Anti-slip Device for Patient Transport External Design Review 2

Providing accessible lateral patient transport while preventing patients from sliding during surgery

Team 9: Jared Pavlick, David Brenton Svacha, Tyler Vallier, Trenton McLean, Scott Westrick, Elizabeth Lombard

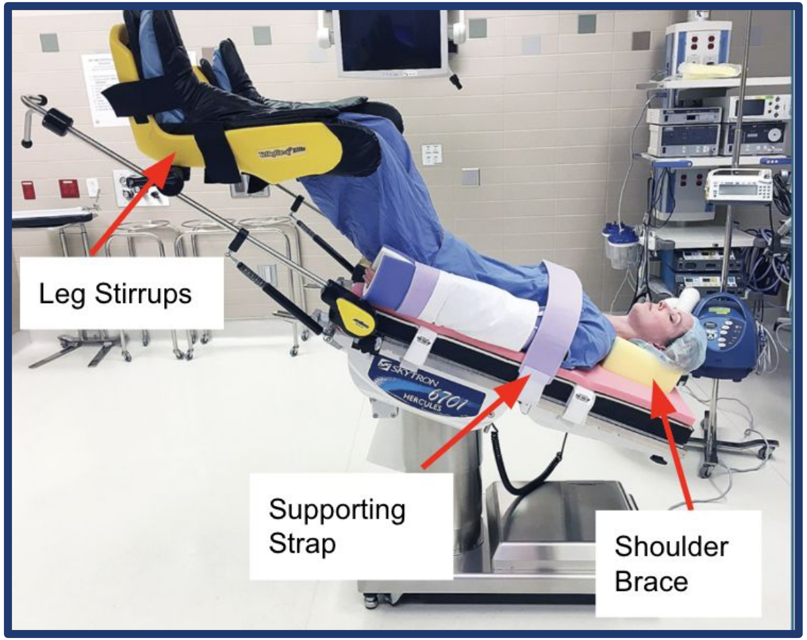
Date: Tuesday, April 18th, 2023

Lateral Patient Transfer Devices

Lateral patient transfer devices allow for easy transport of patient between beds, reducing load on caregivers.

Image: https://hovermatt.com/products/hovermatt-single-patient-use/

Trendelenburg Position



- Patient lies supine with their feet higher than their head.
  - Gravity pulls the organs away from the pelvis
- Used in lower abdominal surgeries
- Risks include:
  - slipping
  - altered pulmonary function
  - airway edema
  - increased intracranial and intraocular pressure
  - nerve injury

Image: https://www.aorn.org/outpatient-surgery/article/2020-August-safe-and-standardized-trendelenburg-positioning [1]

Problem & Need Statement

Problem Statement: Currently, the inflatable air transfer devices used to move patients to the operating table are deflated and remain under the patient during surgery which increases the chances of perioperative slipping.

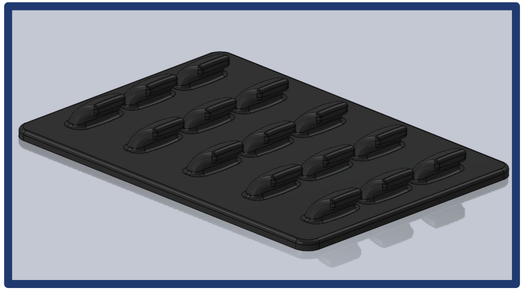
Need Statement: There is a need to reduce the frequency of slipping during surgery by preventing the low friction mat from moving, to reduce the risk of surgical complications while still allowing easy maneuvering of patients pre- and post-operation.

Project Scope

- Our client has expressed interest in functional prototype from modification of existing solution with final production in mind
- Team goals include development of a functional alpha prototype that fulfills design requirements through validation and verification testing
- Future goals include a beta prototype using final product materials and testing of the device within the end environment with healthcare providers

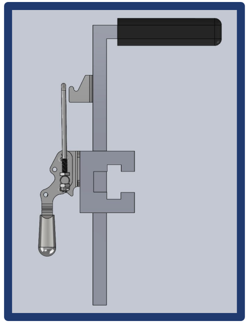
Top 3 Concepts

Cleat Design



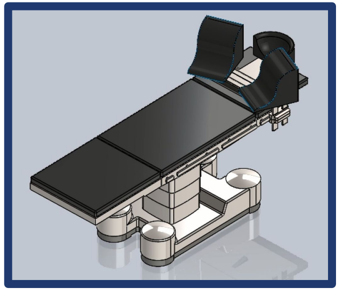
(+) Inexpensive
(+) Custom friction patterns
(-) Potential discomfort interfacing with patient
(-) Increases setup time

Added Clamp



(+) Reuse reduces environmental impact
(+) Minimal setup time
(+) Does not interface with patient
(-) Could be in way of other OR rail devices

Improved Bodily Restraint



(+) Most dynamic to patient needs
(-) Expensive
(-) Complex solution to simple problems

Design Requirements (Updated)

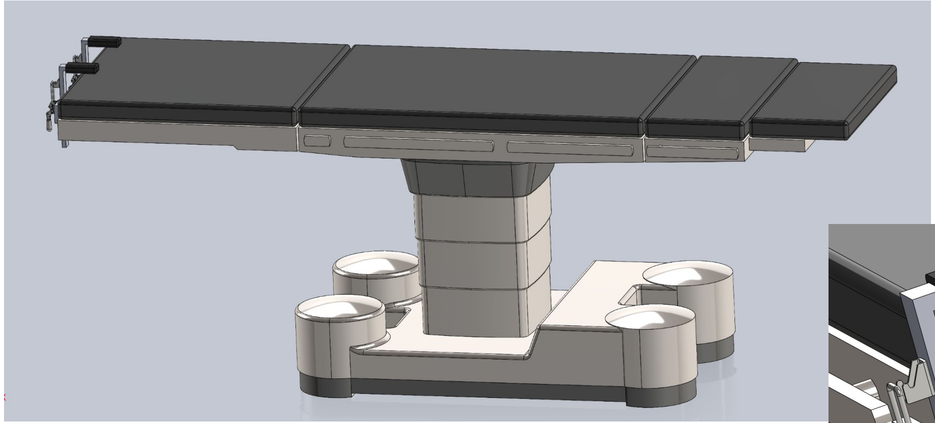
User Need	Critical/Non-Critical	Design Requirement	Design Specification	Justification
1.1 Reduces risk of patient slipping during surgery	Critical	Anti-slip device must be able to counteract the force of gravity at Trendelenburg angle of up to 40 degrees and significantly reduce the slip distance of the deflated transfer device.	The device must provide a reaction force that reduces slipping to less than 1” in order to ensure the safety of the patient during surgery.	The device must be able to counteract the force exerted by the patient, to prevent sliding in the trendelenburg positions. The force necessary to complete this is derived from the equation, $F = \mu \cdot mg \cdot cos\theta$. In order to encompass every patient, the device must be able to support the maximum weight in the highest angle of trendelenburg, with the lowest coefficient of friction. [11]

