

UNIVERSITY OF WISCONSIN – MADISON  
DEPARTMENT OF BIOMEDICAL ENGINEERING  
BME 400 – DESIGN

# Assistive Transfer Device

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## Final Report

5/03/2011

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## Abstract

In many medical situations, patients may be requested to sit on an exam table, however individuals who are post-operative or elderly may find this difficult given only the 10" built into the table. Current lifting methods are inconvenient, uncomfortable, or unsafe for both patients and medical personnel, so a new device to assist patients in accessing an exam table has been designed and constructed. The design consists of a vertical lift platform that is powered by an electric motor and scissor cross links. The platform has a low profile to increase accessibility and has a rotating and locking top plate to assist patients. Collapsible railings are mounted to the turn table to give patients security as they are being lifted or lowered. To ensure safety of the device, the design was subjected to finite element analysis and the prototype was dynamically tested to 300lbs. Future development of the device will include improving ergonomics, and design for manufacturing.

## Motivation and Problem Statement

In many medical situations, it is necessary to lift patients. This need for assistance could be due to reduced patient strength as a result of an extensively invasive operation, inherent weakness, or old age. As people age, their muscles degenerate, causing a reduction in their strength capabilities and increasing their force buildup time [1]. In addition to causing problems for the person in everyday activities (i.e. climbing stairs), it also makes difficult the routine examinations where a patient is required to climb up onto an exam table. This problem is compounded with more frail or obese patients. Generally, elderly or post-operative patients come to examinations in wheelchairs or with the assistance of a walker. In these situations, it is difficult for the medical assistant to help patients out of wheelchairs and lift them up to the top of exam tables.

To facilitate lifting of elderly or post-operative patients, it is necessary to design a device that is capable of safely transferring patients from a standing position on the ground to a level where they can easily get onto an exam table. To reduce patient anxiety, the device will include handles or another similar structure for patients to hold onto as they are being transferred. Finally, the device will be easy to operate and will minimize the required effort by the patient and medical personnel.

## Background

One of the most common methods for lifting patients is manual labor. In this method, trained medical assistant wraps their arms around a patient underneath the shoulder joint (figure 1). The assistant then carefully lifts the patient vertically. Carefully walking backwards while holding the patient, the assistant must then rotate slowly and lower the patient down onto the desired destination which is, in many clinical settings, an exam table. If the patient's lower body is partially incapacitated, it is often



Figure 1 - Medical assistant lifting patient out of wheelchair [3]

necessary for a second assistant to hold the patient while the other assistant steadies the patient's legs. If the patient is totally incapable of using their legs, they are then placed onto a hammock type sling in the lying position. Two assistants are then required to hold the two ends of the sling and lift the patient. Although manual lifting is mechanically simple, it requires a lot of physical exertion by the assistant. The level to which patients can be lifted is solely dependent on the assistant's strength. Because of the large effort required for the lifting, there is a significant risk of injury for the assistant and a risk of injury for the patient if the assistant drops them.

To alleviate the required effort in patient lifting, several devices have been developed. The first and most commonly used lifting device is the Hoyer Lift (figure 2). This device uses a non-automated hydraulic system to elevate patients. It also includes several adjusting mechanisms to widen or narrow the supporting base and wheels for easy transport. The cost of a Hoyer lift can range from \$600-2000 [2]. To lift a patient, the device is first strategically positioned near the patient's desired destination. The patient is then inserted into a nylon or cotton sling that supports their back and upper legs. After the patient is secured in the sling, the assistant elevates the patient by operating a foot or hand pump. When the patient is fully suspended in air, the assistant then rotates the patient over the destination and then releases the hydraulic system so that the patient is lowered slowly into position. Although the Hoyer lift lessens the amount of effort required by the patient and by the assistant, it can cause emotional unease for the patient since they are in full air suspension during the lifting process. Additionally, several expensive modifications to the Hoyer lift are available. These devices include automated systems, a larger weight capacity, finer adjustment mechanisms, and different sling sizes.



