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# Medical Human Factor Engineering and Workspace Design

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**Abstract** - Making India a global healthcare hub, it is not only about bringing new technology but also we have to take care of the existing technology. The healthcare hub is the leading factor for current economic growth of India. Human Factor Engineering (HFE) plays a vital role in this field. In medical or healthcare, the field is named as Medical Human Factor Engineering (MHFE). This paper discusses on how MHFE responsible for strengthen the Technology Management of Hospital, Hazards from device failure and use related, Human Factors consideration in medical device use and case study on (Infusion Pumps) errors committed by users in each clinical area. Now the challenging issue for HFE is to design a proper workspace to avoid human errors and the four workspace design principles of Sanders & McCormick (1993) is also discussed. This paper deals with the Computer-aided-design (CAD) systems and a failure mode and effects analysis (FMEA) technique with Simple Organizational Structure of HFE in designing the workspace.

**Keywords** - component; Healthcare hub; Human Factor; Medical Human Factor; Human error; Workspace; CAD; FMEA.

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## I. INTRODUCTION

This is a phrase used to help understand and optimize how people employ and interact with technology or one can say Human factors engineering is the science and practice of achieving the best fit between people and the engineered worlds within which they live and work [1][5][11], like Physical, cognitive, and social ergonomics analysis of physical and cognitive work Field, simulator, and laboratory behavioral research techniques, resolving selection, training, and equipment design issues. The objective of Human Factors Engineering (HFE) is to minimize the potential for human error and accidents and encouraging the performance of assigned activities as efficiently and effectively as possible. The task of the human factors engineer is to match the design of systems to the requirements and capabilities of their human users [1]-[2]. Human Factor Engineering in Medical field is called Medical Human Factor Engineering (MHFE).

Human Factor Engineering help in strengthening the Management Technology [7], to justify this Izabella Gieras from Beaumont Technology Usability Center (BTUC) conducted evaluation services to medical device and turned to the principles of human factors engineering (HFE) to help with equipment evaluations. "HFE looks closely at the user-device design interface," she says. "Design is so important; the user-device interface should be as intuitive to a user as possible." For example, on a defibrillator, if the on/off button is

too close to the pacing buttons, it increases the likelihood that a caregiver may deliver an unintended shock to a patient. She discovered many resources on the topic, including materials from the Human Factors & Ergonomics Society, AAMI, FDA, and other resources. Department staff began applying these principles to their work and building a case to bring a human factors engineer on staff. On the Result side- "The ultimate numbers, in terms of lives that have been saved, will never be known," says Gieras. "Our case studies provide solid data of our success. Continued improvements in the HFE program will also focus on tracking medical device incident reports on those devices that went through the human factors group, to see how much it reduced adverse events."

## II. HUMAN FACTORS IN MEDICAL DEVICES

Use Human Factors Engineering research to evaluate medical devices and investigate medical incidents, identify critical safety initiatives and provide a short term solutions, collect data for future planning and improvements aiming for optimal product design and quality. A Clinical Engineer is a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology [5][6][10].

More than the number who die from motor vehicle accidents, breast cancer, or acquired immune deficiency syndrome (AIDS). A proportion of these errors may not

directly be attributed to the medical device itself; however, the importance of incorporating human factors engineering principles into the early design and use of these important interfaces is a key concern [1].

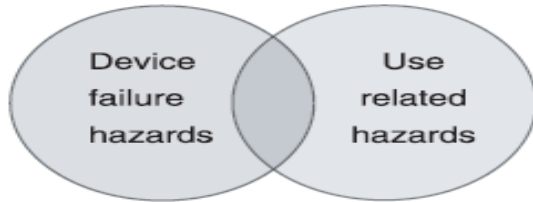


Fig. 1 : Hazards from device failure and use related

A. Use-Related Hazards

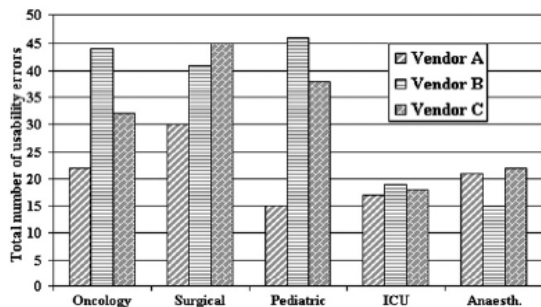
Addressing the hazards related to device use “Fig. 1”, the essential components include (1) device users (patient, caregiver, physician, family member, etc.); (2) typical and atypical device use; (3) characteristics of the environment for the application of the medical device; and (4) the interaction between users, devices, and use environments [1][3].

