Development and Use of an iPad-Based Resuscitation Code-Blue Sheet for Improving Resuscitation Outcomes during Intensive Patient Care

by

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ABSTRACT

The American Heart Association recommended in 1997 the data elements that should be collected from resuscitations in hospitals. (15) Currently, data documentation from resuscitation events in hospitals, termed ‘code blue’ events, utilizes a paper form, which is institution-specific. Problems with data capture and transcription exists, due to the challenges of dynamic documentation of patient, event and outcome variables as the code blue event unfolds.

This thesis is based on the hypothesis that an electronic version of code blue real-time data capture would lead to improved resuscitation data transcription, and enable clinicians to address deficiencies in quality of care. The primary goal of this thesis is to create an iOS based application, primarily designed for iPads, for code blue events at the Mayo Clinic Hospital. The secondary goal is to build an open-source software development framework for converting paper-based hospital protocols into digital format.

The tool created in this study enabled data documentation to be completed electronically rather than on paper for resuscitation outcomes. The tool was evaluated for usability with twenty nurses, the end-users, at Mayo Clinic in Phoenix, Arizona. The results showed the preference of users for the iPad application. Furthermore, a qualitative survey showed the clinicians perceived the electronic version to be more accurate and efficient than paper-based documentation, both of which are essential for an emergency code blue resuscitation procedure.

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CHAPTER 1

INTRODUCTION

The American Heart Association recommended in 1997 the data elements that should be collected from resuscitations in hospitals (15). Currently, data abstraction from resuscitation events in hospitals, termed ‘code blue’ events, utilizes a paper form, which is institution-specific. Problems with data capture and transcription exists, due to the challenges of dynamic documentation of patient, event and outcome variables as the code blue event unfolds. Often key tasks performed or commands given are missed/ entered in error. Oversight may be sub-optimal. This may lead to poor quality metrics, putting patients and providers at risk and provide potentially misleading picture of resuscitation outcomes due to methodological shortcomings.

This Thesis hypothesizes that an electronic version of code blue real-time data capture would lead to improved resuscitation data transcription, and enable clinicians to address deficiencies in quality of care. The primary goal of this thesis is to create an iOS based application, primarily designed for iPads, for code blue events at the Mayo Clinic Hospital. The secondary goal is to build an open-source software development framework for converting paper-based hospital protocols into digital format

The application layout and functionality is explained with the help of screenshots later in this thesis following the literature review. Next, the document elaborates the development procedures, followed by an explanation of how these methods are reproducible for other paper to electronic conversions. Usability testing of the interface along with the clickstream analysis is included next. Finally, the results of the evaluation of the application with respect to user interface are presented, followed by the discussion of results.

The thesis concludes that the developed application is preferable to the current paper-based form being used at Mayo Clinic and it is likely be used at Mayo Clinic in the near future.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses research and studies that have been performed to demonstrate the manner in which electronic documentation for common hospital operations are more effective than paper-based versions. Furthermore, an analysis of the manner in which iPad applications are a more functional tool than paper documentation during emergency cardiac resuscitations will be examined. Lastly, this chapter examines existing applications that are currently present within this domain and discusses the manner in which they may be improved.

2.1 Background

In a paper published from the University of Chicago called "Tablet-Based Cardiac Arrest Documentation: A Pilot Study," the authors found that the paper-based resuscitation records that trained nurses complete lacked the quality and precision that is needed when recording critical events during fast-paced code-blue resuscitations (2). A code blue is an emergency code that indicates that a patient facing a cardiac arrest needs resuscitation (6). The importance of the appropriate execution of fast-paced resuscitations cannot be underestimated. Figure 1a (7) below demonstrates the manner in which the chances of survival from cardiac arrest decrease with every minute delay. In a setting where time is absolutely critical, it is important that appropriate documentation methods are maintained.

