SHOULD YOU HELP?

POSSIBLY. MAKE SURE SOMEONE NEEDS A BADGER BOX AND CAN ACCEPT IT.

If you are a maker space, a light manufacturer or just a handy family, this may be a way for you to give back. There are a just a few things you need to make this happen.

Connections to hospitals

You should figure out who to talk to at a hospital see if they have a need for Badger Box.
See if their infection control or their procurement group will approve use of this enclosure.

Money

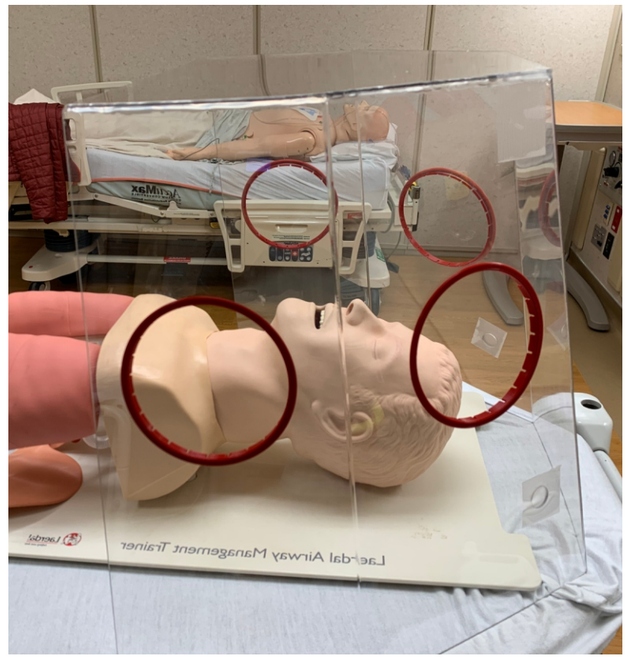
It varies between $10-$50 in raw materials to make a box depending on your strategy and goals.
We suggest selling these to the hospitals, not donating them to make sure
your organization will be able to keep working on this and not lose steam. Incentives work.

Equipment

We used a CNC wood router to cut the polycarbonate panels, a sheet metal brake for bending,
and a hot melt glue system for adhering the top to the sides.
Wear gloves and work in an area you can keep segregated and clean.
The box doesn't need to be sterile but good manufacturing practices are important.

Labor

You need people to fabricate them, package them and ship or transport it.