B. Device Failure Hazards

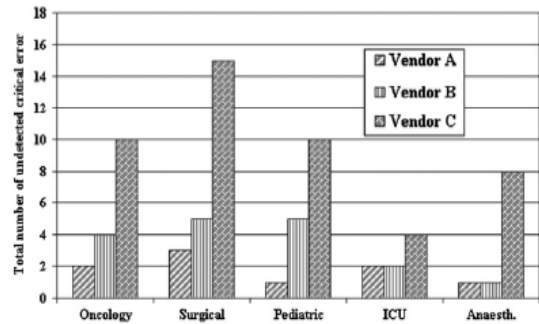
When understanding hazards from the perspective of risk analysis “Fig. 1”, it is common to consider the following classes of hazards as they pertain to device design: (1) chemical hazards (e.g., toxic chemicals); (2) mechanical hazards (e.g., kinetic or potential energy from a moving object); (3) thermal hazards (high temperature components); (4) electrical hazards (electric shock, electromagnetic interference); (5) radiation hazards (ionizing and non-ionizing); and (6) biological hazards (allergic reactions, bio-incompatibility, and infection) [1][3][5].

III. A CASE STUDY OF INFUSION PUMPS

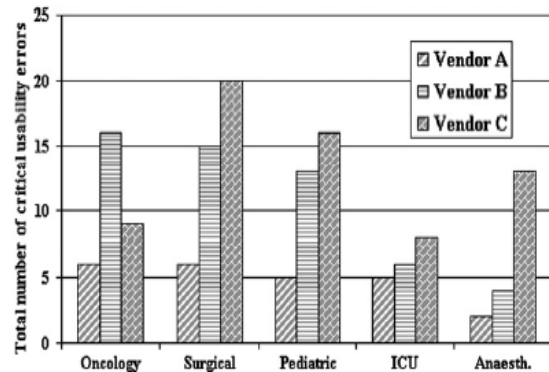
Errors committed by users in each clinical area for each infusion Pumps of three different vendors (A,B,C) are discussed below and graphical representation shown in “Fig. 2”.



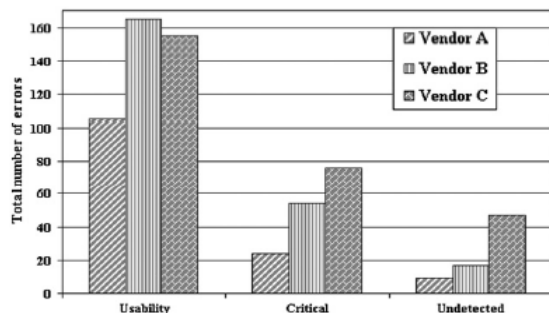
(a)



(b)



(c)



(d)

Figure 2. (a) Total number of usability errors made in each clinical area , (b) Total number of undetected critical errors committed in each clinical area , (c) Total number of critical usability errors committed in each clinical area , (d) Total number of errors across clinical areas.

IV. WORKSPACE DESIGN

A. Sanders & McCormick Principles

From an ergonomic point of view, designing a physical workspace means arranging components within

some physical space (Sanders & McCormick, 1993) [8]. The components are physical entities, such as a patient's bed, the nursing station, supply room, patient care equipment such as IV pulls and pumps, wheelchairs, commodes, respiratory therapy equipment, family waiting areas, private conference space, kitchen areas, and medication preparation areas. Ideally, each component would be placed in an optimal location. This optimal location is dependent on the function of the component (what it is used for) and on human capabilities and characteristics, including sensory capabilities and anthropometric and biomechanical characteristics. The goal for designing an optimal workspace is to facilitate performance and reduce the potential for errors. Sanders & McCormick (1993) have identified four workspace design principles:

(1) Importance principle: Important components need to be placed in convenient locations. Important components for nursing care include nursing patient care supplies, medical surgical supplies, patient gowns, isolation gowns, gloves and hand hygiene materials, CPR response supplies, and medical sharps disposal container.

