IMPROVING PATIENT SAFETY DURING RADIATION THERAPY USING HUMAN FACTORS METHODS

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INTRODUCTION

In recent years, new and advanced technologies have revolutionized the planning and delivery of radiation therapy. However, the treatment process has become more complex, and radiation dose is not always delivered as intended [1]. A recent article in the New York Times described the devastating effects that resulted when human error had gone unnoticed during the treatment process [2]. Given the concerns raised in the media, radiation therapy is now under increased scrutiny and its safety is being questioned [3,4].

To improve patient safety and the quality of radiation therapy, industry has focused largely on creating new delivery apparatus and software systems [5]. While these new technologies can enhance the quality of radiation therapy and reduce error [1,6], it has also been reported that they can create new sources of error for treatment incidents to occur [1,7-9]. This indicates a need to improve the interaction between users and these technologies.

Human factors engineering involves the study of human behavior, abilities and limitations, and the application of this knowledge to design systems for safe and effective human use. As such, a system designed with human factors principles can often improve safety, minimize use errors, reduce training time and increase efficiency. However, there has been limited focus on radiation therapists despite the demanding nature of their work.

This multi-phase study is intended to investigate and address human factors issues in this area. The phased-approach included an evaluation of a treatment delivery process to identify human factors issues, the redesign of the existing system to address the issues found, and finally an experimental evaluation to assess the redesign. This work is recently published in a peer-reviewed journal [10].

MATERIAL AND METHODS

This study was conducted at Princess Margaret Hospital (PMH) in Ontario, Canada. The primary investigator conducted field observations at the hospital to observe how users interact with the radiation therapy delivery system. A workflow analysis was also conducted to identify areas that were associated with a high likelihood of incidents. The existing system was then redesigned using a user-centered approach to address the identified issues. In addition to applying usability guidelines, the redesigned system was demonstrated to experienced radiation therapists through two informal focus groups to refine the design.

To determine if the redesigned system improved user performance and reduce the risk of use errors, a usability test was conducted to compare the current and redesigned systems. Sixteen radiation therapy students enrolled in the Radiation Science Program at PMH were recruited to participate in the usability test. A mock-up of the redesigned system was created for the test. A repeated-measures experiment was conducted where each participant was asked to take part in four scenarios using each system (i.e. eight scenarios in total) and perform regular treatment delivery tasks. Three out of the four scenarios for each system were designed with a high potential for certain use errors to occur. The fourth scenario acted as a control, with no errors planted. The error rates of committing the three planted errors, as well as the overall time taken to complete each scenario, were measured. At the end of the testing session, participants were asked to fill out a questionnaire to compare various attributes of the two systems.

RESULTS

Based on findings from the field observations and workflow analysis, the area that was found to be particularly concerning was the checking process performed by radiation therapists prior to treatment delivery. At PMH, radiation therapists are required by policy to perform many checks to minimize the potential for use errors. However, other than being stated in the policy, these checks are not reinforced in any way, and are highly dependent on individual compliance. In addition, the main user interface that is associated with the checking process is not fully integrated into the workflow of therapists. The necessary information required to complete checks is displayed on multiple screens. As a result, therapists find the checking process inefficient and inconvenient.

Based on the above findings, the main user interface was redesigned to address issues with the checking process, particularly its heavy reliance on policy and inefficient workflow. Figure 1 compares the current and redesigned interface and highlights some of the changes that were made. Important features of the redesign include an automated checklist that ensures proper checks are completed prior to treatment, a more efficient structure with fewer steps, and a more prominent display of important information. With the automated checklist, the system would perform various checks automatically, including new messages, change in approval dates, and image approval status. If any of these items require attention, therapists must acknowledge them before they could proceed to deliver treatment. New and important messages were highlighted, and important information, such as the patient's profile picture and planning images, were displayed on the main screen for easier access.

A usability test was conducted to compare the current and redesigned interfaces. Three errors were planted within scenarios including 1) overlooking an important note, 2) shifting the treatment couch incorrectly, and 3) overlooking a change of approval dates. These use errors can contribute to various adverse events, and were chosen due to their common occurrence.

