Benefits of information visualization on electronic and paper-based Patient Care Records in the interpretation of a patient's medical narrative

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1. ABSTRACT

A Patient Care Record (PCR) is often used by Emergency Medical Technicians (EMT) and paramedics to provide a documented record of care provided to the patient, and serve as a mean of communication among clinicians for pre-hospital and future care. The electronic form of the PCR adopted by many Emergency Medical Services (EMS) is the electronic Patient Care Record (ePCR). Based on discussions with emergency room physicians it was found that the information provided by ePCRs and PCRs was helpful in providing an accurate record of the patient's condition throughout their pre-hospital care. It was noted however that the way in which information was currently represented sometimes overloaded physicians with too much irrelevant data or was otherwise not presented in a usable fashion.

This project attempts to address some of the weaknesses of the current ePCR systems using user-centered and task-centered design [9] and the inclusion of several visualization techniques and principles [10] in a prototype ePCR. . A usability study was used to if the alternate representations of patient data implemented in the prototype allows emergency physicians to be more aware of a patient's condition and allow them interpret a patient's medical narrative faster.

2. INTRODUCTION

2.1 Motivation

A Patient Care Record is often used by Emergency Medical Technicians (EMT) and paramedics to deliver a documented record of care provided to the patient, and serve as a means of communication among clinicians for pre-hospital and future care. Typically, a PCR contains a collection of qualitative and quantitative patient information such as: the date of birth, name, address, medical history, vital signs, electrocardiogram (ECG/EKG), treatment, reaction to treatment, et cetera. This recorded patient information when analyzed, allows clinicians to understand the conditions surround the patient's medical narrative (pre-hospital care information which allows clinicians to understand the patient's current condition) and continue with the patient's care after their arrival at the hospital. The electronic Patient Care Record (ePCR) is the electronic form of the PCR and has been adopted by many Emergency Medical Services (EMS) personnel. Depending on the health setting (emergency ground transport, emergency air transport, and so forth) the purpose of ePCRs often vary in scope, but are commonly provide a more accurate patient-care record management system, automate redundant tasks, and improve clinical information acquisition [1].

ePCRs and PCRS have many unique users, and their use are shown to be beneficial when considering the overall care of the patient [2], however upon discussions with Emergency Physicians throughout Alberta, it was found that the ePCR or PCRs generated by the ePCR systems, was often deemed unhelpful, and at times even detrimental in the task of addressing a patient's emergency medical condition upon their arrival to the emergency ward. In one conversation with an emergency physician, the physician recalled a situation where a patient with a medical emergency arrives at the hospital with a completed ePCR, similar to Figure 1. Despite having the document in hand, the task of filtering out irrelevant information such as the type of protective gear the EMS personnel was wearing, and locating the pertinent patient information was overwhelming. Given the time-sensitive and stressful situation which he was in the document was considered unusable for the task at hand, and instead relied on the quick verbal summary from the EMS personnel. It was also commented that while the PCR document was suitable for record keeping, was not very supportive emergency physicians in the task of treating patients arriving at the emergency ward of a hospital.

2.2 Explanation of the problem

The representations used in current ePCR/PCR's may contain an abundance of information regarding a patient's pre-hospital care, given the time-sensitive and highly stressful environment of an emergency ward, the complexity required to find and interpret the essential information needed to diagnose and treat a patient's condition has resulted in the emergency physicians deviating towards a more an abridged verbal narration, all the while tackling concerns of work repetition, and working with limited patient data.

Since emergency physicians are often faced with scenarios where time is a major factor in determining life or death for a patient, they are forced to rely upon other forms of communication, or approach the patient with a limited understanding of their condition. The design of a system is important in terms of usability, for instance an interface with commonly used options hidden from view of the user can increase task complexity and frustration [3]. The same can be said for PCRs or ePCR generated PCRs, where the information that is critically needed by an emergency physician in the performance of a common task, but is hidden from view by other information, or features.

The purpose of this project is then to study the benefits of applying established information visualization techniques to PCR or other forms of patient data as received by a hospital's emergency department, and determine if the benefits can potentially allow emergency physicians to be more aware of a patient's condition and aid in a faster interpretation a patient's medical narrative. This would be done through the examination of current methods emergency physicians utilize to develop this medical narrative, both using PCR/PCRs. I will be employing a user-centered (relying heavily upon user input for feedback and direction) and tasked-centered (direction based on understanding the user's task domain) iterative approach [9] to determine what kind of information in the current system is essential, important and non-essential, and what should be implemented within the system.

