



NEGATIVE PRESSURE WOUND THERAPY DURING CRITICAL CARE AIR TRANSPORT CLINICAL PRACTICE GUIDELINE (CPG)

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Major updates

1. An algorithm for treating bleeding with a negative pressure wound therapy Negative Pressure Wound Therapy (NPWT) dressing has been included.
2. [Appendix A](#) which describes how to replace the KCI suction pump with the Impact suction has been added.
3. [Appendix B](#) which describes how to convert the KCI Vacuum Assisted Closure (VAC) Freedom to an instillation NPWT dressing has been developed.

Goal

The goal of this CPG is to optimize wound management for the traumatically injured with a focus on the aeromedical evacuation (AE) environment. This CPG provides an overview of negative pressure wound therapy and its uses in the treatment of soft-tissue battle wounds. It describes the technical aspects of troubleshooting negative pressure wound therapy, addresses equipment and dressing failures; and provides an algorithm for how to treat bleeding that may occur during patient evacuation. Throughout the guideline, a focus has been placed on the special conditions associated with en route care.

The series is developed by the Center for Sustainment of Trauma and Readiness Skills, University of Cincinnati Medical Center.

Background

NPWT promotes wound healing through the application of a vacuum paired with a sealed dressing; the benefits of wound healing seem independent of the type of NPWT system used.¹ The continuous vacuum draws fluid out from the wound² and also increases blood flow to the area.³ Studies could not demonstrate, however, that wound bacterial counts were lowered.^{4,5} In general, NPWT decreases wound edema and accelerates the healing process.⁶ The vacuum may be applied continuously or intermittently, depending on the type of wound being treated and the clinical objectives. The continuous mode of suction is most commonly used for surgical wounds. Some NPWT devices allow delivery of fluids, such as saline or antibiotics to irrigate the wound; intermittent removal of used fluid supports the cleaning and drainage of the wound bed.⁷ In addition, NPWT dressings are well-suited for use for patients with an open abdomen or chest after damage control surgery.⁸ For these reasons, NPWT has become the preferred alternative to wet-to-dry dressings and other temporary wound coverage methods, particularly in the aeromedical evacuation (AE) environment. Thus, each Critical Care Air Transport Team (CCATT) member must thoroughly understand the NPWT equipment, how to troubleshoot device and dressing malfunctions, and manage associated complications. The only flight-approved commercial NPWT system is the KCI VAC Freedom. KCI provides a thorough clinical practice guideline for clinicians.⁹

Advantages of NPWT

Negative pressure dressings can be left in place for 24 to 72 hours, depending on wound characteristics. This makes the NPWT dressings generally less labor-intensive to manage and more ideal for AE.

NPWT allows for the accurate measurement of fluid and blood loss from wounds, to include losses associated with temporary abdominal and chest closures after damage control surgery. Understanding wound-related fluid losses is an important part of optimizing post-surgical resuscitation.

Techniques of NPWT

The term "wound VAC" has become synonymous with the KCI negative pressure therapy system. The KCI VAC Freedom is the only commercially approved device certified for use during AE. For that reason the KCI system will be reviewed in detail below, but it is important to understand multiple ways exist to create a negative pressure dressing.

NPWT systems can be fashioned using a standard portable suction device and dressing supplies. For example, NATO and Role 2 facilities often create negative pressure dressings using gauze or surgical towels covered with an occlusive dressing such as Ioban/Tegaderm and surgical drains connected to suction tubing. The open abdomen NPWT dressing, constructed as such, is sometimes referred to as a "Balad Pack" or "VAC Pack".

If a non-KCI device (other than the Impact suction device) is being used in-flight, then a waiver must be obtained for its use. As an alternative, the non-approved suction device can be replaced with the standard CCATT Impact suction device adjusted to a continuous mode of suction.

Components of a NPWT Dressing

There are **six components** to a NPWT system.

(1) Porous material:

- It is usually cut to fit into the wound to conform to its shape. This allows the negative pressure to be distributed evenly throughout wound and facilitates fluid egress.
- Examples of porous materials include (1) Reticulated Open Cell Foam (ROCF) is used in the KCI system and it is the type of material most commonly used; (2) sterile gauze; and (3) sterile surgical towels.