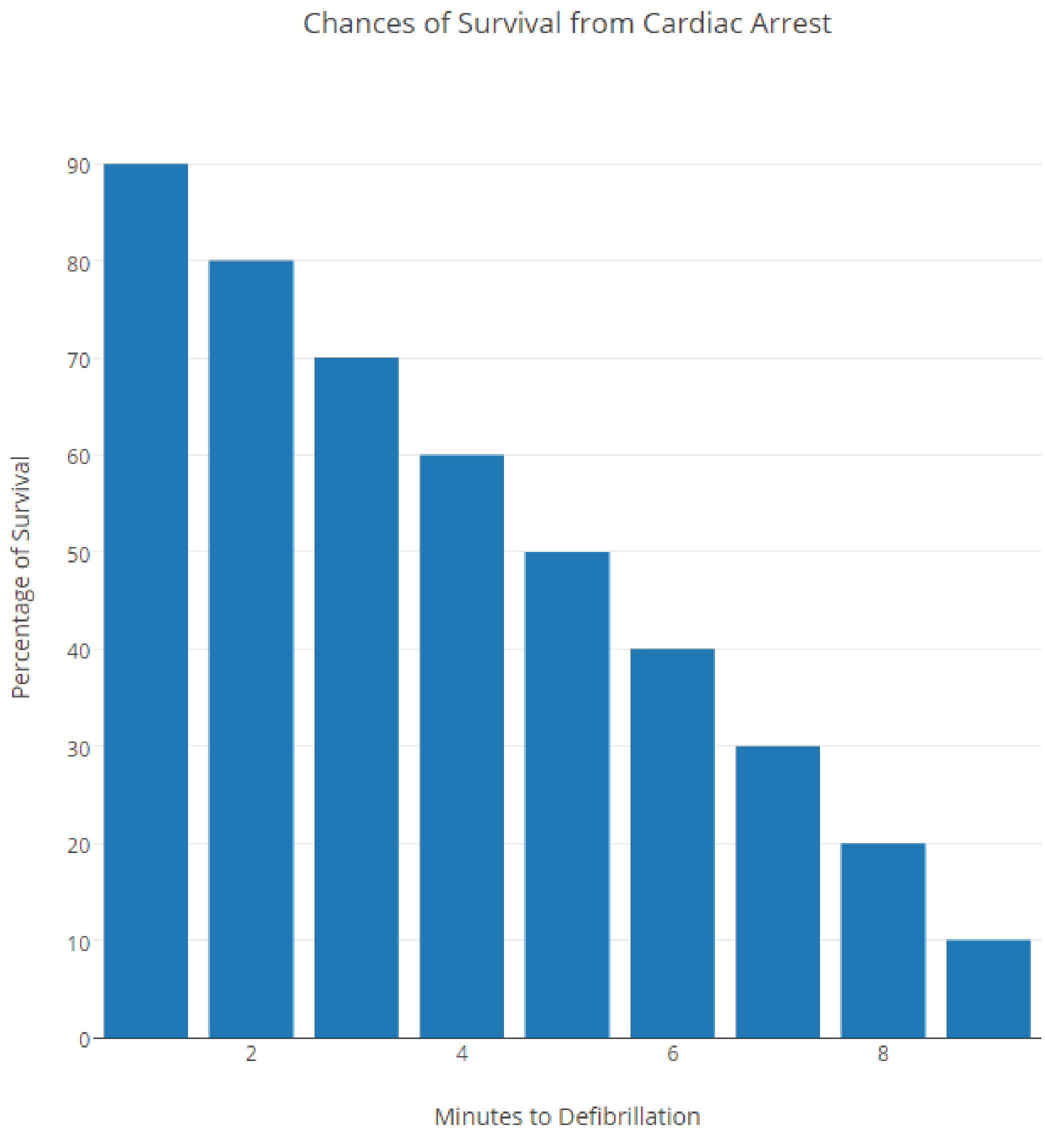


Figure 1a - Chances of survival decrease as minutes to defibrillation increase (7)

The iOS application developed through this thesis study addresses this issue by providing a responsive design that will allow nurses to accurately record data in a timely manner from a code blue emergency procedure. An iPad-based application should reduce clinicians' cognitive load, which is the amount of mental effort required to process presented information, by automating common tasks that have to be frequently accessed for a paper-based documentation system. As a result, this should reduce errors resulting from heavy cognitive load and will then facilitate safer decision-making. A study conducted by the Pritzker School of Medicine found that a tablet application for cardiac arrests had a mean sensitivity, average ease of use, which was more than 20% than the paper-based model (2). This implies that the tablet application was easier to use than the paper document. This shows that electronic forms of documentation can have a significant advantage over paper-based documentation in the medical field.

A successful electronic support will mean that the application will not only be likely to improve the quality of resuscitation documentation but it may also provide a relatively easier and efficient method to document critical events that is not possible through paper-based versions. This assertion is backed up by a study from North Shore University Health System Research center, which concluded that the prediction of cardiac arrest code-blue events were more successfully implemented through the use of electronic medical records (6).

The goal of this research is to develop a novel application that not only improves resuscitation outcomes in patients but also considers events that are not code blue. For example, there can be scenarios in which acute changes in physiology along with vital sign changes may occur without a cardiac arrest. This means that the iPad application has greater generalizability as it can be extended to incorporate events that are not code blue.

Another approach that has been used as an alternative to paper-based resuscitation documentation is live-video recording of entire surgical operation procedures. In this method, the documentation of the operation is recorded from the video feed after the operation has been performed. This approach has not been widely adopted for two main reasons according to the ethical and legal considerations report by the US National Institute of Health. (11) Firstly, numerous legal documents are needed prior to allowing patients' live resuscitation event and procedures performed on them to be recorded in an attempt to comply with privacy laws. Secondly, the data recorded may be complex, voluminous, and require extra time and resources, including management of secure large data handling processes. (11) An iPad-based application does not run into such dependencies, which shows it relevance within such a practice.

2.2 Existing Work

This section compares current tools that are similar to the application developed for this thesis. There are two main electronic applications related to resuscitation that are currently available. These two applications have been demonstrated in figure 1b and 1c respectively along with their drawbacks.

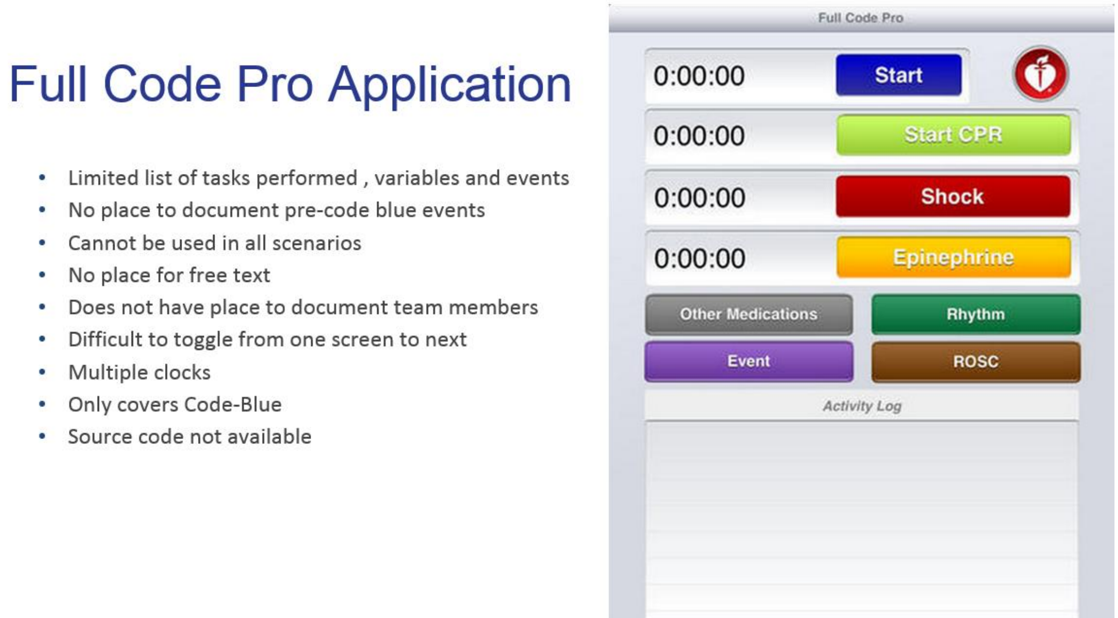


Figure 1b: Full Code Pro Application (20)

This application has certain shortcomings as seen seen in figure 1b above. For instance, this application solely covers code-blue events and covers only a limited list of tasks, variables, and events. Additonally, this application does not include any place to document pre and post code-blue resuscitation events. This application uses multiple clocks rather than having one central clock that can handle different events. Furthermore, this application does not permit the team members' names, who perform the resuscitation, to be recorded. Finally, the source code for this application is not available which makes it difficult to modify for specific needs.