2.1 Device is not obstructive during surgery	Critical	Device needs to maintain a low profile with the operating table to not get in the way of surgical staff	Device should be used at a 90º angle and lay flush with the operating room table in order to take up as little room on the table as possible. The device should not decrease the visual field and range of motion by **more than 5%.**	To keep a 360º view and a nearly limitless motion [Y]. Our design must not exceed a **5%** decrease in overall visual field and range of motion. If the device exceeds 5% it becomes obstructive and can hinder surgical performance.
2.2 Device will not damage the transfer mat	Critical	The parts of the device in contact with the mat are shaped in a way that will provide sufficient contact with the mat, but no tearing or damage.	Material chosen for part in contact with the non-woven polypropylene fiber will not have a sharp edge or be too rough	The top layer of the HOVERMATT® SPU is non-woven polypropylene fiber. The mat remains under the patient throughout the duration of the surgery, any damage to the mat would **prohibit inflation** making it harder and potentially dangerous for staff to transfer the patient.

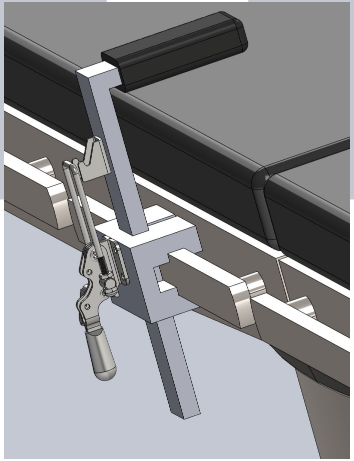
Design Requirements (Updated)

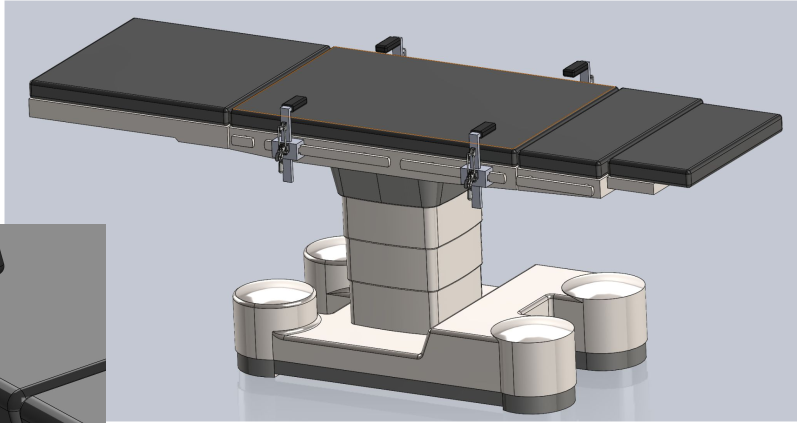
2.3 Device can be reused for multiple operations	Critical	Device material is durable (strong) and will not bend or fracture with repeated use	Our material base must be made of a steel alloy, which has an **ultimate tensile strength of 420 MPa, modulus of elasticity of 200 GPa and a shear modulus of 80 GPa**. The device must undergo **3900** trials to simulate repeated use.	The base of our device must be durable enough to withstand consistent surgery throughout its lifetime. Our team expects the same device to be used around three times per day, every weekday, for five years. This calculates out to 3900 times using the following equation: $Trials = 3\frac{times}{day} \times 260\ days \times 5\ years$
			The material of the rubber tip will be made of a thermoplastic polyurethane and last for **780** trials.	The end grip of our device must also be durable enough to withstand consistent surgery throughout its lifetime. Our team expects the same end grip to be used around three times per day, every weekday, for one year. This calculates out to 780 times using the following equation: $Trials = 3\frac{times}{day} \times 260\ days \times 1\ year$
		Device will withstand repeated sterilization without corrosion	Material chosen for the device base can withstand repeated sterilization in an autoclave **3900** times.	It is important that our device can be reused in multiple surgeries and will need to withstand the proper sterilization requirements. The base of the clamp is made of stainless steel which would undergo sterilization in an autoclave. Using the number of uses for the respective parts (calculated above) provides the basis for the amount of times it would need to be sterilized.
			Material chosen for the rubber tip can withstand repeated sterilization with disinfectant solution or steam sterilization **780** times.	It is important that our device can be reused in multiple surgeries and will need to withstand the proper sterilization requirements. The rubber tip will likely be sterilized using a disinfectant solution. Using the number of uses for the respective parts (calculated in above) provides the basis for the amount of times it would need to be sterilized.

