

Improving Management of Medical Equipment

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Abstract. The wide array of devices used in critical care areas of hospitals creates difficulties in keeping order. Disorganized equipment in these areas can lead to numerous issues including lower task efficiency for health care workers, potential safety hazards and infection control issues. An equipment mounting rail and adapter system is one of the best tools available to help manage and organize critical equipment. Current rail systems perform well in many respects yet but there are still a number of areas that may be improved. Improved interfaces for attaching and positioning equipment are needed to enhance safety and improve ease of use. As equipment rail systems are widely used backward compatibility is important to allow health care facilities to deploy enhanced equipment management systems while still leveraging their investment in current hardware. This will aid effectively and efficiently managing the deployment of new technologies in these settings.

This paper discusses the process undertaken to design and test a new mounting rail for medical equipment aimed at improving the device organization and workflow in critical care areas. The project was sponsored by an equipment management manufacturer, so initial requirements were gathered through meetings with product experts as well as the sales and marketing director. This step helped to ensure that current market conditions and realistic business objectives were considered. Further requirements were gathered through on site observations and interviews. This included observations at the cardiac intensive care unit at Egleston Children's Healthcare of Atlanta in order to gather data on the using environment, to observe users in their natural work environment, and then to follow up the observations with one-on-one interviews to bring further clarity to observed issues. A participatory design process was utilized to engage stakeholders at various stages of the design process in order to identify potential design issues and continually evaluate the usability of the evolving concept.

These were followed by end user usability testing and analysis. The new rail system under development was show improvements in control, secure and flexibility, which will take more care on user experience. The usability evaluation was measured by effectiveness and satisfaction of the design, namely their impact on task efficiency, the impact on infection control and ergonomics of use. The final result showed the design almost meet the requirement, though some features need to be further improved.

Keywords: user experience, rail&adapter, usability, healthcare, medical equipment mounting system.

1 Introduction

There is currently much attention on hospital management and organization in the industries of both design as well as macroeconomics. This attention is not only because of the very nature of hospitals: the curing of diseases and the desire to prolong lives, but also because of the increasing demands brought on by technological improvements and innovations. Clinical engineering professionals need to continually review and improve their management strategies in order to keep up with improvements in equipment technology, as well as with increasing expectations of health care organizations [1].



Fig. 1. Disorganization of equipment in a clinical care environment

Clinical care areas can become unorganized, as shown in Figure 1. There are a lot of devices that need to be used in one room for completing multiple tasks simultaneously or within a given period of time. The issue can be compounded as the need to move patients often arises during clinical care. Disorganized equipment in these areas can lead to numerous issues including lower task efficiency for health care workers, potential safety hazards and infection control issues. An important question is what system provides the best tool to manage and organize equipment in these environments. There are many companies which manufacture organizational railing systems which are wall mounted with the goal of making nurses', doctors' and patients' live much easier and less overwhelming while in the hospital environment.

Current rail systems perform well in many respects yet but there are still a number of areas that may be improved. One major shortcoming, according to marketing research, is that the rail system cannot deal with some scenarios, though it is flexible to manage the disordered equipment with the system. For example, they may require specific tools to lock and there is no adapter profile for vertical pole, etc. New designs must also better meet the ergonomic requirements for the many different tasks that are performed in dynamic care environments. New devices must be able to keep pace with the iteration of clinical care and developments of new technology.

Hospitals are places many patients are gathered who bring with them a variety of different bacteria and viruses. As patients can come in contact with new infections in this environment, cleaning in hospitals is critical. Adverse outcomes or illness among patients or health care workers can occur from medical device use due to

inadvertent exposures to environmental pathogens, improper ventilation and distribution of airborne exposure. Thus, the ability to sterilize, reliably clean, and maintain the integrity of medical devices is a critical design feature [2].

2 Prototype Development through User Input

The most salient feature of the medical equipment innovation process appears to be the fact that the end user of the equipment often plays an important role in its initial invention and subsequent development [3]. Stakeholders such as manufacturers also participate in the design iteration phases [4].

This project is based on a graduate course project sponsored by an equipment management manufacturer. Many of the manufacturer's users are existing customers. A primary goal was to create a new design that support the existing installed base and allow sales growth through differentiation. The ideal scenario would include the new adapter fitting on the existing profile rail, and the old adapter fitting on the new rail.

In order to gather data on the usage environment and gather end user feedback, observations and interviews were conducted at the cardiac intensive care unit at Eggleston Children's Healthcare of Atlanta. Apart from the ease of use, the nurses desired a solution that would work in both vertical and horizontal and horizontal orientations without the need to remove the adapter from the equipment. Vertical systems are needed to work better in small spaces. It is preferable that equipment can be removed. Nothing but hand sanitizer was mounted on the wall because of the need of portability, so a movable and portable adapter is desired.