(2) Frequency-of-use principle : Frequently used components need to be placed in convenient locations. They include thermometer, blood pressure cuffs, medical sharps disposal containers and disposable examination gloves.

(3) Functional principle : Components should be grouped according to their function. For instance, IV supplies should be grouped together because they correspond to the function of IV insertion and line care. Another example is to sort supplies by the body system that the nurse works on.

(4) sequence-of-use principle : In performing certain tasks, the worker goes through a specific sequence or patterns of activities. The components should be arranged in order to fit the sequence or pattern of activities. For example, surgical instrument trays or custom packs should be ordered by item sequence use, i.e. urinary catheter insertion kits are arranged by placing sterile gloves on top with the insertion supplies continuing in layers below as required by the steps in the procedure.

#### B. FMEA

A failure mode and effects analysis (FMEA) is an engineering technique used to define identify and eliminate known and/or potential failures, problems and errors from the systems, design, process and/or service before they reach the customer (American Society for Quality Control Statistics Division, 1983; Stamatis, 1995). It is a method of identifying and preventing product, service, or process failures before they occur.

FMEAs focus on prevention (i.e., “fix it before it breaks”). The objective of an FMEA is to look at all of the ways a device or process can fail, analyze risks, and take specific actions to prevent any future occurrences from happening. Typical applications include preventing material or device defects, improving patient care processes, identifying potential safety issues both to patients and care providers, and increasing patient satisfaction (Stamatis, 1995). FMEAs are typically conducted by multidisciplinary teams within the organization on everything from patient care processes to device design. There are both design FMEAs and process FMEAs. FMEAs are not just for new product selection or new processes; but rather, organizations can benefit from conducting FMEAs on existing products or processes. The FMEA process includes forms and customized evaluation criteria that provide a standardized, comprehensive approach, greatly reducing the variation of this preventive action process. The process allows the multidisciplinary, cross-functional teams to share and understand information in a common language. Both technical and non-technical people can easily use the FMEA [8] process. The FMEA process involves the following steps (Joint Commission Resources, 2002):

- (1) Select a high-risk process and assemble a team
- (2) Diagram the process
- (3) Brainstorm potential failure modes and determine the effects
- (4) Prioritize failure modes
- (5) Identify root causes of failure modes
- (6) Redesign the process
- (7) Analyze and test the new process
- (8) Implement and monitor the redesigned process. Implementation of a FMEA can result in numerous benefits (Joint Commission Resources, 2002):

- identify potential failures and warranty problems associated with medical devices both after purchase and in new product selection
- identify cost reductions and quality improvement opportunities throughout the system
- reduce the cost of making changes by identifying issues early in the policy and procedures cycle prior to full implementation
- demonstrate an organization's commitment to a comprehensive quality system

#### C. ASSIMILATION OF HFE

The integration of HFE with managerial and other disciplines helps in the development of designs that

effectively match human capabilities and limitations. It is important that management mandates the use of HFE as a design discipline as well as monitor the HFE program efforts. Management should provide the same oversight of, and attention to, HFE, and with the same enthusiasm and scrutiny, as is provided to the other engineering disciplines. HFE requirements should be as important as any other engineering discipline and given equal consideration in all design decisions. HFE should be expected to define its activities, successes, setbacks or shortcomings, and overall progress, and should be required to do so at all in-house or customer based project design review meetings. HFE should not be required to justify its presence in a design project (economically or technically) any more or any less than any of the other engineering specialties. Project management should physically and organizationally locate the HFE activity such that it promotes interaction between HFE, Engineering, Operations and Health, Safety, and Environmental (HSE). Below “Fig. 3”, is an example of an organizational location for HFE that has proven to be very effective in past capital design projects [11].