Device Setup on OR Table



Test Case: 2 clamps secured to the foot of the table

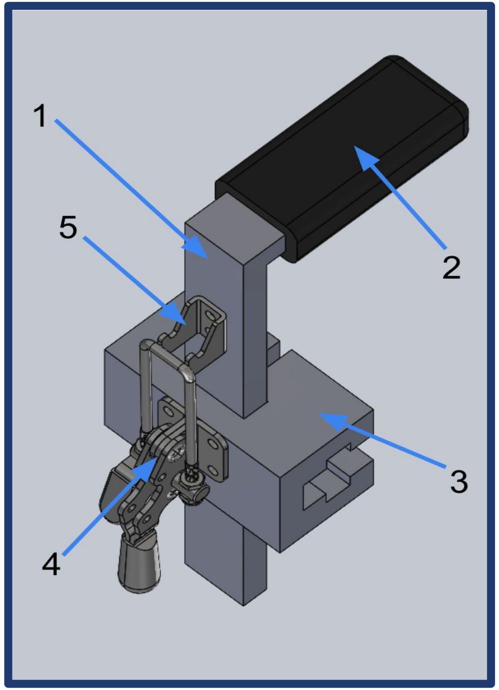


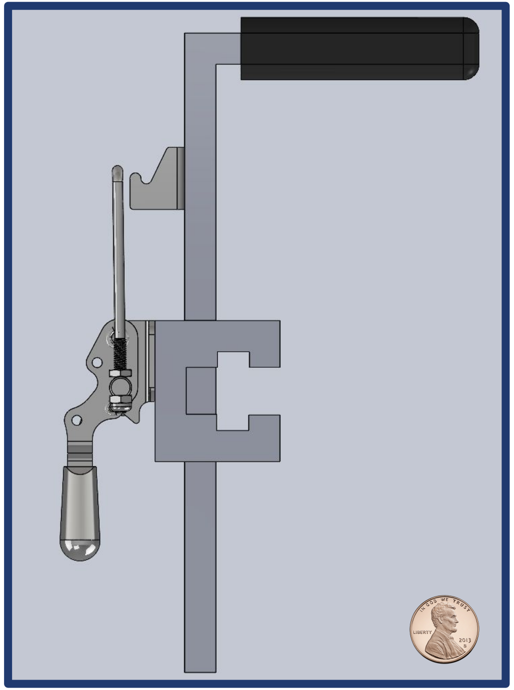


Alternative Use case: 2 clamps secured to either side of the table

Prototype Design

LEGEND:
1. L-shaped stainless steel arm
2. Rubber grip piece
3. Aluminum Clamp housing body
4. Adjustable Toggle latch-clamp
5. Latch plate

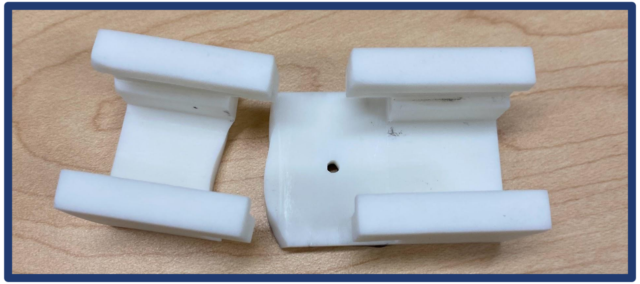




3 Prototype Phases were Needed to Finalize Design

- Initial design had inadequate length and too much height for arm
- 3D printed parts - speed of prototyping and lack of machining capabilities
  - Easy to break and bendable
- Initial latch did not have desired flexibility in extension length

Bending and inadequate surface area on bed



Lack of material allowed easy breaking

Prototype Phases

α - PDR Design

(-) Short grip/lateral arm does not adequately grab hovermat

(-) Plastic Housing - fails under stress

β - Intermediate Prototype

(-) Plastic arm - easily deforms

(+) Extended grip - grabs hovermatt better

γ - Final Testing Design

(+) Thicker housing - withstands increased stress

(+) Extended latch - more range of motion

Principle of Operation

- A clamping device that effectively holds transport devices in place and prevents slipping
  - Transport devices are prone to slipping along OR table surface, carrying patients with it
- Our solution mechanically holds patient transport devices tightly against the operating room table
  - This fully restricts the mattress from slipping by mechanically preventing transport devices from moving

User operation

Remove the device from its packaging	Locating the rail and engaging the lever	Releasing the lever and removing the device	Cleaning the device	Storage of the device
• Requiring no technical knowledge • Final packaging still to be determined	• Surgical staff locate desired position on the OR bed rail • Slide the device onto the rail • Transfer mat aligned and lever engaged to active the device	• Surgical technicians disengage lever after procedure • Transfer device removed • The housing is slid off of the OR table rails	• Separate the clamp housing from the central arm • Parts of the device are individually sterilized in accordance with user manual	• Following sterilization re-assembled parts • Store within the supply closet according to hospital procedures

Testing Apparatus

- Stryker Glideaway 1015 Stretcher Mattress
- Added rail to mimic height and dimensions of OR table
- Siderailes unavailable due to sizing and timing limitations
- 2 Clamps deemed adequate for current testing

Product in Use

FMEA

Task	Failure Mode	Failure Mode Cause	Remedy	Severity	Occur-ence	RPN		Revised severity	Revised occurence	Revised RPN
Engaging Clamp	Clamp not fully engaged when initiating clamping	Tightening knob is ambiguous and does not provide feedback to user when sufficiently tightened	Auditory and physical cues to show clamp is engaged by using new latch mechanism	3	4	12		3	1	3
Securing Clamp to Rails	Clamp placed in location that interferes with surgical operations	Ideal location of clamps not indicated while preparing OR table	Create specific locations where the clamps can only be attached to the OR table, so that they are non-obstructive during surgery	2	3	6		2	1	2
Removing Clamp from Rails	Healthcare provider is not able to intuitively unlatch clamp	Unclear how to unlatch clamp	Visual cues (such as specific labeling) which instruct users how to remove clamp	1	2	2		1	1	1

Verification and Validation Overview

User Need	Critical/ Non-Critical	Design Requirement	Design Specification	Verification or Validation	Test Method	Pass/NOT Pass
1.1 Reduces risk of patient slipping during surgery	Critical	Anti-slip device must be able to counteract the force of gravity at Trendelenburg angle of up to 40 degrees and significantly reduce the slip distance of the deflated transfer device.	The device must provide a reaction force that reduces slipping to less than 1" in order to ensure the safety of the patient during surgery.	Validation	A slip test to determine if there is a significant reduction in slip distance between the engaged and disengaged clamps. Distances will be measured both from the foot of the bed and for the "patient's" head.	PASS
1.2 Capable of supporting patient	Critical	Device must be able to withstand the weight of the patient	Device can withstand a patient weighing **1000 lbs**.	Validation	A finite element analysis test, through the COMSOL software to analyze the amount stress and strain exerted onto the device during the operation.	PASS
		Device must be able to fit around the operating table	The device must be able to tightly attach to the rails, having an unattached dimension of **1.125 inches high x ½ inches thick**, and be able to tighten snugly to the **1 inch high x ⅜ inches thick** rail.	Verification	Measure the unattached design to confirm the correct dimensions, clamp the design down, and measure the attached dimensions of the rail attachment. If all dimensions are met, device passes test	PASS

Verification and Validation Overview

User Need	Critical/Non-Critical	Design Requirement	Design Specification	Verification or Validation	Test Method	Pass/NOT Pass
2.1 Device is not obstructive during surgery	Critical	Device needs to maintain a low profile with the operating table to not get in the way of surgical staff	Devices must not add more than **2.4 in,** in overall width to the final design.	Verification	Measure the width of the current design and then measure the width of the final design, compare the two widths.	N/A
2.2 Device will not damage the transfer mat	Critical	The parts of the device in contact with the mat are shaped in a way that will provide sufficient contact with the mat, but no tearing or damage.	Material chosen for part in contact with the non-woven polypropylene fiber will not have a sharp edge or be too rough	Validation	Perform 5 different complete trials of the entire operation of the HoverMat including inflation, transport, clamp engaging, clamp disengaging, and Hovermat removal. If no damage is observed in the 5 operations the device is considered passing for prototyping.	PASS

