The Safe, Basic Fundamentals of the:
Brake Bar Rack,
Tandem Prusik Belay, and
Radium 3:1 Load Release Hitch

Presented by:
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Rope rescue presents special challenges, especially in remote areas. With new equipment constantly appearing on the market and techniques continuously being refined, the craft is a very dynamic experience. This presentation will explore three areas: brake bar rack, tandem Prusik belay, and Radium 3:1 load release hitch. It will expose new students to safe, basic fundamentals. Advanced students will increase their knowledge of concept development and proper techniques. All experiences are based on current testing and review the techniques of application used by different groups, from cave explorers to mountain rescue personnel. At the end of the presentation, a listener should be able to make safe decisions based on their own needs and budget restraints.

About the Presenter

Kenneth N. Laidlaw has been a practitioner of Search and Rescue skills with ten different types of organizations over the last thirty years. He is current qualifications include rescue curmudgeon, Red Cross Emergency Responder, NASAR SAR-Technician Evaluator, National Cave Rescue Commission Instructor certification, SPRAT Rope Access Technician qualification, Joel Hardin Sign Cutter certification, Type II Wild land Firefighter certification, Hazardous Materials Operations certification, Confined Space Operations certification, MSHA Trained, Mountain Rescue Association qualification, public safety dive tender qualification, amateur radio operator N6GFE, California Rescue Dog Association Mission Ready Support Person, Alameda County Sheriff’s Search and Rescue member, technical skills consultant for the Fire Department for the East Bay Regional Park District, and a retired seasonal Police Officer with that agency.
Brake Bar Rack

A brake bar rack, invented by John Cole, a cave explorer, is a descending device that directs the rope straight through the device and allows the amount of friction to be adjusted when under tension. Its original design evolved from early carabiner rappels which allowed the rope to pass over one or more carabiners placed across another carabiner. In the 1960’s the Holubar Company of Colorado began selling aluminum brake bars that could be slid on a carabiner gate and clipped over the spine. However, brake bars across a carabiner gate, the weakest point, proved disastrous when later tested with larger loads. Cole simply formed a steel frame to accommodate several of these brake bars.

The common commercial design brake bar rack has a welded eye on one leg and a nut on the other leg. These devices have become very popular in rope rescue. Though these welded eye versions are rated by manufacturers at around 44.44 kN (10,000 lb.), during informal testing by Kim Aufhauser, of West Valley College, with an applied force generated by six persons pulling on a 3:1 it has been discovered that the regular first bar tilts, the rack frame deforms, and other bars will bind. With a force of 26.22 kN (5,900 lb.) Bruce Parker, of CMC®, reports that a standard SMC® folded stainless steel bar began to collapse. Some rack versions have a wrapped eye, but Butch Feldhaus, of NCRC, reports they tend to unwrap with a 5.33 kN (1,200 lb.) force. A knowledgeable welder, familiar with racks, can retrofit the wraps and weld an eye. Avoid placing unintended forces on a brake bar rack.