PRIMARY SURVEY - EXAM			
	Level of consciousness:	situation;	
A	Airway status:	Patent (Open);	
B	Breath Sounds:	**Left Upper:** Clear; **Left Lower:** Clear; **Right Upper:** Clear; **Right Lower:** Clear;	
	Breathing signs:	No abnormal breathing signs;	
	Breathing quality:	**Rate:** 24 BPM**Regularity:** Regular; **Effort:** Non-laboured ; **Depth:** Deep;	
C	Skin:	**Temperature:** Cool; **Colour:** Normal for Patient; **Moisture:** Diaphoretic; **Cap Refill:** Less than 2 seconds; **Turgor:** Normal;	
	Pulse:	**Site:** Left Radial; Right Radial; **Rate:** Rapid: **Rhythm:** Regular; **Strength:** Strong;	
	Neck veins:	No JVD;	
	Estimated Blood Loss:	None;	
D	Pupils:	(L): **Size:** 3mm; **Reactivity:** Brisk; **(R): Size:** 3mm; **Reactivity:** Brisk;	
	Mental status:	Agitated; Anxious; Cooperative;	
	Distal CMS:	**All extemities:** Movement present; Sensation present;	
	LOC:	No;	
O Anatomical	Thorax:	**Chest - LLQ:** Unremarkable on Exam; **Chest - LRQ:** Unremarkable on Exam; **Chest - ULQ:** Unremarkable on Exam; **Chest - URQ:** Unremarkable on Exam;	
	Abdomen:	**Lower Left Quadrant:** Unremarkable on Exam; **Lower Right Quadrant:** Unremarkable on Exam; **Upper Left Quadrant:** Pain /Tenderness; Pain; **Upper Right Quadrant:** Unremarkable on Exam; **Epigastric:** Pain /Tenderness; Pain; **Periumbilical:** Unremarkable on Exam; **Suprapubic:** Unremarkable on Exam;	**Upper Left Quadrant:** No Rebound tenderness;
	Pelvis:	**Perineum:** Unremarkable on Exam; **Right Hip:** Unremarkable on Exam; **Left Hip:** Unremarkable on Exam;	
	Back/Spine:	**Upper Back:** Unremarkable on Exam; **Left Flank:** Unremarkable on Exam; **Medial Lower Back:** Unremarkable on Exam; **Right Flank:** Unremarkable on Exam;	
	Upper Extremities:	**Front Upper Left Arm:** Unremarkable on Exam; **Front Upper Right Arm:** Unremarkable on Exam; **Back Upper Right Arm:** Unremarkable on Exam; **Back Upper Left Arm:** Unremarkable on Exam; **Upper Back: Left:** Unremarkable on Exam; **Upper Back: Right:** Unremarkable on Exam; **Uppr Back: Center:** Unremarkable on Exam; **Central Chest:** Unremarkable on Exam;	

VITAL SIGNS																
Time	HR	RR	BP-Sys	BP-DIA	MAP	SPO2	ETCO2	WEDGE	TEMP	GCS	Position	Glucose	Peak Flow	Pain	Pain: Visual	Done By
M- 2:24:00 PM	115 BPM	24 Resp/Min	106 mmHG	82 mmHG	90.00 mmHG	98 % - RA;			35.8 Celsius	E 4 V 5 M 6 15	Sitting					DM

Figure 1. Screenshot of an Alberta Health Region PCR

In order to solve the questions proposed by this project, I examined the weakness and strength of the current ePCR and PCRs, and the process in which emergency physicians use them to interpret the medical narrative of a patient. This was completed by observing doctors while they used the current PCR or ePCRs, and getting the user to vocalize his or her thoughts by "thinking aloud" (vocalizing his or her thoughts) [5] while using the system. Questionnaires and interviews were also used to determine the system requirements. From the collective feedback provided, low-fidelity prototypes were drafted up with pen and paper. This process was repeated to create the medium fidelity prototype (an interactive prototype containing partial or complete functionality), and the proposed system prototype.

3. RELATED WORK

At the present time, research on information visualization techniques in the context of an emergency situation is sparse. A number of ePCR systems exist, which provides different solutions to address pre-hospital ePCR requirements.

