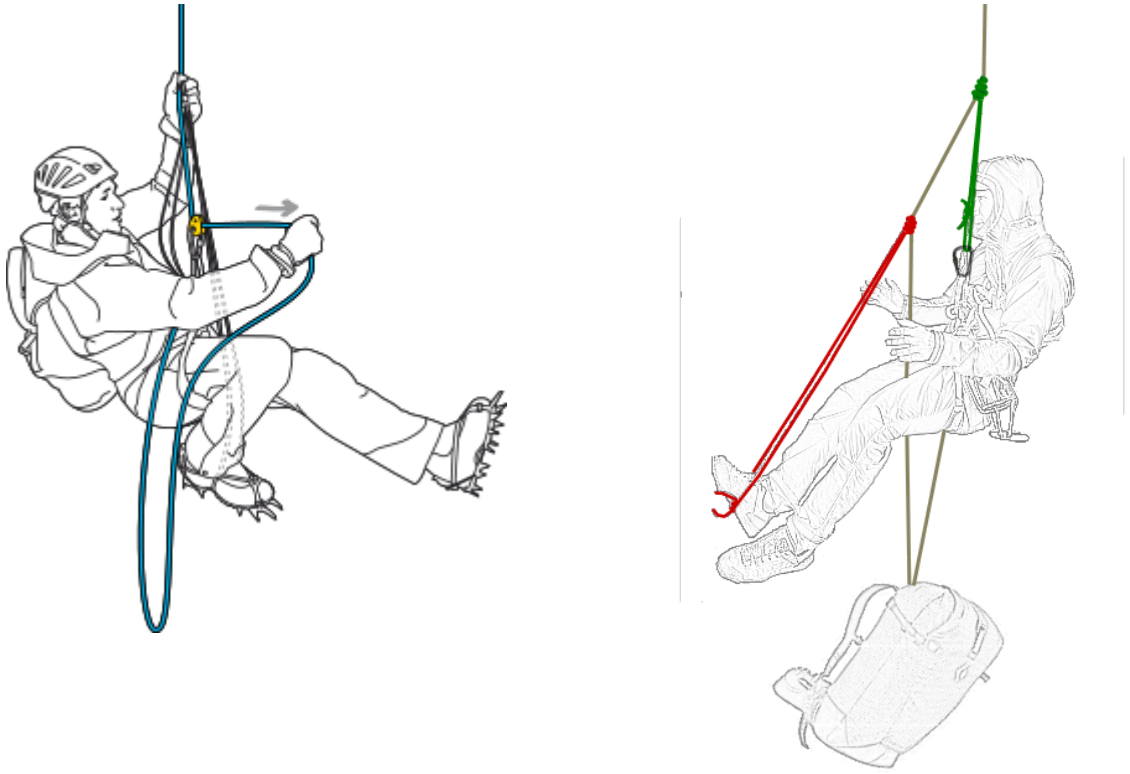
Companion crevasse rescue for a roped fall requires the rescuer to first hold the fall and then transfer the load to a suitable anchor. This might be all that will be required and allow the victim to get out either by ascending the rope or climbing the wall of the crevasse. Alternatively, a simple haul may be required. The likelihood of needing to do a complicated hauling system on an unresponsive victim is low for a roped crevasse fall.



Self-extraction

Most of the time, when someone comes across a hidden crevasse, they may find themselves up to their waist, the added surface area of the underside of their backpack stopping them from falling further. If they end up further in the crevasse and the sides are not too steep, then they may be able to climb out with a belay from above. If hanging in space, then the easiest solution is to ascend the rope.

The options to ascend the rope are using two prusiks or a microtraxion® and a prusik. With two prusiks, there is a 'waist' attached to the belay loop of the harness and a longer 'leg' prusik below. Alternating the load on these two prusiks allows the other to be moved up the rope. When using a microtraxion®, these are flipped so the single 'leg' prusik is above the micotraxion® attached to the belay loop.