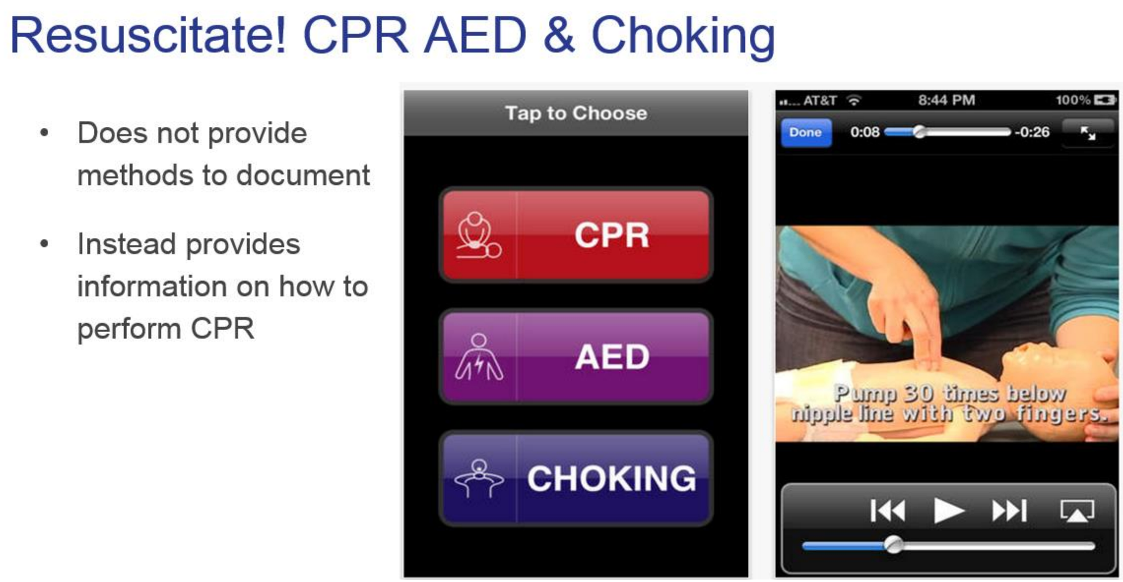


Figure 1c: Resuscitate! CPR AED & Choking Application (21)

This application cannot even be considered as an alternative to the paper-based resuscitation documentation, since it does not provide any method to document the critical events. Instead, it only provides information on how to perform certain emergency procedures using educational videos.

The two applications discussed above are the main resuscitation applications that are currently available. However, there are some paper-to-electronic conversion tools present that can potentially be used to convert the paper-based form to an online form. The three major tools are given below in figure 1d, along with their drawbacks.

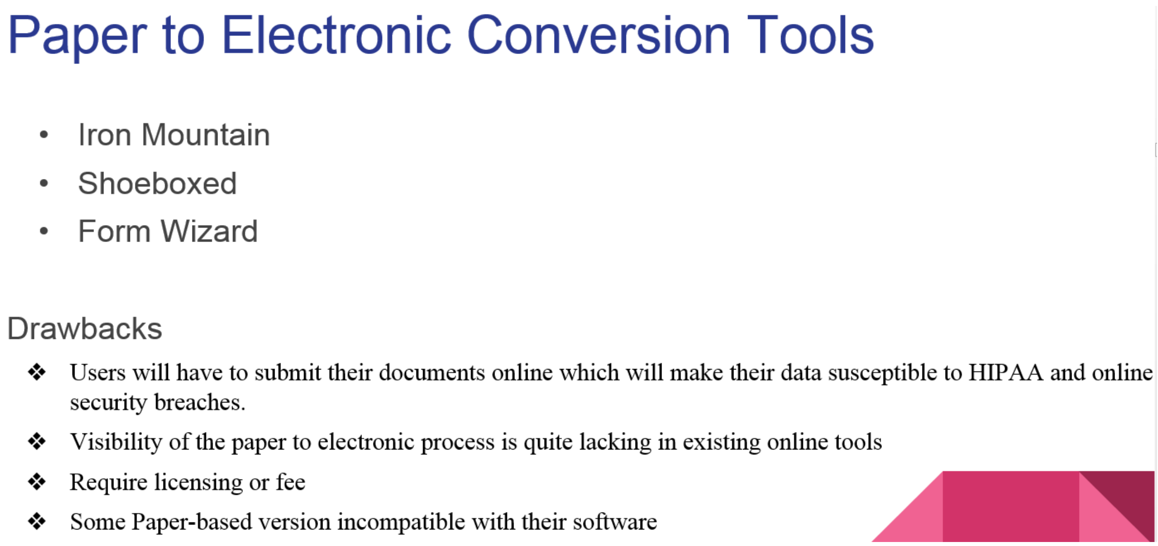


Figure 1d: Existing Paper to Electronic Conversion Tools (22) (23) (24)

The figure shows that the existing tools have certain disadvantages in terms of privacy, visibility of process, cost and compatibility. This means that the existing applications have not been able to manage a successful implementation of the resuscitation documentation. Some applications are restrictive, and lack adequate features, whereas others have major drawbacks that have been depicted above. The application developed for this thesis addresses all these shortcomings as discussed later in this section.

2.3 Thesis iPad Application Advantages over Existing Work

The design and development section featured later in this document will reflect upon the design of key features of the iOS application developed for this thesis. The generalizability of this application will be shown through screenshots displaying how each segment of the paper-version is mapped to the electronic application. The advantages featured within this application are further examined below:

Once Mayo Clinic approves the application to go into production, it may then be easily downloaded and modified by its users. This results from the source code being available through open source. In addition, users will not be required to register an account or acquire a license in order to utilize this application. This gives this application a competitive advantage over other applications like Iron Mountain, Shoeboxed etc. as they require a license in order to get the paper form converted to electronic form, or they have a monetary fee that needs to be paid before any conversion can take place.