REVISION

V1 INITIAL RELEASE
V2 ADDING ADDITIONAL DOCUMENTATION, UPDATE TO LOGO
V3 ADDING IMAGES, UPDATED TERMS

BADGER SHIELD

OPEN SOURCE BADGER BOX V3

TABSYNTH DESIGN WORKS | UW MAKERSPACE
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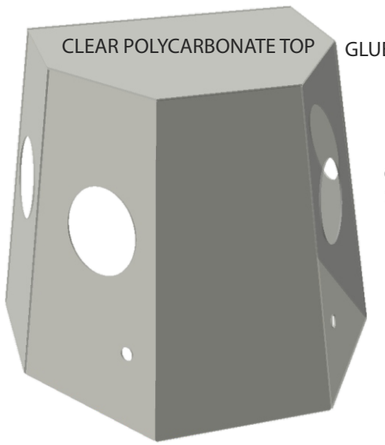
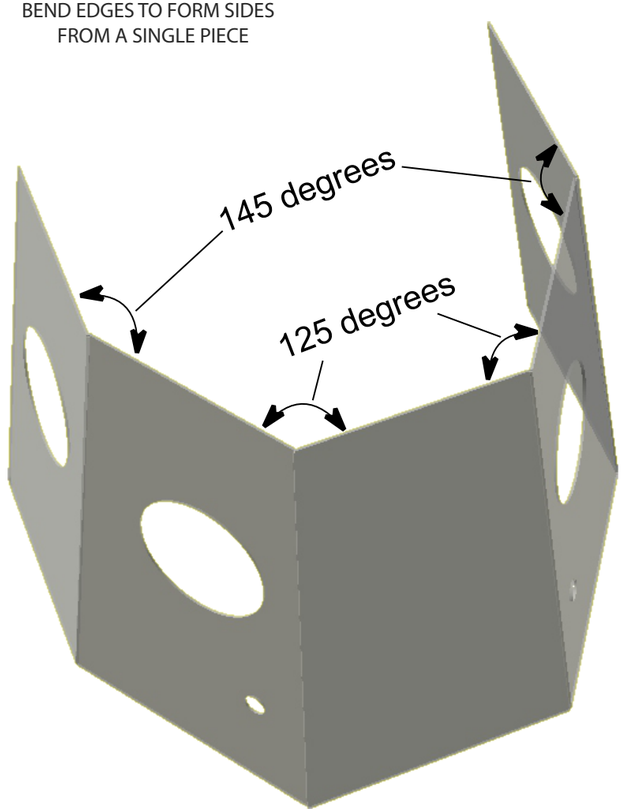
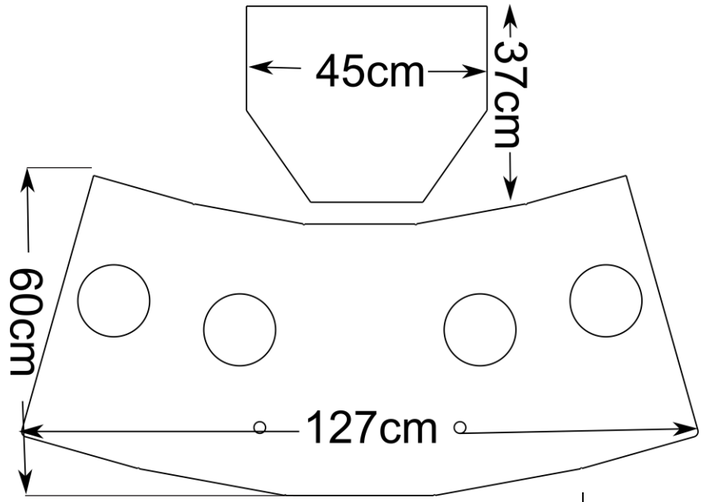
MATERIALS LIST

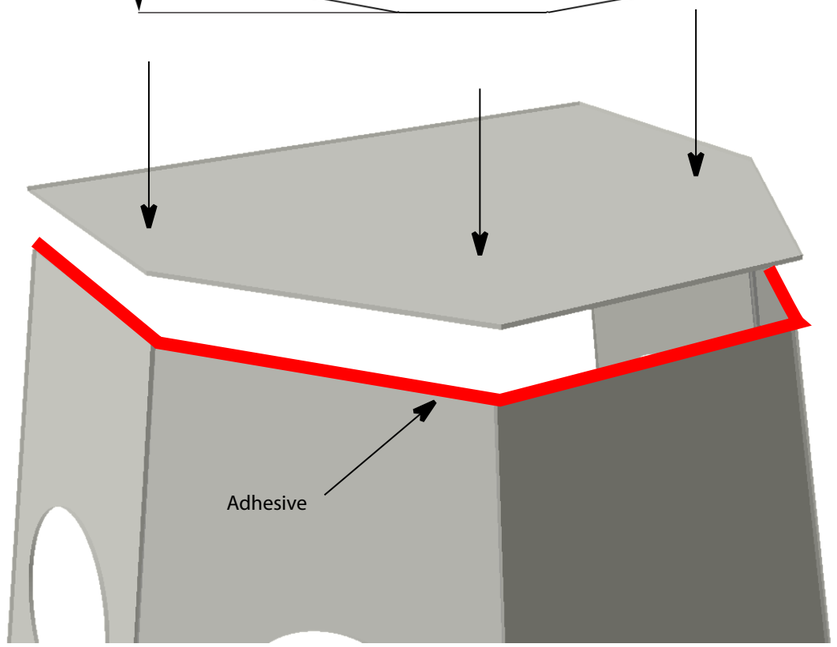
~$500 TO MAKE 10 BADGER BOXES WITH POLYCARBONATE PARTS AND A HOT MELT GLUE SYSTEM.