Ascending a rope using a microtraxion® and leg prusik (Petzl) and 2 prusiks

The weight of a heavy pack will be uncomfortable so it is best to clip to the live rope between the victim's harness and the lip. A pre-rigged tether makes this easier. It can then be shrugged off their shoulders and left to dangle beneath their feet. The weight of the pack puts tension on the rope, making sliding prusiks up the rope easier and creating a basic pulley system to pull the pack out once you get to the surface.

When using two prusiks, the victim is relying on the waist prusik to grip. As the rope is ascended a loop of slack rope will be created between the victim's harness and their ascending prusiks. If these prusiks were to slip, they would end up back where they started at the end of the tight live rope. Attaching the slack rope to a carabiner on their belay loop with a clove hitch acts as a backup and limits any slip. Using a clove hitch means that every few metres they can bring up the slack without untying the hitch.

If ascending the live rope with brake knots, they will need to be passed. Bight knots can be clipped into directly to allow the ascending devices to be manoeuvred past them.

Holding a crevasse fall

Whilst mountaineering or trekkers will be roped up on glaciers having to hold an unexpected crevasse fall where the victim falls deep in a crevasse is uncommon but can be very difficult, especially in icy conditions. If at all unsure of crevasse crossings build an anchor and belay the team across.

If a member of a rope team unexpectedly falls into the crevasse, all other team members must react quickly and appropriately. Ski tourers may not be roped up which increases the severity of any crevasse fall. Unroped victims should be secured as soon as possible. Hauling systems used will be similar to those below but without the tensioned live rope with brake knots.

In the event of a roped crevasse fall, team members on the surface will feel a resounding jolt in the rope and should instantly drop their bodies towards the snow trying to maintain stability or grip with their feet as much as possible. Getting the centre of gravity down quickly reduces the risk of being dragged off their feet and into the crevasse along with their climbing partner.

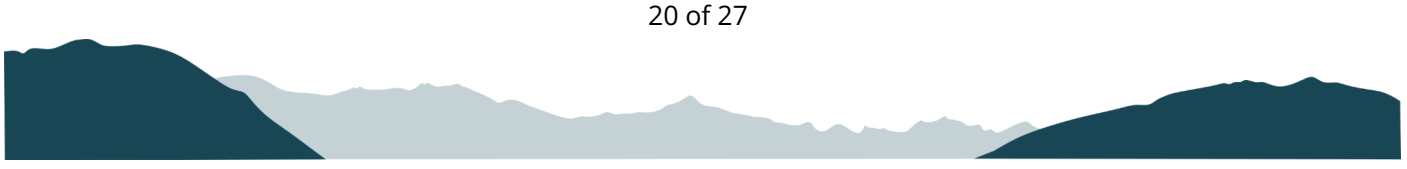
If the rope continues to pull, get into the self-arrest position using your ice axe and the front points of your crampons to stop the slip from escalating into an uncontrolled slide. Brake knots in the rope will also assist with this.

Once stationary they should stamp the heels of their feet into the snow and manoeuvre into a strong upright sitting position.