Furthermore, other applications like ‘Full Code Pro’ do not provide their source code for the conversions. This means users will not have significant control for customizing the application. Also, when using other conversion applications like Iron Mountain, the users will have to submit their documents online which will make their data susceptible to HIPAA and online security breaches. This could prove to be a significant hurdle for paper-based applications since they may consist of sensitive data that should not be submitted nor accessible online. In addition, the visibility of the process is quite lacking since the process is a black box in which the users cannot see how their data is being utilized.

Despite such challenges, the application developed for this thesis considers and resolves all of these challenges by providing an effective method that is not dependent upon an online tool to make necessary conversions from paper to electronic forms. This particular application is beneficial for users, since they do not need to submit their data online. All that they are required to do is download the code and adapt its functionalities to meet their specific requirements. Nonetheless, one significant drawback to this approach is that users will need to be experienced in programming in order to modify any existing codes.

The programing featured within this application provides greater flexibility, since the developers who possess suitable experience may reuse this code for conversion of any kind of paper application. On the other hand, the online tools present on the web such as Shoeboxed consist of various limitations that make some paper-based forms incompatible with their software.

In addition, the software for this application is written in objective C, which means that it can be used on any type of iOS application. This ensures that this code can be used for iPhones and iPods as well, and it is not limited to iPads only. Moreover, the method used for the development of this application can be applied to Android devices however the code must be rewritten to suit Android platforms. Current electronic conversion platforms featured on the Internet like ‘Form Wizard’ may only be converted to one specific platform (24).

Lastly, there is clear division between the tabs in this iPad application. These clear divisions show what segment of the paper version relates to which corresponding section of the iPad version. Moreover, the content of this thesis, and the screenshots that have been added in this paper, have provided extensive documentation concerning the design and development of this application. This demonstrates the significant visibility and control available to users, which is lacking in current online tools.

The following sections will demonstrate how this application is accomplishing such a task and show how the researcher has come up not with an online tool but a method for the conversion, which may be easily replicated.

CHAPTER 3

METHODS

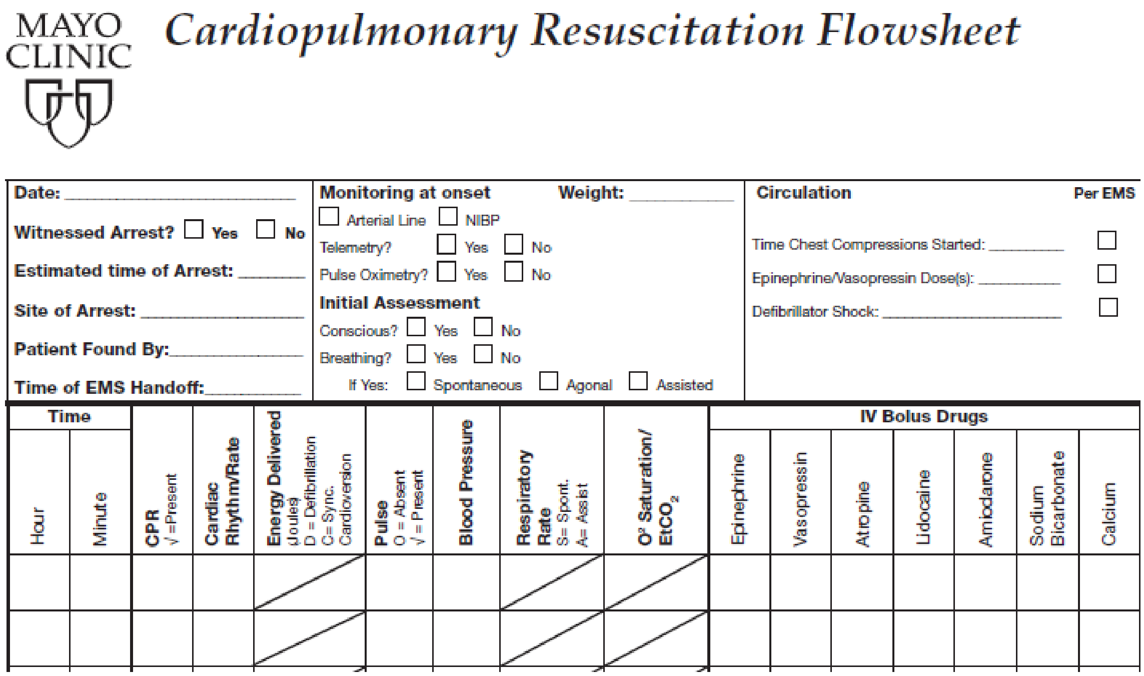
This chapter highlights the methods used to develop an efficient and effective resuscitation documentation iPad application for the clinicians that will improve the resuscitation outcomes for patients in intensive care. It has been divided into two parts: design and development.

3.1 Design

This section describes the goals and functions of the application. This is followed by screenshots of the actual application with design decisions to elaborate the final product. Finally, the development section that goes over the steps taken to build the application will follow.

3.1.1 Shortcoming of Paper-Based Form

The goal of the application is to replace the paper based form that is being currently used at Mayo Clinic to document code blue variables. The actual paper based form is given in Appendix A. A part of this document can also be seen in Figure A below.



MAYO CLINIC

Cardiopulmonary Resuscitation Flowsheet

Date: ____________

Witnessed Arrest? ☐ Yes ☐ No

Estimated time of Arrest: ______

Site of Arrest: ____________

Patient Found By: ____________

Time of EMS Handoff: ________

Monitoring at onset Weight: ________

☐ Arterial Line ☐ NIBP

Telemetry? ☐ Yes ☐ No

Pulse Oximetry? ☐ Yes ☐ No

Initial Assessment

Conscious? ☐ Yes ☐ No

Breathing? ☐ Yes ☐ No

If Yes: ☐ Spontaneous ☐ Agonal ☐ Assisted

Circulation Per EMS

Time Chest Compressions Started: ________ ☐

Epinephrine/Vasopressin Dose(s): ________ ☐

Defibrillator Shock: ____________ ☐

Time									IV Bolus Drugs						
Hour	Minute	CPR √ =Present	Cardiac Rhythm/Rate	Energy Delivered Joules D = Defibrillation C= Sync. Cardioversion	Pulse O = Absent √ = Present	Blood Pressure	Respiratory Rate S= Spont. A= Assist	O² Saturation/ $EtCO_2$	Epinephrine	Vasopressin	Atropine	Lidocaine	Amiodarone	Sodium Bicarbonate	Calcium

Figure A - Mayo Clinic Paper Resuscitation Document

(Complete document shown in Appendix A)

It is evident from the document that there is a great deal of information for the user in a single sheet. There are several boxes and the spaces to complete the entries are small, making it inflexible to use for a clinician. Four main problems listed from using this sheet according to the Resuscitation Central (12) journal are

1. “The data on the CPR record are often incomplete.
2. The data on the CPR record are often illegible.
3. The names of all CPR members are not present on the CPR record, and.
4. Several different clocks are used to enter times onto the CPR record.” (12)

Along with these problems, use of the paper-based documentation is also slow and prone to errors making it relatively inaccurate. The iPad application developed for this thesis takes care of all these hurdles. To understand how the application takes care of these hurdles, it is important to first get a feel for the application by studying its design, aided with some screenshots.