(2) Occlusive dressing:

- The entire wound must be covered and the dressing adherent to the intact surrounding skin; an additional topical adhesive (such as benzoin) can improve the success of creating an airtight seal.
- The materials most often used are either the KCI-branded adhesive dressings or Ioban (particularly for large wounds), however, other adhesive plastic dressings, such as Tegaderm may also be used.
- The skin must be dry for the dressing to stick well and remain occlusive; an airtight seal is required to allow the suction device to maintain negative pressure within the wound.

(3) Suction conduit:

- Tubing transmits the negative pressure from the suction device to the dressing.

- With the KCI system there is a device called the SensaT.R.A.C. Pad that is attached to the end of the tubing. The SensaT.R.A.C pad is placed over an opening created in the underlying dressing. This part of the dressing is also referred to as the “lily pad”.
- Other conduits may include non-collapsible chest tubes, suction tubing, and surgical drains (with or without Heimlich valves).

(4) Y-connector:

- Allows a single suction device to be used for multiple small wounds.
- This arrangement may be less effective in maintaining negative pressure if the combined size of the wounds is too large.
- A challenge with y-connected dressings is that a leak in any one of the attached dressings will cause loss of suction in all wounds and result in fluid accumulation within the dressings and wounds themselves.
- Contaminated or infected wounds should not be connected via y-connector to any other wound.⁹

(5) Fluid collection canisters:

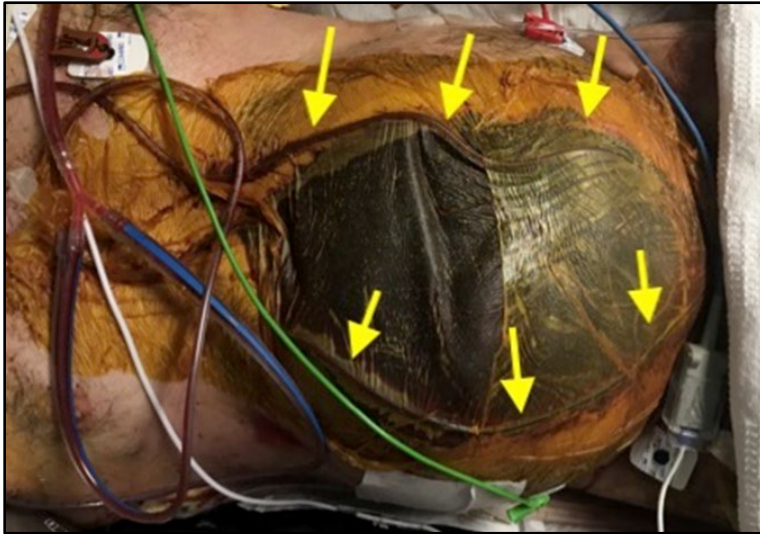
- Canisters collect blood and fluids removed from the wound and facilitate accurate I/Os.
- The VAC Freedom collection canisters are small (300 ml) and contain a gel pack to solidify fluids removed from the wound; these canisters cannot be emptied or reused. Calculate canister requirements carefully before departing on any AE missions.
- Fluid can be collected in standard suction canisters using the Impact suction device. These canisters may be reused if adequate supplies during flight are not available, but this should be avoided.

(6) Suction device:

- The KCI VAC Freedom is the only NPWT device approved for use in AE.
- The Impact suction device can also be used for NPWT. If the Impact suction device is used, ensure settings reflect the original orders for NPWT (i.e. continuous at -125mmHg). See [Appendix A](#).

Figure 1. Temporary abdominal closure

Figure 1 demonstrates a temporary abdominal closure following a trauma laparotomy. A perforated clear plastic sheet was first placed directly on the bowel, followed by blue OR towels (usually a black sponge is used). Two nasogastric tubes (NGTs) were then placed on top of the towels (see arrows), followed by an loban seal. Finally, the NGTs were attached to an Impact suction device.



Operation of the KCI NPWT System

Continuous versus Intermittent Settings

Continuous therapy provides a constant level of negative pressure, and intermittent therapy cycles between negative pressure and zero pressure. Most wounds are managed with continuous therapy.