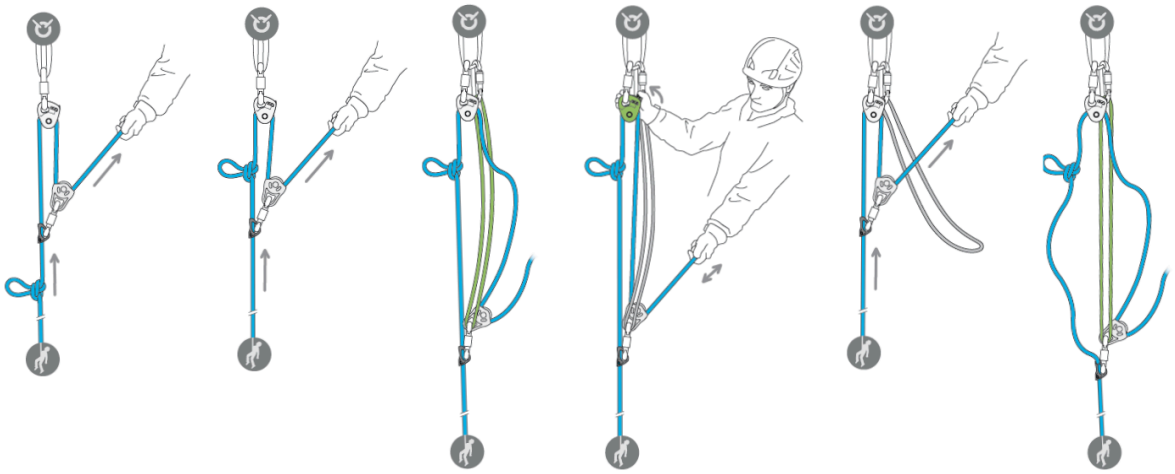
Live line or rescue line hauls

The live line, or the rope that joins the two members of the rope team is likely to have dug into the snow soft on the edge of the crevasse. It is possible to haul someone up on this line in the case of a simple scenario and this will be necessary if no spare rope is carried. Using a live line haul introduces further considerations:

- There will be increased resistance of the brake knots travelling through the snow.



- The brake knots will need to be removed from the loaded rope using a simple releasable load transfer.
- If the victim is unable to assist, they can get pulled into the snow at the edge or lip of the crevasse.



Live line haul (Petzl)

The hauling systems described below are all created using the spare untensioned rope and although contain a few more steps than a direct live line haul, allow for problem-solving and avoid the potential issues of a live line haul.