3.1.2 Design Motivation

The application has been designed taking into account the Nielson Usability Heuristic Metrics. These metrics are general principles for interaction design. (13) A detailed heuristic evaluation is presented below, and the Nielsen's Metrics have been elaborated for better understanding of the design. Moreover, screenshots that illustrate the design and screen flow of the application are also included in this section. The aim of the application is to enable resuscitation processes to be documented in a timely and accurate way. Furthermore, the descriptions along with the figures show how the design can be represented as an effective choice from the HCI (Human Computer Interaction) perspective.

3.1.3 Heuristic Evaluation

Heuristic evaluation is a commonly used method to test the usability of a device. Nielsen in 1995 wrote, "Heuristic evaluation is a usability engineering method for finding the usability problems in a user interface design so that they can be attended to as part of an iterative design process. Heuristic evaluation involves having a small set of evaluators examine the interface and judge its compliance with recognized usability principles" (13). The subjects for a heuristic evaluation are experts who are familiar with the usability principles. These subjects are not necessarily the end users of the application.

For the evaluation of this application, three doctorate students, who were specializing in human computer interaction, volunteered to inspect the interface. A prototype of the application was used for the heuristic evaluation since the application was not developed at that time. All three evaluators walked through the interface independently and were only allowed to communicate with each other when all of them had completed their evaluations. They had Neilson's metrics sheet with them while using the interface. The author of this thesis acted as the observer to "assist the evaluators in operating the interface in case of problems and help if the evaluators had limited domain expertise and need to have certain aspects of the interface explained." (13) The evaluators judged the application to see compliance with Nielsen's Usability Heuristics for User Interface Design. These heuristics are general principles or rules of thumb for good interaction design.

After the completion of the heuristic evaluation, the design of the actual application was modified as needed to meet Nielsen's Heuristic Metrics as discussed below. The metrics with their detailed definitions are given in Table 1 below. (16)

#	**Heuristics by Jakob Nielsen**	**Description**
1.	Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2.	Match between system and the real world	The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms.
3.	User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state.
4.	Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5.	Error prevention	Even better than good error messages is a careful design, which prevents a problem from occurring in the first place.
6.	Recognition rather than recall	The user should not have to remember information from one part of the dialogue to another.
7.	Flexibility and efficiency of use	Allow users to tailor frequent actions.
8.	Aesthetic and minimalist design	Dialogues should not contain information, which is irrelevant or rarely needed.
9.	Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
10.	Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search.

Table 1: Ten Usability Heuristics by Jakob Nielsen (16)

These metrics have been numbered below along with a description that explains how each metric has been incorporated in the design. The ninth heuristic has been combined with the fifth heuristic below as both are closely related.

1. Visibility of system status

As seen from Figure 2a below, there is a bottom tab that shows all the possible tabs of the application. Moreover, the current tab screen is highlighted in blue that makes the system status visible. For example, in Figure 2a, we see Team Members at the bottom being highlighted in blue.

Figure 2a – Bottom bar of application

2. Match between system and the real world

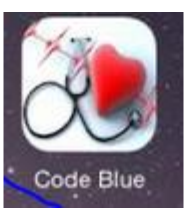


Figure 2b - Code Blue Application logo

The application (Code Blue) logo is shown in Figure 2b above. The second metric for the heuristic evaluation is a match between system and real world. The description given from the heuristic evaluation form states, “The system should speak the user’s language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.” Since the application is dealing with cardiac arrests, the intent was to use real world symbols as part of the heuristic metric; hence there is a heart with the doctor’s stethoscope as the application logo. This shows a good match between the developed application and the real world significance.

3. User control and freedom

This is maintained brilliantly by using a singleton class. A singleton class in software engineering is a design pattern that allows one class to coordinate actions across the whole application. (16) This allows the application to preserve data across different tabs. This means that the users can switch using the bottom bar from one tab to another without losing data from the previous tab. This gives user great control and freedom while navigating through the application.

4. Consistency and standards

Consistent standards have been maintained throughout the application. All tabs have similar look and feel with same contrast, which maintains good consistency across the application.

5. Error Preventions and help users recognize, diagnose, and recover from errors. This is covered in the description in figure 2c below. Basically, by allowing only one selection at a time, it helps users prevent errors.

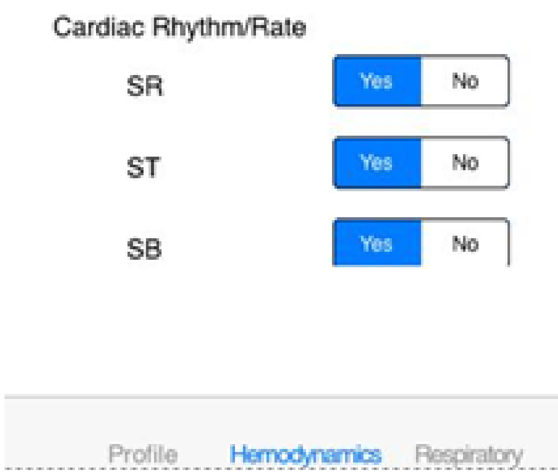


Figure 2c – Cardiac Rhythm in Hemodynamics tab

In the cardiac rhythm heading, the fifth heuristic evaluation measure has been followed, which is error prevention. According to the requirements, one of the key drawbacks for the paper-based documentation is that it is difficult to choose one rhythm and cross down the other as only one can be true at one time. The iPad application solves that as once you select one of them as yes, all others default to no automatically. This not only helps meet the heuristic evaluation of error prevention but also makes the process remarkably easy.