3.1 Medusa Siren ePCR Suite [6]

The Siren ePCR suite (shown in Figure 2) is integrated with many medical devices allowing concise and accurate capture of patient data. This system allows hospital staff to periodically monitor incoming a patients' PCR through a customizable text-based Hospital Notification Board (HNB). As shown in the figure, patients are classified by color coding based on their chief complaint. Users of the HNB can modify the visibility of 19 different information columns (4 are shown in the figure), to suite their requirements.

siren3 — INBOUND EMS — SISTERS OF MERCY

Complaint	Priority	Incident Time	Name
Cardiac Arrest	1	3/23/2011 7:50:57 AM	Cochrane, Zachary
Diabetic Emergency	2	3/23/2011 8:01:34 AM	Comeau, Danielle
Allergic Reaction	3	3/23/2011 7:59:41 AM	Morand, Gilbert
Respiratory Distress	4	3/23/2011 6:58:14 AM	Hill, Ethel

Figure 2. Siren ePCR Hospital Notification Board

3.2 ZOLL RescueNet ePCR and Link [7]

RescueNet integrates with many medical devices and provides users with the ability to attach ECG results, and other vital signs to the ePCR. The raw patient information as viewed by the EMT and paramedics can be streamed in real-time to the hospital running the same system. Figure 2 illustrates the representation of ECG information.

Figure 3. Zoll RescueNet Link interface

4. ANALYSIS AND DESIGN

In order for emergency physicians to interpret a patient's medical narrative or provide advice in treatment for the patient, qualitative and quantitative is taken into consideration. Qualitative data could include: the patient's medical history, allergies, feedback from the Emergency Medical Technician (EMT) or paramedic such as, the patient's reaction to the medication administered. Quantitative data would include things such as: the patient's blood pressure, ECG, and pulse. Individually each piece of data varies in importance, however it must also be kept in mind that multiple pieces of data are often compared in order to determine the trend or relationship.

In order to address the shortcomings on the current systems which the emergency physicians were utilizing, constant feedback was solicited during this study from the physicians. This user-centered approach was important in ensure that the system correctly reflects their needs. The first task of addressing the shortcomings of ePCR and PCRs (as a means of communication between clinicians during the patient's transfer of care) was to represent the data in a form that better reflected the style that was actually used by emergency physicians.

This was completed through a survey submitted to a total of 14 emergency physicians with a response rate of 42%. The survey asked:

1. Which patient data is essential, important, and non-essential in determining a medical narrative?
2. What is your current method of interpreting a medical narrative for an incoming patient?
3. How do you determine a patient's condition with the current ePCR/PCR systems? What are the pros/cons of this system?
4. What suggestions could you recommend that you believe would aid you in developing a faster medical narrative.
5. If you were able to receive a complete ePCR upon arrival to the hospital (ECG, pulse, treatment logs, charts, etc), how would you arrange and represent that information so that you could derive a medical narrative in the quickest time possible?

Many emergency physicians responded negatively to the third question, noting that they had difficulty with the layout and presentation of the data in the ePCR or PCR. Emergency physicians also expressed their interest in a system which could provide them the most amount of pertinent information in the shortest amount of time.

From the survey, it was also determined that the not all of the data available in the ePCR/PCR was essential, and most of which could easily be partitioned into three categories.

The three categories which ePCR/PCR data can be partitioned into:

1. Essential (information that is required in all cases)
2. Important (information that is required in most cases)
3. Non-important (information that is not immediately required but available)

Most of the responses overlapped and generally agreed upon what was essential, important, and non-important.

Essential:

- Vital signs and pertinent physical examination(ECG, blood pressure (systolic and diastolic), respiratory rate, oxygen saturation, temperature, and Glasgow Coma Score).There are typically two types of ECG graphs present. One is a continuous rhythm strip which captures the condition of the heart throughout the duration of a patient's pre-hospital care. The other is the 12-Lead ECG, which is provides comprehensive snap-shot of a patient's heart for a very short duration of time by gathering the rhythm readings from all leads placed on a patient. The Glasgow Coma Score (GCS) is a score which provides clinicians with a quick overall summary of the condition the patient is in. The GCS score is rated from 3 to 15, with 3 being the worst and 15 the best.
- Presenting complaint and time of onset/Context specific circumstances (i.e., suspended upside down belted in the submerged car)
- Diagnostics/therapeutics performed by EMS staff

Important:

- Patient demographics
- Allergies (unless this is the main complaint of the patient)
- Current medications along with doses
- Previous medical history with emphasis on history of similar medical conditions

Non-essential:

- All other details present on the PCR.

4.1 Usability study of current PCRs

An important step in developing a user-centered or tasked-centered system is to gain an understanding of the work flow and tasks of the user using the existing system or prototype. This was accomplished by utilizing several usability study techniques such as silent observation, think aloud, and interviews.

4.1.1 *Silent observation*

This approach is when the researcher simply watches the user as he or she goes about their everyday regular usage of the system. In is important to note that since observer does not interfere with the user throughout the process, silent observation allows the observer to understand what was done, and the work flow of the user, but does not reveal the reasoning behind the user's actions.