BEND EDGES TO FORM SIDES
FROM A SINGLE PIECE







A NOTE ON MATERIAL SELECTION

WE CHOSE THESE MATERIALS BECAUSE THEY ARE SIMPLE TO ORDER AND COME FROM MANY SUPPLIERS. WITH OTHER PROJECTS USING MATERIALS LIKE THESE, IT IS LIKELY SHORTAGES WILL CROP UP.

WE ENCOURAGE YOU TO FIND ALTERNATIVE SUPPLIERS. OTHER TRANSPARENT PLASTICS WILL WORK, JUST BE SURE THAT THEY MEET THE DESIGN GOALS OF RIGIDITY, AND CLEANABILITY.

CLEAR SHIELD

CLEAR POLYCARBONATE SHEET - APPROX 3MM (1/8") THICK.
MCMASTER-CARR PART NUMBER 8564K73 - https://www.mcmaster.com/8564k73
(OTHER THICKNESSES AND MATERIALS SUCH AS PET, PETG, OR ACRYLIC ARE POSSIBLE SUBSTITUTES, BUT BE SURE TO CHECK ADHESIVE COMPATIBILITY.)

SHEETS ARE 48" X 96" AND YOU GET 10 BOXES FROM 3 SHEETS OF MATERIAL, EACH BOX COSTS ~$50.

NOTE: VECTOR LINE WORK IS INCLUDED ON PAGE 4 OF THIS DOCUMENT FOR ROUTING OR DIE CUTTING.

ADHESIVE CHOICES

ACRYLIC GLUE / EPOXY / HOT MELT ADHESIVE
SELECT AN ADHESIVE APPROPRIATE FOR THE MATERIAL USE AND WHICH WILL PRODUCE A SMOOTH CLEANABLE SEAM.

TAPE CAN BE USED TO JOIN THE SEAMS, PROVIDED IT IS SUFFICIENTLY STRONG AND RESISTANT TO TEARING, AND CAN BE CLEANED WITHOUT LOSING ITS ADHESIVE PROPERTIES. TAPED JOINTS MUST RESIST EXCESSIVE FLEXING.

PLEASE NOTE THAT ANY ADHESIVE MUST NOT OFF GAS OR PRODUCE NOXIOUS ODORS WHEN IN USE

FINISHING EDGES

ALL EDGES AND CORNERS MUST BE DEBURRED AND CHAMFERED TO REMOVE ANY AND ALL SHARP CORNERS OR DEFECTS FROM THE CUTTING PROCESS.

YOU SHOULD BE ABLE TO RUN A SHEET OF PAPER ACROSS ALL EDGES WITHOUT IT SNAGGING OR BEING TORN. ALL CORNERS SHOULD BE ROUNDED. THE INSIDES OF ALL THE HOLES MUST BE CHAMFERED.

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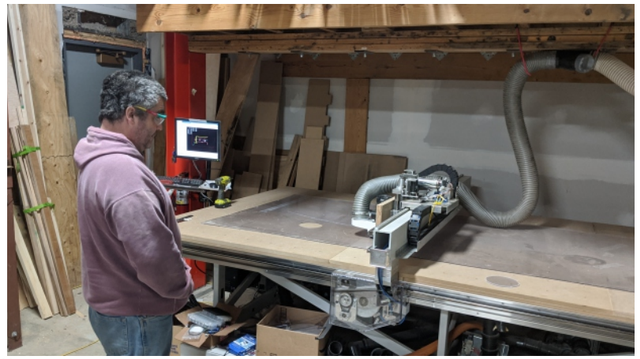
HOW TO MAKE IT

THIS IS OUR METHOD, BUT PLEASE EXPERIMENT AND FIND A BETTER WAY.

PREP COMPONENTS

First step is to source material and design around what's available to you. Size your material to fit on your machine bed.