6. Minimize memory load

Basically, by providing a list of selections for the user to choose from, recognition rather than recall is being encouraged, as users do not have to recall the selections. This reduces the cognitive load on the users, which is not happening for the paper-based version.

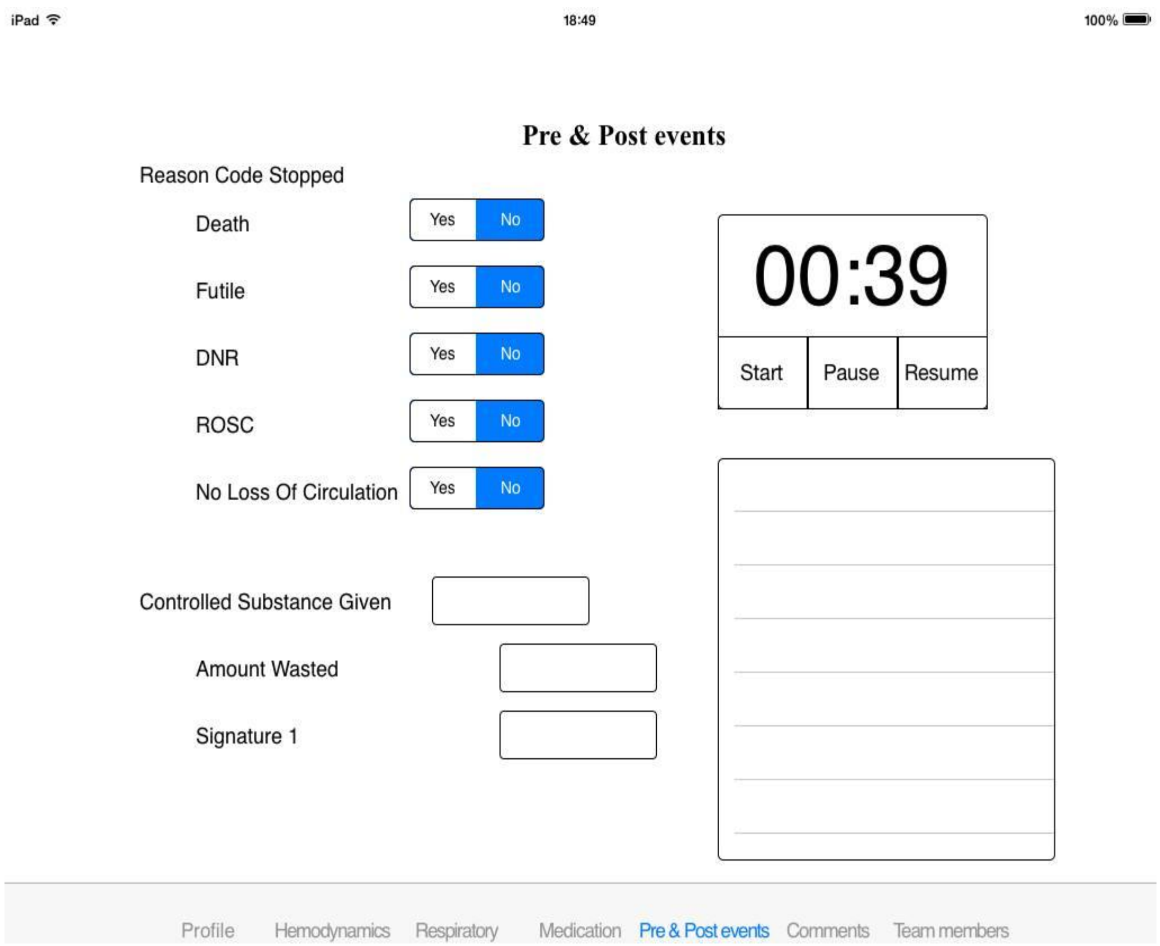


Figure 2d- Pre and Post events tab of electronic application

In this tab given in figure 2d, the goal is to minimize the memory load for the users. In the paper-based documentation, users have to think of the reason why code (resuscitation operation) stopped. However, in the iPad application, as seen at the top of figure 3d, there are already some choices given and the user simply has to select one of them. This meets a key usability feature, which is recognition rather than recall as the users are recognizing rather than recalling the actual reason.

7. Flexibility and efficiency

Currently, there are not multiple ways to find information on the application. For future work, there is plan to have a side cheat menu on the tabs where the users can click and jump to a specific portion of the tab. This will make searching for specific information more efficient. Introducing a search button is also an option that can be added later.

8. Aesthetic and Minimalist Design

As mentioned earlier, the beauty of this application lies in its simplistic design. By keeping simple white background, using blue buttons and black text, this application certainly meets aesthetic and minimalist design, which is a must requirement for a hospital emergency application, as having a lot of flashy design and unnecessary information could confuse the user.

9. Help Option

A key principle proposed by Nielson as part of his heuristic metric is availability of a help button. This was initially lacking in the application but was later added after the heuristic evaluation as shown in figure 2e below. The help button has been circled in red in the figure. This help button opens up a pop window and sends an email to the developer of this application. The users have the option to add a message to the email to explain the task or feature they are having difficulty with.

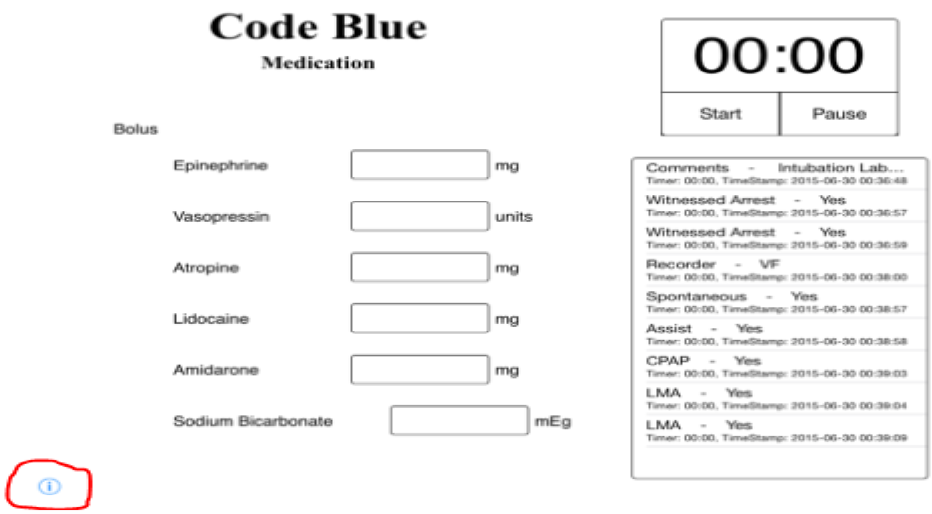


Figure 2e – Help button circled in red

Overall, heuristic evaluation is a useful method that enables the system to be critiqued so that the usability problems could be identified and diagnosed by the experts. Initially, most of the above heuristic features were not being met in the prototype, and after the thorough evaluation by the experts, there were changes made to the design so that these requirements were met in the application as shown above.

