The Diminishing Loop Counterbalance

Thomas Evans
Western Washington University, Geology Department, 516 High Street, Bellingham, WA 98225, cavertevans@gmail.com

Disclaimer:

The Diminishing Loop Counterbalance (DLC) is not my idea, but a technique that was taught to me by others. Credit for this system belongs to someone unknown to me. However, the idea was brilliant, so I am sharing it with the broader technical rescue community, in as much detail as I can, to be used to help others in need.

Introduction:

The DLC is a light rigging option that requires little equipment and just, a single rescuer. It is fast, efficient, can be incredibly simple, and is easy to use under the right conditions (in conjunction with an edge transition plan). The system allows a single patient and rescuer to ascend, and can be used either with or without a litter. As with most rope rescue systems it requires practice to rig and operate efficiently, but it can be an elegant solution under the right conditions.

This document is intended as a study and practice aid for technical rescuers of all kinds to learn and practice the DLC. Consequently, this document includes information on how to determine if the DLC is the right choice to use in solving a rigging problem, how to rig the DLC, and two ways to solve the edge transition problem. It also covers the basic physics of the system.

The DLC is a counterbalance system operated by one rescuer who attaches a patient to a rope that runs up and over a pulley. The rescuer then attaches to the patient with a tether (e.g., cows tail), and ascends the rope on the other side of the pulley (Figure 1a). This system simultaneously raises both the rescuer and the patient with an effective ideal mechanical advantage of 2:1.

Required Conditions:

The DLC can be incredibly efficient when skillfully rigged and executed – but can be problematic if rigged or operated poorly. Addressing the following three conditions will facilitate success:

1) Rig for a free hang. The DLC works efficiently when the rope runs up and over a pulley without contacting walls, edges, or other surfaces. Even a modest amount of friction can make the system difficult or impossible to operate, so care must be taken when rigging to achieve a free hanging condition. Two options for accomplishing this objective (rigging to a high point, or using a series of systems) are discussed in the Edge Problem section. If a free hang is not possible, it may be better to utilize another method other than the DLC.
2) Have enough rope. Since this is a full length counterbalance system, it requires a rope at least twice the length of the pitch. If rope length is a limiting factor, a standard haul, or a standard counterbalance with the counterweight positioned at the top, may be more appropriate.
3) The rescuer should possess and employ excellent single rope technique skills. In this system, the rescuer serves simultaneously as the haul team and patient attendant. The rescuer must be competent on rope and must have an efficient climbing system. The rescuer must be able to climb rope efficiently, change over from climb to rappel, and

from rappel to climb. Additionally, it is useful for the rescuer to know how to change ropes while hanging, to cross knots both while ascending and rappelling. All these skills are more easily accomplished if the climber is using mechanical ascenders for on-rope maneuvers.

Rigging:

To rig the DLC, start by selecting an anchor suitable for a two-person load – it will need to support both the patient and the rescuer, plus the rope and other rigging, with a sufficient safety margin. Suspend a pulley from the anchor so that it and the counterbalance rope hang free. Run the counterbalance rope through the pulley and position it so that both ends of the rope are at the base of the pitch (where the patient is assumed to be located). Attach the patient to one end of the counterbalance rope and have the rescuer attach their climbing system to the other side of the rope. Then use a tether (cows tail, webbing, strap, tail of the rope, etc.) to connect the patient's harness rigging point to that of the rescuer. The choice of tether length is up to the rescuer: a short tether keeps the rescuer and patient close for ease of monitoring and positioning during the ascent and while negotiating edges, while a long tether can make climbing easier by physically separating the climber and rescuer. Tether length may be modified during the rescue if needed, provided the rescuer ensures at least one tether is positively connected from the rescuer to the patient at <u>all</u> times. To raise the patient, the rescuer climbs their side of the counterbalance rope, causing the rescuer and the patient to rise as a unit. As the rescuer climbs the loop gets smaller, thus the name the Diminishing Loop Counterbalance. See Figure 2 for a picture of the system rigging (minus a patient tether), and Figure 1a for a simple schematic of the rigging.