Cutters from best (left) to worst (right): single flute, two flute upcut, two flute straight, two flute down cut

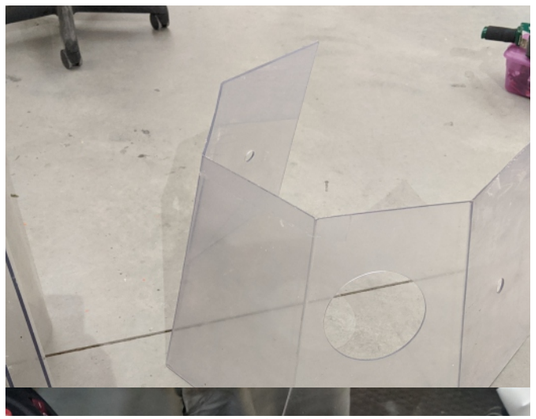


We set up a corner stop for repeatable cuts, you can screw down material or use a vacuum if you have it available.

Verify your cuts and deburr all edges

ASSEMBLE

We used a sheet metal brake to accomplish the bends, you could also heat bend the material.

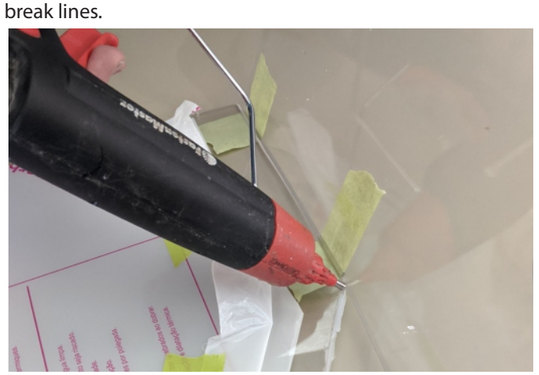


Before gluing, verify that your bends leave the shape flush against a flat surface, otherwise you aren't bending along the break lines.

Prepare the base by peeling the edges of the guard and add tape to hold the edges while the glue is setting.

We used FastenMaster hot melt construction adhesive to carefully seal the corners. This eliminates time for curing or off gassing.

Use tape to act as a hinge and keep things aligned, walk glue and tape from the center to the corners.



Apply glue in an even consistent bead making sure to wet both sheets leaving behind a wipeable fillet.

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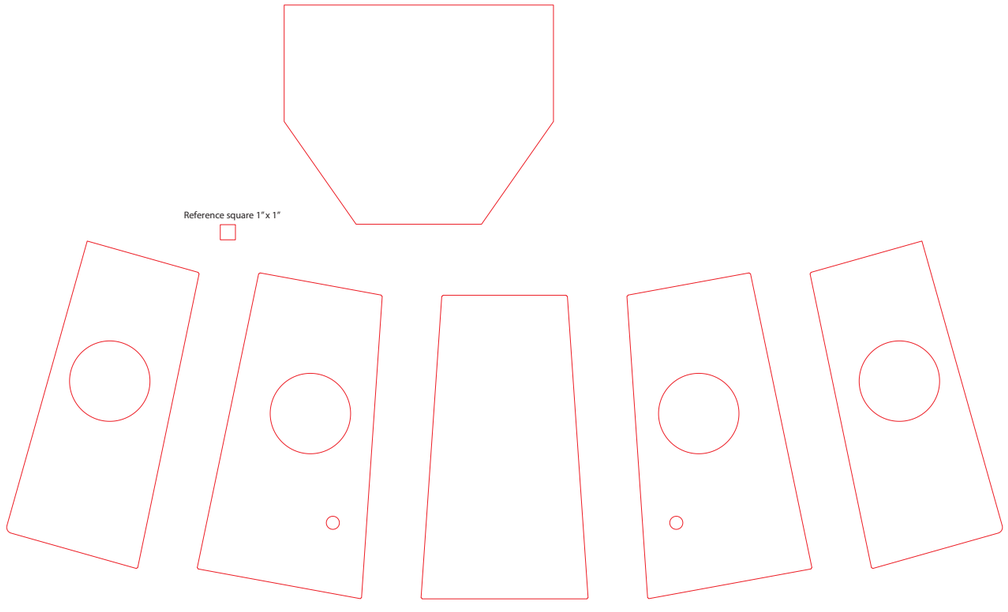
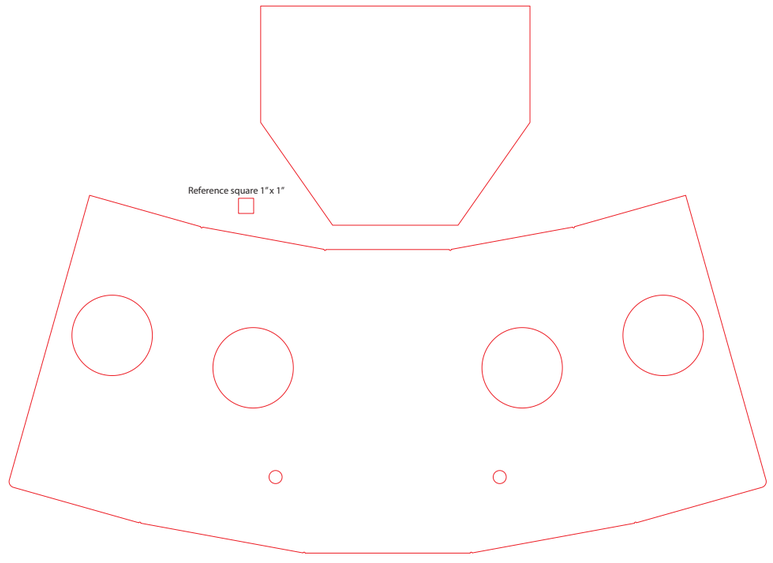
PANELED CONFIGURATION FOR CUTTING AND GLUING