Verification and Validation Overview

User Need	Critical/Non-Critical	Design Requirement	Design Specification	Verification or Validation	Test Method	Pass/NOT Pass
2.3 Device can be reused for multiple operations	Critical	Device will withstand repeated sterilization without corrosion	Material chosen for the clamp base can withstand repeated sterilization in an autoclave **3900** times.	Validation	Following each test conducted for User Need 2.2, the sterilization process will be completed and the device will be inspected for any flaws. If all 5 tests are able to be conducted without any damage or corrosion the device will pass for prototyping.	PASS
			Material chosen for the rubber tip can withstand repeated sterilization with disinfectant solution, as well as warm soapy water **780** times.	Validation	The device is sterilized 300 times and then subjected to a standard bench top universal tensile testing system. The device can then be evaluated to decipher the tensile force required for failure [F].	N/A
		Device material is durable (strong) and will not bend or fracture with repeated use	Our material base must be made of a steel alloy, which has an **ultimate tensile strength of 420 MPa, modulus of elasticity of 200 GPa and a shear modulus of 80 GPa**. The device must undergo **3900** trials to simulate repeated use.	Verification	A finite element analysis test, through the COMSOL software to analyze the amount of stress put on each of the devices to confirm bounds of mechanical properties. The clamp must be able to withstand repeated use in high stress situations.	PASS

Verification and Validation Overview

User Need	Critical/Non-Critical	Design Requirement	Design Specification	Verification or Validation	Test Method	Pass/NOT Pass
2.4 Complies with hospital fire safety standards	Critical	Material chosen is noncombustible	Materials used must comply with standards **ASTM E136** and **ASTM E2652**.	Verification	Study to evaluate if the materials used in the device meets the standards according to **ASTM E136** and **ASTM E2652**.	PASS
		Device storage must comply with medical fire safety standards	Device must be able to be stored at a maximum depth and height of **0.9 x 0.76 m**.	Verification	Study to evaluate if the device meets the standards according to **NFPA 99: Health Care Facilities Code, section 3.3.25-2015.**	PASS
3.1 Device can be assembled in a reasonable amount of time	Non-Critical	Device must not inconvenience caregivers or risk patients' health	Time from opening device to patient transfer must be below **2 minutes**	Validation	Device must successfully pass 6 different usability tests with total setup time below 2 minutes.	PASS
3.2 Low cost of production	Non-Critical	Cost of the device stays near current market costs.	Device production cost less than **$80.**	Verification	Conduct a financial analysis of each of the devices and compare the overall cost of each.	PASS

Testing Aimed to Mimic Real Use at Medium Fidelity

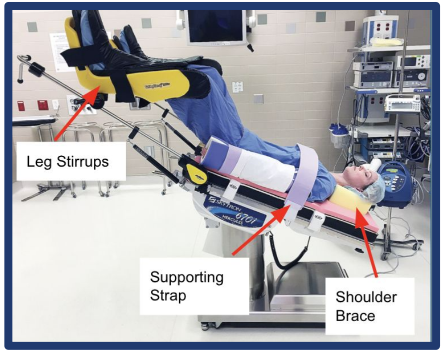
Accurate:

- Testing Conducted at 30 degree incline
- Similar Faux-Leather surface
- Hovermatt used in most surgical operations

Inaccurate:

- Stryker bed compression
- Bariatric patient dimensions
- No patient bracing
- No use of stirrups or other surgical toolings

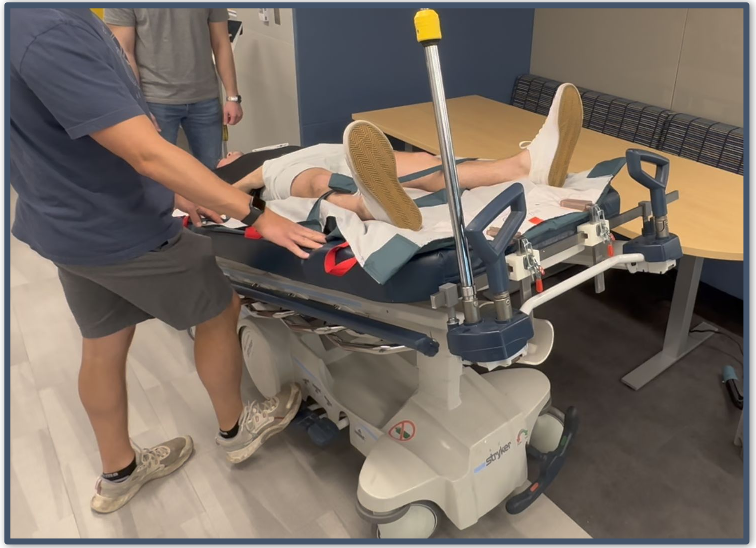
Real Use Case:



Testing set-up:

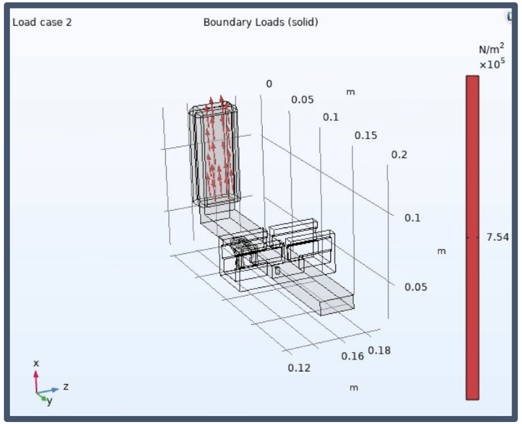
1.1 Reduces Risk of Patient Slipping During Surgery

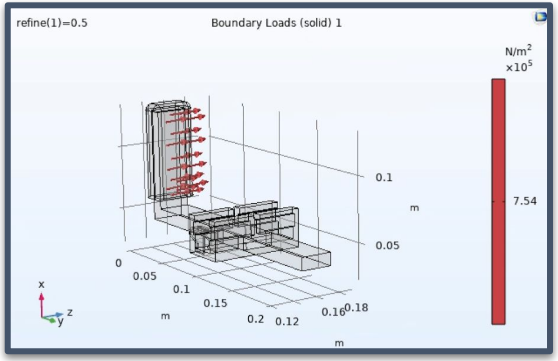
- The most critical design requirement for our device is the prevention of perioperative slipping
- To test this, we conducted slip tests using our testing apparatus
  - A subject from our team was put into the Trendelenburg position both with the clamps and without
  - The total distance moved was measured for each trial, and a significant reduction of slipping distance would PASS the test



