



Wānaka Mountain Guides

Mountaineering Manual

Section 3: Glacier Travel and Crevasse Rescue

Travel 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 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.

Roping up for glacier travel

Mountaineers typically carry a rope between 30 and 60 metres 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 crevasse falls. Any crevasse fall could potentially result in injury and at the least prove time consuming.

For two people to move together with even 30 metres of rope between them is difficult to manage so the rope is typically shortened to between 8 to 12 metres with the excess rope divided and carried by each person. Having excess rope is important for companion rescue. This spacing is dictated by what is known about the size of the crevasses and the distance between them in the area that they are travelling. 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.

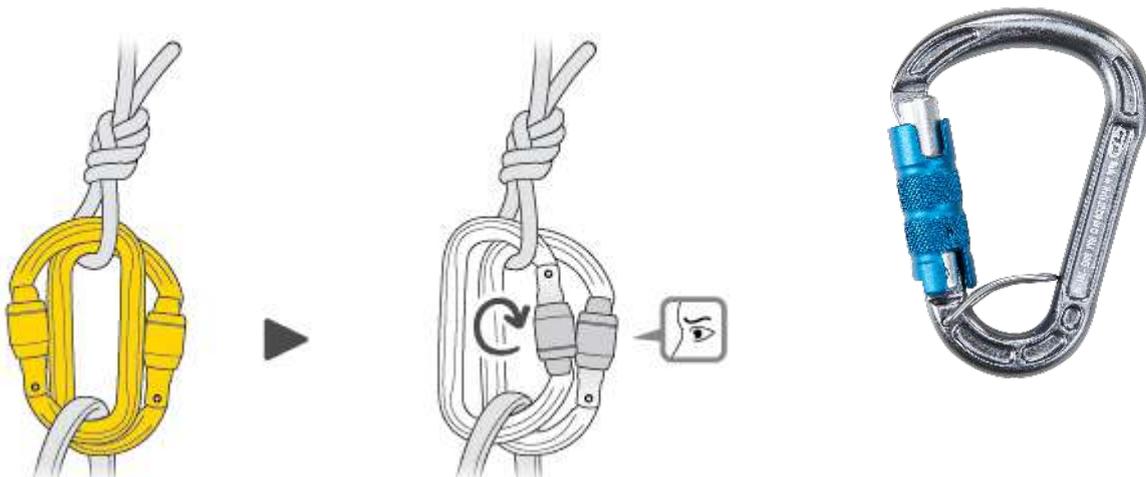
Shortening the rope

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.

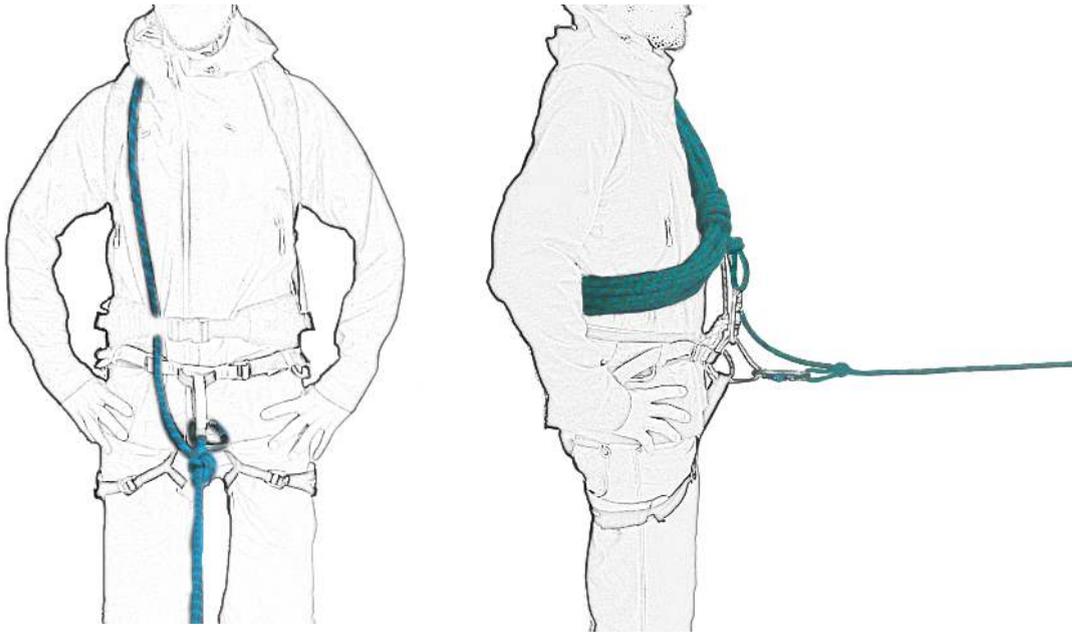
To stack the rope, start by feeding the end of the rope or from the tie-in to the harness into the top of the pack or a stuff sack until the bight knot at the chosen spacing is reached. Stacking the rope into a stuff sack before putting in the pack is useful as the sack can easily be taken out to access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