COMBINED CONFIGURATION FOR BENDING AND GLUING



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Sheet Scale 1:10

Overview

Given the limitation in PPE availability and negative pressure rooms to treat COVID-19 patients, a variety of solutions have been presented to minimize exposure to hospital workers from alert or intubated patients. In reviewing options, we've worked closely with many departments at UW Hospital to arrive at this construction and geometry.

Design Guidance

Access Holes

Number:
Minimally, two arm holes are needed for the intubation procedure. Practically, it was found that four arm holes are preferred. The reason for this is that frequently, assistance is required, which requires a third or fourth hand to be inserted into the working space. In the absence of extra arm access holes, the surgical drape would need to be un-taped and opened up to provide access.

As a practical matter, as long as the arm access holes can be sealed when not in use, it does not hurt to have extra arm access holes.

Sealing the arm access holes:
The access holes can be lined with tubular sleeves constructed from large (8.5) or XL surgical under gloves, placed around a snap ring grommet that then inserts into the arm hole opening. These sleeves serve to reduce flow into the hood, and provide an additional barrier to the direct flow of aerosols out of the box. Additionally, the sleeves can be plugged when not in use.

Flaps can also be constructed over the arm access holes, by taping an appropriately sized drape over each opening. Such flaps will naturally lie against the side of the box, providing a barrier against direct outflow.

See chart below for various considerations when deciding how to provide patient access:

	Drape	Cover Flaps	Gloves in Rings
Ease of Access			
Consumable Requirements			
Sealing for Air Evacuation			
Stability			

Negative Air Pressure:
Testing at UW Hospital and the University of Wisconsin-Madison, has established the effectiveness of providing for a negative pressure inside the box. This can be accomplished by applying suction to one or more ports on the side of the box. Such suction can come from hospital vacuum or through a stand-alone vacuum system, both requiring appropriate modification to minimize flow restrictions and added filtering.

The negative pressure created serves two important functions. First, it continuously cycles the air out of the box replacing it with room air, drawing any suspended aerosols out with the air removed. Second, it establishes a continuous inflow across any and all openings in the box, such that the inflow of room air works to prevent suspended aerosols from migrating out through any openings.

Shape

The commonly used square box construction with two arm access holes in one face of the box doesn't provide good ergonomics nor access for someone assisting in a procedure. The pentagonal shaped box presented here places the primary arm holes at approximately a 55 degree angle which improves the ergonomics and provides for a more comfortable working environment for performing the intubation procedure.