The development process of the prototype drew heavily upon the results of provided from silent observation of emergency physicians utilizing the current PCRs. The results aided in the understanding of which data was significant, and which parts tend to be irrelevant. It also aided in the understanding which areas users were experiencing difficulties.

It was determined that emergency physician using the PCR often flipped back and forth between pages, trying to find the essential information about the patient. Many of the physicians had to spend a significant amount of time reading the narrative and finding the correlating information in the document to gain an understanding of the patient's condition. Many also noted that the similar font size for all fields, and organization was very frustrating.

4.1.2 *Think-aloud*

Using this approach, physicians vocalized their thoughts as they went about their normal usage of the PCRs/ePCRs. The vocalization of the user's thought process allowed further understanding of where the difficulties lied in the current ePCR/PCR In addition to aiding in the understanding of which areas users were having difficulty it but it also allowed users to vocalize what they liked, comment about the design, and provide a more specific understanding to the reason of their difficulties.[5]

The emergency physicians all seem to possess a very organized thought process in terms of what information they are looking for. Typically many want to know the summary of a patient's pre-hospital care, any treatment they received, the initial vital signs, and vital signs during transport. However since the organization of information of the PCR or ePCR generated PCR did not match the work flow of an emergency physician, there was many pauses and self-confirmation in attempt to retain information that was spread out across several pages.

4.1.3 *Interview*

An interview was carried out after the usability tests. These ensured users were able to express their ideas, and provide insight to the way they perform certain tasks.

Emergency physicians again reinforce the fact that they don't utilize the PCR or ePCR very often. The time and effort that it takes to "decipher" a PCR could be used instead to saving a patient's life. Instead physicians prefer the verbal narrative which an EMT or paramedic provides upon transfer of care for the majority of the information they need. This method can be problematic as incomplete communication can easily lead to repetition of work, and other similar problems.

4.2 PROTOTYPING

4.2.1 *Low fidelity prototype*

The low fidelity prototypes were developed on pen and paper from the feedback provided in the usability studies during the analysis and requirements gathering of the system. Considering the essential and important categories in which the ePCR/PCR data can be organized, along with the results gathered in preliminary studies using the simple observation and think aloud techniques, a primary layout was created along with ideas on how the essential and important data can be represented.

Feedback on low fidelity prototypes were obtained through interviews with the emergency physicians to determine area of improvement, comments and inclusion of suggested feature. Iterative improvements that were included in the low-fidelity prototype based on user feedback. Such changes (Figure 4) included: the patient information box at the top, a table of vital signs, and individual graphs representing the electrocardiogram (ECG), the blood pressure, and pulse oximeter over time was favorable.

Other concepts that was considered was the color coding of vital signs to assist in visual identification of deviations from the norm and interpretation, and semantic zooming on graphs for detailed analysis.

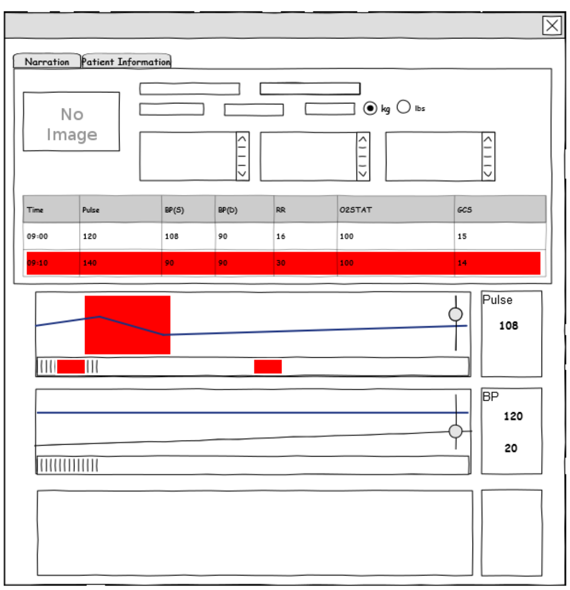


Figure 4: Screenshot of the low-level prototype

4.2.1.1 Color coding of vital signs

When a healthy patient's vital signs fall within a range of values as shown in Table 1.What is considered a vital sign can vary, however there are a structured set of norms which hold true:

Table 1. Normal vital signs for average adult human [8]

Vital Sign	Range
Pulse	60 to 100 beats per minute (bpm)
Blood Pressure	90 systolic/60diastolic to 120 systolic/80 diastolic millimeter of mercury (mm Hg)
Temperature	37 degrees Celsius to 36.5 to 37.2 degrees Celsius
Respiratory Rate	20-60 breaths per minute

These ranges of normal values can be then used as a basis to define anomalous cases and used to determine when to represent these deviations from the norm. For example, if a patient's respiratory rate was to suddenly fall to 10 breaths per minute, a digression from the range of normal respiratory rate of 20-60 breaths per minute, the proposed prototype will represent these deviations by highlighting the area within a table or graph (Figure 4), to bring to an EMS clinician's attention the change in a patient's condition.