Bruce Smith, author of On Rope, considers it important how the bars are arranged on the rack. With standard bars, the first bar has about 90 degrees of contact with the rope. The second through the fifth bar each have about 180 degrees of contact. The sixth bar’s contact varies. The first three bars will generally take the majority of the load and absorb the most energy. Bar four less, bar five still less, and bar six the least. The user also takes a small amount of the load. As an enhancement, an oversized stainless steel bar can be placed in the second bar position. This large bar will increase the rope contact area, but may develop more heat. This bar should be hollow to help dissipate the heat. Avoid using an oversized aluminum bar in the second bar position, as it may absorb too much heat. Nylon will start to melt, glaze, or become tacky at about 122°C [250°F.] and a liquid at about 248°C [480°F]. During a 70 m. rappel, with a descent rate of one meter per second, Bruce Smith has measured an aluminum bar at 150°C [300°F], but the heat dissipated quickly. Other testing has been done to analyze the temperatures of each stainless steel bar during 800 foot descents. Some results indicate a 204°C [400°F] peak in a 5 minute descent and a 127°C [260°F] peak in a 9 minute descent. Always pass the rope directly over the first bar when you attach the rack. With the traditional racks, orient the short leg away from you or on the bottom to allow the rope to be passed back and forth when bars are added or subtracted. Bars three through six should pivot on the long leg so when they are not being used they can be stored in the ‘well’. Another rack improvement is to replace the first bar with a snug
fitting, extended stainless steel bar. William Shrewsbury is credited with this idea, and Carroll Bassett, of BMS®, was one of the first to produce this revised modification. The bar, referred to as a hyper-bar, extends about one inch past the short leg and has a vertical steel pin in the end. This allows the rack to be tied off with ease and offers a leverage point, if needed to move the bars closer together, to more efficiently increase the friction created by the regular bars. If this technique is used, bar six should be a round type rather than a folded type with edges. In order to save money, a round aluminum bar may be used here since bar six experiences the least friction. Pure aluminum brake bars may generally create more friction; but wear excessively, are hotter to the touch, and transfer aluminum oxide to equipment and clothing. Bars with titanium over aluminum have been experimented with, but in practical use it was discovered that the bars wore out quickly on excessively dirty ropes. Heavier gauge titanium is prohibitively expensive in the United States. Current practice in the cave rescue community favors using only stainless steel bars. The hyper-bar will also make locking off the rack easier. With the standing rope over the hyper-bar pass it under all the bars and bring a bight of rope back up towards the hyper-bar pin. Put a full twist in the bight so the ropes cross and hook the bight over the vertical pin and remove any slack.

An improved rack design is now available that may be more appropriate for rescue forces. It is U-shaped with nuts on both ends and is anchored from the bend in the frame. A current version with heavy gauge stainless steel bars is manufactured by BMS® in West Virginia and is comparably priced to the traditional racks. In testing that the manufacturer had done by LTI, Inc. of Dublin, PA, the nuts did not fail until 97 kN (22,000 lb.) of force was applied. In further testing with an 11 mm. rope in its proper function, but tied off, the second round stainless steel bar started to deform when it experienced 27.5 kN (6,200 lb.) of force. In the same sequence of tests, an NFPA approved rack with standard aluminum bars had the third bar shatter when it experienced 17.7 kN (4,000 lb.) of force. It may take more skill to operate this U-shaped style of rack, as three brake bars are fixed to the frame. This U-shaped rack is the standard width of SMC® rack frames and comes with a hyper-bar that extends from both sides of the frame. For increased efficiency, as an accessory, an oversized steel bar could be placed in the second position.

To place this rack on a rope, rotate the three moveable bars away from the frame. (Figure 3.) Push a bight of rope through the frame and engage a bar. Check that this bar is orientated to lock correctly. Push a bight through the frame for the other two moveable bars and engage them. Remember to engage ALL available bars and pass the rope over the hyper-bar before starting to use a rack. Check again that the rope is threaded properly over the bars. (Figure 4). With all bars engaged and the rope over the hyper-bar, the rack can be tied off by taking a bight of the standing rope and push it through the frame. Placing a full twist in this bight, hook it over a pin on the hyper-bar and remove any slack. (Figure 5).

A smaller version of the U-shaped rack, MICRO-RACK™ manufactured by BMS® has only four bars. The first bar is a fixed hyper-bar with pin pointing up, second bar is moveable, third bar is a fixed hyper-bar with pin pointing down, and fourth bar is moveable. The rope weaves through the bars and passes over the top hyper-bar when in use. The frame strength exceeds 62 kN (14,000 lbs.) and the second bar will start to
collapse around 23 kN (5,200 lbs.). To tie off the rack, pass the standing rope line under the bottom hyper-bar, place a full twist in the bight, and hook it over the top pin. This rack will handle rescue loads but requires considerable experience.