3.1.4 Overcoming Paper-based Shortcomings in iPad Application

Now with some insight into the look and feel of the application from the previous section, it can be explained how the design of this application overcomes some of the biggest hurdles that the paper-based documentation faces. These hurdles are collected not only from the Resuscitation Central (12) journal but also have been reported by the clinicians at Mayo Clinic from the author's discussions with them regarding shortcomings in the paper-based form. The hurdles were mentioned earlier in section 3.1.1 but they are recapped along with their solution in Table 2 below.

Main Challenges in paper-based Documentation	**How it is overcome in the designed iPad Application**
Overload of information	The information has been divided across multiple tabs with data preserved across each tab so that a user does not have too much information on a given page at any time.
Illegible handwritten data on CPR record	Since data is either typed or selected from a range of options, it is always legible.
Incomplete data on CPR record	Each tab has certain boxes that need to be filled in ensuring that the final record is complete.
Names of all members not present on CPR record	Once the members are added to the application, it will allow the user to choose members from a dropdown, which makes it easier to select all present members.

Several different clocks used to enter time	A master clock that is built in the application has replaced all the other clocks. Every event is time stamped using this clock whereas the CPR time is also recorded using the in-built clock. This makes documentation much easier as the user does not have to keep account of different stopwatches and the times on them.
Slow Paced	The simplistic and intuitive design enables users to easily move across different tabs and enter information, which enables the user to keep up with the fast paced nature of the resuscitation process.
Inaccurate	All the above solutions contribute to making the iPad application more accurate. Moreover, in paper-based documentation, errors have to be crossed out often not leaving enough space to fill in the correction, as most boxes are really small. In electronic application, mistakes can easily be retyped or undone.

Table 2: How iPad application overcomes challenges faced in paper-based documentation

3.2 Development

This section will focus on the exact steps taken to build the application. It will depict how the development steps are generalizable for other paper to electronic versions. Essentially, the actual development of the iPad application began after the feedback was received from the heuristic evaluation of the prototype. This meant that the development was based on meeting the Nielsen's usability metrics as mentioned above.

Moving on, all the development was done on Xcode using a MacBook, since this is an iOS application. The primary programming language that was used was Objective C, and the data was stored in a temporary online database. Table 3 below lists the further specifications and versioning of this particular development.

Setup	**Version**
Platform	iOS SDK 8.3
Integrated Development Environment (IDE)	xcode Version 6.3.1
System	Mac OS X Version 10.10.3
Primary Programming Language	Objective C

Table 3: Specifications of Development Setup

Additionally, as far as the bulk of the application is concerned, an object-oriented code with well-defined functions was used. The code written was well commented and documented, which means that it can be delegated to other programmers. This would allow them to build new functionality on this application, or make changes to the existing work.

Furthermore, the key design feature that has been used in the development process is reproducibility. The code is written in a structure that allows it to be reused for similar paper to iPad conversions. As far as the paper-based form is concerned, it has been divided into various segments, and each segment has been developed on a specific tab of the application. This method of development will further be cleared in the next section when the application interface is reviewed in relation to the paper version.

3.2.1 Graphical User Interface of iPad Application versus Paper Form

In this section, the graphical user interface (GUI) of the application will be examined in comparison to the paper-based form. This section will focus on each tab of the application one by one, and then each tab will be compared with its corresponding section in the paper to explain how the application was developed. The complete paper-based form can be found in Appendix A located at the end of the paper. However, the relevant parts of the paper-based form that relate to a specific tab of the application have been included below.