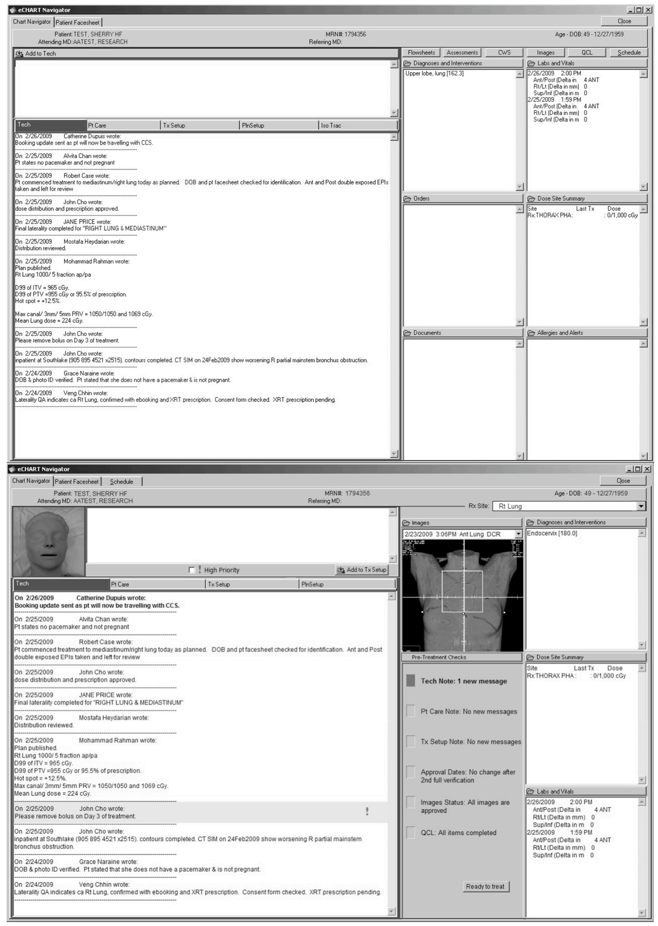

Figure 1: Screenshot of current (top) and redesigned (bottom) interface. Some new features on the redesigned interface include the patient's picture, planning images, highlighting of important messages and an automated checklist.

As shown in Figure 2, the error rate for overlooking an important note decreased significantly from 73% to 33% when the redesigned interface was used ($p<.04$), while the error rate for overlooking changes in approval dates decreased from 56% to 0% when the redesigned interface was used ($p<.01$). However, the rate for shifting the treatment couch incorrectly did not differ across the two interfaces and remained at 44%. Data for one participant was removed due to technical difficulties that may have affected their ability to detect the error.

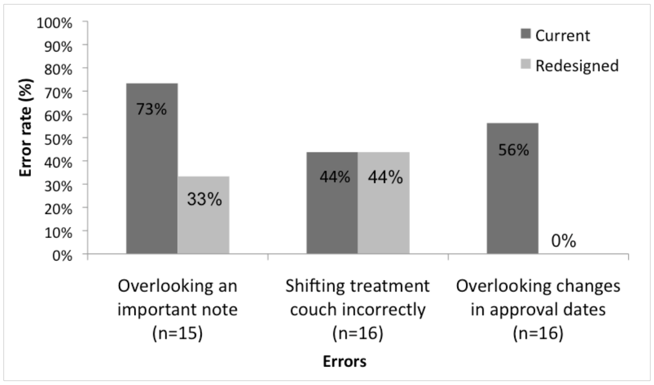

Figure 2: Error rates for current and redesigned interface

The mean overall task completion time for the redesigned interface was 6.0±0.2 min (363±13 sec), which was 5.5% faster than the time of 6.4±0.2 min (384±13 sec) for the current interface. An ANOVA analysis showed the interface effect was significant ($F(1,15) = 7.91$, $p<.02$).

Results from the questionnaire showed that significantly more participants thought the redesigned interface was better at showing the information that they needed ($p<.01$), at drawing their attention to important items ($p<.01$), at helping them detect various errors ($p<.01$), and at enabling them to deliver treatment more safely ($p<.01$).