Figure 2 - Elderly patient being lifted by Hoyer lift. [4]

Another commonly used device is the ambulation assistive device (figure 3). This device implements an automated hydraulic system to lift patients [5]. To facilitate storage and mobility, the device includes multiple wheels. This automated system is designed for helping patients from the sitting position to the standing position (e.g. from a chair or wheelchair). During operation, the patient is inserted into a harness and their arms are strapped to the top of the device. When the patient is properly secured, the top portion of the device will elevate, bringing the patient with it. When the patient is brought to the standing position, the top of the device is locked, the base wheels are unlocked, and the patient can then use the device to steady themselves as they ambulate. During the lifting process, the patient is often uncomfortable due to the number of straps and harnesses that are required to keep the patient secured to the device.



Figure 3 - Elderly patient using ambulation assistive device. [5]

## Design Requirements

Before developing a unique device to assist in patient transfer, a list of constraints was established, taking into consideration functionality and user-friendliness. All the constraints considered can be seen in the attached PDS (Appendix A). The mechanical constraints are also summarized in table 1.

Figure 4 is an image of the exam table in the clinic, which is 32 inches tall. The bottom drawer is a 10 inch step that can be pulled out to assist the patients in getting onto the exam table. Unfortunately, many of the patients’ legs are not strong enough to climb such a large step. Due to this, any step implemented in the design it must be 4 inches or less in height, which our client claims that the patients will be able to navigate. This height will be verified and refined through a research study in the future.



Figure 4 - Picture of typical exam table present in vascular surgery unit of UW West Health Clinic

We are designing the device to help individuals at least 4.5 feet tall and with a maximum weight of 300 lbs. With use of anthropometric tables, we were able to determine that, on average, the knee of a 4.5 feet tall patient is located 15.4 inches off the ground. Therefore, our device will have to raise the patients a minimum of 15 inches. Our client requests that we build the device for a subject of 300 lbs because it is well above the average weight of the standing from the wheel chair and the doctor would either examine them while in the wheel chair or would use the Hoyer lift to get them onto the table.

Qualitatively, the device also needs to be user-friendly during its operation. It needs to be simple, requiring very few steps to get the patient from the standing position to the table and back down. If an electric motor were to be implemented in the device, the required user input would be extremely minimal—just the touch of a button to raise and lower the platform. To reduce patient anxiety during use, additional safety features would be considered such as additional straps or railings so the patient feels secure.

In addition to making the design user-friendly during operation, we considered the ease of storage in the design—another constraint our client feels important. The design needs to be as compact as possible for two reasons: to allow for storage in a tight area and easily fit up next to the exam table during use. The device should be able to be stored behind a table or in the back of a closet somewhere when not in use. It would need to be easily moved from location to location, either by wheels or easily carried, which would require the device be less than 50 lbs in weight.

Table 1 - Summary of design specifications

Mechanical Design Constraints
Safely lift minimum of 300 lbs with a safety factor of 2.
Steps must be less than 4 inches off the ground.

Device must lift patient a minimum of 15 inches off the ground if from a standing position, 32 inches from seated or reclined position.

Total weight of device must be less than 50 lbs.

As compact as possible to allow for easy storage.

### Generation 1 prototype

The first prototype of the assistive transfer device was constructed with a scissor link mechanism. The links were actuated with a hydraulic cylinder. The force was transferred from the hydraulic cylinder to the platform through a steel crossbar. A mechanical turntable was mounted onto the top platform and attached to a fitted sheet of corrugated metal to provide a rotating surface. A walker was securely attached to the rotating surface to provide assurance and balance to the patient. A small stop was attached to the rotating surface to prevent over-rotation. Patients were intended to mount from the side of the device with the aid of the walker, rotate 90°, and then sit on the exam table (after lifting).