Clipping into rope with a bight knot and rope in stacked in pack

Blocked 'Kiwi' coils with low tie-off

Blocked 'Kiwi' coils

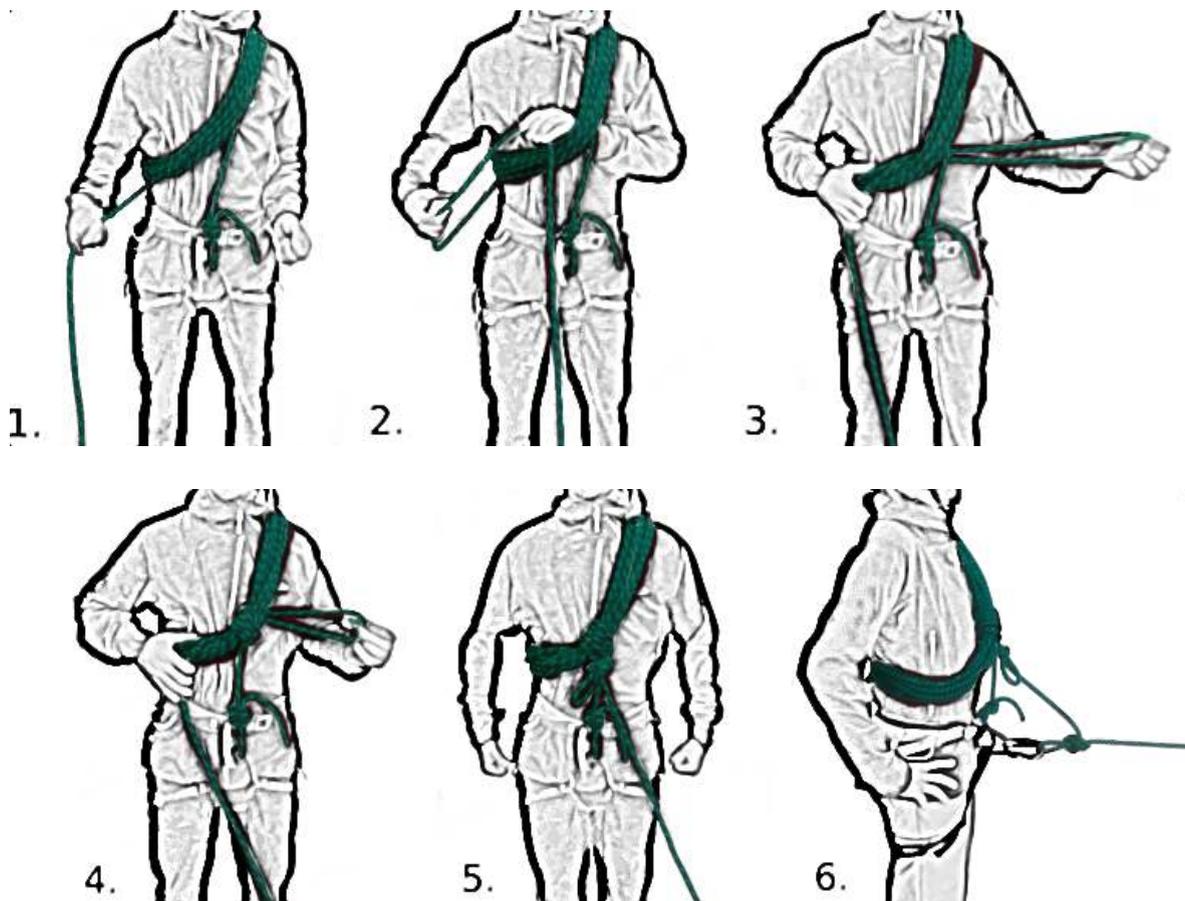
If backpacks are too full to stack the excess rope in, or the rope needs to be more easily accessible, the rope can be secured around the body in coils. Blocked 'Kiwi' coils are most commonly used for glacier travel. They take longer to adjust than unblocked coils but have the advantage of staying neat 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 course of 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 left shoulder so coils are taken around 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 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 it loosening during movement.



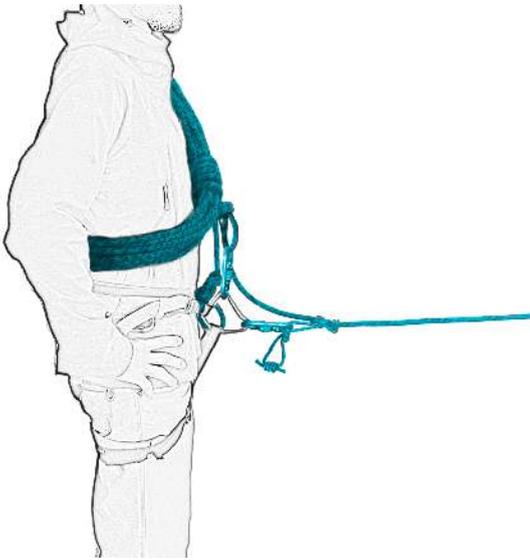
Blocked 'Kiwi' coil for shortening the rope for glacier travel

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 belay loop into a bight knot in the middle of the rope using a directional carabiner. Alternatively they could tie directly in with a rethreaded overhand knot. The distance between each person should still be between 8 to 10 metres.



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.

Brake knots

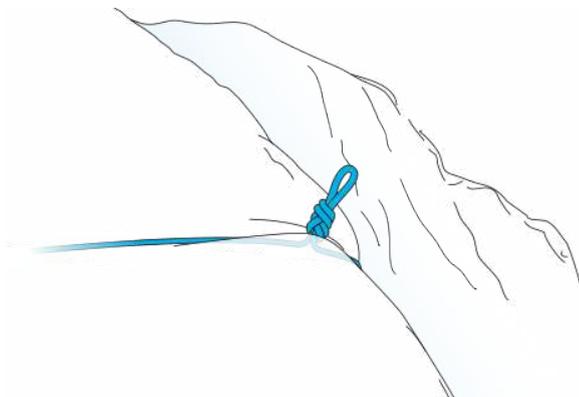


Figure 8 on a bight brake knot (Petzl)

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 metres 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)



Glacier travel

Identifying crevasse hazards



Good route finding on snow covered glaciers will reduce exposure to falling in a crevasse. Complex crevasse systems are likely to be found by analysing the terrain and identifying areas of the glaciers that are steeper, in tension (over convexities) or where there is more friction (towards the sides).

Crevasses may be visibly indicated by cracks or slumps of the snow surface and it is possible to extrapolate outwards to give an indication of other areas. can be avoided or

managed. Surface 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 temperature¹ commonly encountered mid winter, will be weak, whereas older snow that has consolidated through a number of melt freeze cycles will be stronger, more typical of the warmer spring season.