Progress capture can be integrated into the system by employing a prusik minding pulley (PMP) at the apex of the system and placing a prusik on the rope on the patient side of the PMP (see Figure 1b). Note that by including progress capture the rescuer's ability to easily lower the patient is lost, thus reducing the flexibility of the system. If needed, an integrated prusik can be monitored by another rescuer at the edge. Omitting the progress capture allows patient movement up and down easily using one hand to pull the patient to the elevation desired. This facilitates passing obstacles (vegetation, boulders, etc.), and can prevent hanging up the system during the ascent. In addition, if no prusik is used the entire system can be converted from raise to lower with ease. Consequently, it is <u>not necessary</u>, and <u>often detrimental</u>, to install a progress capture device. The decision to include internal progress capture should be made with consideration of the constraints of the environment, equipment, personnel, and the situation.

This system has some distinct advantages in that the climber can always escape the load. They simply change over from climb to rappel. This may seem difficult, but in practice the rescuer only feels a maximum of their mass plus half the difference in the mass of the rescuer and patient (this is explained in detail in the Mechanical Advantage section). Since little or no extra weight is felt, it is easy for the rescuer to perform changeovers at any time. In addition, because of the counterbalance between patient and rescuer, the patient can be moved with little force (one handed), making it easy to move up or down to the patient to assess or maneuver them during the climb. Lastly, the patient can help in their own rescue (when capable) by pulling down on the end of the rope the rescuer is climbing. With the assistance of the patient, the load (patient and rescuer) rapidly moves upward since climbing becomes fast and easy!

If two ropes are tied together to achieve the entire pitch length, place the knot on the climber's side of the counterbalance. Rigged this way, the knot does not pass through the pulley during the raise. On the ascent the climber can simply cross the knot and continue the climb.

To Belay or Not To Belay, That IS the Question:

Belays provide a backup in case of equipment failure, anchor failure, or human error. Many rescuers have been taught to utilize them as a matter of protocol, without questioning their contribution. In reality, belays can in some cases reduce overall system safety or hinder a systems operation to the point of becoming counterproductive. When constructing a DLC, consider the following then determining if incorporating a belay is appropriate:

Potential for Equipment Failure: Equipment rarely fails, however, when it does, a belay can protect the patient and rescuer from a catastrophic fall. In the case of the DLC, the upper anchor, carabiner, pulley, or rope could fail. If the system is rigged in a free hang configuration, then no force, other than the load is placed on the carabiner, pulley, and rope. The question becomes, will any of those components spontaneously break? Practically speaking component parts in good working order do not simply break without the application of some external force, so this event can be considered nearly nonexistent. As such, if a DLC is rigged in a free hang there is a low probability of equipment failure, and a belay provides less additional security, but can provide a source of problems (like rope twist and dislodging rocks). However, if the DLC is not in a free hang, but against a wall where ropes could rub or get cut, then adding a belay deserves careful consideration.

Potential for Anchor Failure: Anchor failure could be a plausible scenario during DLC operation. The system experiences a two-person load, at a minimum, and the effective load will increase if the patient drags against the rock face (causing the rescuer to apply additional force to continue the raising operation). While incorporation of a belay may be a reasonable response to this situation, the most effective approach would be to utilize a stronger anchor (bombproof), or back up the main anchor to provide redundancy or added strength.

Human Error: Human error is a very real concern in any rope rescue system. A belay mitigates the risk of human error. As such, belays are almost always appropriate during training operations, and should be used in rescues whenever they do not hinder system operation or cause an unacceptable risk of rock fall.

Potential for Rope Twist: An efficiently rigged DLC will be free hanging. In this configuration the two sides of the counterbalance rope can become twisted, causing substantial friction in the system. In situations where rope twist is anticipated, adding a belay rope may further complicate the rescuer's work, in some cases rendering the entire system inoperable. While there are many factors that contribute to rope twist, it is generally more likely on long raises, where the ropes hang close together, and/or in operations taking place in turbulent air (such as a cave pit with a waterfall). Rope twist can be mitigated by rigging the DLC with two separated upper pulleys on two different anchors, though this subjects the anchors to additional forces and the configuration of the pit/pitch may not always allow it. Incorporation of tag lines may help in some situations, but they are unlikely to be effective for long raises. Some experienced cave rescue technicians consider rope twist of sufficient concern that they omit belays to ensure the system as a whole remains operational.

Potential for Rockfall: Rockfall can be a significant hazard to rescuers and patients. Rescuers go to great measures to minimize rockfall potential, but we often overlook the potential for our rescue system ropes to cause rockfall. Ropes moving over an edge can easily dislodge rocks and other debris. The DLC mitigates potential for rockfall by positioning its moving components in free space – only the static, non-moving connection to the anchor passes over the edge. Adding a belay in this situation could negate this benefit.