Although the device met the weight, size and mobility requirements, it was incapable of lifting the required load of 300lbs. Because the device was constructed with a very low mechanical advantage, it was only able to lift 150lbs before failing due to excessive bending of the bottom frame. There was also a great deal of instability during lifting and lowering due to friction in the scissor links. The patient would shift side to side as they are lowered, causing anxiety. There is also a need to automate the lifting and lowering of the platform, as the device required manual pumping of the hydraulic cylinder. This proved to be awkward and uncomfortable for the medical assistant.

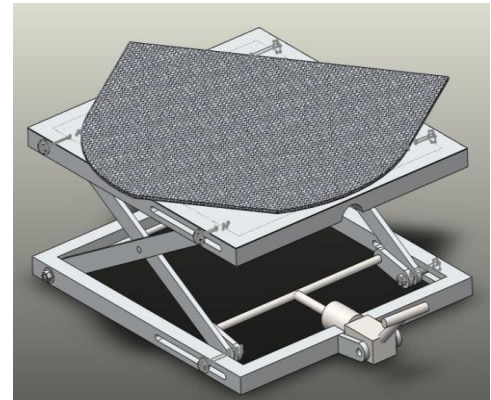


Figure 5 - SolidWorks Model of Generation 1 prototype

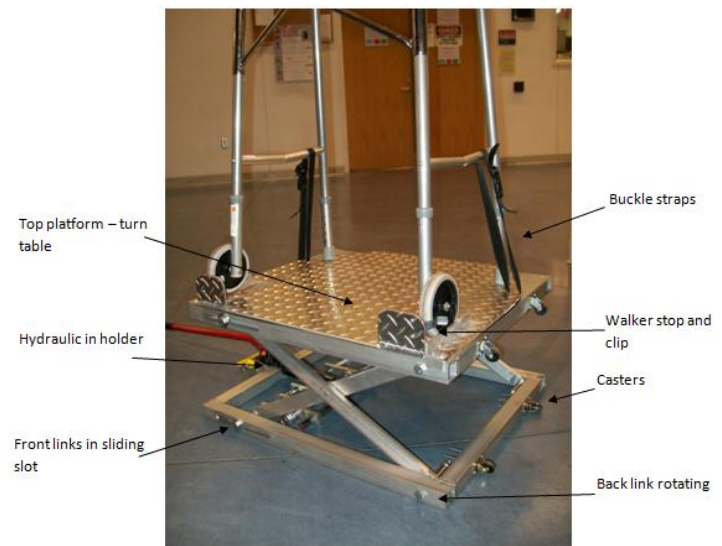


Figure 6 - Picture of final design, shown with walker strapped in place and slightly raised

## Generation 2 prototype

The second prototype also made use of a scissor link mechanism to raise the top platform. The scissor links are powered by a small motor. The motor turns a driveshaft through a small nut which is connected to one end of one set of links. A chain and sprocket system transfers the torque across the device to drive the other set of links. A turntable is bolted onto the cross bar supports and a diamond plated 23 inch diameter circular sheet is bolted to the turntable. Wheels underneath the frame transfer all vertical force on the device to the ground to prevent any bending or plastic deformation. The top platform of the device is too narrow to attach a standard walker so a different patient support system must be used. The device is designed such that patients will mount from the front and be rotated 180° so that they are in proper position to mount the exam table.

This device met the client weight requirements for lifting and portability, however there were several necessary improvements to be made on the design. Since was no support system for patients and the turntable could rotate freely, the device would be very unsafe for patients to use. The lifting mechanism also applied a large force on the sprockets and aluminum abutments supporting the driveshafts. This would cause misalignment and a lot of lost energy in the system.

## Design Alternatives

The major issue with the prototype from last semester was the lack of support railings for patients. Since the platform is too narrow to accommodate a standard walker, a different support system would need to be constructed. Each alternative needed to be stable, easy to store, be simple to assemble, and promote patient comfort.