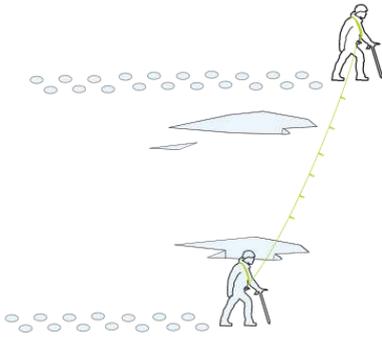
When travelling near visible crevasses, determining the characteristics and shape of the shape of the crevasses will assist with route finding. Bell shaped crevasse get wider as they get deeper and should be given a wide berth. Narrow parallel or constricting crevasses can often be stepped over.

Crossing crevasses

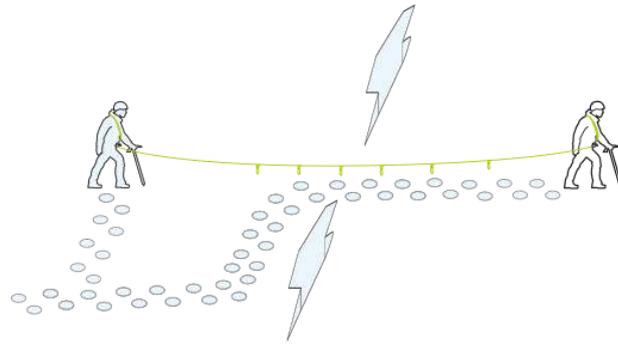
When crossing visible or potentially hidden crevasses it is important to try to keep the rope between members of the team tight and as close to 90° to the crevasses as possible. This may require different team members to take different lines.

¹ Snowpack metamorphosis also has implications on avalanche problem formation.





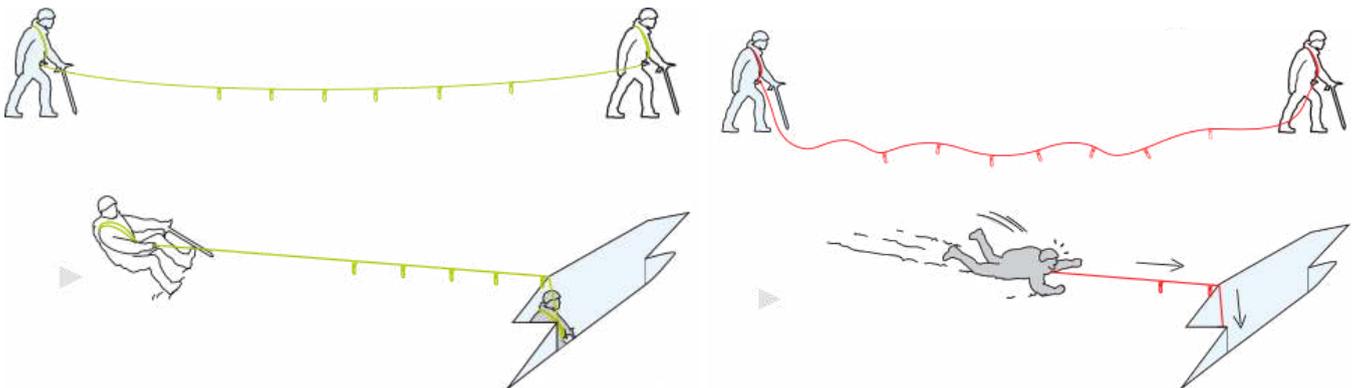
Echelon formation



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.

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.



Crevasse rescue

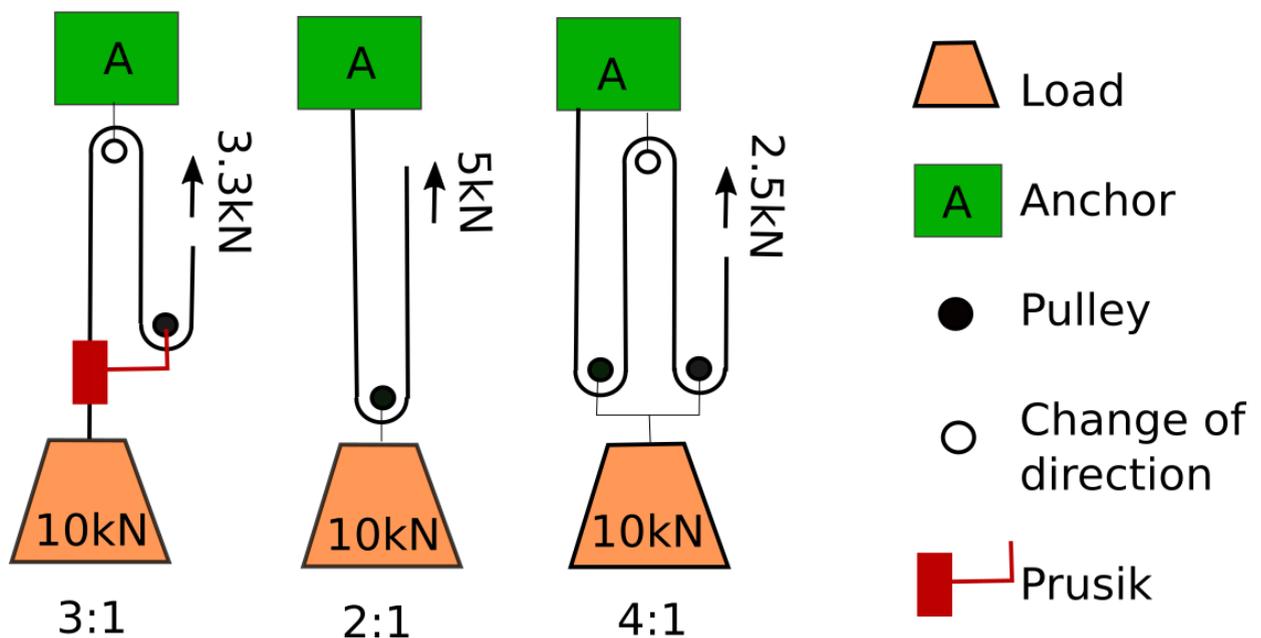
For any crevasse fall where the victim is injured and unable to extract themselves, the team members on the surface will have to execute a companion rescue.