Given these considerations, belays for the DLC should be employed when the potential to protect against anchor/equipment failure or human error outweighs the potential for causing rockfall or tangling the system. When employed, the DLC belay must be capable of catching a two person load, and should generally be attached to the patient rather than the rescuer. This configuration frees the rescuer to perform a variety of on rope maneuvers with the patient belayed the entire time. The drawback is that the rescuer could take a fall of up to twice their tether length if they are climbing above the patient. If no belay is desired during the climb (to prevent rope twist or rock fall hazards, etc.), a belay can still be provided at the lip where a dynamic event is most likely. A belay at the lip can be implemented by building a short belay and clipping it to the patient when they reach the lip prior to negotiating the edge transition.

Because the DLC is an effective small party rescue tool which efficiently utilizes minimal equipment and personnel, it is likely the DLC will often be employed without a belay due to lack of resources. However, when the equipment and personnel are available, a belay can be beneficial, and in many cases its use may be dictated by agency protocol.

The Edge Problem:

The DLC, as described to this point, only raises the patient to the edge, but not over it. Two solutions to this problem will be presented here: rigging from a high anchor, or suspending the DLC from a second counterbalance system. Other options exist for solving the edge transition problem, however these two techniques will solve most edge transition issues.

Rigging to a High Anchor: When feasible, any counterbalance system will benefit from being rigged from an upper anchor high enough that the patient will clear the lip in a free hang. The patient can then be pulled to the landing zone using a tag line or short, secondary haul system. Incorporating a load-releasing device (load releasing hitch, locked off Munter, locked of descent device, etc.) between the anchor and the DLC pulley makes for a smooth transition. See Figure 1c for a schematic diagram of this system. The system can be run by two rescuers if the climber clips the patient to the pulley or carabiner when they reach the top. This frees the rescuer to get off of the counterbalance system and operate either the lower or the second haul system.

A Second Counterbalance System: This rigging can be conceptualized as rigging the DLC in a free hang, suspended from a second counterbalance system draped over the edge. This second system is used to overcome edge friction (and typically is rigged with a higher mechanical advantage). It can be operated by the original counterbalance climber/rescuer.

Start by building a normal DLC system (rope, pulley, and carabiner). Attach a second pulley, facing upward, to the first DLC carabiner. Using a second rope, anchor one end, then run the rope through the upper pulley (creating a 2:1 haul system), then run the rope back through a redirect prusik minding pulley at the anchor. A progress capture device (prusik) is required on the redirect pulley at the anchor on the 2:1 (load) side. The tail of this upper system rope is draped over the lip and must be long enough that a climber can switch over to this rope when ascending. Position the two pulleys on the same carabiner at the lip, but not over the lip, since rope stretch will pull the pulleys down and over the lip when the system is loaded. It is useful and advisable to pad the lip where the pulleys will slide over the edge to help minimize friction when the upper system is operated. Keep in mind that the carabiner connecting the two pulleys will be dragged over the lip twice, so make sure the gate is facing away from the rock (or use a screw link). See Figure 3 for a schematic rigging diagram of this system and Figure 4 for a picture of the system minus a tether between patient and rescuer.

To use the system the rescuer climbs the original DLC and raises the patient up to the DLC pulley. The rescuer uses a tether (cows tail, webbing, tail of the rope, etc.) to attach the patient to the DLC pulley's carabiner. A short tether is most useful here. The rescuer then switches ropes and climbs on the tail of the upper counterbalance system, using it's added mechanical advantage The rescuer remains connected to the patient via a tether, so at this point the upper haul system becomes a 3:1 diminishing loop when fully tensioned because three strands of rope are holding up the patient and rescuer, and as the rescuer climbs, the loop becomes smaller. (If the tether between the patient and rescuer is slack, the system is only a 2:1 haul with a redirect.) Once the rescuer is on the second system, climbing commences, which brings the patient up again (remember that the patient and rescuer are still tethered together). Pulling the two pulleys up and over the edge can seem daunting, but if the rescuer simply grasps the carabiner connecting the two pulleys and pulls up and out, the entire assembly usually slips up and over the edge with little problem. Rocking the patient side to side while tensioning the haul system, can also help move the load up and over rough areas. In addition, the patient can assist (if medically able to do so) by pulling down on the rope the rescuer is climbing. Once over the lip, the patient can be raised and clipped to the anchor if a safety is needed. Alternatively they can be transported or attached to a new system. A step by step depiction of this sequence of actions is shown in Figure 5.