Negative Pressure Settings

The units are set in millimeters of mercury (mmHg) and the surgeon who placed the device will generally set the suction parameters; the majority of wounds will be managed with -125 mmHg of continuous suction. NPWT dressings that cover skin grafts may have lower settings such as -75 mmHg of continuous suction.

Suction Intensity

This determines intensity with which the pump reaches the set negative pressure. The value is set between 0 and 10. NPWT may cause mechanical deformation of the wound edge that can cause increased pain to the patient. Adjusting the suction pressure and intensity can help with the patient's pain, while ensuring therapeutic NPWT goals are still met.

Preflight NPWT Checklist

There are **eight elements** to consider when planning an AE mission with a patient that has a NPWT dressing.

(1) Understand the nature of wound:

- An understanding of the nature of the wound and underlying injury will aid the provider in troubleshooting NPWT dressing issues. This is critical for both soft tissue wounds on the extremities and for NPWT management on the abdomen. For example, patients with a midline abdominal wound VAC may have the abdominal wall (fascia) closed with a wound VAC applied to the skin/soft tissue only (called an “incisional wound VAC”), or the abdominal wall (fascia) may have been left open temporarily with the wound VAC communicating directly with the intra-abdominal contents (called a “temporary abdominal closure,” “TAC,” or AbThera).
- Failure of an incisional wound VAC (fascia closed) in flight can be remedied by simply switching to wet-to-dry dressings.
- Failure of an open abdominal wound VAC/AbThera in flight will likely lead to evisceration.
- Placing a NPWT dressing directly over a vascular repair is contraindicated. However, if a vascular repair has good soft tissue coverage (i.e. muscle), some surgeons will utilize NPWT to manage large associated soft tissue injuries. It is important to understand whether the wound contains a vascular repair; the location of the repair would be the best place to first apply manual pressure if life-threatening bleeding were to develop (see section, [Special Considerations](#)).

(2) Ensure the dressing has an airtight seal:

The NPWT adhesive dressing should have an airtight seal along all wound edges. With suction applied, the dressing should be firm and obviously under negative pressure. If it does not, then examine and repair the dressing with the surgeon that placed it if available.

(3) Identify any areas at risk for leakage during flight:

Examine the edges of the dressing closely to determine whether there are areas at risk for developing leaks (i.e. skin folds, creases, dressings applied over hair). Address these areas by modifying or reinforcing the dressing prior to departing the MTF.

(4) Identify any undrained fluid under the dressing:

It is important to inspect the dressing for any undrained fluid building up under the dressing. If this fluid continues to accumulate, the dressing will ultimately separate from the skin with loss of the airtight seal, failure of the dressing to maintain suction, collection of fluid in the wound bed, and leaking of fluid from the dressing. If not corrected fairly quickly, the dressing may not be able to be repaired without completely replacing the entire dressing.

(5) Prepare extra supplies that may be necessary during flight:

Extra canisters, (2) Ioban and/or Tegaderm to reinforce the dressing if an in-flight leak develops, (3) benzoin or other topical adhesive to facilitate dressing adherence if repair is

required, (4) additional suction adjuncts such as additional bubble tubing, Y-connectors, and "football" connectors, and (5) a shaving razor to remove hair prior to dressing reapplication may all be required to successfully troubleshoot and repair a malfunctioning NPWT dressing.

(6) Determine the number of canisters required for flight:

- The VAC Freedom NPWT canisters are small (300 ml). They cannot be emptied or reused; the pump will automatically shut off when the canister is full.
- It is imperative that enough canisters are taken as extra supplies to last for the duration of the flight. Check the hourly wound output for the prior 24 hours to help estimate the number of required canisters. If the Impact suction is being used instead of the KCI pump, the impact canisters are larger and can be emptied and reused if absolutely necessary.

(7) Develop an in-flight NPWT failure plan:

Prior to departure, it is reasonable to discuss with the surgeon whether a particular NPWT dressing may be safely converted to a wet-to-dry dressing if equipment issues cannot be overcome. This is easiest in smaller wounds with minimal output.

(8) Consider power and outlet access:

- Electrical cable assembly system (ECAS) setups may support as few as 4-7 power outlets per patient. The number of wound VACs per patient may exceed this capability. Constant vigilance will be needed to ensure the wound VACs remain charged. Rotating power cords between devices may be necessary.
- Each VAC Freedom draws 1 ampere of power; this must be taken into consideration in pre-mission planning with AE.
- In the event of power cord shortage, the Ranger Glidescope power cable is compatible with the KCI VAC Freedom.