Pulley systems

The aim with 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



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 metres 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 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.



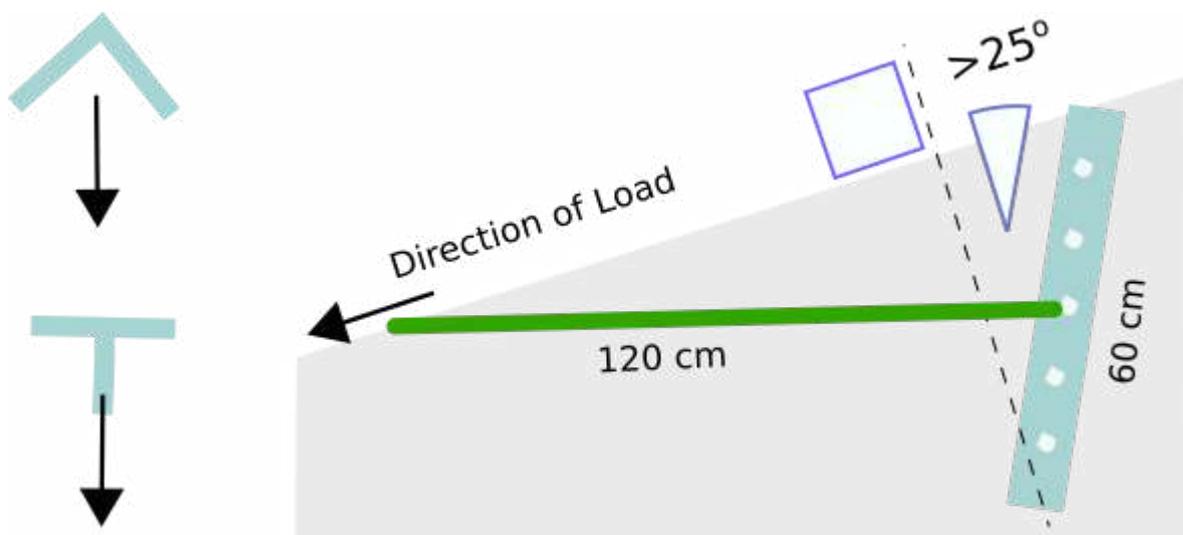
Snow anchors

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 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 potential for twisting and crushing the stake or sliding towards one end causing rotation of the stake. A clove hitch performs better.

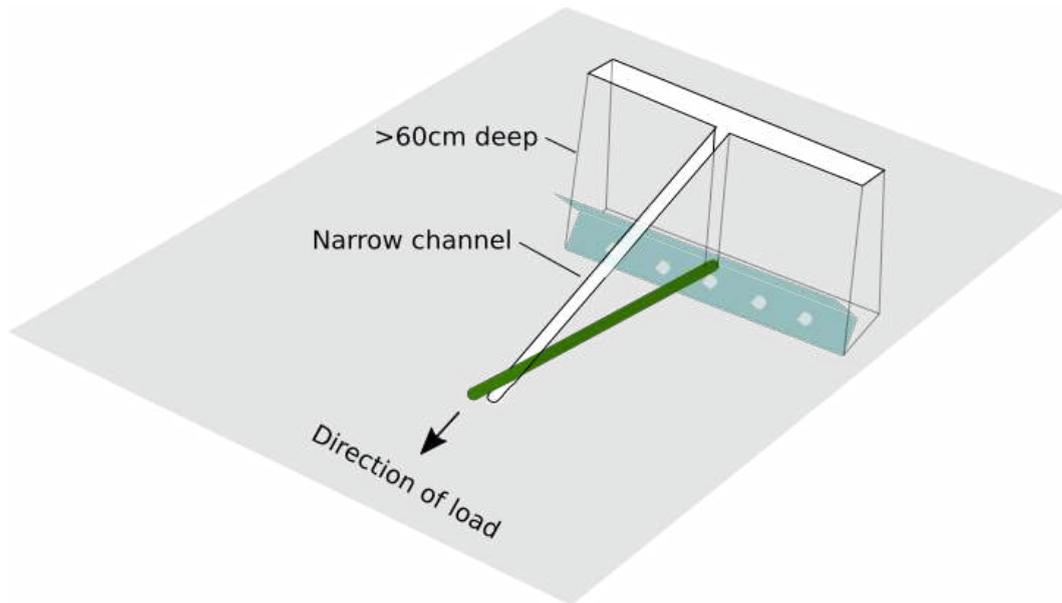


Crushing of snow stakes by improvising a mid clip ([Aspiring Safety](#))

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)