Figure 1 – Break bar rack, before rigging.

Figure 2 – Use of a rack with a hyperbar

Figure 3 – Break bar racks, tied off.

Always have the rack set up and off to the side in case a change of direction is required in any exercise. Two rack safeties are often used. One connects a 6 mm. Prusik to the rope as it enters the rack. The other uses an 8 mm. Prusik attached to a Load Release Hitch and connects to the rope as it leaves the rack. Both methods pass the whistle test.
Figure-of-eight descending devices’ are still used but cannot be adjusted under tension, tend to twist the rope, will cause problems in the internal rope construction, must be unclipped to attach, are difficult for many to control a rescue load of 200 kg. (441 lb.), and are not a good choice for use in rope rescue.

**Belaying**

A basic philosophy is that the belay line is only used for the belay function and it is not used in shifting the load during a working operation.

During World War II, for airborne operations, testing by the US Army determined that the human body is usually damaged when it experiences a force of about 12 kN (2,700 lb.). It might be concluded that all techniques and devices must allow a dissipation of force before 12 kN is experienced or injury can occur. OSHA revised the force issue to 8 kN per person. BCCTR decided on 15 kN for an entire load, consisting of 6 kN for patient, 6 kN for barrow boy or attendant, and 3 kN for gear.

The BCCTR proposed that for a belay device to be acceptable, it must arrest a 200 kg. (441 lb.) load free falling 100 cm. (3’ 3”) on an initial rope length of 300 cm. (9’ 9”). The resulting Mass Arresting Force must be less than 15 kN (3,400 lb.) and that the stopping distance must be less than 100 cm. (3’ 3”). Afterwards, any releasing hitch or other device must be easily undone and used to lower the mass under the control of one person. By definition, the mountain rescue community considers 80 kg. (176 lb. or 13 stone) as a one person climbing load; 200 kg. (441 lb. or 32 stone) as a two person rescue load; and 280 kg. (617 lb. or 44 stone) as a three person large rescue load or NFPA two person load.

A popular belay involves the use of an Italian hitch on a large steel carabiner. Some books may call this an HMS, a Münter, or a carabiner hitch. The background I have heard is that the Italian mountain guide Garda first came up with the Garda hitch which was named for him. He then came up with another hitch which was presented to the Alpine Council by Werner Münter and it was then referred to as Münter’s hitch. Italian hitch best describes it’s origin. When applied correctly it can provide friction in both directions. For some applications, involving equipment only, or a single person load on a steep incline it will be an excellent choice. However, informal tests have repeatedly shown that many persons cannot control a 200 kg. rescue load using an Italian hitch once the load starts to move. In 1½ seconds, a normal reaction time that includes the thinking time, plus movement time, plus response time, an object will travel approximately 2.9 meters (9 ft.) in free fall, less with friction. Further testing by Kirk and Katie Mauthner has shown that there is a wide range of gripping abilities among the general population, ranging from 46 N. (10 lb.) to 426 N. (96 lb.) in their inferred statistical population range. The average person probably has a gripping ability, of about 209 N. (47 lb.) with one hand. The angle of the rope in and out of the Italian hitch, edge padding, presence of a shock absorber, and the length of the rope all may increase the effectiveness of this belay. It is best applied with a 0 degree angle on the
ropes and the load rope dragging over a padded edge surface. In conclusion, it is unlikely that an average person can hold a rescue load with an Italian hitch and be able to tie the hitch off. A version of the Italian hitch, from Canada, places an additional bight around the standing part on the rope and passes it through the carabiner a second time to create a double Italian hitch which might be more appropriate for any two person loads. This hitch may require an extra large steel carabiner to allow it to change direction. Another idea to make the Italian hitch safer is to use a tied off Prusik hitch on the control side of the Italian hitch. Without modifications, the fact that a Italian hitch belay works is conditional on the belayer holding on to and controlling the rope. **BELAY EXPERIENCE IS ESSENTIAL.**

