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Published in:
Building Continents of Knowledge in Oceans of Data

DOI (link to publication from Publisher):
10.3233/978-1-61499-852-5-810

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

A. Ugon et al. (Eds.)

doi:10.3233/978-1-61499-852-5-810

A Decision Support Tool for Healthcare Professionals in the Management of Hyperphosphatemia in Hemodialysis

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Abstract. Hyperphosphatemia is known as one of the more challenging conditions in end-stage renal disease patients. This study set out to present and evaluate a healthcare-oriented decision support tool in the management of hyperphosphatemia within hemodialysis therapy. A prototype module was designed to fit into the interface of a modern dialysis machine (Fresenius 5008). The prototype included three main functions: 1) immediate bedside blood sample access, 2) a model based prognosis tool with estimates of P-phosphate and 3) an overview of the user´s phosphate related activities during dialysis treatments. The prototype was evaluated by a) heuristic evaluation with five human computer interaction experts and b) user testing with think-aloud by three users as (clinical) domain experts. The two evaluation procedures identified a total of 103 usability problems and led to some specific amendments to improve its practical potential. The overall results will guide further development of the decision support tool to ensure that the functions will support the user's needs. In conclusion, the prototype was evaluated to be relevant and potentially beneficial in the management of hyperphosphatemia in hemodialysis patients. Furthermore, it was found that some of the functions could be used for educational purposes or as decision support for some patient groups, e.g. for patient doing home-dialysis.

Keywords. Chronic kidney insufficiency, decision support systems, compartment modelling, phosphate, hemodialysis.

Introduction

Hyperphosphatemia represents one of the most challenging and frequently observed electrolyte disturbances in end-stage renal disease patients [1]. The condition is associated with severe complications such as secondary or tertiary hyperparathyroidism,

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renal osteodystrophy and vascular calcification [1]. Prevention and treatment of the condition include dietary restrictions, oral phosphate binders and dialysis [2]. However, the management of hyperphosphatemia seems challenging due to a number of factors e.g. compliance problems related to diet restrictions and inadequate phosphate binder intake. One study indicates non-adherence in 80% of patients according to diet recommendations [3]. Other studies show that the prescription of a standard phosphate binder regimen only covers about 30 % of the meals [4]. An alternative approach includes extended dialysis regimes [5]. However, there is currently no standardised guidelines of, how long the dialysis should continue in order to achieve an optimal phosphate balance. Therefore, hemodialysis (HD) patients often follow a standard treatment program of HD four hours three times weekly.

The removal of phosphate during a dialysis are depending on patient individual factors and the P-phosphate level before dialysis [6]. Hence, the regulation of dialysis treatment to achieve an optimal phosphate balance would require some suggestions about the phosphate kinetics of the individual patient. An approach to increased understanding of individual intra- and interdialytic phosphate behaviour could be the use of physiological models. Different kinetic models [7-8] have been proposed but only cautious suggestions have been made about the practical use of these models [7-9].

The objective of this study was, using a model based approach, to develop and present a decision support tool to help healthcare professionals in the prescriptions of HD therapy in order to achieve an optimal phosphate removal in the individual patient case during a specific dialysis.

1. Methods

1.1. Concept and design

A prototype was developed to support healthcare professionals in the management of hyperphosphatemia in HD patients. The prototype consisted of a module for the software of modern dialysis machines. Table 1 presents the three main functions of the module. The interface of the machine Fresenius 5008 was used as a proof-of-concept to present the prototype.

Table 1. The three main functions of the phosphate module.

"PO_4 samples"	"PO_4 prognoses"	"PO_4 activities"
Provides immediate bedside access to P-phosphate sampling results. → the user to compare sampling results of different treatments including the ongoing HD.	Provides decision support for the healthcare professional: a P-phosphate prognosis tool with predictions about intra- and interdialytic P-phosphate levels based on model simulation. This function presupposes point-of-care or machine blood sampling.	Provides an overview of the user's activities related to phosphate during the ongoing or previous dialysis treatments. This includes time for blood samples, use of the prognosis tool and changes in HD time.

1.2. Heuristic evaluation and think-aloud

The prototype was evaluated by heuristic evaluation (HE) and user testing with think-aloud (TA) to identify usability problems and to improve user experience. Alternating HE and TA produces the best result, as the methods identify different flaws [10].

HE aims to identify and correct user interface design flaws. It involves experts evaluating a prototype according to recognised usability principles ("heuristics"). The participants included five human computer interaction experts (HCIs). Three of the HCIs had a MSc in Biomedical Engineering and Informatics, and two had a MSc in Clinical Science and Technology. All HCIs had an understanding of the healthcare sector in general, and three had experience with usability testing. The HCIs were asked to evaluate the prototype individually against Nielsen's ten heuristics [11]: 1 – *System status*, 2 – *Match between system and the real world*, 3 – *User control and freedom*, 4 - *Consistency and standards*, 5 – *Error prevention*, 6 - *Recognition rather than recall, 7 - Flexibility and efficiency of use,* 8 – *Aesthetic and minimalist design*, 9 – *Help users recognize, diagnose, and recover from errors, 10 - Help and documentation*. The usability problems were evaluated on a severity scale from 1-4 (cosmetic problem to catastrophe) [11]. If a problem was found to fit different heuristics, it was evaluated individually for each heuristic. Results can lead to ideas for refinements of the system.