Based on the users input from the observation and interviews, design requirements were concluded as following.

- Special requirements for hospital environment- Anti-microbial and safety:
In this controlled environment, the rail system has to meet the demand of sanitation. It should easy to clean, like rails and adaptors must not have areas that cannot be easily cleaned such as small crevices and hard to reach areas. All surfaces must lend themselves to a thorough cleaning. Some items required permanent stability. These items must be secure to ensure stability. Falling equipment raises costs and injury. And the rail and adapter system themselves should not be a hazard. Materials used must be non flammable and avoid sharp edges.
- Ease of use:
The use environment contains many different devices, and the users' activities within it are very complex. The adapter and rail system must therefore be as simple to use as possible. Installation must be timely as to not impede other hospital activities. Easy use helps ensure a correct installation every time. The adapter must also avoid the need to use tools to lock it on to the rail.
- Vertical and Horizontal mounting:
The ability to be mounted both vertically and horizontally is necessary for creating systems that can be adapted to any patient environment. It provides configuration flexibility and allows hospitals to manipulate space as patient demand changes.

— Appearance and affordability:

The device should have an aesthetic appearance that gives the user a comfortable feeling. Also, the perceived and actual properties of it should demonstrate the right conceptual model of how it could be used. These requirements contribute to satisfaction of use.

According to the design requirements, a first iteration prototype was made, and being evaluated by users at Dekalb Medical at Atlanta. The vertical pole design was found useful, especially the rotation from vertical and horizontal which helped reduce nurses' effort a great deal. Height adjustability was also found to be a helpful feature. This gives users the flexibility to adjust the height of the height of the device to best facilitate their work. The vertical pole adapter can be used to hold temporary items such as alcohol sponges so that the nurses do not need to worry much about find somewhere to store or throw them. The initial feedback also suggested ways to expand usage of the vertical pole adapter. In order to achieve compatibility, there is a slot on the rotatable square, so the current adapter can be mounted on this vertical pole adapter. Sometimes the device mounted on the vertical pole is very heavy, which requires that the vertical pole adapter lock firmly so that the device is secure and stable. The clamp structure must be carefully determined and tested. For a general adapter, it was suggested that the pull stick should not seem too weak that easily broken.

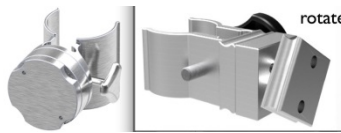


Fig. 2. Initial/revised vertical pole adapter

3 Method

Eight healthcare workers were recruited to participate in a usability evaluation of a new rail adapter product. The participants had never used similar management tools before, so an introduction of the use of medical equipment management solutions was given. The new prototype adapter product is shown in Figure 3. The general adapter can be mounted and lock on the rail or the pole adapter without using any tools, the only thing need to do is aim at the slot and buckle up it onto the rail or the pole adapter. When release it off, the user just pull the stick and the adapter could be easily demounted. For the operation of the pole adapter, if users need to change the direction between horizontal and vertical, they just need to pull the rail out, rotate it, and then push it back to lock. Participants completed the following three simulation tasks which demonstrated the main feature of the new design:

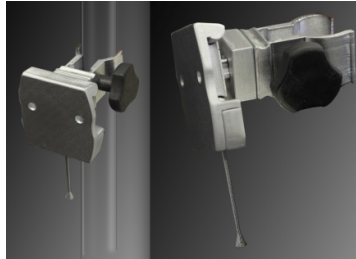


Fig. 3. The newly designed rail adapter

1. Mount and unmount: Hold the medical equipment, find out ways to mount it on the rail and find out ways to demount it.
2. Adjust the height on the vertical pole: hold the medical equipment, find out ways to mount it on the vertical pole, and adjust the height on the vertical pole and try to fix it.
3. Rotate from horizontal to vertical: mount the rail on the vertical pole adapter in horizontal, mount equipment on the rail and find out ways to rotate it from horizontal to vertical.

An evaluation survey designed to measure users' level of satisfaction and effectiveness was completed immediately after the tasks were completed. It consisted of 12 Likert items related to effectiveness and satisfaction. The items categorized by ease of use, time of use, function and complexity, effectiveness, appearance, conceptual understanding, safety and infection control and overall satisfaction. Each survey item had five possible answers (1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree).