1.2 Capable of supporting patient

- Due to the target population for this device, it is important for our device to support the patient (>500 lbs)
- To test this, we conducted slip tests with large amount of weight and verified the structural integrity of the device using COMSOL
    - A subject from our team, along with added weight, was put into the Trendelenburg position both with the clamps and without
    - The COMSOL Solid Mechanics module was used to calculate the stresses exerted on the device and whether or not the device was capable of withstanding maximum loading





2.1 Device is not obstructive during surgery

- Physician field of view and range of motion are critical to the success of a procedure
- The goal is to ensure our device does not hinder the physician in any way
- This requirement can be satisfied by having a diverse group of 20 caregivers performing their respective duties while the device is in place
  - No obstruction to duties reported constitutes as a PASS

2.2 Device will not damage transfer mat

- It is crucial that our device does not damage existing devices in its environment
  - Primary concern would be the damage incurred by current transfer technology from our device
- This test involves engaging and disengaging the device in cycles to determine if damage is done to transfer technology

2.3.1 Material is durable and will not bend or fracture with repeated use

- We want to ensure that the material chosen for each component of our design will be able to withstand repeated use
- Used COMSOL's Fatigue and Structural Mechanics modules to test whether our device may withstand multiple fatigue cycles (loads)
    - Subject metal parts of the device to 3900 load cycles (life expectancy of the device)
    - Subject rubber tip to contact load (friction) to note surface stresses exerted

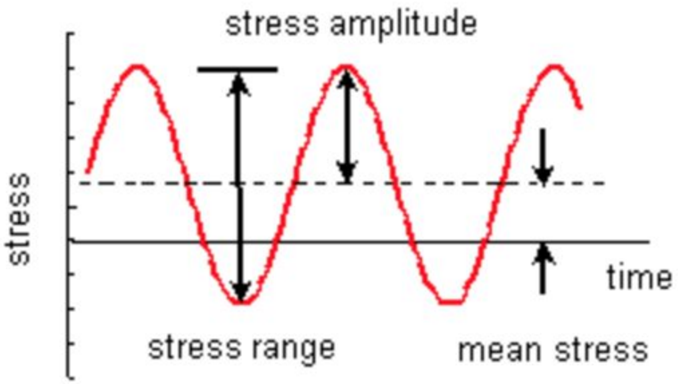


Diagram depicting a typical load cycle

Image: https://www.efatigue.com/glossary/

2.3.2 Device will withstand repeated sterilization without corrosion

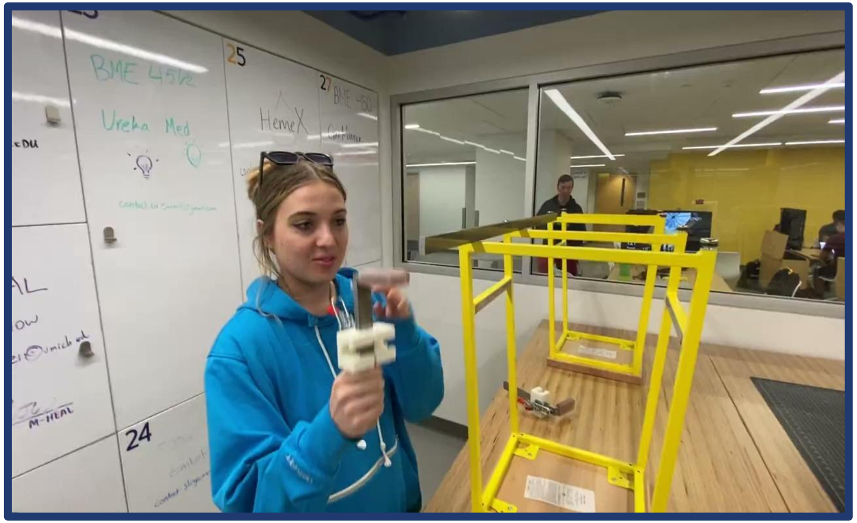
- Subject metal parts of the device to 3900 rounds of sterilization (life expectancy of the device)
- Subject rubber tip to 780 rounds of sterilization (life expectancy)
- We are limited in time for this design requirement, however given more time we could thoroughly conduct these tests
  - A literature review confirmed that the chosen materials are expected to survive for the needed time-frame

2.4 Device complies with hospital fire safety standards

- Requires our device to meet the standards ASTM E136, ASTM E2652, and NFPA 99
  - The device must not be composed of combustible materials, as well as follows hospital storage and safety guidelines
  - A literature review of the component materials for our device was conducted to ensure that our materials comply with guidelines

3.1 Device can be assembled in a reasonable amount of time

- Time of assembly is crucial in an environment where time is a critical factor in success of an operation
- To assess our assembly time, 6 BME 450 colleagues of diverse background are asked to assemble our device
  - Total time and errors committed are taken into account to get an accurate estimate of our setup time
  - Resulting time must be under 2 minutes to satisfy requirement



3.2 Low cost of production

- The goal of our device was to increase safety for patients and caregivers, while maintaining a practical price point
- Sum of the total cost of device production divided by the lifetime of the device is used to calculate cost per operation
  - This price must not significantly increase the cost of operation, so that it can be practically implemented in an OR

Testing: Reduces risk of patient slipping

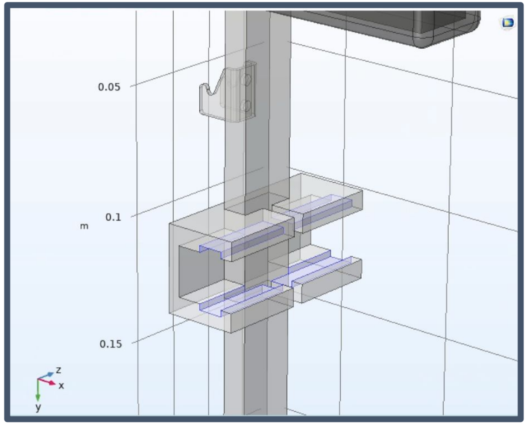
- Clamp design reduces/prevents patient from slipping on the OR table at steep Trendelenburg angles (at 30°)
- Once disengaged, patient slides down stretcher and is at risk of falling off

Two clamps engaged at the foot of the bed to secure the HoverMatt to the stretcher for the slip test