TA was performed to evaluate the interface and functions of the refined version of the prototype through analysis of user interactions with the system [12]. During the test procedure, the participants were encouraged to think-aloud as they were performing specified work-related tasks. The participants were guided individually by a test leader through the prototype in sessions of 30-45 minutes. A test assistant observed and noted each session. The participants included two dialysis nurses and one nephrologist. They were included as work-domain professionals (WDPs) and were all familiar with the Fresenius 5008 software. Results can lead to ideas for refinements.

2. Results

2.1. Presentation of the prototype

Figure 1 provides a screen dump of the "PO4 prognoses" tool to illustrate part of the user interface and content of the prototype.

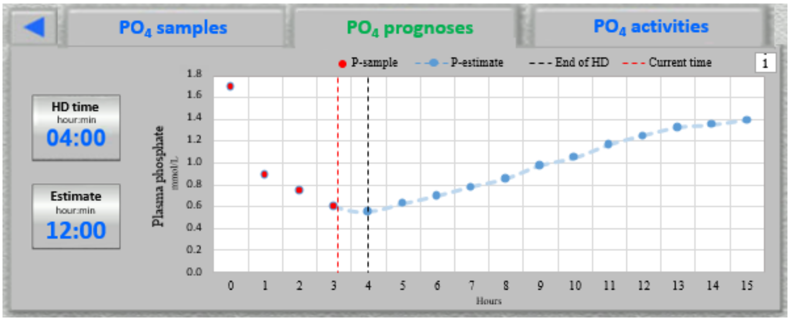

Figure 1. Screen dump of the "PO4 prognoses" tool. The graph shows P-phosphate samples (red dots) and estimates (blue dots), end of HD (dotted black line) and current HD time (dotted red line). "HD time" is treatment time the user chooses to see P-phosphate estimates, and "Estimate" is length of the estimate.

2.2. Heuristic evaluation

The HE identified 66 usability problems after 27 duplicates were removed. The heuristics were rated 104 times on the severity scale. Figure 2 shows how the violations were distributed against the ten heuristics and the four severity grades. The severity grades 1-4 were used 21, 36, 30 and 17 times, respectively, and the average severity rating for the ten heuristics was 2.6. Heuristic 8 was assigned the highest number of violations with a total of 23. However, 18 of the violations were rated 1. The most severe usability problems included heuristics number 2, 6 and 7.

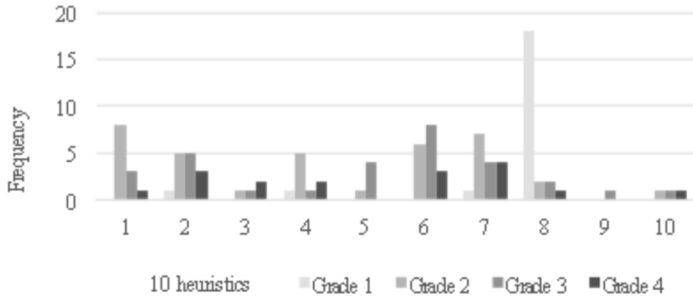

Figure 2. Number of times the HCIs used each of the ten heuristics and the distribution of heuristic violations for each heuristic against the four severity grades (1-4).

2.3. Think Aloud

The TA identified 37 usability problems related to the design and functions of the prototype. Table 2 summarises the function related feedback from the WDPs.

Table 2. Summary of the function related feedback from the think-aloud evaluation.

	"P-phosphate samples"	**"Phosphate prognoses"**	**"Phosphate activities"**
Possi-bilities	1) Bedside information about the efficiency of the ongoing HD, 2) educational tool.	1) Indicate if the patient could benefit of a prolonged HD, 2) educational tool, 3) tool for some patients, e.g. home-HD.	Overview of the phosphate activities.
Limita-tions	Frequent blood sampling would provide the most applicable tool.	Requires fast blood analysis, e.g. point-of-care or machine sampling.	Questionable, if the function would be used.
Sugges-tions	Accessibility of numerous Pre-HD P-phosphate levels → educational tool.	1) Requires profound information, 2) an app to improve self-management skills in patients on home-HD.	Could include blood sampling plan.

3. Discussion

This study set out to develop and test a decision support tool to help healthcare professionals in the management of hyperphosphatemia in HD therapy.

The evaluation results revealed 103 usability problems. More participants would likely have increased the significance of the results. However, according to a statistical formula, 3-5 experts will identify 75-80 % of usability flaws [13].

The overall results indicate that the decision support was functioning. This tool could be beneficial to both healthcare professionals and, as suggested by WDPs, HD patients. Access to repeated bedside P-phosphate analysis gives opportunity to individualise the duration of HD for the single patient at each dialysis. The patient will be able to see how pre-dialysis P-phosphate influences duration of the dialysis. This may motivate the patient to stay on the recommended diet and take the oral phosphate binders as prescribed. A possibility could be to develop a patient app with the tool. This would be a help, especially for patients doing home-HD. However, some challenges are present and need to be addressed. One issue includes the required point-of-care or machine blood sampling, as this feature is not currently available. Another issue is how well the integrated model will fit the patient's actual P-phosphate levels. This part would require further evaluation of current phosphate models [7]. A third issue is how the estimates can consider dietary intake during HD and residual kidney function.

In conclusion, it was possible by use of HE and TA to develop a prototype of a phosphate decision support tool for healthcare professionals in the management of hyperphosphatemia within HD. However, it remains to be tested whether the patients will choose an extended treatment regimen based on model estimates.

Acknowledgments

This work was supported by research grants from The Danish Diabetes Academy, which is supported by the Novo Nordisk Foundation.

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