4.2.1.2 Semantic zooming

Differing from normal zooming in which changing the zoom level only changes the size of the object, semantic zooming at different zoom levels may change the representation of the same information at each level so that it provides the most meaningful presentation at each size [11].

This form of zooming was considered for all the graphs presented in the low level prototype. When applied the electrocardiogram (ECG) graph for example (Figure 5), the lowest level of zoom presents the patient's complete rhythm strip, with sections highlighted to show points in time which the rhythm deviated from the norm. In the each successive level of zoom, the representation of the same information changes, to present additional detail of the rhythm and additional details such as a patient's heart rate at the particular time

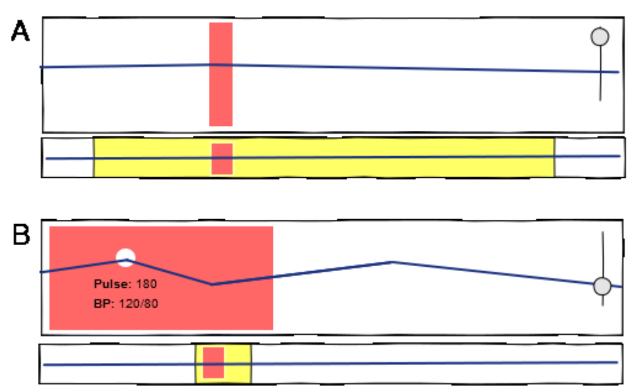


Figure 5: Low level prototype example of semantic zooming

4.2.2 *Medium fidelity prototype*

The next step after low-fidelity prototypes was the transition to medium fidelity prototypes after considering feedback from the users. In this project the medium fidelity prototype was a series of mockup screenshots that allowed users to visualize and provide feedback. The progress to medium fidelity prototypes allowed a better understanding of the layout, and simulation of different features for testing.. Moving from paper to screenshots allowed for testing of each component in detail yet provided the freedom to make changes quickly and inexpensively. It soon became apparent became apparent that simple categorization of the patient's information from the PCR such as his or her narrative (initial assessment, history, chief complain, cardiovascular system, respiratory system, abdominal health, gastrointestinal, genitourinary, skin and treatment) was hard to interpret and read.

Suggestions to reduce the clutter led to the implementation of several ideas. An example experimentation included an "accordion view" (opening a section collapse all others), or an expandable list view (where all categories are expandable as needed). In both case the accordion effect , and expandable view was found to address the issue of information overload, but also introduced another issue where the important information becomes hidden as users have find the information through scrolling , or repeatedly expanding sections to read and re-read a section in the narrative.

After these preliminary studies a hybrid compromise approach ("dynamic tabs") was implemented and appears to strike a balance between hiding the information and displaying the information. This feature (shown in Figure 7) works by providing additional details for each item in the list in the area immediately to the right of the element.

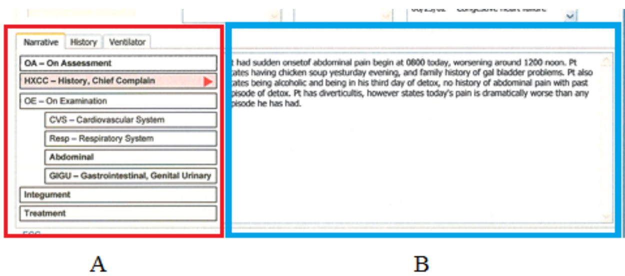


Figure 6. Dynamic tabs: selecting an tab element in A, changes the contents in B to reflect contents selected

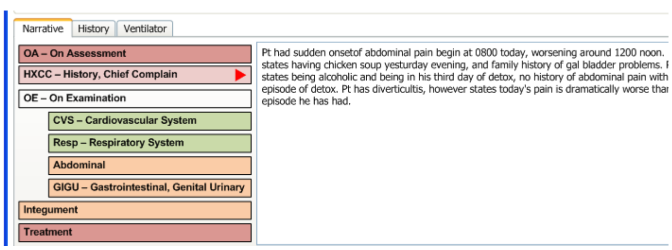


Figure 7. Dynamic tabs with color coding

Another feature that was considered with was the use of different shades of color as a method of distinguishing essential and non-essential data throughout the system. As shown in Figure 7, the addition of color to the tabs as an attempt to ensure to classify tabs in order of importance. However, the implementation shown in Figure 7 was left out of the final system, as it introduced problems associate with color blindness, and added the extra complexity of deciphering the meaning of the different shades of color.