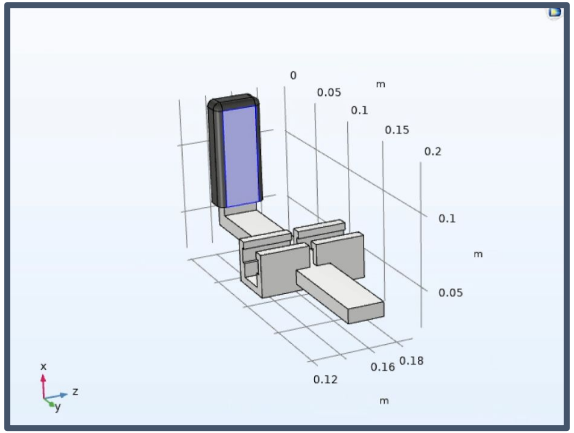
Testing: Capable of supporting patient

- The intended use case for our clamp design will be with bariatric patients undergoing lower abdominal surgeries
  - Patient weight: 200-≥500 lbs
- Testing how the clamps withstand an increased mass at steep Trendelenburg
  - Test subject weight: ~180 lbs
  - Added weight: 110 lbs
  - Total weight: ~290 lbs
- Further testing would include simulating weight of patients at the extreme end (≥ 500 lbs) to determine the maximum weight the clamps could reliably support

Testing: Capable of supporting patient



Fixed boundary – where clamp attaches to railing (blue)



Boundary load – where clamp makes contact with table (blue)

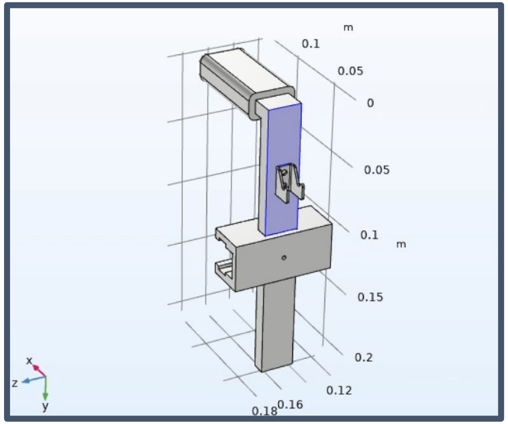
- Boundary conditions:
  - Free boundary: free to move
  - Boundary load: derived from

    $$\vec{F} = F_N \hat{i} + \mu mg\cos\theta \hat{j}$$

  - Fixed boundary: constrained to not move
- Test for von Mises (maximum) stress using coarse mesh
  - Afterwards, perform mesh independence analysis

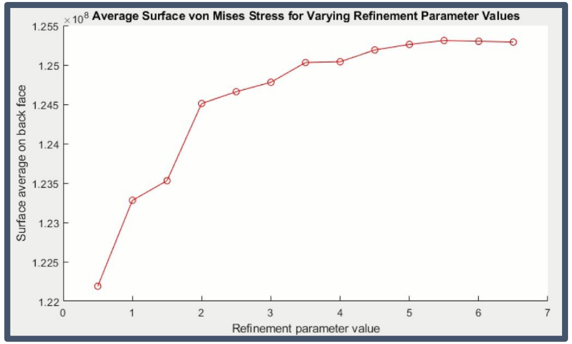
Testing: Capable of supporting patient

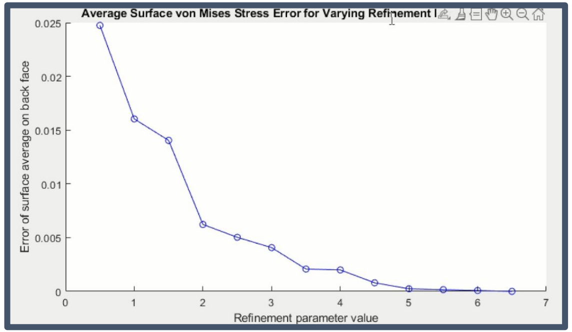
- Mesh independence analysis performed on face with maximum stress
  - Parametric sweep with varying values of refinement parameter (0.5 to 6.5)
  - Mesh size calculated by (initial mesh size) / (refinement parameter)
  - Final mesh size: 0.00167 m (refinement parameter of 6)



Face where average surface stress was calculated for mesh analysis

Surface stress (top) and error between values (bottom)





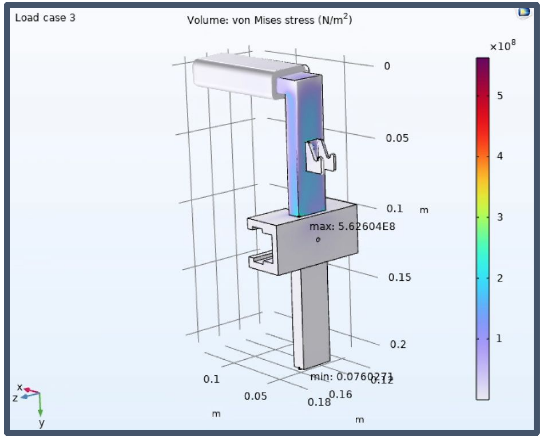
Testing: Capable of supporting patient

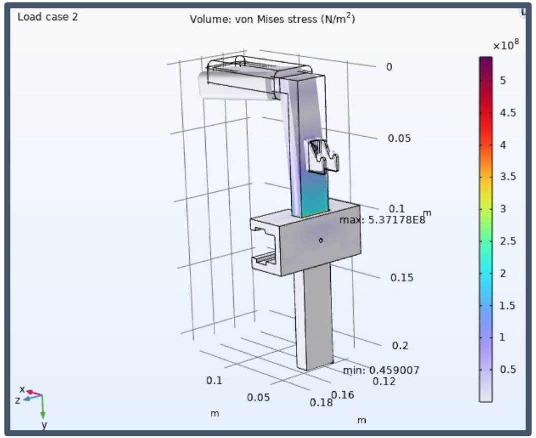
- Below is the parameter table used in the COMSOL testing

Test Parameter	Assigned Value	Description
F_normal	300 N	Grip force from clamp on table
F_patient	1307.4 N	Force exerted by patient in Trendelenburg position
Youngs_Modulus	200 GPa	Elastic modulus of steel alloy
Poissons_ratio	0.3	Poisson's ratio of steel alloy
mesh_size	0.01 m	Initial mesh size in mesh independence analysis
refine	6	Refinement parameter which the mesh size is divided by