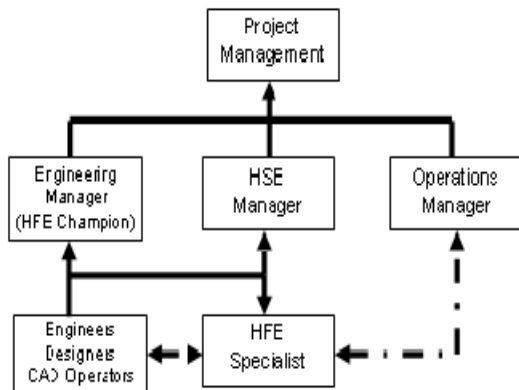


Fig. 3 : Sample Organizational Structure for HFE

D. Implementation of CAD

Computer-aided-design (CAD) systems have revolutionized the method of engineering design [9]. With its advanced functions, a CAD design can progress from the conceptual to the manufacturing stage, without the necessity of constructing a physical model for design evaluation. There are several powerful tools available for two dimensional (2D) and three dimensional (3D) designing. Using software Kit like CAD, Autodesk, Maya, Solid Works Premium 2010 and can easily design 2D and 3D picture or diagram of Workspace. “Fig. 4”, and “Fig. 5”, [10] designed with Auto-CAD software which describes simple design of patient bed along the position of patient on the bed and the other one describes about the wheelchair. “Fig. 6”, describes about

the two dimensional simple design model of an imaging center workspace.

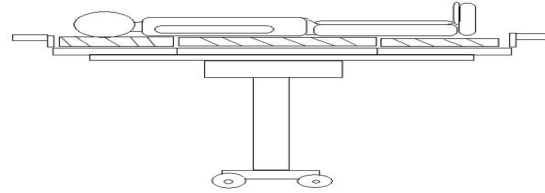


Fig. 4 : Patient with patient bed

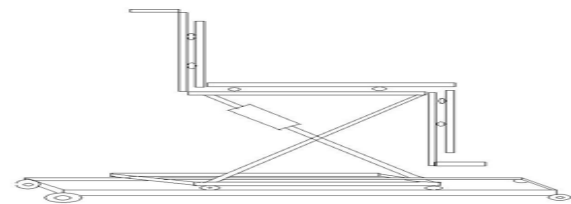


Fig. 5 : Wheelchair

“Fig. 7”, includes the complex lighting booms from Stryker over the operating tables and the convenient placement of the paper towel holders and “Fig. 8” describes the conceptual model 3D design of the same imaging center. This two pictures show how every item placed correctly in the room, the casework could be finalized and all electrical, plumbing, and exhausts run correctly behind the wall. Correct design of Workspace not only help in avoiding human errors but also responsible for efficient way of using electricity and electric power saving, efficient use of devices in right time and place.

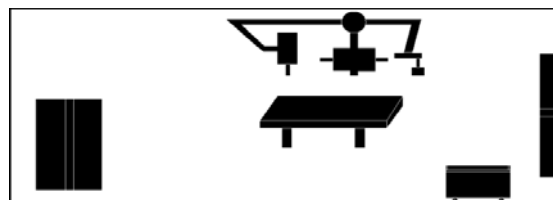


Fig. 6 : A 2D Simple model of Workspace of imaging center

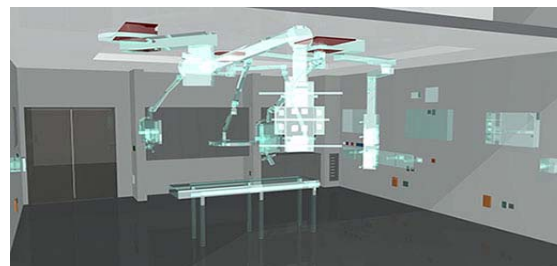


Fig. 7 : A 3D model of Workspace of imaging center



Fig. 8 : Conceptual design of the 3D model

While this sounds like a no-brainer, think of how many examples you've seen where the room doesn't match the needs of the occupant. In this case, though, the Owner had set a goal of absolutely no change orders. Who knew that some physicians prefer to stand on the right of the patient, while others prefer to stand on the left? This small detail determined the placement of the monitor which influenced the placement of the CPU, with in turn determined the outlet placement. The Assimilation group of HFE will take care of all these problems regarding designing the workspace.

## V. CONCLUSION

Ergonomics is the applied science of adapting work and/or workstations to workers. We have highlighted the many different facets and elements on Medical Human factor engineering which tells about the need of proper workspace to avoid human errors and the workspace design can impact patient safety via many different pathways and mechanisms: Workspace redesign may directly target the causes or sources of patient safety problems, improved efficiencies by removing performance obstacles, freeing up time and reducing workload for nurses to provide better, safer patient care.

## VI. ACKNOWLEDGMENT

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