A variety of other techniques and devices are often also described as belays. Some may be satisfactory for their intended use for a single person load of 80 kg. (176 lb.) in rock climbing. But in rope rescue, they are also conditional at best. A proper belay should pass the "BTCCR critical point test", that asks, 'Is there any one point in the system, that were it to fail, it would lead to catastrophic failure?’ For maximum safety the belay device should also engage without attention. The "BTCCR hold up [or] whistle test" is for objective hazard and asks, 'What happens to the patient, attendant, and other rescuers if everyone were to let go?’ At the sound of a whistle have everyone let go of the rope and hold up his or her hands. If the belay holds, it should be safe to proceed. In spite of its popularity, an Italian hitch fails this test.

**Tandem Prusik hitches** may be the safest and most inexpensive technique to use, however, their use may require the most training and aptitude. This hitch comes from seamen’s traditional techniques of ‘strapping a rope’. Use two pieces of 8 mm. cord, 1.35 m. (53 in.) and 1.65 m. (65 in.) long, the accepted North American standard. Joining the ends with a double overhand bend creates each loop. Tie three wrap Prusik hitches with each loop around your belay line. Tie them neatly with the hitches’ bridges matching and double overhand bend offset to a side. When both are snug and positioned, the hitches will be about 10 cm. (4 in.) apart. Generally, when engaged, Prusik hitches were thought to slip slightly before other parts of the system were stressed. The compatibility of cordage to rope may be a real issue as with some combinations the loop breaks before the hitch slips. It was first thought that the Prusik hitches worked in tandem, but it appears that one Prusik hitch takes most of the load. As it grips, it bends or tilts the line being engaged at an angle. The second Prusik hitch is then unable to bend the rope and therefore is not effective in gripping. Close observation of how Prusik hitches work is warranted. The BCCTR and other groups have repeatedly tested tandem Prusik hitches and they have been found to be a very reliable belay with a proper technique of application. Current knowledge shows that the 10 cm. offset between the hitches is not critical but makes them easier to work with and allows them to sustain higher falls. Two wrap Prusik hitches do not have enough dynamic capability and tend to heat up too much. The rope entry issue into Prusik hitches cannot be proved. **But properly dressed, snug hitches, with good technique is a major issue.** Users must be very attentive, and keep the hitches snug but free running. A properly tied Prusik hitch will make a noise as the rope is pulled through it. The BCCTR speculate that the first Prusik takes between 7.0 kN and 9.5 kN of force (90%). The second Prusik only increases that force to 10.5 kN (10%). Users should experiment with their chosen cordage to try to determine when their Prusik hitch will slip or if the loop will break.
On a lowering, the correct technique for the belayer is to grasp the front Prusik hitch, closest to the load, with one gloved hand. Pull out any slack in the anchor rope. Rotate the gloved hand 90° so the Prusik hitches are orientated vertically. Grasp the belay rope with the other gloved hand. With an upward motion pull out some belay rope. Move your hands next to each other creating about a 30 cm. (12”) bight of slack. Keith Schafter’s study concluded that a 30 cm. shift in a rescue load would not have an adverse affect. As the load takes this slack the gloved hand rotates, feels the load, and allows the belay line to slide. When the bight is gone the gloved hand pulls out another bight of slack. Listen for the noise the rope makes as it passes through the Prusik hitches. The gloved hand held at 90° holds the front Prusik steady so it will not tighten and keeps any slack out of the anchor rope.

Figure 4 – Belay hand position sequence.