Testing: Capable of supporting patient

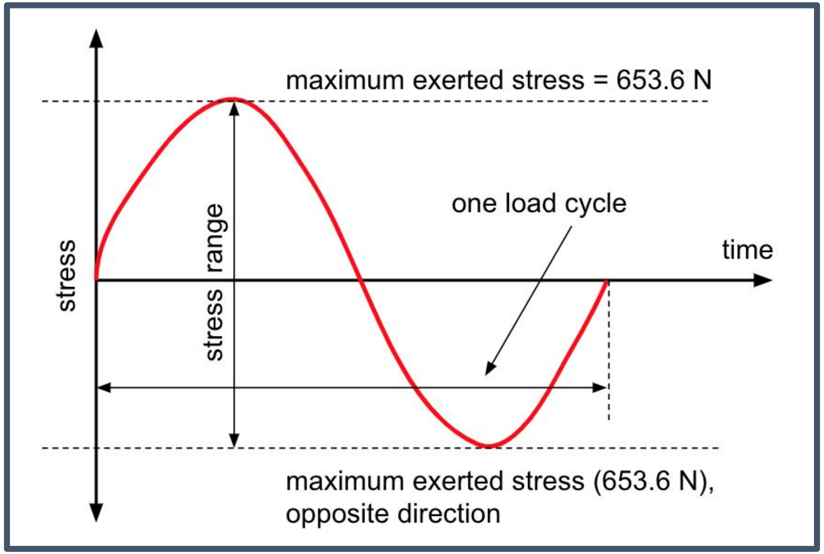
- Exerted maximum possible force for a clamp on the side (left image) and top (right image) of bed
  - Shear force of 1307.2 N = all force exerted on one clamp
- Maximum stress barely exceeds ultimate tensile strength of steel
  - Interpreted as a PASS due to the unlikelihood for only one clamp to be used





	Side of Table	Top of Table
Maximum stress (MPa)	562.6	537.2
Maximum displacement (mm)	0.783	0.826

Testing: Device material is strong and will not bend – clamp body testing



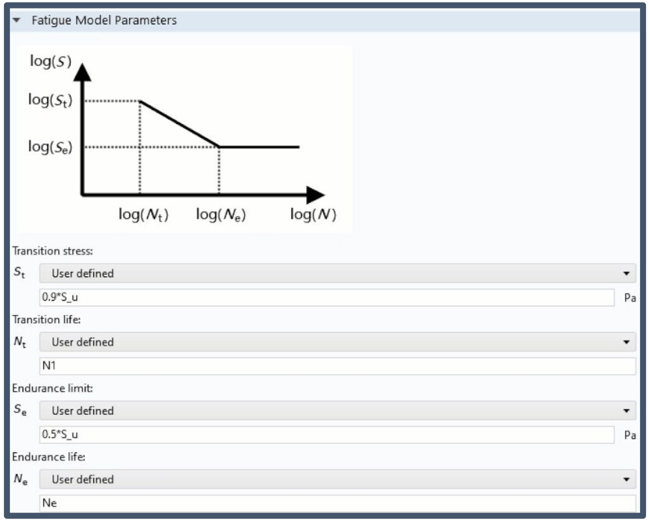
- Fatigue module was applied to previous file
  - Same mesh size and model
  - Load was decreased by half to accommodate for the use of a second clamp
  - Use stress-life analysis to obtain number of cycles to failure
- Load cycle with no load and maximum load in either direction
  - Test whether the device will exceed enough fatigue cycles to surpass the endurance limit
  - Endurance limit = safe stress below which failure will not occur

Testing: Device material is strong and will not bend – clamp body testing

- Endurance limit given in terms of the ultimate tensile strength of steel alloy
  - Approximate S-N curve used to approximate number of cycles to failure

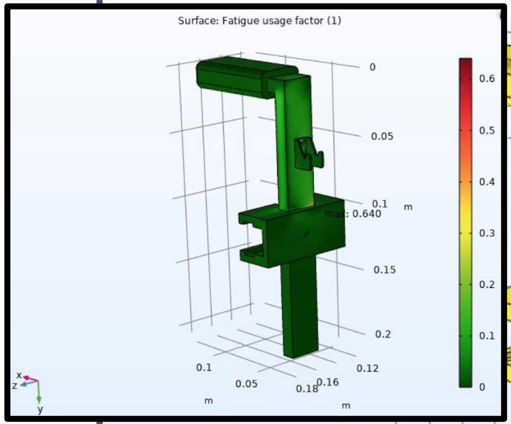
Test Parameter	Assigned Value	Description
S_u	420 MPa	Ultimate tensile strength of material
N1	1000 (cycles)	Number of cycles for initial portion of S-N curve
Ne	1×10^6 (cycles)	Number of cycles for ending portion of S-N curve

Parameters used for approximate S-N curve to calculate cycles to failure

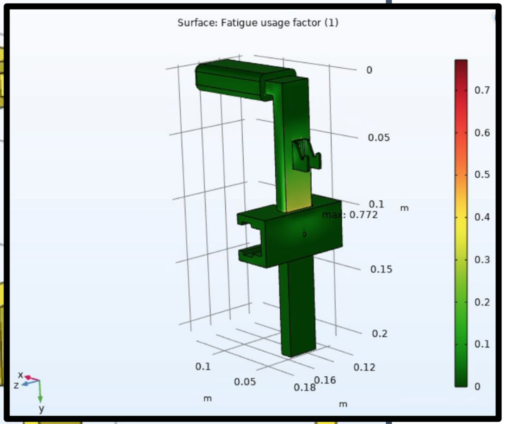


Testing: Device material is strong and will not bend – clamp body testing

Side of table



Top of table

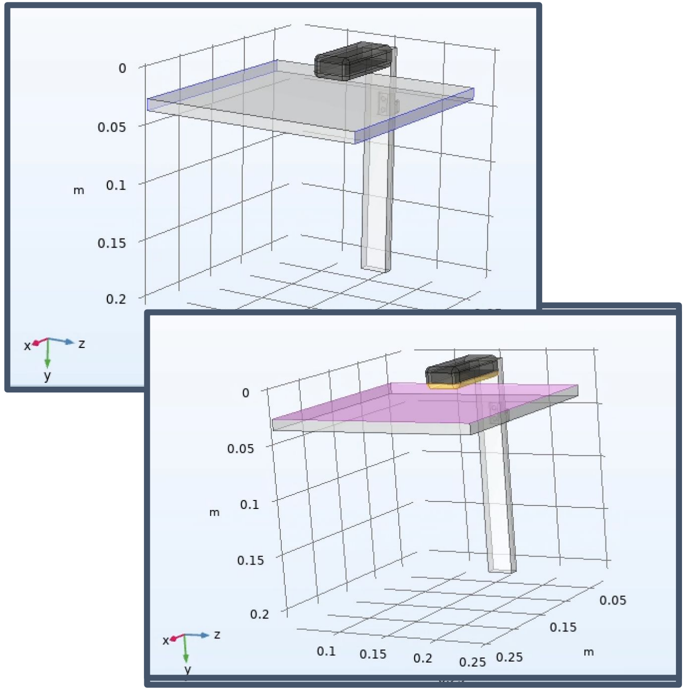


	Side of Table	Top of Table
Fatigue usage factor	0.640	0.772
Cycles to failure	1×10^6	1×10^6