Five of the survey items were related to the satisfaction of the device, and seven of the items were related to effectiveness. An effectiveness score and a satisfaction score were obtained by adding the scores for the related items. A total usability score was obtained by totaling all 12 of the Likert items. The survey used can be found on the appendix.

An additional non-Likert item was stated at the end of the survey. This item was aimed at evaluating the overall opinion of the device immediately after its use. The item was as follows: Please place an X by the statement that most closely matches your overall opinion of the system.

- The product design is very good. I like almost everything about it.
- The product design is mostly good. There are only a few things about it that I do not like.
- The product design is average. There are about as many things that I like as dislike.
- The product design is mostly poor. There are only a few things about it that I like.
- The product design is very poor. I do not like anything about it.

The answers to this question were scored from 1 (the worst answer) to 5 (the best answer).

The averages of all responses for each task were used to describe the performance of this product in different tasks. The average of all responses for each of the three tasks is used to show comprehensive and overall performance of the product.

4 Results

The evaluation survey was tested before use to make sure that questions were understandable. A total of 24 healthcare workers performed the evaluation and

Table 1. Average scores of three different tasks

#		Task 1	Task 2	Task 3
1	Overall, I am satisfied with the ease of completing the tasks in this scenario	4.5	4.375	4.625
2	Overall, I am satisfied with the amount of time it took to complete the tasks in this scenario	4.75	3.375	4.875
3	It was easy to understand how to operate the product	3.25	4.75	4
4	Using the device to complete the task felt safe.	3.875	4.25	3.625
5	I would be satisfied if I had to use this system frequently.	4.125	4.125	4.25
6	I found the system unnecessarily complex.	1.5	1.625	1.25
7	I could easily complete the task with the system	4.5	4.375	4.5
8	I found the various functions in this system were well integrated.	4.125	4.25	4.625
9	I would imagine that most people would learn to use this system very quickly	3.625	3.875	4.25
10	Aesthetically, I like the overall look of the system.	4.375	4.125	4.375
11	Compared with other methods or products to aid with managing the medical equipment, the actual functionality of this system is better	4.125	4.375	4.25
12	The product is easy to clean which reduces the risk of infection	3.375	3.875	4.125
overall	The product design is very good/mostly good/average/mostly poor/very poor.	4.125	4.25	4.375

completed surveys. Table 1 displays average scores of three simulation tasks that participants completed with the rail system.

The data was categorized into 7 groups to evaluate 7 different features of this system. Questions #1, #5, #7 were used to describe ease of use. Question #8 and #11 were grouped together to evaluate the functionality. For safety and infection control issue, question #4 and #12 were given to users to evaluate. The aim of question #3 and #9 was to estimate whether it was a good conceptual model. Questions #2, #6, #10 were used to estimate the feeling of time of use, complexity and appearance. Figure 4 shows the results from the survey. For easy to use, time of use (efficiency), better function and aesthetics, most participants chose agree or strongly agree, and a few of them chose neither agree or disagree. For good conceptual model, safe and no infection issue, a lot of responses were agree or strongly agree, and some of responses were neither agree or disagree. For complexity, none of the participants thought the system was unnecessarily complex. Overall, most participants thought the product design was mostly good; some of them chose the statement that the product design is very good; two responses were the product design was average.

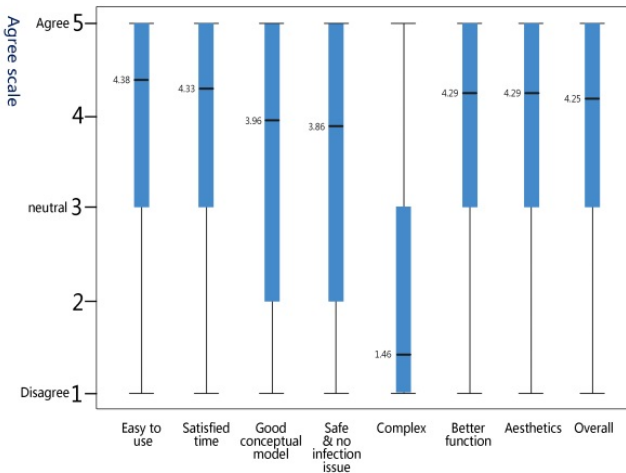


Fig. 4. Survey results based on various evaluation categories.

5 Discussion

The survey seemed to indicate that users basically are satisfied with the using product, as they were agreed with that the product design is mostly good.