Tapering the side walls, towards the top, serves a similar purpose in improving the ergonomics when bending over the patient's head. The tapered side walls have a second function, in that a drape taped over the access holes will tend to lay against the wall and provide a better seal. Lastly, by tapering the side-walls the box is made more stable because the base is wider and the top is less likely to be bumped.

Height is crucial in designing the box. It was found through testing that a minimum of 50cm overall height is required to provide sufficient working clearance for the intubation procedure.

Rigidity is important as long as thicker material is available. The box walls should be sufficiently rigid to support a human leaning against the box or the arm holes. It should also be stiff enough

to prevent collapse with the use of a negative pressure system like the hospital vacuum system. The box should not sag with the weight of the drape or shift if bumped during the procedure.

Any new design should be evaluated carefully and tested by actually performing a simulated intubation procedure to evaluate any constraints the system imposes.

Materials used for construction

The box can be constructed from a variety of transparent or semi-transparent materials. A clear top is obviously required for patient comfort and provider visibility. Clear side-walls, while not necessarily a requirement are desirable, as they create a less claustrophobic environment for the patient. Clear materials that are appropriate are acrylic (PMMA), polycarbonate (Lexan), PETG, or vinyl. Each has advantages and disadvantages, see chart below:

	Polycarbonate	**Acrylic**	**PETG**	**Coroplast**	**Vinyl sheet**
Transparency	Excellent	Excellent	OK	Poor	Adequate
Bending	Cold bending Heat bending	No cold bending Heat bending	Folds easily	Corrugated, must be scored/routed for bends against corrugation	Folds easily
Fabrication	Router	CO2 laser Router	Tangential blade Router Scissors	Tangential blade Router Scissors	Tangential blade Razor Knife Scissors
Durability	Durable Prone to scratching	Crack prone / shatters Scratch resistant	Durable Scratches easily	Durable Scratches easily	Soft Scratches easily
Bonding	Hot melt glue Silicone caulk Methylene chloride	Hot melt glue Silicone caulk Solvent welding	Double sided tape Tape Sewing	Double sided tape Tape	Double sided tape Tape Sewing
Cleaning	No Abrasives	No alcohols or solvents	No Abrasives	No Abrasives	No Abrasives

Cleanability is an important consideration if the box is to be reused. Both the material choice and the construction method need to be carefully considered with regards to how cleanable the finished product is. If the joints or seams cannot be effectively sanitized then the box should be considered single use. The material used for the transparent window should be tested to remain usably transparent after the expected number of cleaning cycles or it can be installed in a manner that allows it to be easily replaced. Careful consideration should be given to the

materials used to make the box and the chemicals used to clean it for their compatibility so you don't have any mechanical breakdown of the material or degradation in transparency.

Currently (April 2020), there is a significant shortage of transparent plastics for the construction of boxes. This is due to the large number of projects across the world using these materials to create safety barriers. Backorders and long lead times can occur so make sure to work with your supplier to verify material availability before proceeding with any design. The materials used should be of sufficient but not excessive thickness, so as to produce a box of reasonable weight that is easy to handle and move on or off a patient.

Material Selection

Polycarbonate - Routed

Our systems were constructed from CNC routed polycarbonate. Polycarbonate (Lexan) is an extremely durable material. Although it is slightly softer and more prone to scratches than acrylic, it is more chemically stable and easier to clean. Generally, polycarbonate is a little more expensive than acrylic. It can be solvent bonded with methylene chloride or a solvent glue specifically designed for polycarbonate. Fasteners can be used with care, but must not be overtightened to avoid stress concentrations that could lead to cracking.

Acrylic - Laser Cut/Routed

Acrylic is certainly an option, it provides easy manufacturing, reasonable durability, and good scratch resistance. Care must be taken when selecting cleaning materials. Laser cut acrylic can be prone to cracking if not adequately annealed. Acrylic can be solvent welded and glued with a variety of adhesives. Care should be taken to be sure that any solvents used, have completely off-gassed before the box is put into service. Acrylic can be heat bent and formed. Care should be taken with any fasteners used, as stress concentrations can quickly lead to cracks in acrylic.