- Results of stress-based simulation showed that the cycles to failure exceeded the endurance limit
- We decided to extend our results by incorporating a stress-based analysis, which outputs a fatigue usage factor
  - Shows location of most likely failure, along with a ratio of maximum stress experienced over ultimate tensile stress

Testing: Device material is strong and will not bend – rubber end piece testing

- Structural mechanics module was used to test stresses exerted on rubber end piece by operating table
- Boundary conditions:
  - Free boundary: free to move
  - Prescribed displacement: displacement which allows for contact between surfaces
  - Fixed boundary: constrained to not move
  - Contact pair: interface of table and rubber end piece which come in contact, with friction
- Mesh independence analysis was not performed due to runtime difficulties and time constraints

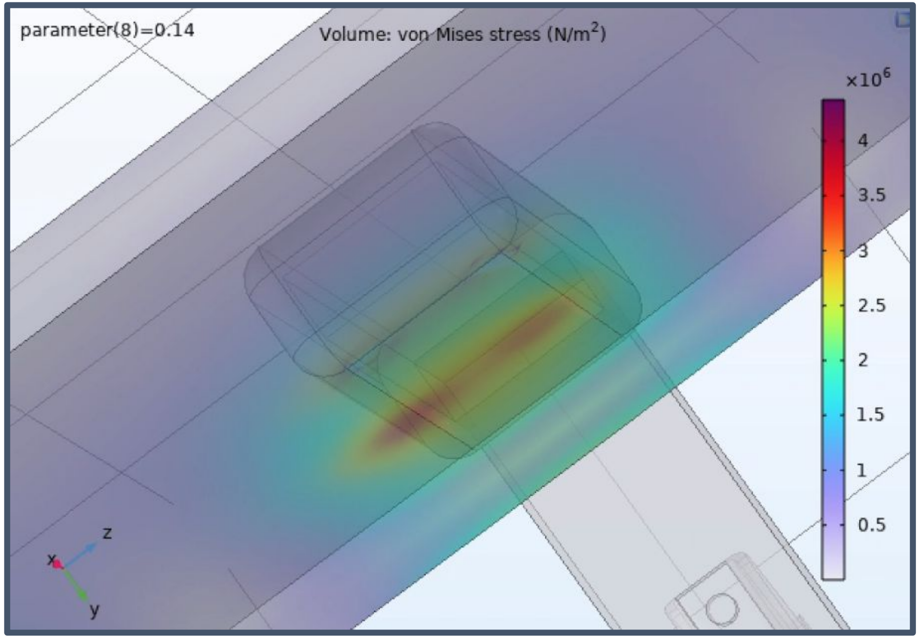


Testing: Device material is strong and will not bend – rubber end piece testing

- Below is the parameter table used in the contact COMSOL testing

Test Parameter	Assigned Value	Description
rubber_E	1 GPa	Young's modulus of rubber
rubber_mu	1.2	Coefficient of static friction between rubber and polyurethane
poissons_rubber	0.45	Poisson's ratio of rubber
density_rubber	1.74 g/cm^3	Density of rubber
max_displacement	0.015 m	Maximum downward displacement of clamp onto surface of table

Testing: Device material is strong and will not bend – rubber end piece testing



- Results show that the maximum contact/frictional force is 0.45 MPa, localized on the end of the rubber grip piece
  - This is much less than the ultimate tensile strength of rubber, which is 30 MPa

Testing: Device can be assembled in a reasonable amount of time

- The clamps do not interfere with the ability of nurses to use the lateral transfer device as intended
- Clamps do not significantly extend setup time
  - Setup time for 2 clamps: approximately 42 sec
  - On a real OR table the rails would already be attached and there would be no need to properly position them
  - Using more clamps (4-6) would take between 1 min 20 sec - 2 min total

Future Steps

- Add texture to rubber to increase traction
- Make clamp housing out of aluminum to reduce chance of fracture
- Improve mechanism to adjust clamp length on bed in accordance with clinician recommendations
- Work with nurses to determine how many clamps to place
- Develop efficient machining/manufacturing process
- Add clear labels to help position clamp correctly and guide users on operation

Thank You!

Q&A

Contact: bme450-sticktion@umich.edu

Usability Evaluation Showed that the Mat Clamp Design is Optimal for Caregivers

	Current Design	Cleat Design	Deflated Mat Clamp Design	Improved Bodily Restraints Design	Weight (multiplier)
Effectiveness	0	2	2	1	3
Safety	0	1	2	1	3
Reduce Strain on Caregivers	0	-1	0	0	3
Feasibility	0	1	2	1	2
Assembly Time	0	-1	-1	0	1
Minimal Training	0	0	0	-1	1
Sub-total	0	7	15	7	-

The largest factors that set the Mat Clamp Design apart from the others was safety and strain reduction

- The added 'cleats' provide extra friction, optimal for the anti-slip, detrimental to transferability

Device Evaluation Showed the Mat Clamp Design Provides Optimal Qualities

	Current Design	Cleat Design	Deflated Mat Clamp Design	Improved Bodily Restraints Design	Weight (multiplier)
Durability	0	0	1	1	3
Safety	0	2	2	1	3
Anti-slip mechanism	0	1	2	1	3
Hypoallergenicity	0	0	0	-1	2
Non-Obstructive	0	0	-1	-1	2
Comfortability	0	-1	0	-1	1
Sterility	0	0	-1	-1	1
Cost to Manufacture	0	-1	-2	-2	1
Sub-Total	0	7	10	2	-

Clamp design is advantageous in what we felt our more important criteria is

- Specifically, durability, safety and anti-slip

Flaws exhibited in the less important criteria, which we will address in our future steps

Complete Evaluation Concluded that the Mat Clamp Design is, overall, the Optimal Design

	Current Design	Cleat Design	Deflated Mat Clamp Design	Improved Bodily Restraints Design
Device Sub-Total	0	7	10	2
Usability Sub-Total	0	7	15	7
Total	0	14	25	9

The Mat Clamp Design is the most advantageous design option

- Second and third options also have many benefits over the current design