The first design alternative, the “U-shape” design, consisted of three poles that would be attached to the rotating turntable. The three poles would support a U-shaped top bar that would serve as a railing for patients. Because of the tripod design, it wouldn’t be able to collapse onto itself and would therefore have to be removed before the device is transported. There would be small base supports mounted onto the turntable that would secure the poles in place. They

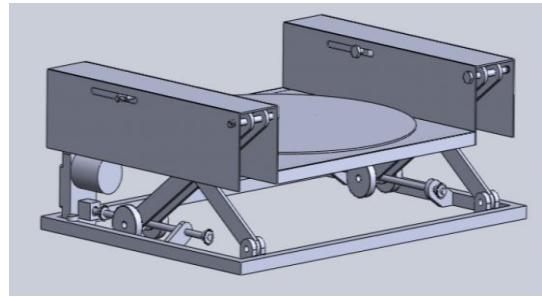


Figure 7 - SolidWorks Model of Generation 2 prototype



Figure 8 – Picture of final design, shown with ~270lb loading

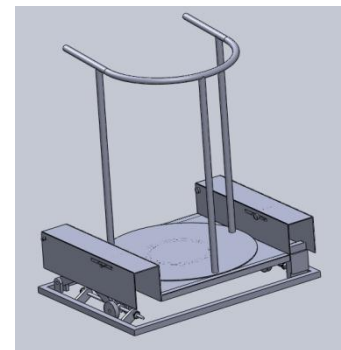


Figure 8 – SolidWorks model of U-shape design

could be disengaged using detents to allow for easy removal of the frame. While this design may be ergonomic, it would be difficult to construct (due to the curved top bar). Additionally, since it would be separated from the device during transport, there is a risk of the part being misplaced.

The second design alternative involved remodeling a standard walker so that it would fit onto the top platform of the device. This would include shortening the distance between the handles and installing supports on the turntable that would allow the modified walker to be removed or collapsed onto the device when not in use. Modifying an existing walker might involve a lot of fabrication and would compromise the structural integrity of the final assembly.

The final design alternative, the “Double Bar” design, consisted of two vertical handles that would be placed on opposite sides of the turntable. Each handle would be supported by two poles that would be permanently attached to the turntable. Detents in the upright poles would allow for them to shrink vertically—to accommodate users of differing heights and to facilitate storage. A detent at the base of the poles would disengage so that the uprights could fold onto each other. Magnets or clips would then be employed to make sure the collapsed handles remained in position until they the device was ready for use.



Figure 8 – Picture of standard walker [8]

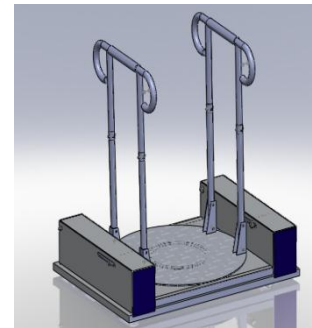


Figure 8 – SolidWorks model of Double Bar design

All three design alternatives were evaluated in a design matrix (table 1). The alternatives were evaluated in the categories of stability, storage, patient comfort, cost, adaptability to current devices, ease of operation, and feasibility. All categories were weighted equally since they were deemed to be equally relevant to the success effectiveness of the final device. The alternatives were scored on a scale of 1-5, 1 representing the lowest possible score and 5 representing the highest possible score. As shown in Table 1, the Double bar design was decidedly the best option for the final design. Although the stability may be a bit less than a standard walker, it would be considerably easier to adapt to the existing device and it would less cumbersome to store.

	Stability	Storage	Patient Comfort	Cost	Adaptability to Current Devices	Ease of Operation	Feasibility	Total
<b>Walker</b>	5	2	5	4	1	4	3	24
<b>U-shape</b>	4	4	3	3	4	2	2	22
<b>Double Bar</b>	4	4	4	4	5	3	3	27



## Final Design

Our final design (figure 9) has been adapted from the alternative chosen in the design matrix. The railings are made from 1" outer diameter aluminum tubing and the collapsing portions are made from 0.85" outer diameter tubing. The tube thickness is 0.05". The railing supports are held in place by brackets that are welded to the turntable. The supports are fixed to the brackets permanently with a bolt and a detent engages to form a secondary fixture for when the railings are in use. The railings can be adjusted or collapsed entirely by detents that are inserted inside each tube. The detents are installed such that the railings can be adjusted to either a 29" or 33" setting, similar to a walker.