Addressing NPWT Dressing Failure in Flight

The most common problem CCAT teams face is the inability to maintain negative pressure. This is most commonly the result of a leak at the edge of the adhesive dressing.

Review of the KCI System Alarms

- **Leak detected alarm:** sounds if the device is unable to maintain negative pressure in the wound; strategies for repair are detailed below.
- **Tube obstructed alarm:** sounds if the tubing is obstructed or if the canister is full.
 - First check the canister and replace it if it is full; ensure the canister is properly seated on the pump. Replace the canister if no other causes are found.
 - Check the tubing to ensure that there are no clamps or blood clots occluding it.
 - Increasing the level of suction may help maintain tubing patency but this should generally only be done after consulting with the physician who placed the device, if possible.

How to detect the loss of negative pressure:

- The dressing (or dressings if “Y” connected) will no longer be firm and collapsed.
- The KCI alarm sounds.

Note that there is no “loss of suction” alarm on the Impact suction device.

How to identify the site of a NPWT dressing leak:

- Begin with a thorough inspection of the pump, canister, and all tubing connections to quickly eliminate these as a source of suction loss.
- Leaks around the edges of the adhesive dressing are the most common source of leaks. To identify the exact leak site, push along the edge of the dressing in sections to determine if the leak seals with manual compression.
- Large leaks may make a hissing sound that may be detected by listening closely; this may be nearly impossible to detect in-flight due to aircraft noise, so check prior to departure.

How to repair a dressing if the leak site has been identified:

- Simple reinforcement with additional adhesive dressings can repair most leaks.
- Before placing a patch on the dressing (most commonly the edge with require repair), the skin should be thoroughly cleaned, dried, hair removed, and a supplemental adhesive (i.e. benzoin) should be applied to maximize the chances of a successful seal.
- In complex dressings with multiple wounds attached to a single suction source, it may be possible to preserve suction on the dressing by excluding a single wound that is responsible for the loss of pressure on the entire dressing. After excluding the wound with the leak, work to identify the leak in the dressing and repair if possible.

How to repair a dressing if the leak site could not be identified:

If no obvious leak source is identified, an attempt should be made to cover the entire existing adhesive dressing with a larger sheet of Ioban. Depending on the size and location of the wound, this may or may not be possible. Again, drying the original dressing and skin and following with benzoin may increase the chances of obtaining an airtight seal. Avoid circumferential limb dressings.

What to do if a dressing leak cannot be repaired:

If efforts to resolve the loss of suction are unsuccessful, teams should resort to the contingency plan established before flight departure; discuss these options with the sending physician prior to departing the MTF. Depending on the remaining transport time, size/location of the wound, and wound output, one of the following strategies can be selected:

1. Leave the dressing in place and attach Impact suction at higher suction level. The higher suction may help overcome losses from small leaks.
2. Remove the dressing and replace with a traditional wet-to-dry dressing for any wound except for an abdominal or thoracic temporary closure. If you remove a VAC dressing, document number of sponges removed from the wound so that none are inadvertently left behind.

What to do if the equipment fails:

- If the KCI VAC Freedom fails in flight, it is usually appropriate to attach the dressing to a standard Impact suction device.
- In small extremity wounds with minimal output, it may be appropriate to switch to wet- to-dry dressings.

In-flight management and patient monitoring:

- Quantity and quality of drainage should be monitored hourly. Changes in either the quantity or character of the output should be discussed with the CCATT physician.
- The drainage should be monitored for frank blood; see the special considerations section for strategies to deal with bleeding from a NPWT dressing.
- Additional vigilance is required when using the Impact suction unit for NPWT as there are no alarms to alert the team to malfunctions or changes in output.
- For negative pressure therapy to extremities, document distal pulse exams hourly. If a change in pulse exam occurs, CCAT teams should urgently evaluate the reason for the change, and ensure that large or near-circumferential extremity dressings is not restricting blood flow due to worsening edema.⁹
- Negative pressure should be applied continuously to all NPWT dressings. Prolonged periods without suction allow fluid to accumulate in the wound, which will lead to dressing failure.
- Use padding to prevent pressure injury for wounds located on dependent areas of the body (i.e. back or buttock wounds on a supine patient).