At this point it is useful to step back and consider what was built. A DLC was built then a 2:1 haul system with a redirect pulley was added, effectively making the system a 3:1 when used as a diminishing loop. To convince yourself that this is the case, consider the geometry when the climber is attached to the second DLC system (after they have switched climbing ropes). Since the rescuer remains tethered to the patient, a loop is formed composed of the rescuer, tether, patient, two pulleys on a carabiner, the second rope up and over the redirect pulley, and back to the rescuer (see Figure 5d and 5e).

Solving the edge transition problem utilizing DLC's in series is an elegant solution which was taught to me by National Cave Rescue Commission instructors John Punches and Anmar Mirza. Like many rigging techniques, it is unclear who discovered or rediscovered the idea however these two have championed this system and its use, so deserve some credit for its development and dissemination.

Mechanical Advantage:

At first glance it can be difficult to determine the mechanical advantage the DLC provides. It took me quite a while to convince myself that the DLC is a 2:1 haul system. The easiest way I have found to think about the problem is to use the equation for work:

Work = Force X Distance

To utilize this formula to calculate the mechanical advantage of the system, we must invoke the conservation of work when performing a task. Lifting a mass will require the same amount of work regardless of how it is performed. Thus by increasing the distance we haul the load, the force needed is reduced proportionately.

In our DLC example, the load consists of both the patient and the climber (because they are connected via the tether). The distance climbed is twice the pitch length (the rope goes up and comes back down, and the rescuer must climb its entire length). If we assume that the pitch length a patient and rescuer are raised is 50 feet, the rescuer has to climb 100 feet of rope utilizing the DLC, then the mechanical advantage is: MA=100/50 = 2. In other words, the rescuer (part of the load) had to climb twice as much rope as the distance the patient (also part of the load) had to be raised, which equates to a 2:1 mechanical advantage.

The elegance of the system is not in the 2:1 mechanical advantage, but in the force the climber experiences during the rescue. The system as a whole will feel the combined force of the patient and the rescuer. Because there are two strands of rope, the force on each strand will be half the combined load. The consequence is that if the rescuer is lighter than the patient, the force on the tether between the rescuer and patient is half the difference in the mass between the rescuer and patient. Thus, the force the climber feels is their own mass plus half the difference in the mass between the rescuer and patient. If the rescuer is heavier than the patient, then the tether will be pulling up on the rescuer, thus the force the rescuer experiences is their mass minus half the difference between the rescuer and patient. Because the rescuer feels little difference between climbing on their own on a fixed line, and climbing with the patient using a DLC, performing on-rope functions (changeovers from climb to rappel and rappel to climb), and moving the patient are simple tasks for rescuers with strong single rope technique skills.

Conclusions:

The diminishing loop counterbalance system is simple (once learned and practiced), easy, fast, efficient, and uses little equipment and personnel. As such, it is an elegant rigging solution when conditions are favorable for its use. It is a valuable small party or self-rescue rigging tool, and if practiced and implemented well, it can be used equally effectively in larger call out rescues with more equipment and personnel. It is hoped that rescuers will learn this information, try it for themselves, learn the system’s strengths and weaknesses, and apply it when it is most useful and effective. So please try this at home! However, keep in mind that this technique is but one of many that a versatile rigger can and should learn to solve rigging problems, so the DLC should be considered just one of many useful tools in a rigger’s technical rescue toolbox.

Acknowledgements:

I am deeply indebted to the instructors who taught me how to build and operate the DLC, as well as how to analyze system function and operation. In particular, this article would not have been possible without the editorial support of John Punches and Aaron Stavens. Both provided corrections to the factual content, philosophical suggestions on how to present the information, and made suggestions on additional information to include. In addition, the document greatly benefited from the editorial critique of Sarah Truebe. The advice from all these editors greatly improved the final document and its content, though I am solely responsible for any errors.