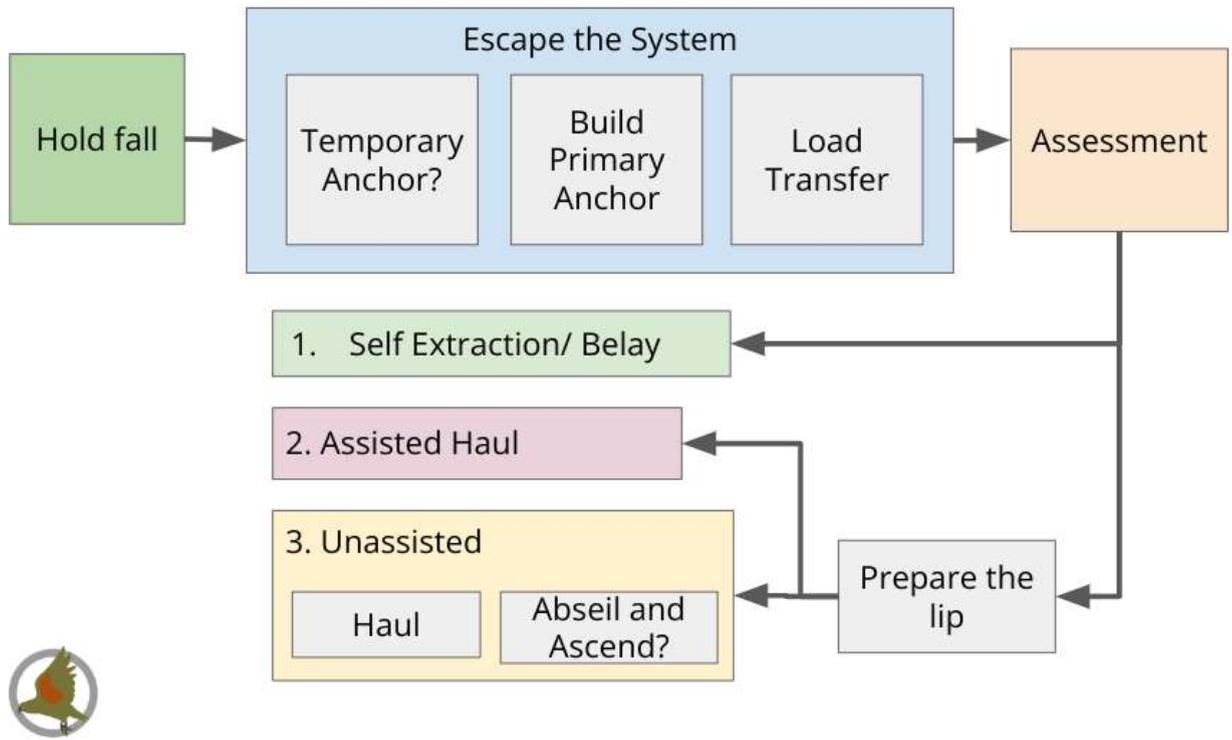
Whilst digging the slot, observe the snow hardness and any weak layers that will affect the strength of the placement. The channel for the attachment must be as narrow as possible and the front face of the slot can also be undercut. The channel must be deep enough for the attachment sling to run straight 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 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.

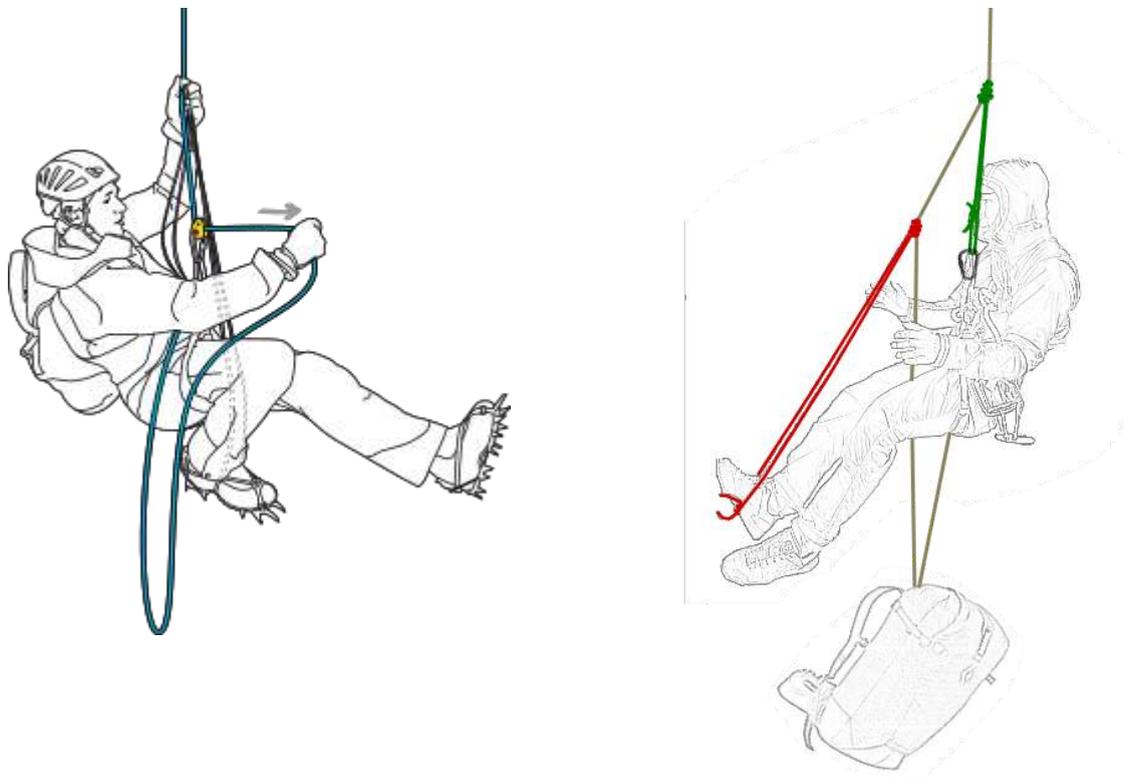




Self-extraction

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 on a snowbridge 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. By 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 microtraxion® 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 but 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. By 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 escalating into an uncontrolled slide. Brake knots in the rope will also assist with this.