- Participants thought it was easy to use this rail system. On one hand, for question #1, #5 and #7, the average scores of three tasks are all above 4.00. On the other hand, the average score for the complexity of the product is very low. Based on the feedback from healthcare workers, the disorder in patient room can disturb them

and increase the workload, and sometimes may lead serious problems. They do need a management system to deal with medical equipment, particularly in a patient room which has a large number of equipment or in a scenario where nurses need to move equipment frequently. Functional management system which is easy enough to use allow for the possibility that controlling the disorder to provide a better and more efficient environment.

- Overall, users are satisfied with the time to complete the tasks. The average score for the second task is relatively low, but the other two are very high. Based on nurses' feedback, it is crucial to complete some tasks, like attach or detach equipment, very quickly, especially when it is an emergency. In other scenarios, nurses may need to repeat some tasks several times a day. Using this product should reduce the time of these tasks rather than increasing it, otherwise, it will be unnecessarily trouble.
- For average scores of functions, they are all above 4.00. Most of responses believed the various functions in this system were well integrated. Besides, the average scores of question #11 (comparison between this product and other methods or products) are satisfied. The evaluation of functions indicates that this rail system is helpful to manage medical equipment.
- For the appearance of the system, users found it was acceptable and satisfied. The hospital should be an environment for care giving, which means products in hospital should be pleasurable, especially products used in patient room. From the point of user centered design, the appearance can be a key point influencing the use process.
- One of the main concerns of this product was addressing safety and infection control issues. Safety is one of the priority requirements. As activities in hospital have a close connection with patient's life and health, any mis-operation or potential safety risk could lead to severe problems. As a result, safety is always one of the top considerations. Also, infection control is an important issue which healthcare workers mentioned frequently. Deaths from the infections more than doubled from 1999 to 2007, to more than 17,000 a year from 7,000 a year, the Centers for Disease Control and Prevention reported. It means the infection control has to be emphasized in hospital environment to avoid unnecessary death. However, the average score of safety & infection control is just passable. Some responses were the product was not safe enough for a specific task, and some responses were the product was not easy enough to sterilize.

The goal of this survey was to evaluate the effectiveness and satisfaction of the new rail system. The results of ease of use, time of use, appearance and functionality are basically favorable. However, some problems needed to be improved also showed in the results:

- First, only one task got an average score more than 4.00 for question #3, and a few responses collected revealed that user did not agree with that it was easy to understand how to operate the product. Second, question #9 had similar responses. The average scores were relatively low and there were a few disagree responses. Based on that, a conclusion was drawn that the design did not have a powerful

conceptual model. Norman [5] mentioned that there are two gulfs between user goals and physical system, which are gulf of execution and gulf of evaluation. For gulf of execution, Norman means that the product should have good affordance to imply user to avoid confusion and mis-operation. To achieve a better performance, the product should have more clues of how to use. The clues may be specific shapes, colors or icons to indicate the operation.

- Users gave some feedback according to safety and infection control issues: 1) the pull stick on the adaptor may be a potential danger if it is broken because of unintentional behavior; 2) the pull stick may have infection control problem, so does the vertical pole adaptor. As mentioned above, both safety and infection control is crucial issues in hospital environment. Consequently, the pull stick is about to be replaced by a metal chain to avoid being broken and control infection. It is also considered that either widens the gap for easy cleaning or minimizes the gap for infection control.

6 Conclusion

Overall, the results of the survey meet the preset goals. However, there were some trade off may influence the accuracy of the result. First, there are a lot of tasks for this rail system. There may be large differences in the performance of the new adapter when attaching different types of equipment. The participants were all from the same organization so they may have similar experiences and opinions which prevents the generalizability of the results. Second, the prototype used in the survey was a prototype embodying most of the intended functionality but was not a final product. There is a large gap between prototype and final product with regards to the weight, feel, audible feedback, appearance, etc. The gap could lead to a less accurate user experience. For example, users may have better experience of the appearance with the final product and the sound feedback can make user feel more safe and easy to use. The most important difference is the functionality difference which may influence the evaluation of ease of use and functionality. Third, the rail system was evaluated in a simulation environment. Users did not actually use the system during their daily activities. Instead of that, they were asked to imagine the scenario, so there is a possibility that they overlooked or did not experience some potential problems.

The overall effectiveness and satisfaction of the device almost met the expected requirements. Scores were high for ease of use, efficiency, function and appearance. However, the evaluation of conceptual model, safe and infection control were not satisfactory. To improve these scores for the vertical pole adapter, adjusts to the shape, color and instructions (such as added icons) may be added to more clearly indicate proper use. To improve infection control the existing gaps must be widened to facilitate easy cleaning or reduced to eliminate the need. The general adapter might be improved by changing the stick into a chain.

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