Figures:

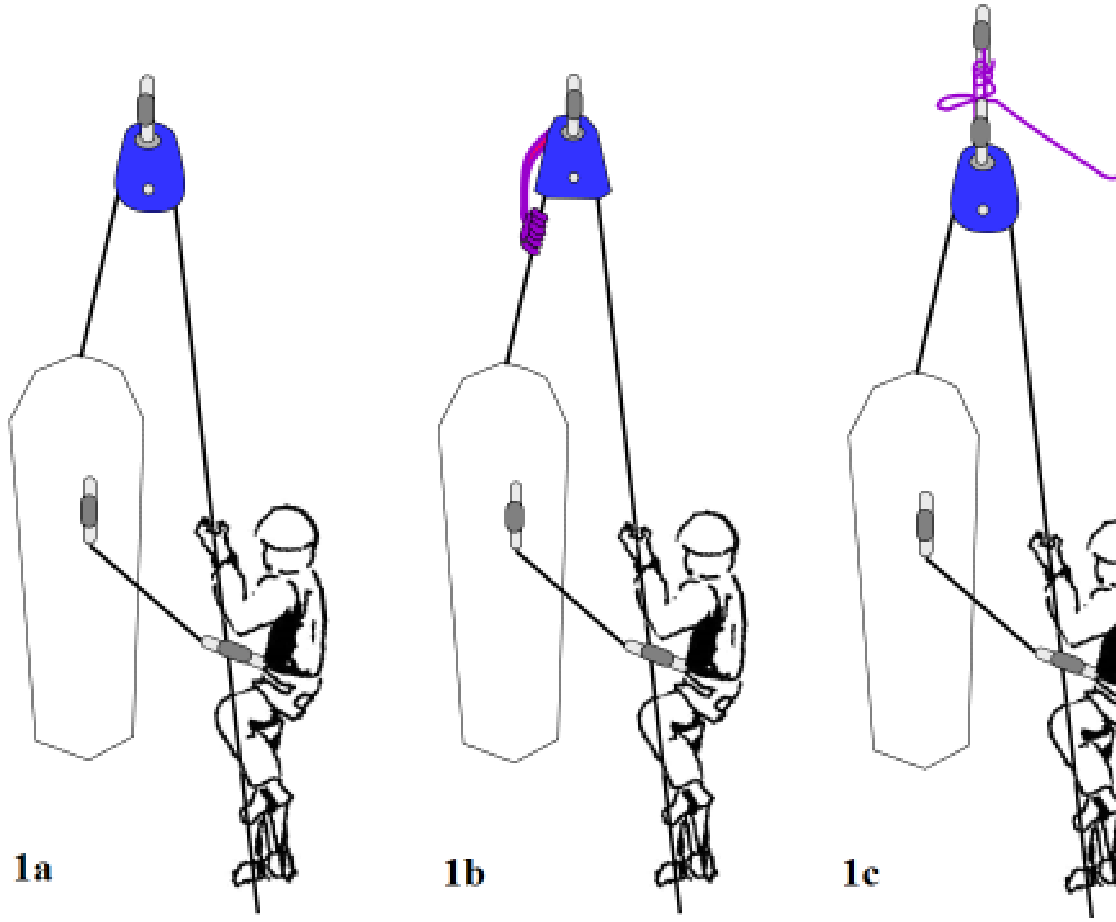

Figure 1: a) A schematic diagram of the basic DLC system. **b)** A schematic diagram of the basic DLC system with internal progress capture. **c)** A schematic diagram of the DLC system with a releasable upper anchor.

Figure 2: A picture of the basic DLC rigging minus a tether between the rescuer and patient.

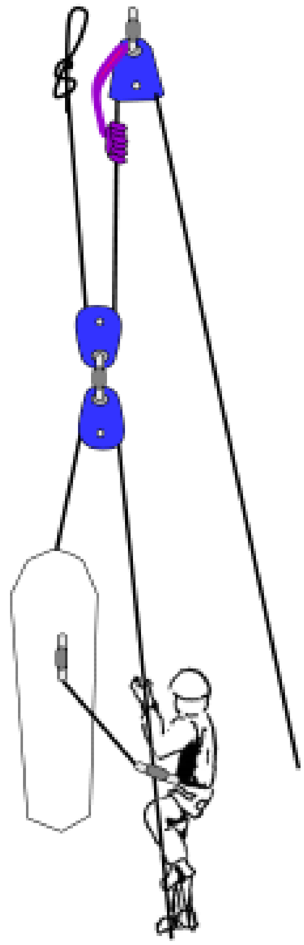

Figure 3: A schematic diagram of the DLC rigged hanging from a second counterbalance system.

Figure 4: A picture of the DLC attached to a second counterbalance system, minus a tether between the patient and the rescuer.