Special Considerations

Placing a NPWT dressing directly over a vascular repair is contraindicated. However, if a vascular repair has good soft tissue coverage (i.e. muscle), a NPWT may be used to manage large associated soft tissue injuries. New or continuous bleeding from a wound with an underlying vascular repair should raise suspicion for failure of the vascular repair; this is an emergency that requires immediate attention. Significant bleeding can also occur from small branch vessels in the wound.

What to do if significant bleeding develops in-flight:

These steps apply to extremity/junctional wounds only, not to temporary abdominal or chest closures:

1. If a large amount of blood rapidly fills the wound VAC then apply manual pressure over the NPWT dressing, remove the suction, and call the other CCATT members for help.
2. If life-threatening bleeding from an extremity wound is identified (the patient is tachycardic or hypotensive):
 - a. Maintain direct pressure over the wound and have a second CCATT member place a CAT tourniquet 2-3 inches proximal to the wound and tighten it until the bleeding stops. The NPWT dressing can be removed and the wound tightly packed with Kerlix or Combat Gauze and then wrapped with an ACE bandage or Coban. Arrange for a diversion to the nearest surgical facility.

- b. Next decide when to release the tourniquet. This decision should involve the surgeon from the sending facility, if possible. Factors to consider are the patient's hemodynamic status, blood availability, experience level of the provider with packing surgical wounds, likelihood of arterial bleeding, and the projected time of arrival at a surgical facility. The tourniquet time should be less than 2 hours, if possible.
3. If extremity wound bleeding is significant but not life-threatening (the patient is normotensive and not tachycardic):
 - a. Maintain direct pressure over the wound and have a second CCATT member position a CAT tourniquet 2-3 inches proximal to the wound; the tourniquet does not have to be tightened, but rather pre-positioned if bleeding worsens. The NPWT dressing can be removed and the wound tightly packed with Kerlix or Combat Gauze; and then the entire limb can be wrapped with an ACE bandage or Coban.
 - b. If bleeding is significant during packing, then the tourniquet can be tightened for control until wound packing and pressure dressing are completed.
 - c. Wound packing and a pressure dressing can control most wound bleeding. A surgical consult would be appropriate; consider emergency diversion if bleeding is not controlled.
4. If life-threatening bleeding is identified from a groin or axilla junctional wound (the patient is hypotensive or tachycardic):
 - a. If direct pressure does NOT control the bleeding, rapidly remove the NPWT dressing, pack the wound with Combat Gauze or Kerlix, and again apply direct pressure. Divert to the nearest surgical facility; obtain an in-flight surgical consult.
 - b. If direct pressure over the NPWT dressing DOES control the bleeding (the NPWT dressing no longer fills with blood), continue holding pressure and consult surgery in-flight.
 - c. Next decide whether the NPWT dressing should be removed to pack the wound. This decision should involve the surgeon from the sending facility, if possible. Factors to be considered are the patient's hemodynamic status, blood availability, experience level of the provider with packing surgical wounds, likelihood of arterial bleeding, presence of a vascular repair, and the projected time of arrival at a surgical facility.
 - d. If the patient-to-CCATT ratio allows, maintain manual pressure using a team member rather than converting to a junctional tourniquet as manual pressure may be more reliable. Placement of the junctional tourniquet is not always straightforward and may increase limb ischemia.
5. If non-life-threatening bleeding is identified from a groin or axillary junctional wound (the patient is not hypotensive or tachycardic):

Remove the NPWT dressing and pack the wound tightly and apply a pressure dressing to the entire limb. The junctional tourniquet can be used (may not need to be fully inflated) to maintain pressure if manual compression cannot be maintained because CCATT members cannot be spared from other patient care. Emergency diversion should be considered; an in-flight surgery consult would be appropriate.

6. Bleeding from a neck wound can be managed with direct pressure, then remove NPWT dressing followed by wound packing as described above. Emergency diversion should be considered for surgical evaluation; discuss with sending surgeon in-flight.
7. Anticipate resuscitate requirements for a bleeding patient. Do not wait for shock to develop. Replace blood with blood, not crystalloid.