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

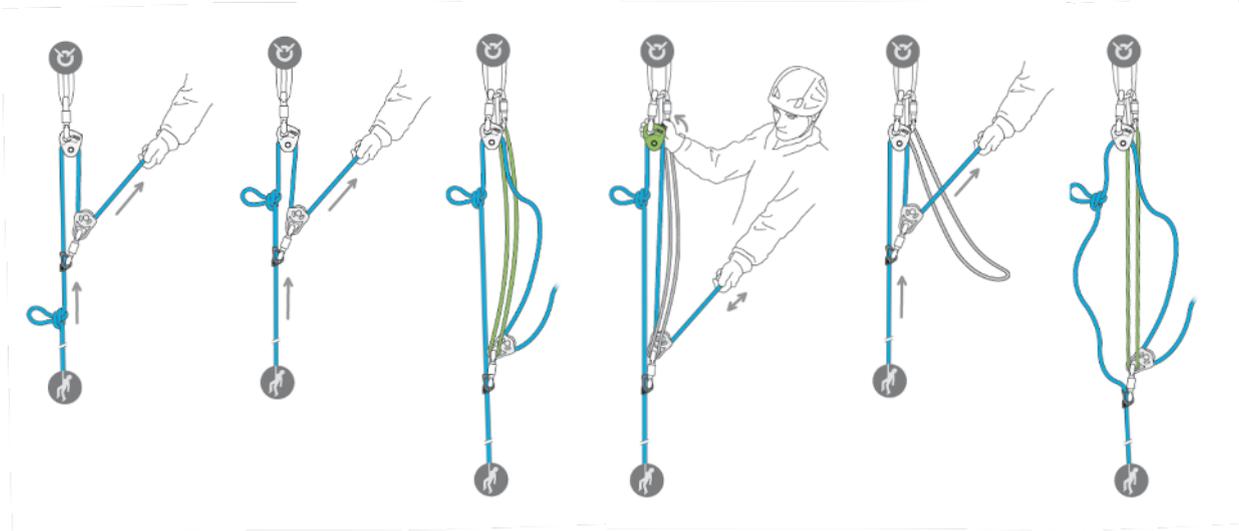
Live line or rescue line hauls

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 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

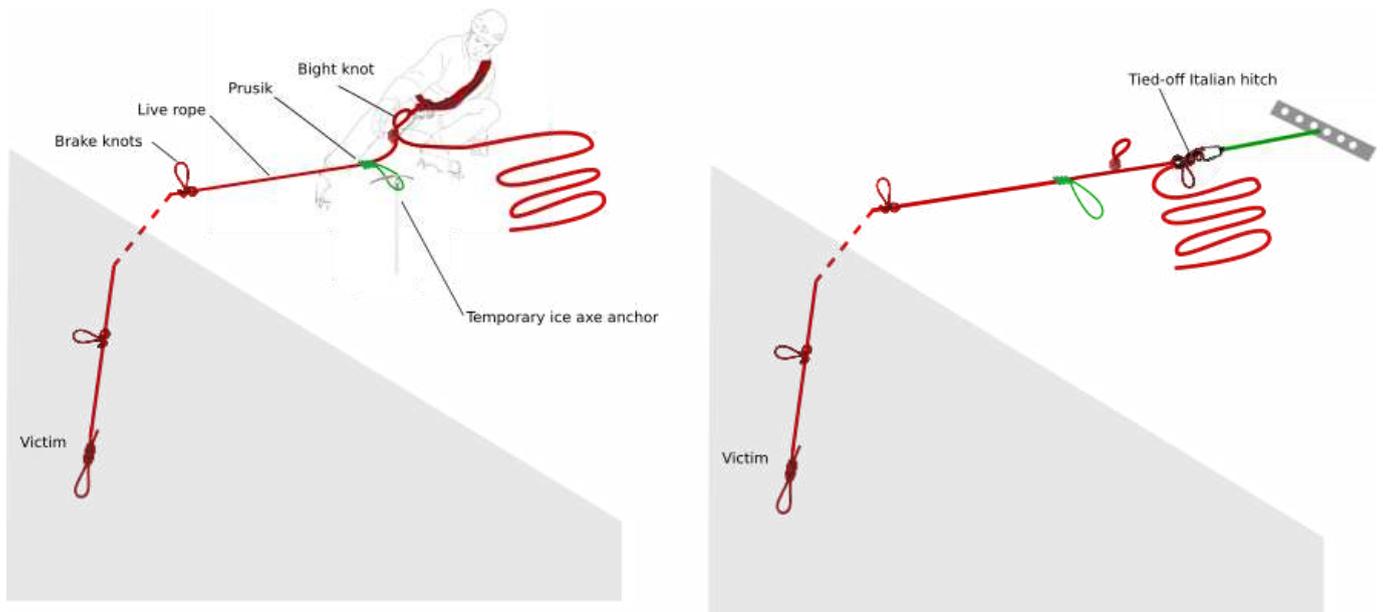
The most important stage of companion rescue is successfully holding the initial fall. The next step is for the rescuer on the surface to escape the system so they are free to proceed with the later stages of crevasse rescue:

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 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 and low uncertainty situations, a microtraxion® can be used for a live live haul.

- 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.

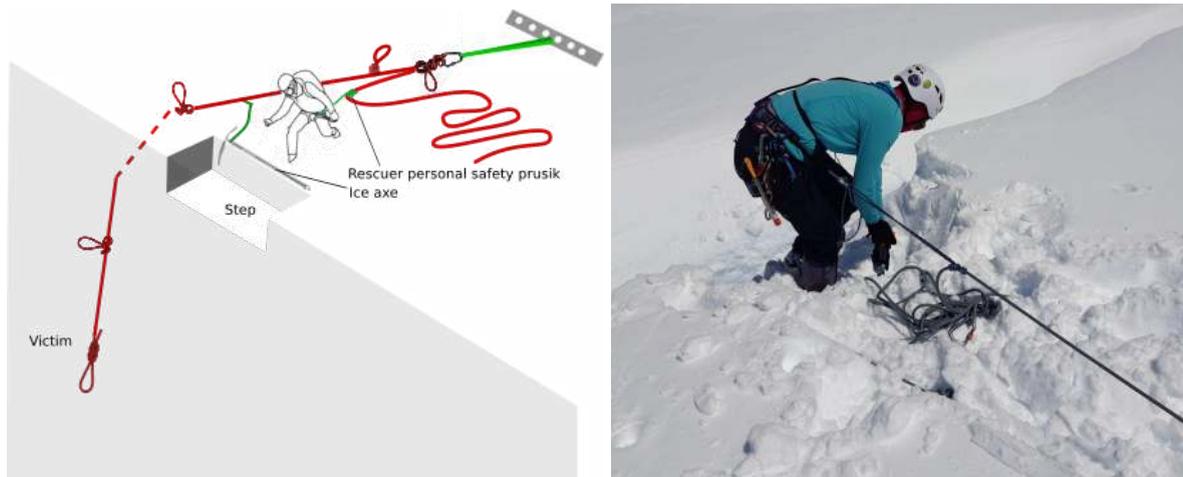
Once at the edge, the rescuer will be able to re-establish communication with their partner and assess the situation. More often than not the victim has been busy extracting themselves and it is not uncommon to find them just below the crevasse lip struggling with the last metre or so where the live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