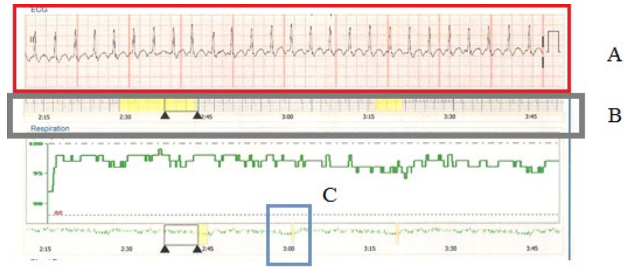


Figure 8. Medium fidelity prototype of a graph with semantic zooming capability.

The medium fidelity prototype retained the concept of semantic zoom for graphs with slight modifications from the low-level prototype. These changes are: the ability to select the level of zoom by range using the sliders located in the graph over view (B). The zoom is then reflected in the zoom window (A). Deviations from the norm are also highlighted in the graph overlay (B).

4.2.3 *Medium fidelity prototype testing*

Medium fidelity prototypes were tested with the same procedure as low-level fidelity prototypes. Users' feedback was obtained through interview and their suggested changes were incorporated in the final implemented system.

5. PROPOSED SOLUTION

5.1.1 *Screen layout*

From the feedback gathered from the prototypes, the layout of the final system was designed with the concept of reducing unnecessary information and providing emergency physicians with the necessary information in the quickest way possible. Compared with the medium fidelity prototypes, the cluttered layout has been addressed. Each section was moveable and collapsible, to take into account the different workflows of different users in the system. With each data set differentiating from the one another other (narrative, tables, charts) it was also important to maintain a consistent look-and-feel to minimize the learning curve when moving from one section to the next.

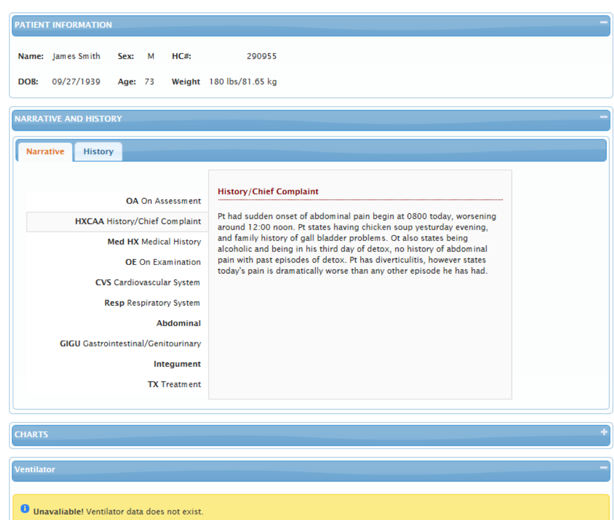
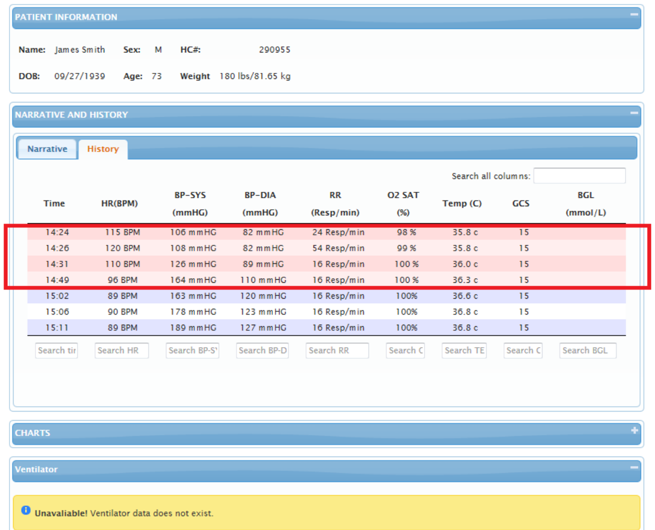


Figure 9. Overall layout of the final prototype

5.1.2 *Color*

Color was an important feature in the final implementation of the system. Based on user studies the usage of color in the final prototype allowed doctors to quickly note when vital signs that deviating from what is considered normal for a patient type. In Figure 10, patient vital information that fell out of what was considered normal in any field was highlighted in red to bring to attention users of the system.