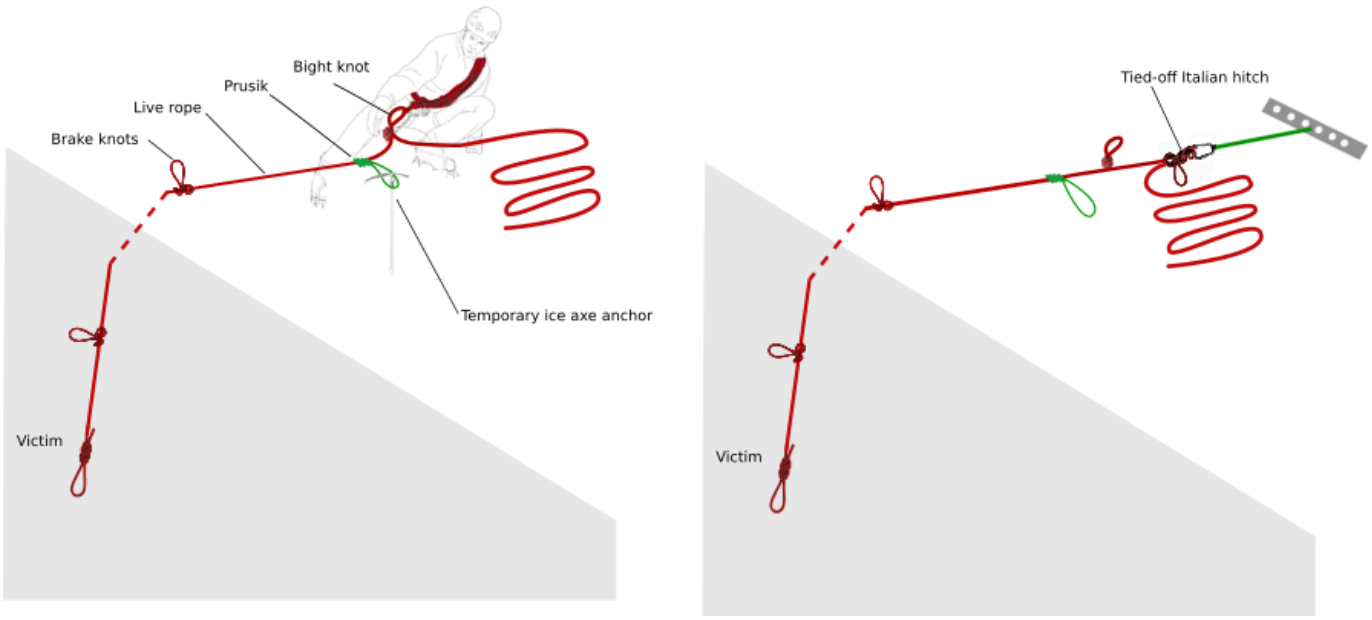
Escaping the system

The most important stage of companion rescue is successfully holding the initial fall. The next step is for the rescuer on the surface to escape the system so they are free to proceed with the later stages of crevasse rescue:

1. If the brake knots in the live rope are dug into the snow and take most of the weight the rescuer may have enough freedom of movement to construct a good snow anchor comfortably from their seated position.
2. Otherwise, they can use an ice axe with the shaft through a prusik on the live rope in front of the bight knot attachment to create a temporary anchor. Slowly ease the load of the fallen climber onto the ice axe, keeping a foot on the head of the ice axe to prevent it from lifting out. This will then provide enough freedom to take off the pack to access a snow stake and build a primary anchor. The rescuer must stay attached to the bight knot as a backup to the temporary anchor;
3. Attach the rope to the primary anchor. This will be the unloaded spare rope stored in a sack or coils behind the attachment to the live rope. A tied-off Italian hitch is the

preferred way to attach the live rope to the anchor as it leaves options open for multiple scenarios and rescue line hauls. For simple situations, a microtraxion® can be used for a live line haul.

4. There will be slack rope between the temporary anchor and the tied-off Italian hitch. Take the load on the bight knot, remove the temporary anchor and ease forward until the load comes slowly directly onto the primary anchor. The rescuer will then be able to detach themselves from the tensioned live rope.



Escaping the system using an optional temporary anchor and live line tie off

Preparing the lip

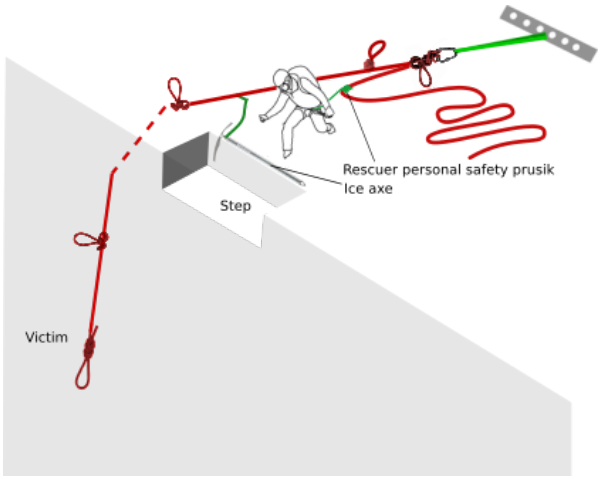
In order to safely approach the edge of the crevasse to assess the situation, the rescuer needs to be attached to the anchor and protected from falling into the crevasse. Place a personal safety prusik hitch around the rope attached to the anchor, extended if required using a cowstail or PAS, and keep it tight as the edge is approached.

Once at the edge, the rescuer will be able to re-establish communication with their partner and assess the situation. More often than not the victim has been busy extracting themselves and it is not uncommon to find them just below the crevasse lip struggling with the last meter or so where the live rope has dug in.

Whether the victim has self-extracted or is incapacitated and requires being hauled up, it is vital to prepare the crevasse lip to make it as easy as possible to get them out. This is done by building an inset step into the crevasse edge with feet or an ice axe (or snow shovel if available). Warn the victim before doing this so they can be prepared for the snow and ice

that will likely be knocked down on top of them. The rescuer will also need to take note of where the buried rope is cut into the snow to avoid digging through it. Take the time to do this well as it will make getting the victim out of the crevasse a lot easier.