The lifting mechanism was modified using thrust bearings to decrease friction and increase efficiency of the system (figure 10). A thrust bearing capable of supporting 700lbs is mounted on the end of each drive shaft. It is held in place by an aluminum plate that is connected to two eyebolts. The assembly is able to counteract axial force produced by the motor when the device is running.

## IRB Research

Patient comfort was one of our highest concerns when building this device. Therefore, we would like to ensure that the step height and stance width parameters used to build our prototype are comfortable for the average patient. Current research indicates that 80% elderly females (ages 75-93) were able to step higher than an 8" step [6] and that stance widths range from 2" to 11.4" [7] from a point centered below the body to the center of the foot. This research indicates the maximum flexion and step height for elderly people, but does not give us any indication of what is comfortable for the patients. Ideally, our device would not force patients to strain themselves to get onto the device.

A qualitative research study will be done to determine the step height and stance width most comfortable to the average patient. Subjects will be recruited at a nursing home, to represent the elderly patients that will most likely be using this device, and asked to step onto stationary platforms of different heights. The subjects will also be asked to fill out a survey rating the step heights based on difficulty and filling out some demographic information. This information will further define our product specifications and determine whether a step height of 2" and a stance width of 23" are reasonable parameters for the average elderly patient.

## Future Work

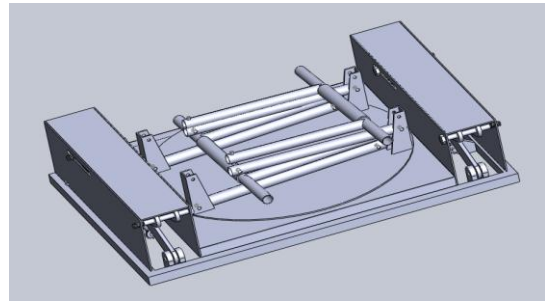


Figure 9 – SolidWorks model of final design with railings collapsed onto top platform

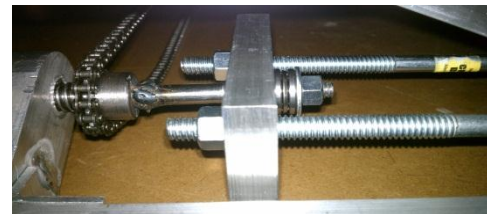


Figure 9 – Picture of thrust bearing assembly

Safety is very important for our device, therefore the device needs to be put through more rigorous testing to ensure safety. In the design process, we based our calculations and dimensions on a maximum load of 600 lbs even though we only want to lift patients with a maximum weight of 300 lbs. In the future we would test the device with a load of 600 lbs to make sure it meets the safety factor. The prototype will need a few adjustments to make sure that it can handle 600 lbs. This will be easily done by welding some components instead of bolting them. In addition, the device will be subjected to the “Drop” test, similar to most mainstream devices. The device will be checked for structural integrity as it will be dropped from multiple angles onto various surfaces. This will ensure that the assembly is robust and will survive daily use.

The ergonomics of the device also need to be improved. Specifically, wheels and handles should be installed to aid with the device transport. A more refined locking mechanism for the turntable is also needed to ensure patient safety. The open areas like the gaps between links and the chains to transfer power need to be covered so that there are no pinch points or dangerous areas. The covering would also prevent users from tampering with the driving mechanism and compromising the performance of the device.

After thoroughly validating the device design, our next step will be to modify the designs for manufacturing. A few improvements we have already considered would be to eliminate awkward welding angles and locations and redesign areas that are hard to access. We would then create a simple bottom-up assembly for the device.