What to do for small amounts of bloody output:

If bleeding develops from a NPWT dressing that doesn't cover a vascular repair, and if the volume is small, monitor the character and volume of output and consider reducing the suction. Reducing the suction may decrease the wound output, but it may also allow buildup of blood under the sponge where you can't see it. If there is concern about persistent ongoing active bleeding, get help and good lighting and remove the dressing, control the bleeding if possible, and pack the wound with Kerlix or Combat Gauze and wrap the limb with an ACE bandage or Coban.

The open abdomen:

- A leak from a NPWT dressing on an open abdomen may rapidly progress to evisceration if not repaired. A malfunctioning open abdomen dressing should be aggressively repaired in flight but not removed/replaced. (See strategies for NPWT failure in flight.) Chemical paralysis will help reduce the chance of evisceration in the event of malfunctioning open abdomen dressing.
- A temporary abdominal closure does not always evacuate all the blood in the abdomen, so it is possible for a patient to bleed into their abdominal cavity without a significant increase in the wound VAC output. This diagnosis requires close observation and continuous evaluation of hemodynamics. Markers of intravascular volume status (i.e. urine output, PPV, base deficit, TTE) should be also used.
- It is important to recognize that abdominal compartment syndrome can occur in spite of an open abdomen. If there is clinical suspicion (hypotension, low urine output, elevated peak airway pressures on the ventilator in volume mode), assess intraabdominal pressure by transducing a bladder pressure – greater than 20 mmHg may indicate abdominal compartment syndrome.

The open chest:

A chest that has been temporarily closed should have a chest tube(s) placed inside the chest, as well as a suction catheter coming from the wound itself. The chest tubes AND the suction catheter need to be kept to suction per surgeon instructions, and the output from all chest drains needs to be monitored hourly. A malfunctioning NPWT on an open chest should undergo troubleshooting but not removed/replaced in-flight.

Fixed (Expected Clinical Proficiency)

CCATT members are expected to understand the following:

1. The KCI VAC Freedom system.
2. The open abdomen and chest NPWT dressing.
3. The instillation NPWT dressing.
4. The troubleshooting and repair of the various NPWT dressings encountered in the AE environment.

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Appendix A: Use of Impact Suction

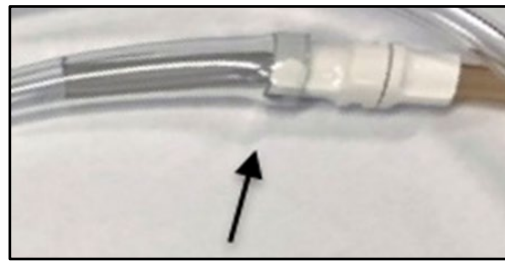
This appendix describes one way to use the Impact suction if the KCI pump malfunctions in-flight.

1. Cut the NPWT/KCI tubing approximately one inch from the white connector on the canister side (left arrow). Cutting the tube on the canister side (not the wound side, right arrow) will allow a new KCI pump to be reconnected without forcing a NPWT dressing change/repair first. See Figure 1.
2. Place bubble tubing over the cut end of the tubing and partially push it over the white connector (marked by arrow) to create a seal; see Figure 2).

Figure 1



Figure 2

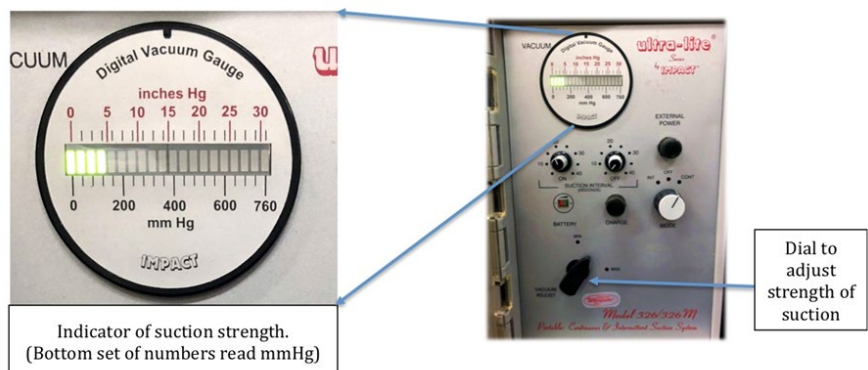


3. The bubble tubing can now be connected to the Impact suction as shown in Figure 3.
4. Ensure the suction strength is adjusted to reflect the surgeon's orders. For example, -125 mm Hg is approximately four green lights on the digital indicator, left side Figure 4.