Time	HR(BPM)	BP-SYS (mmHG)	BP-DIA (mmHG)	RR (Resp/min)	O2 SAT (%)	Temp (C)	GCS	BGL (mmol/L)
14:24	115 BPM	106 mmHG	82 mmHG	24 Resp/min	98 %	35.8 c	15	
14:26	120 BPM	108 mmHG	82 mmHG	54 Resp/min	99 %	35.8 c	15	
14:31	110 BPM	126 mmHG	89 mmHG	16 Resp/min	100 %	36.0 c	15	
14:49	96 BPM	164 mmHG	110 mmHG	16 Resp/min	100 %	36.3 c	15	
15:02	89 BPM	163 mmHG	120 mmHG	16 Resp/min	100%	36.6 c	15	
15:06	90 BPM	178 mmHG	123 mmHG	16 Resp/min	100%	36.8 c	15	
15:11	89 BPM	189 mmHG	127 mmHG	16 Resp/min	100%	36.8 c	15	

Figure 10. Table of vital signs, with box showing highlighted patient information that deviated from the norm

5.1.3 *Semantic zooming*

The graph on the final prototype provided the user with the ability to control the amount of information a user sees on each zoom level. In addition to controlling the magnification of the graph,

Each successive level of zoom changed the view of the same information, presenting additional details. For example, users are able to move their mouse over each point in the graph to see the patient's rhythm, and heart rate, at that particular point in time. In each chart in the final prototype, the user is able to control the level of zoom, and how much of the chart they would like to see. In addition

While the data in the graph was not an accurate portrayal of a patient's information (e.g. electrocardiogram (ECG)), it allowed for a conceptual demonstration of how semantic zooming can be applied to such a graph.

Figure 11. Semantic zooming for graphs in the final prototype represented as ECG

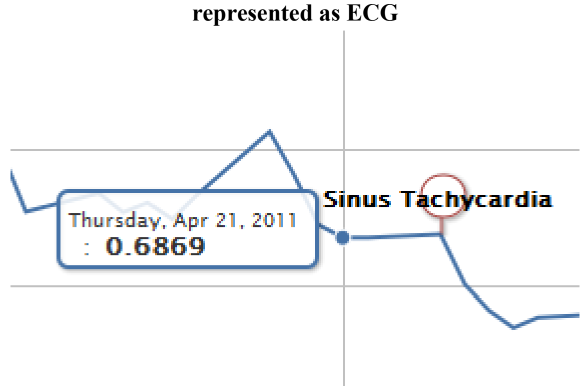


Figure 12.Semantic zooming: Graph zoomed in with different representation of the same information

6. FINAL PROTOTYPE EVALUATION

6.1 Evaluation Techniques

The usability study was broken down into three steps.

The first step was the preliminary interview, where the users were asked a series of questions, to determine their experience and background in ePCR and PCRs. Next users were shown the prototype, told to treat the PCR as if the patient was arriving shortly, and to gather the necessary information required to understand and treat the patient's condition.

Due to the fact that the number of users involved in the study was very low, and the demographics of the three users are very similar. I could not determine if previous experience, age, or professional experience played a role the outcome of the result. As a result the information from the first step was largely unconsidered in the analysis.

The emergency physicians were asked to use the think-aloud method to express their ideas and thoughts while working through the scenario.

It is important to note that the scenarios which the test took place in does not reflect the real-life scenario of an emergency ward (e.g., the test of the prototype was conducted as an emergency was taking place with an actual patient).

6.2 User Profile

Although there are many different users of ePCR systems and PCRs, this project focuses on the interaction of PCRs and PCRs by emergency physicians. An emergency physician is someone who specializes in the short-term care and treatment of patient with illnesses or injuries which require immediate medical attention. The targeted user should have experience with PCRs, with varying degrees of familiarity in ePCRs.

For this project a total of six users participated throughout the various stages of the project and were between the ages of 30 to 55. Most users had limited experiences with ePCRs and most of the experience that they did have was with the Medusa Siren ePCR and the STARS ePCR. Most emergency physicians relied on the paper based PCR rather than ePCR as a source of patient information. The six users who participated in parts of the study were spread across Alberta, but were limited to the city of Calgary, Edmonton and Grande Prairie. All users are emergency physicians with designations of FRCP(EM) through the Royal College of Physicians and Surgeons of Canada (Emergency Medicine Board Certification-Emergency Medicine Consultant) or a CCFP(EM) through the College of Family Physicians of Canada. Since the final prototype was just a mockup running on Internet Explorer 8, it was important to note that all users were familiar with the browser. This removed the need to differentiate for the user which interface was the prototype and what belonged of the browser. Of the six users contacted, 2 were beginner users, and 4 were intermediate users. Due to the time constraints, of the six contacted, only three were available to participate in the testing of the system; all three were intermediate users. The input of one of the users was not used in the study, as his input was used to drive the design of the prototype and ensure the validity of the testing scenario.