Once dug, the ice axe can be placed lengthwise along the top edge of the step to run the rope over. This avoids the rope cutting further into the snow and also helps to reduce friction when hauling. It is a good idea to clip the leash of the ice axe into the live rope to avoid it being dislodged and losing it into the crevasse.



Preparing the lip

Simple pulley systems

Rescue line hauling

If the rescuer reaches the edge of the crevasse and the victim is not able to prusik out themselves, then the rescuer needs to construct a pulley system to haul the victim out. In the unlikely event that the victim is also incapacitated to the extent that they can't clip themselves into the rescue rope that is sent down to them, the rescuer will have to abseil down, attach the victim and prusik out - a more time-consuming and complicated procedure.

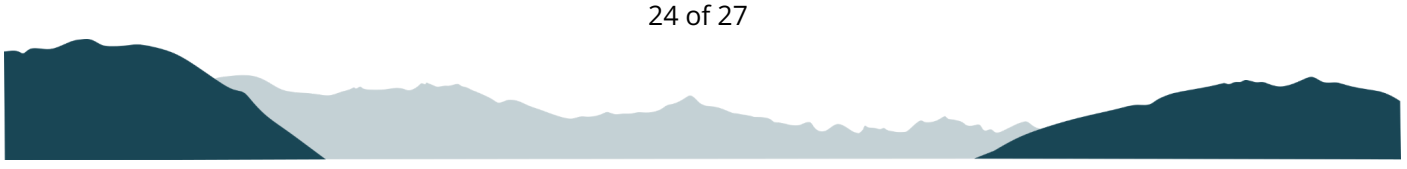
Hauling is hard work, no matter what system the rescuer has created. For best results keep the pull rescue close to parallel with the snow surface and use stronger leg muscles rather than arms. A seated rowing position works well. Another option is to attach the rescue rope to a carabiner on the belay loop (a clove hitch can be adjusted and relatively easy to release after being loaded), face away from the crevasse and 'climb' along the surface using legs to pull the rescue rope.