Whether the victim has self-extracted themselves or are incapacitated and require 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

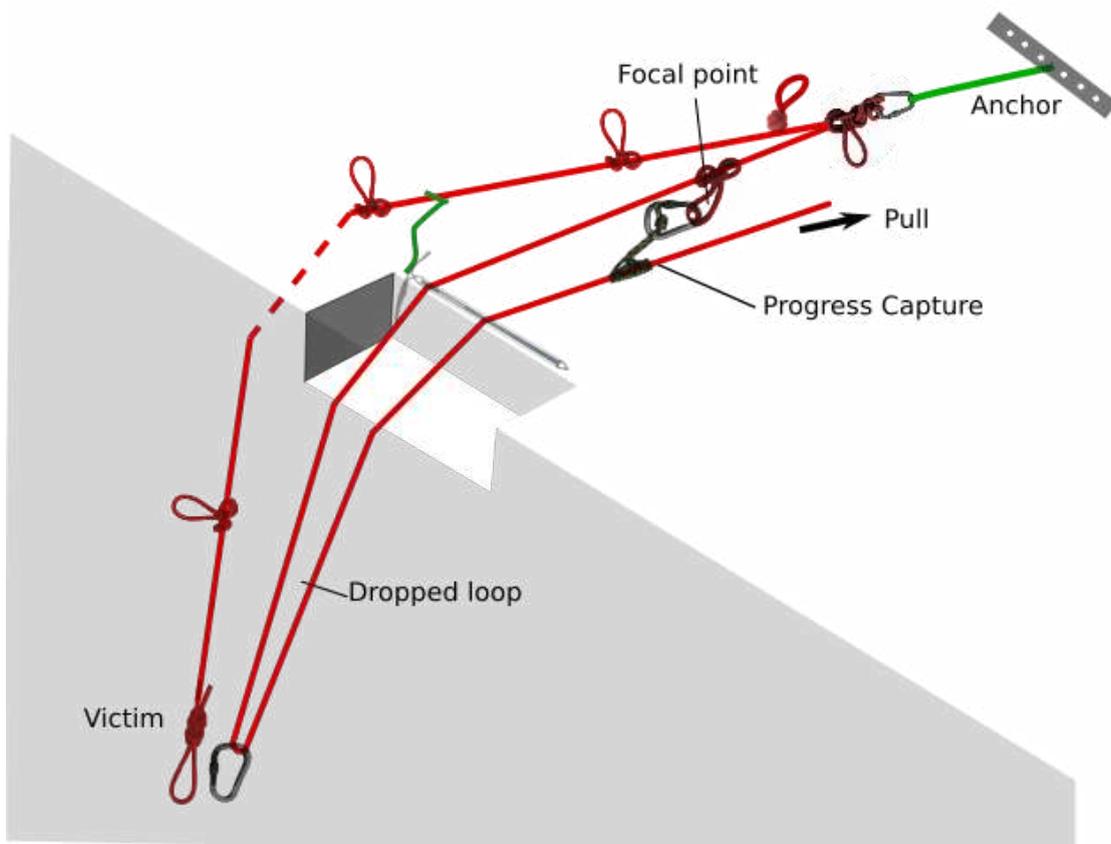
The simplest pulley system is an assisted hoist (also known as a drop loop). It has a 2:1 mechanical advantage so works best when the victim is able to help or there are a few people



on the surface to pull. If the victim is incapacitated and/or there is only one rescuer, a more complicated hauling system with more mechanical advantage will probably be needed.

To build an assisted hoist:

1. Drop a loop of rope down to the victim with a screwgate carabiner freely attached that the victim can clip to their harness. If the rescuer or the victim has a pulley, this is the best place to use it;
2. If the victim is able to assist, or may be able to climb up the sides of the crevasse, then putting a micro traxion on their harness creates a quick and efficient system. This is the 2:1 direct pull.
3. Alternatively, a progress capture is created on the surface. Take the slack out of the drop loop by pulling up on the rescue rope and add a progress capture to the rescue rope. This can be a simple prusik or more efficient mechanical device;
4. 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 whilst making sure that the slack rope travels through the progress capture.