During a haul, the back Prusik are held by one gloved hand and the belay rope pulled up through both hitches to prevent any droop of slack. If you have two sets of loops available you will be able to safely pass a bend. On a long haul the belayer may need help bringing up the rope. The belay rope may also be pulled up through a Prusik Minding Pulley. For optimum efficiency the lengths of the Prusik loops can be shortened to custom fit the type of the pulley and rope you use. (Figure 9.) Experiment with the cordage you use so the first Prusik hitch is a thumb width away from the pulley sides and the second Prusik hitch is 10 cm. (4”) from the first. If you change ropes the relationships may also change. In a belay mode the loops are placed on the carabiner first, then the pulley. This puts the hitches closest to the carabiner spine. Before using with a Prusik Minding Pulley, hold both ropes at 0 degrees to each other and carefully set the Prusik hitches against the base of the pulley sides. With a Prusik Minding Pulley in a system, when you are in a lowering mode let the rope pass through the pulley. Holding the tandem Prusik hitches at 90° allows them to effectively grip the rope. If a shock load were to be experienced the Prusik hitches just rotate 90° and lock. Your hands will move with the hitches.

Figure 5 – Prusik minding pulley with fitted Prusik loops
Load Release Hitch

To overcome the problem of a belayer allowing the hitches to lock at the wrong time, place a Load Release Hitch above the tandem Prusik hitches so they can be released. This hitch, developed by Arnor Larson, exceeded the BCCTR testing model. The hitch also acted, it was thought, as a shock absorber, increasing the safety factor of the unit. This may be just a myth with 200 kg. loads on modern ropes. Also, if this hitch did function as a shock absorber, you would increase the distance the load would travel causing increased forces.

In December 1999 Kirk and Katie Mauthner published a comparative analysis the eleven most popular release devices. The original British Columbia – Load Release Hitch continues to be acceptable, but has been over shadowed by the Radium Release Hitch 3:1, which was developed during the study, while enjoying the Radium Hot Springs, and is now recommended for use by the Mauthner’s. Start with 10 m. (33’) of 8 mm. low stretch cord and two locking, 25 kN rated, carabiners. Tie a figure-of-eight on a bight or a bowline with the Yosemite back-up and clip it into the load-side carabiner on its spine side. Run the standing part of the cord up through the anchor carabiner, back down through the load carabiner, and up to the anchor carabiner again. Allow about 12 cm. (5”) between the carabiners. Tie an Italian hitch on the anchor carabiner on its gate side. Ensure that the Italian hitch is in the release position with the in-feed cord towards the gate side of the carabiner. Secure the Radium Release Hitch by using a bight of the in-feed cord to tie a half hitch around the long axis just below the Italian hitch. Then back that up with an overhand-on-a-bight knot, again around the long axis, but do not capture the standing part of the in-feed cord. If you do capture the standing part any pull on in-feed cord will tend to untie the overhand knot. The excess cord can be chained, but the best choice is to use a very small stuff sack (3 in. by 3 in. by 8 in.) from B & B Enterprises to store the cord in. A loop can be placed in the other end so it can be clipped to a secure anchor if desired.

Figure 13 – Radium Release Hitch 3:1.
NEVER use a Load Release Hitch until you have determined where the load is being shifted to and you have estimated the distance necessary to accomplish this. This distance may be roughly estimated. If 30 m. of rope is in use, with 2 kN of force applied, a two person load, and the rope stretches about 5% it will require about 1.5 m. of distance to remove the rope stretch from the loaded rope and about another 1.4 m. of distance to transfer the load to another rope. This is a total of about 2.9 m. (9½ ft.), and this is close to the limit for the Radium Release Hitch 3:1. If one cannot determine this distance, do not untie the load release hitch.

A compact alternative with 5 m. of 2.54 cm. tubular webbing is to use a Mariner's hitch. The Mariner’s hitch does not use an Italian hitch, but after the midpoint bend, wraps the webbing through both carabiners several times. The excess is tucked. This version could be dangerous as it does not seem to offer the control the rope version does. Remember, the use of tandem Prusik hitches require skill and careful attention. A BELAYER SHOULD BE YOUR MOST EXPERIENCED PERSON. After using a Load Release Hitch always retie it, so it will be ready for its next application.