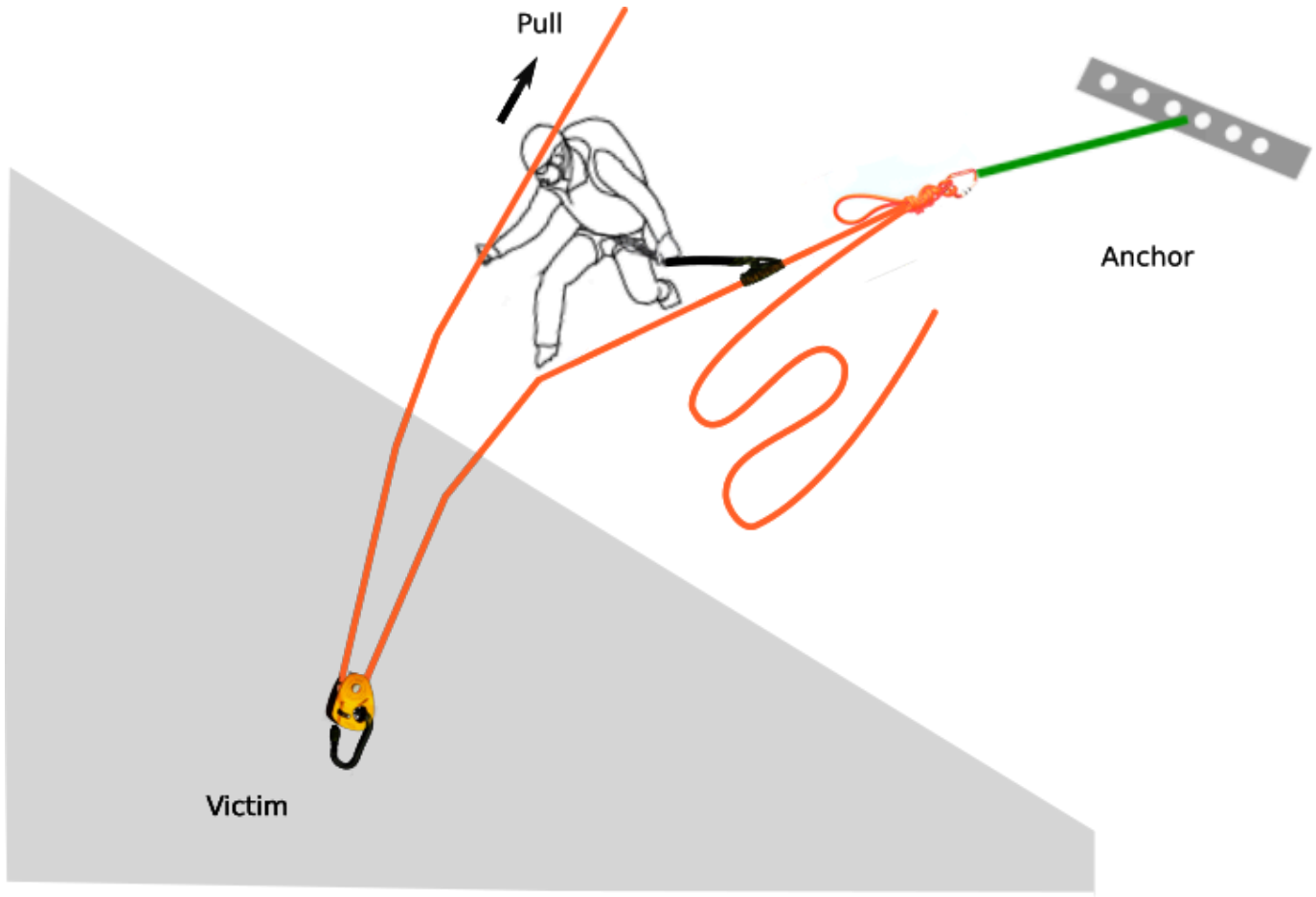
Assisted hoist

The simplest pulley system is an assisted hoist (also known as a drop loop). It has a 2:1 mechanical advantage so works best when the victim can help or there are a few people on the surface to pull. If the victim is incapacitated and there is only one rescuer, a more complicated hauling system with more mechanical advantage will probably be needed.

The rescuer can drop a loop of rope down to the victim with a progress capture device attached freely that the victim can clip to their harness. The end of the rope should be secured to the anchor to close this loop. This makes the hoist a direct haul and very efficient. If the victim is capable, minimal lip preparation is required.

The victim can assist by pulling on the anchor rope. This is the strand of rope that is moving towards them as they travel upwards. The rescuer will pull on the rescue rope.