DISCUSSION

Based on our findings from the field observations and workflow analysis, the checking process during treatment was found to be an area associated with many human factors issues. A number of studies from the literature have also shown that it is a common behavior for health professionals to omit checks when not reinforced [11,12]. This is particularly true when there are interruptions or distractions [13,14]. Occasionally, radiation therapists would also omit some of the required checks, especially when the patient requires extra attention or when therapists are pressured by time. According to guidelines provided by the Institute for Safe Medication Practices (ISMP), the use of policy tends to be one of the least effective approaches in preventing errors (See Figure 3) [15]. Therefore, other more effective approaches such as simplifying the checking process, or implementing some forcing functions to limit therapists' actions, may be needed to ensure the proper checks are being performed. The automated checklist was a form of a forcing function that was expected to reinforce the checking process, while the highlighting and relocation of important information was expected to simplify the process.

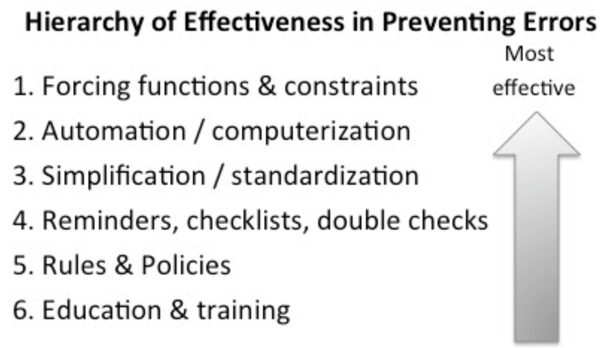

Figure 3: The hierarchy of effectiveness in preventing errors [15]

The formal evaluation showed that the error rates for two of the three planted errors were significantly reduced when the redesigned interface was used. Specifically, when an important note was highlighted as opposed to appearing in plain text, the rate of detection improved by 40%. Also, when the system was able to detect changes in the approval dates and alert users in the form of a checklist, the error rate was reduced to 0%. With the current interface where the system relies heavily on users to check for any changes, more than half of the participants failed to do so. Hence, the automated checklist was found to be a useful feature that can assist users in performing the required checks during patient setup and draw their attention to outstanding items. However, the rate for shifting the treatment couch incorrectly did not differ across the two interfaces. By displaying the planning images on the main page, it was expected that participants would be more likely to notice the discrepancy between the planning images and the actual setup. Yet, results from the usability test proved otherwise, and couch shift errors were often undetected. This indicates the limitation of the design method when only a single iteration is performed. Further design changes should be made and tested in the future in order to optimize the interface, based on the findings of the experiment.

While the participants had limited experience, they were still more familiar with the current interface than the redesigned interface. Hence, it was initially thought that they would perform more efficiently using the current interface. However, results from the usability test showed that the redesigned interface enabled them to perform tasks more efficiently. Although the mean task completion time associated with the two interfaces only differed by 0.4 min, the difference was found to be statistically significant. With more familiarity and experience using the redesigned interface, efficiency and benefits over the current interface would likely continue to improve.

In addition, responses from the post-test questionnaire indicated that participants were generally in favour of the redesigned interface. Therefore, the redesigned interface achieved an improved error rate, lower task completion times, as well as a higher level of user satisfaction.

There are several limitations to this study. Firstly, the sample population (i.e. radiation therapy students) only represents a small subgroup of the end-users, and experienced radiation therapists were not considered. Secondly, the redesigned interface used in the usability test was only a non-functional prototype. Some non-essential features were not simulated in the mock-up. Thirdly, only one iteration of usability testing was conducted to formally evaluate the redesigned interface. A user-centered design approach often involves multiple iterations of designing and end-user testing. If possible, future iterations of the design cycle can incorporate findings from this usability test to improve the design and further enhance user performance.

While this study was based specifically on the treatment delivery system at PMH, the process of identifying human factors issues and designing a user-centered system is highly adaptable. Many opportunities still exist to apply these methods to other radiation therapy treatment systems and process to improve patient safety.

ACKNOWLEDGEMENTS

This study was funded by the Natural Sciences and Engineering Research Council of Canada, the Canadian Patient Safety Institute, the National Patient Safety Foundation, and The American Association of Physicists in Medicine. The authors wish to thank Elekta for providing information on its products, as well as Catherine Dupuis from Princess Margaret Hospital and Varuna Prakash from the University of Toronto for their contributions.

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