PETG/Coroplast - Die/Blade Cut

Either PETG/vinyl or coroplast can be cut on a die cutter or tangential cutting system. PETG/vinyl have better transparency but coroplast has increased rigidity. These materials are a low cost option which can be mass produced by any die cutting shop, or made in smaller quantities by a CNC tangential knife or CO2 laser. For even smaller runs it can be cut with a box cutter and a metal straight-edge.

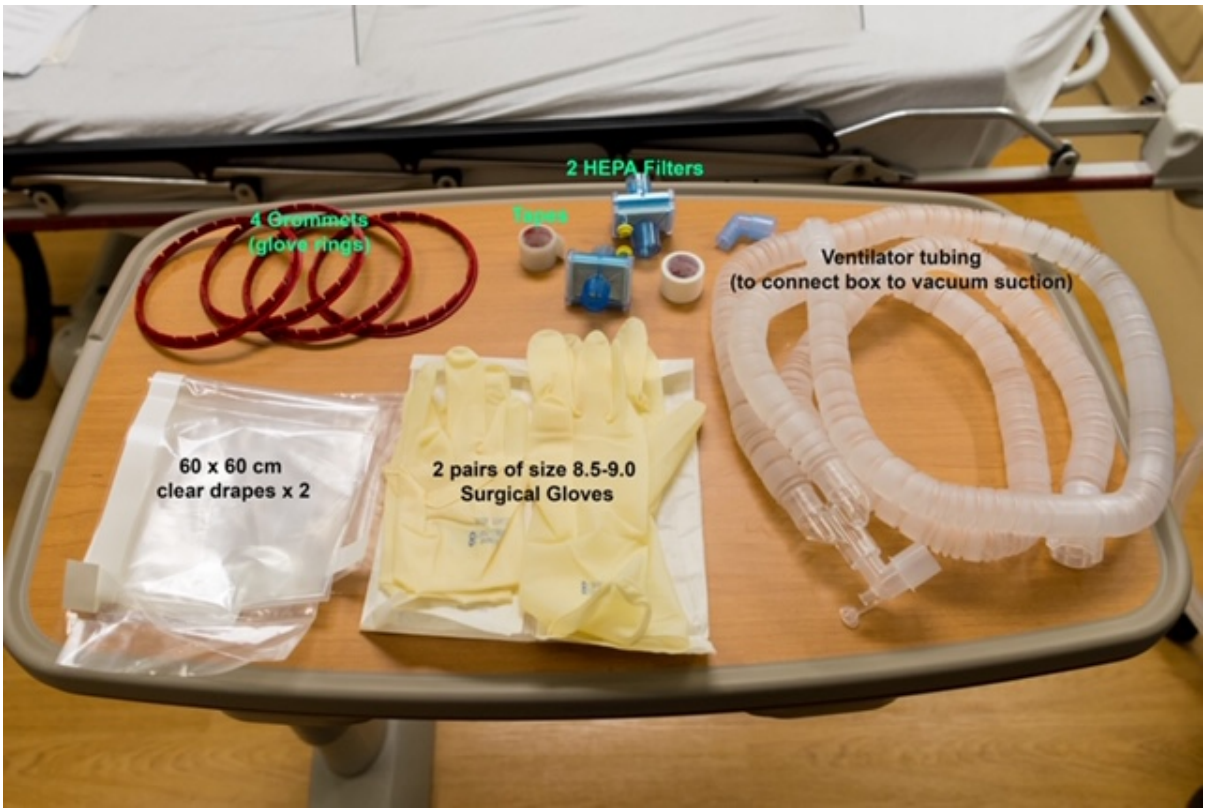
Finishing Details:

Regardless of the material choice and design specifics, great care should be taken when finishing the build. All sharp edges should be chamfered. Cut pieces and all holes must be deburred. Any corners should be rounded. Joints should be filled completely and smooth, to provide cleanable surfaces.

You can increase the stability and rigidity of any of these systems by simply taping the bottom edge to the operating table with wide surgical tape. This has the additional benefit of improving the seal, when providing for negative pressure.

Additional Materials

Materials shown below may assist in the utility of the Badger Box.



Images