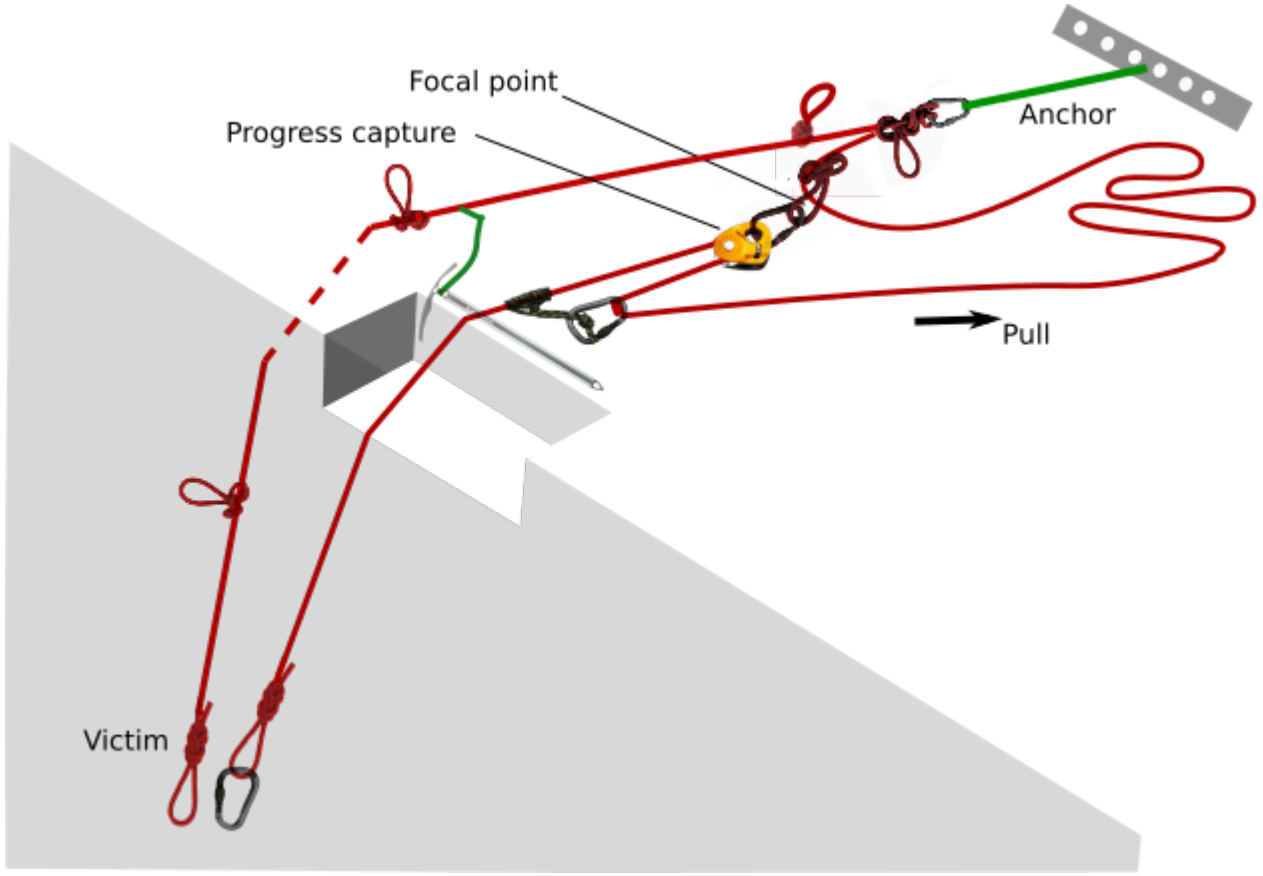




Assisted (drop loop) hoist (2:1)

Unassisted hoist

If the victim is unable to assist, more mechanical advantage is needed. An unassisted hoist (also known as a Z haul) has a mechanical advantage of 3:1 so will require more effort on the surface to haul out the victim. This is constructed in a similar way to the assisted hoist but instead of dropping a loop down to the victim, the rescuer sends the end of the rope for the victim to clip into and all the moving elements of the hauling system are created on the surface.