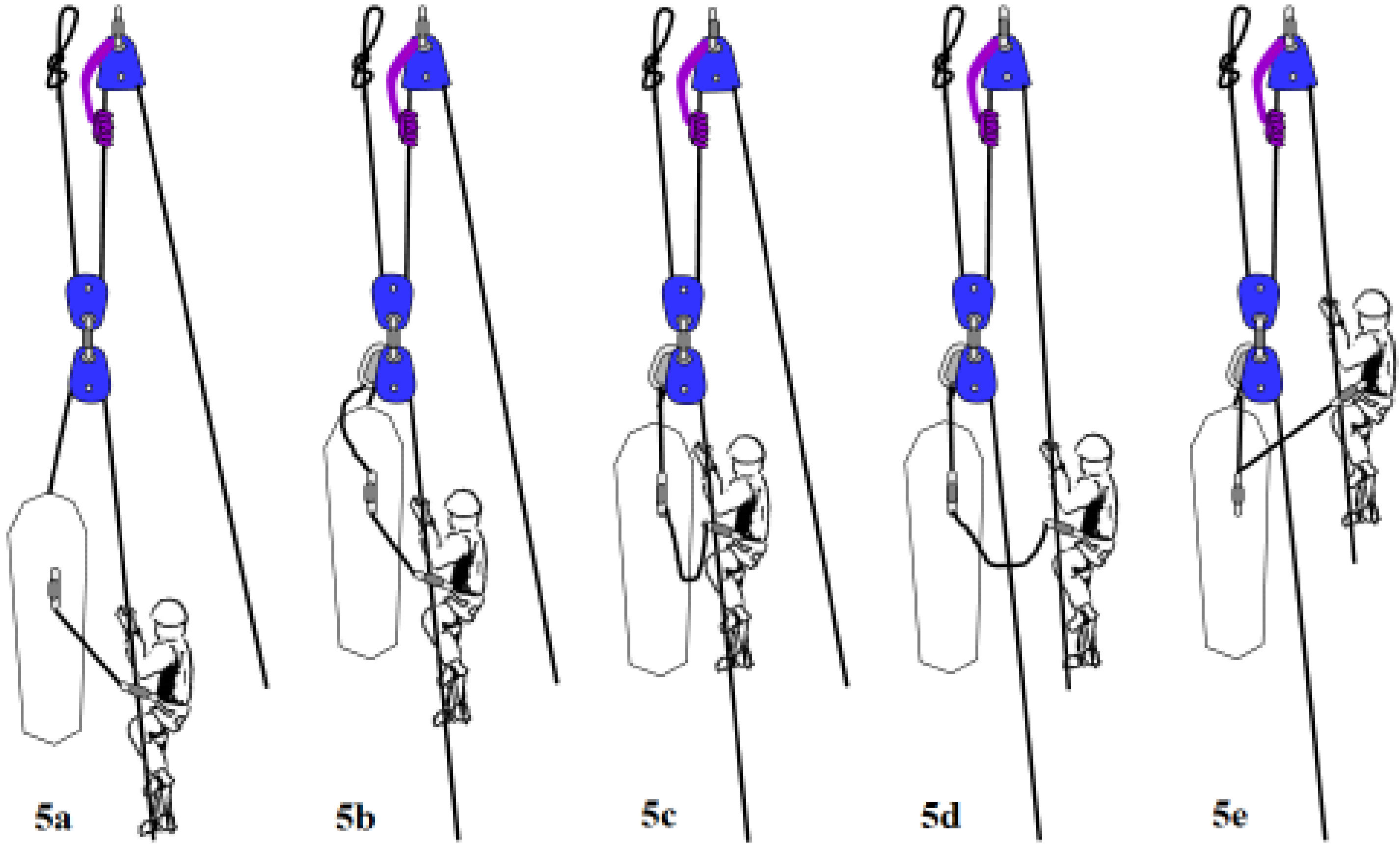

Figure 5: A schematic diagram of how to operate the DLC when suspended from a second counterbalance system. **a)** The two systems built and in operation with the rescuer climbing. **b)** Securing the patient to the DLC carabiner with a separate tether. **c)** Lowering the patient onto the tether which places slack in the tether between the patient and rescuer. **d)** The rescuer transfers ropes to the tail of the second counterbalance rope. **e)** The rescuer climbs on the new system, and raises the patient up and over the edge.