## **Conclusion**

Overall, the design team was very pleased with the outcome of the semester. Though the device will not yet be implemented in the clinical setting, the prototype is a sufficient proof of concept. In the end, the device maintained a low step profile, an acceptable NIOSH and OSHA lifting rating, a compact, mobile design, and a reasonable lifting capacity. Initial testing determined that the design was unable to handle the maximum weight capacity, but the team has analyzed the structural deficiencies within the frame and can modify them to achieve higher weight capacities. Additionally, the instability and friction within the design were addressed in order to produce a medical lifting device that lives up to the client’s safety requirements. Finally, the team will conduct the aforementioned IRB study to determine the optimal step height for the device and make additional design changes as needed.

## References

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- [5] LiteGait Mobility Research. 2010. Mobility Device.< <http://litegait.com/md.html>> Accessed February 15,2011.

## Appendix A – Budget

The total costs for the project materials are summarized in the table below:

McMaster Carr	Structural material	\$186.31
Menards	Wood for Research boxes	\$67.92
Ace Hardware	Hardware, AC/DC converter	\$60.65
<b>Total</b>		<b>\$314.88</b>

## Appendix B – Product Design Specifications

### Assistive Transfer Device Product Design Specification (PDS)

5/03/11

Gerhard van Baalen, Luisa Meyer, Sarah Springborn, Scott Sokn

**Function:** Develop an assistive device to safely transfer patients from the floor to a level at which they can easily sit on exam tables. Patients will be able to stand and hold onto the device while simultaneously being lifted and rotated into position on the exam table. The design will reduce physical exertion by the patient and medical personnel.

#### Client requirements:

- Small base , able to fit through door-way / easy storage
- Able to lift 300lbs
- Simple to operate; automated or manual
- Easy to sterilize
- Mobile in clinical setting
- Avoid in-air suspension of patient
- Cost-effective
- Reduce patient anxiety during transfer

#### Design requirements:

##### 1. Physical and Operational Characteristics

- a. *Performance requirements:*
  - i. 3-5 minutes per lift
  - ii. 5-10 cycles per day
  - iii. Handle loads up to 300 lbs
  - iv. Lift to height of 15 in
  - v. Rotate patient 90°
- b. *Safety:*
  - i. Safety factor of 2 – hold 600 lbs
  - ii. Few pinch points
  - iii. Stable
  - iv. Slow, constant raising and lowering rates
  - v. Lockable turntable
  - vi. Attachable walker for support
- c. *Accuracy and Reliability*
  - i. Consistent performance
  - ii. Does not let patient slip, tip, or fall

- d. *Life in Service:*
  - i. 10 years
  - ii. Approximately 50,000 cycles
- e. *Shelf Life:*
  - i. Oil joints
  - ii. Motor maintenance
  - iii. Non-corrosive
- f. *Operating Environment:*
  - i. Room temperature
  - ii. Used by nurses
  - iii. Possible human fluids
  - iv. Impact resistance
- g. *Ergonomics:*
  - i. Intuitive use/interface
  - ii. Patient comfort
  - iii. Non-abrasive materials
  - iv. Minimal operator effort ( <50 lbs)
- h. *Size:*
  - i. Less than 3 ft wide (approximately 25 x 28 in)
  - ii. Less than 4 in height when compressed (initial step height)
- i. *Weight:*
  - i. Able to be moved on wheels
  - ii. Less than 50 lbs
- j. *Materials:*
  - i. Prototype – Steel, Aluminum frame
  - ii. Wheels
  - iii. Electric jack
  - iv. Polymers – acrylic, Plexiglas
- k. *Aesthetics, appearance, and finish:*
  - i. Paint – Blue
  - ii. Safe appearance

## **2. Production Characteristics**

- a. *Quantity:*
  - i. *One prototype this semester*
- b. *Target Product Cost:*
  - i. Less than \$500

## **3. Miscellaneous**

- a. *Standards and Specifications:* FDA approval, IRB review board
- b. *Customer:* Hospitals, clinics, nursing homes
- c. *Patient-related concerns:* Elderly, frail patients, amputees
- d. *Competition:*
  - i. Hoyer Lifts
  - ii. EZ way

- iii. Litegait
- iv. Lift tables