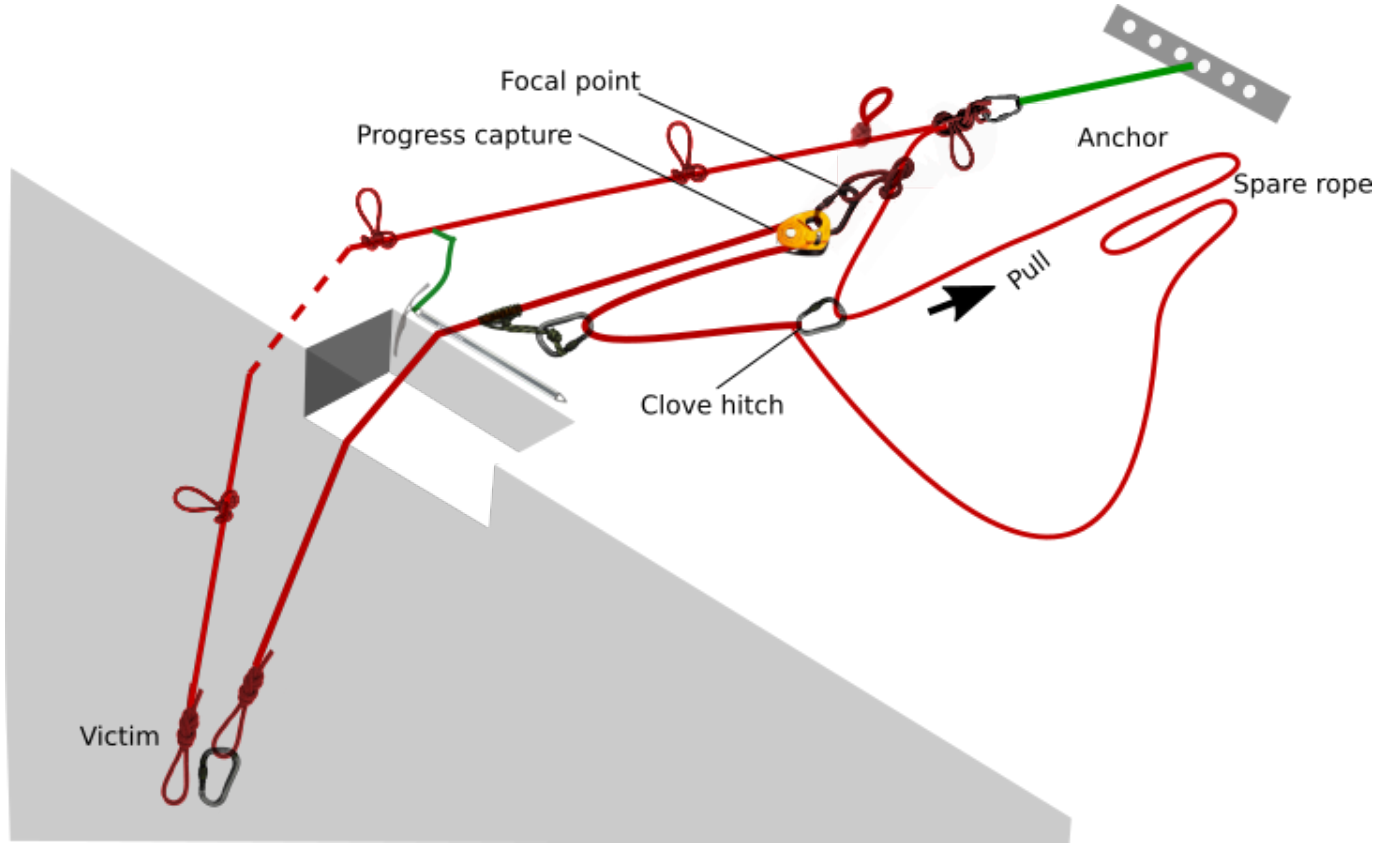
Unassisted hoist (Z haul) (3:1)

It is also possible to construct an unassisted hoist directly onto the live rope without dropping an end of the rope down to the victim. This may not work efficiently if there are brake knots in the rope and they have dug deep into the snow.

Compound pulley systems

For a simple pulley system, increasing the theoretical mechanical advantage beyond 4 or 5:1 tends not to increase the practical advantage due to increasing friction and inefficiencies of the equipment.

If a simple hauling system is not working then a bigger mechanical advantage may be required. This can be achieved by combining two simple systems into a compound system. The mechanical advantage of a compound pulley system can be determined by multiplying the mechanical advantage of the individual systems together. Compound systems can be identified by having individual pulleys that travel towards the anchor at different speeds during the haul.



Compound (6:1) - Z haul 3:1 with extra 2:1