6.3 RESULTS

6.3.1 *Evaluation of screen layout*

Many of the users really liked the look and feel of the final system design. The interface was commented on as being simple and easily to use. During the user testing, users had little difficulty locating the information that was required to interpret the patient's medical narrative. It was suggested by two of the three doctors that the charts were a bit of a distraction at first, and would benefit more if minimized initially. The ability to modify the workspace was well, as different medical scenarios required varying focus on different sets of data. For instance, if the patient was experiencing and medical emergency on his or her foot, an emergency physician might not want to see options for ECG, or ventilator setting, instead opting to only monitor the blood pressure. Other suggestion by users was the potential inclusion of icons in the interface to make sections that were collapse more easily differentiable, or modify the functionality of the search box to include ranges.

6.3.2 *Evaluation of color*

Color when used as a visual variable was considered extremely helpful in the diagnostic of a patient's narrative. It was noted that many emergency physicians attempted to find trends in the vital signs which can potentially result the correct diagnostics. However it is important to note that the usage of color to highlight deviations from the norm as shown in Figure 10, was found to not benefit in anyway in comparison to viewing the charts without color. The suggestion to how this could be address was if each vital sign (pulse, blood pressure (systolic, diastolic), respiratory rate, et cetera) was each independently colored by a gradient, allowing for easy contrast of each vital sign with each other. For instance, a patient had an elevated heart rate which decreased over time, whereas the oxygen saturation increased over time, the chart in the system could represent these changes with the column for heart rate transitioning from green to red, and the column for oxygen saturation transitioning from red to green. This representation could allow physicians to interpret the two vital signs together, and possibly identify a diagnostics which relates to the correlation of the trends of both data.

6.3.3 *Evaluation of semantic zooming*

The opinion received in regards to the ability to visualize the patient's vital signs was mixed. Although the emergency physicians were supportive of the idea, two out of three expressed concern that the section being very visual can be distracting from the table of vital signs. If the charts were initially minimized and accessible upon command, then it would address that issue. Another suggestion provided was that instead of having three or more charts, that there should be a timeline which supports semantic zooming. Zooming into the timeline would display the events that occurred during the pre-hospital care (patient picked up, medication given, et cetera), with the ability to see the vital signs and segment of the charts for each particular point in time. This implementation would be very similar in context to that of a jQuery widget called Timeglider JS, as shown in Figure 13.This applet allows users to pan and zoom across the timeline. In addition, each level of zoom changes the appearance the information, to show more information otherwise hidden when zoomed out, and offers the ability to select points on the timeline for further details.

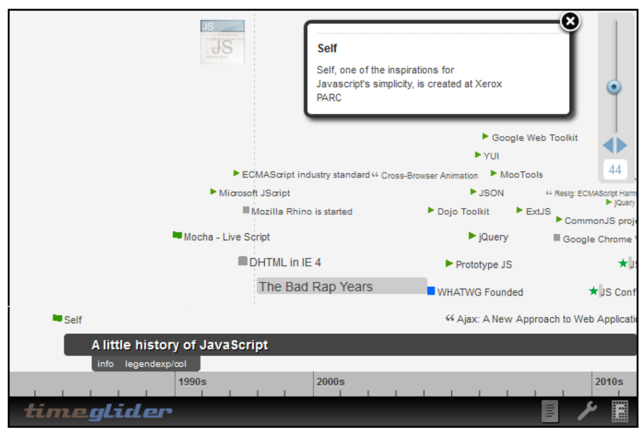


Figure 13. Sample timeline with semantic zooming [12]

7. CONCLUSION

For this project it can be concluded that a system which combines user-centered and item-centered iterative design, along with well-established information visualization techniques and principles to an ePCR or other forms of patient data will greatly benefit emergency physicians, in the interpretation of a patient's medical narrative in a time-sensitive and stressful environment. Applying information visualization techniques to a PCR or ePCR allows emergency physicians to more quickly find the information they need to understand a patient's circumstance and potentially aid in saving a patient's life.

8. FUTURE TASKS

Given the potential benefits of this research future work into this might include the exploration of information visualization on other patient data not explored in this project. For instance, patients may also have a 12-lead ECG reading, I would also like to revise this research with potentially more emergency physicians, or include additional user groups to determine if the benefits are not limited to one user group. It would be beneficial to continue developing the system, with the provided feedback given by the emergency physicians and continue with the research as it can be beneficial in how things are done in changing present or future in terms of the care a patient receives upon their transfer from pre-hospital care.

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