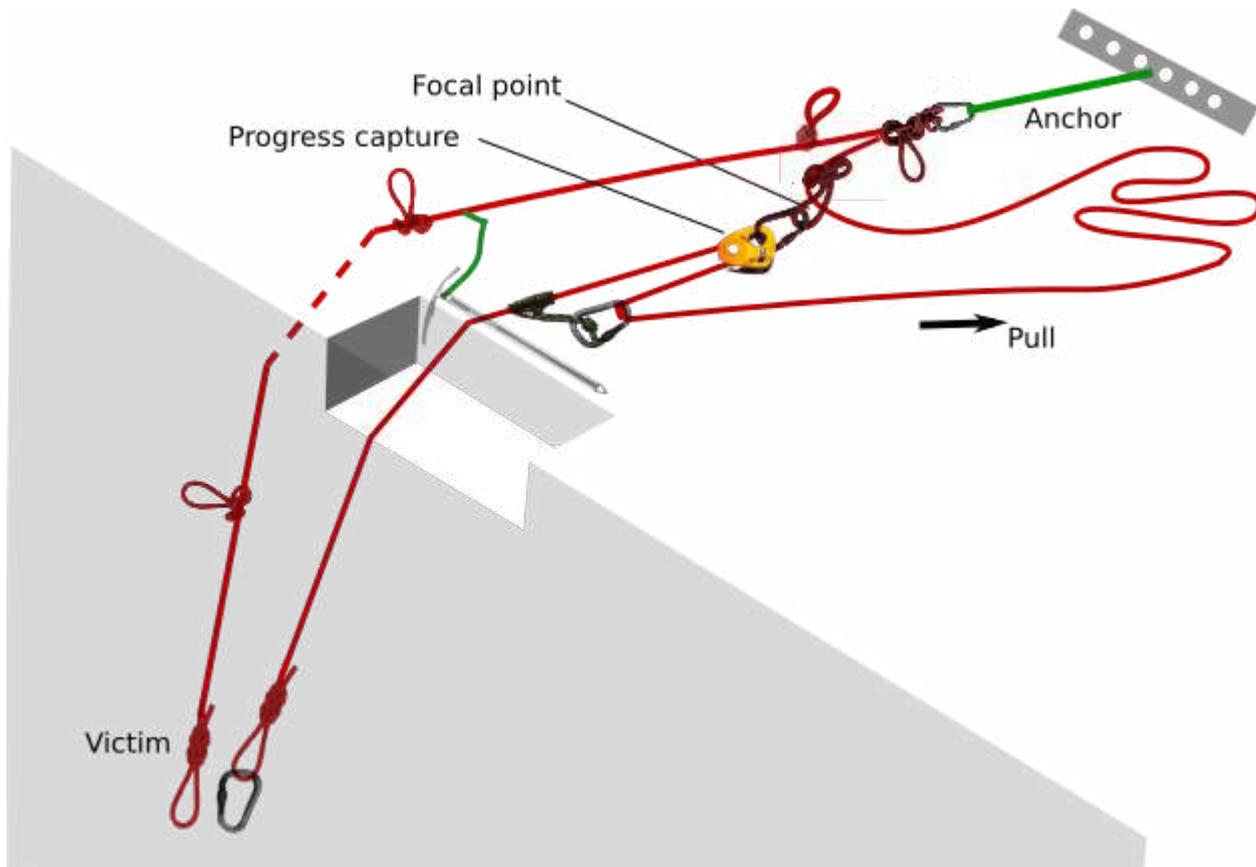


Assisted (drop loop) hoist (2:1)



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.



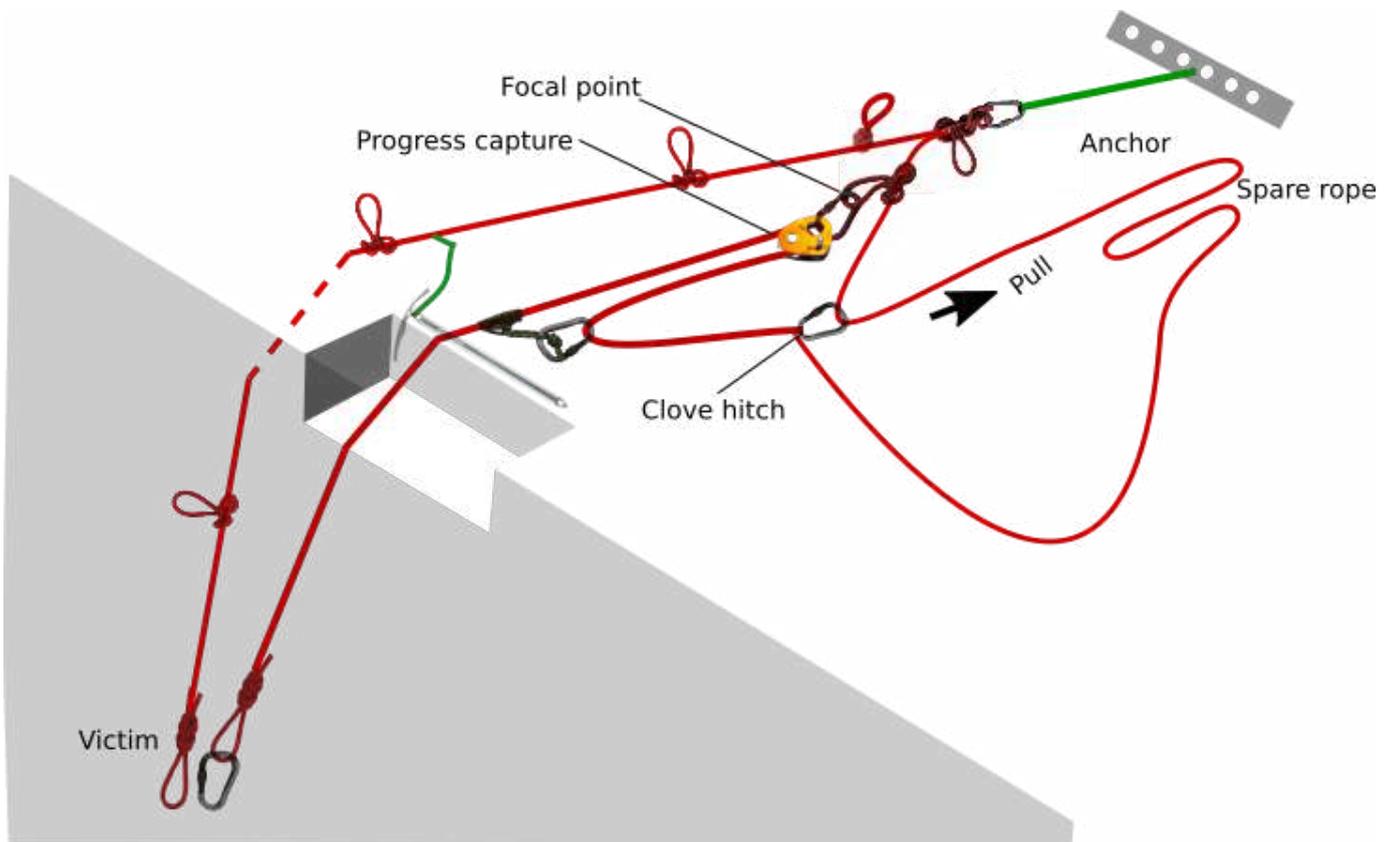
Unassisted hoist (Z haul) (3:1)

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 especially if 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 simple systems are not working, then a bigger mechanical advantage can be achieved by combining two simple systems into a compound system. Mechanical advantage of a compound pulley system can be determined by multiplying the advantage of the individual systems together. Compound systems can be identified by having individual pulleys that are travelling towards the anchor at different rates.



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