Figure 3

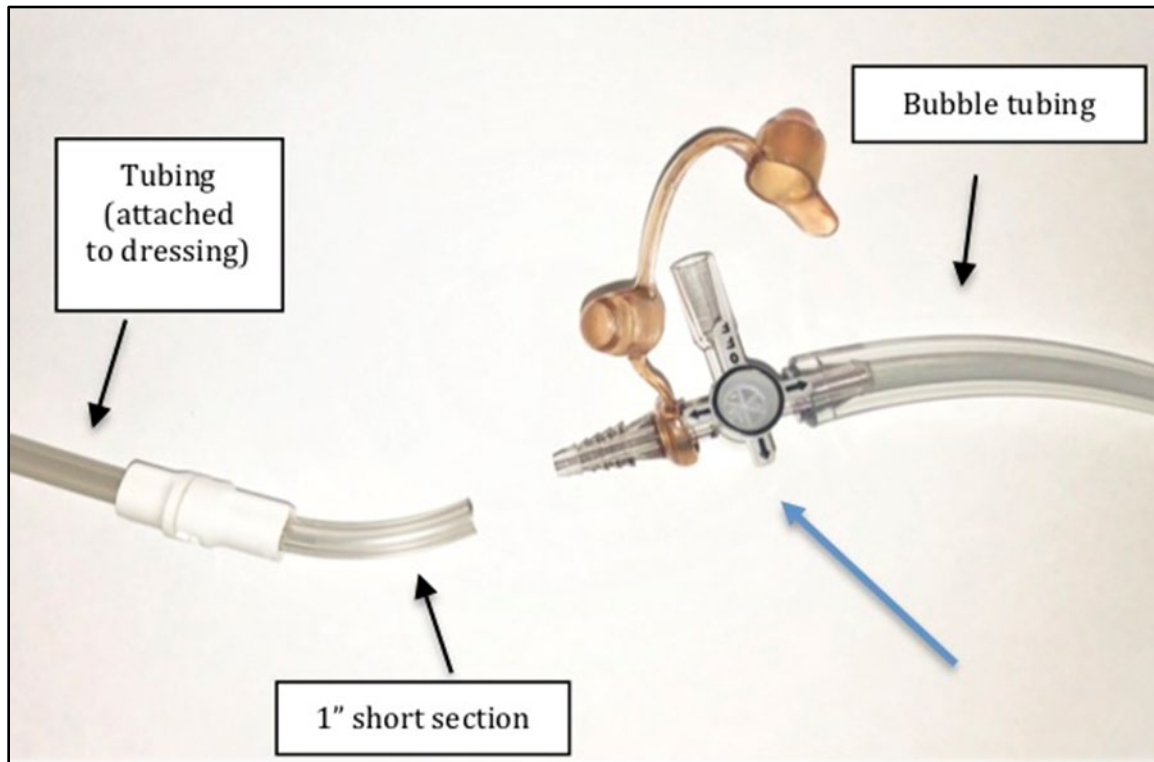


Figure 4



Appendix B: How to Construct an Instillation or Irrigation NPWT dressing

Refer to instructions below.



1. Cut the NPWT/KCI tubing approximately one inch from the white connector on the canister side.
2. Attach 3-way enteral stopcock (large arrow) between the bubble tubing and the one-inch short section; the other end of the bubble tubing connects to the suction.
3. Connect the two tubing sections in the figure to complete the NPWT circuit.
4. Irrigation procedure:
 - a. Turn stopcock off to "suction."
 - b. Instill medication.
 - c. Keep suction off during medication dwell time (defined by surgeon.)
 - d. Turn stopcock off to "syringe" and resume suction at previous settings.
5. Identify additional supplies and solution that will be needed during flight and retrieve items from the MTF prior to departure.
6. Using the impact suction is preferred because it has a larger capacity to collect irrigant and wound output.