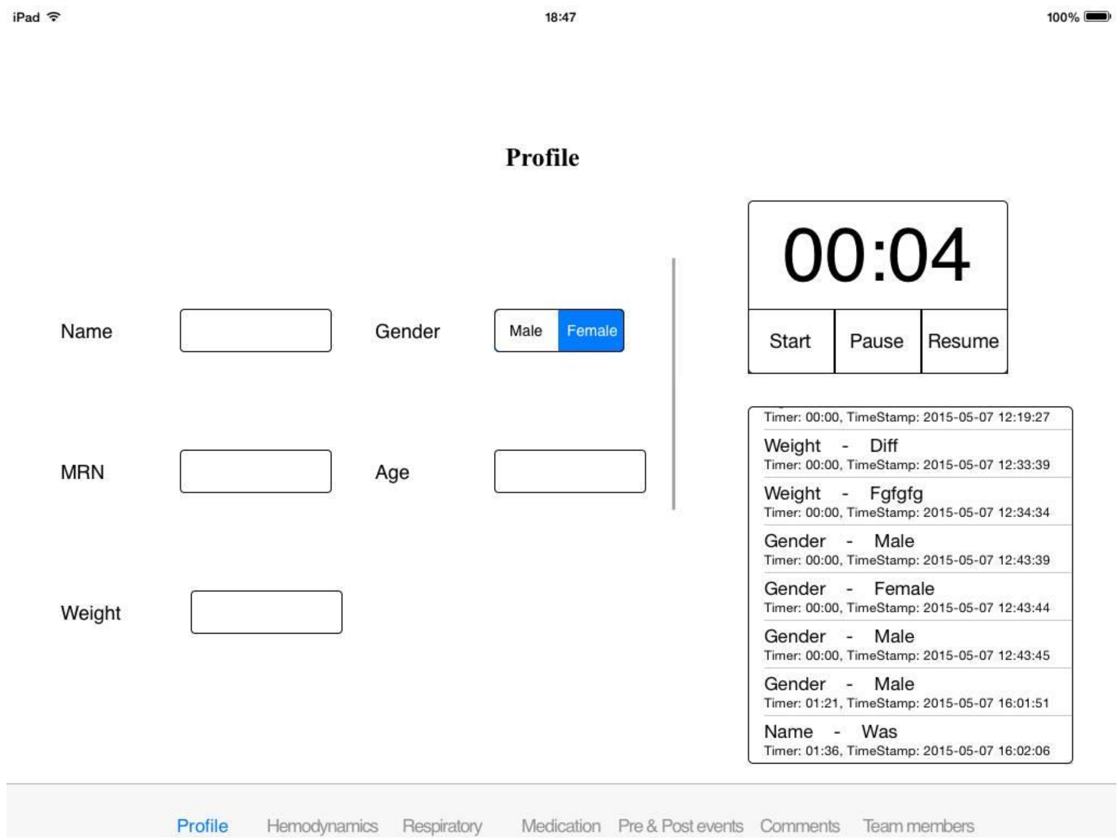


Figure 3a - Profile Tab

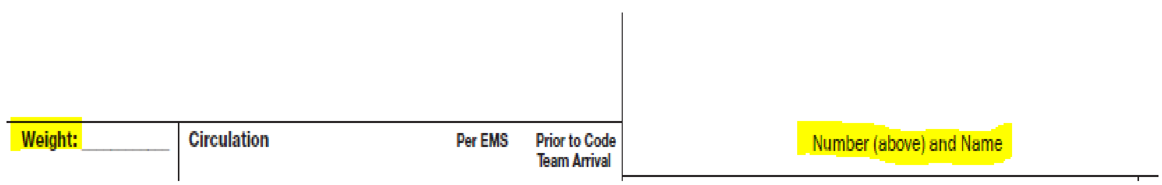


Figure 3b – Paper version

The screenshot at the top of this page (figure 3a) shows the profile tab. This is the first tab out of the seven that are included in the application. This page would assist the nurses in recording their patients' data, such as their name, gender, age, MRN and weight. The corresponding paper-based version is shown in Figure 3b, and the relevant sections have been highlighted in yellow. As far as the paper-based version is concerned, we can see that the patient profile information is added at top right corner of the page.

However, the ‘weight’ section can be found towards the left side of the paper. According to the clinicians working at Mayo Clinic, this usually proves to be confusing for the new staff. For this profile information, the conversion from paper to tablet required introducing text boxes with appropriate labels, so that users could type their information there. The labels used can easily be modified for use in a different application. This allows the tab to be generalizable for other paper to electronic conversions.

Finally, the right side of the application screen from Figure 3a consists of the stopwatch and the activity log that is present in all other tabs of the applications. Their features are discussed below.

Figure 3c – Electronic Clock

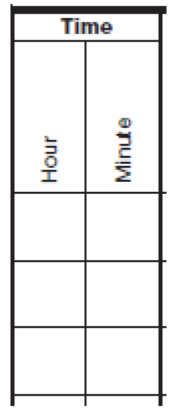


Figure 3d – Paper-based Time Recording

The clock that can be seen in Figure 3c is a stopwatch, which is preserved across all tabs. Programmatically, this is achieved by using a global variable to record time that retains its state across different screens. Furthermore, the clock has a simple interface with "Start", "Pause" and "Resume" Buttons. Including a stopwatch within the application is important, since it can be used to accurately record the time of critical events. For example, the time at which a certain dose of medicine is given or when CPR is started. Similarly, since the interface of the stopwatch has been kept simple, it would help in recording data in a timely manner.

Moving on, figure 3d shows the method of 'time-keeping' for the paper-based version. After examining the time-keeping card, we can see that the space on the card is limited. Moreover, the time has to be manually noted and recorded in addition to keeping a separate clock in hand. This makes the process harder in paper-based version compared to the electronic application.

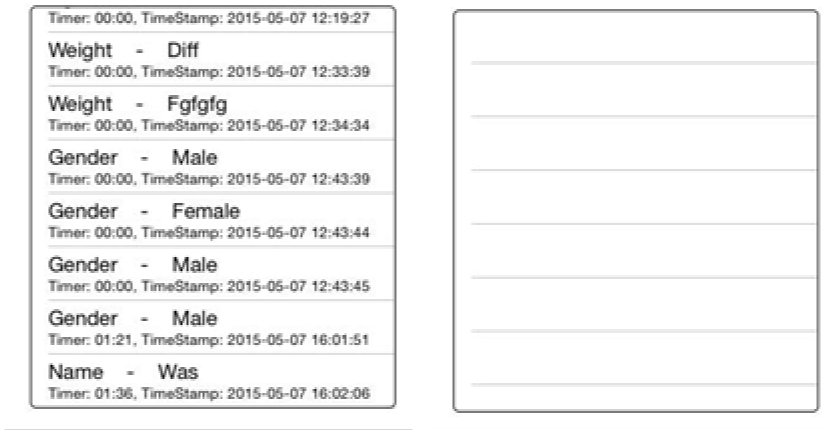
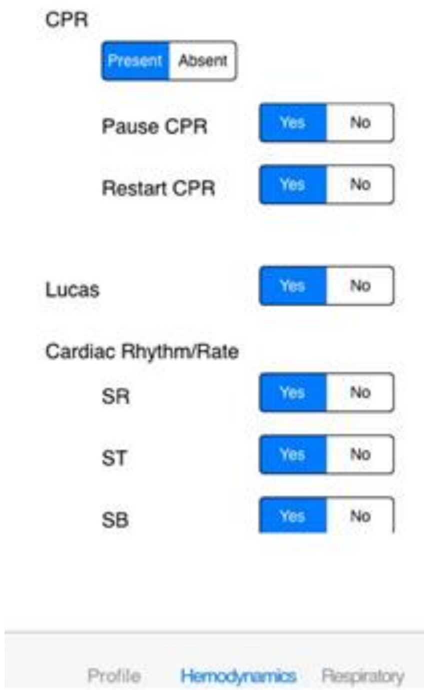


Figure 3e - Activity log (filled and empty)

Figure 3e depicts one completed activity log that has each click recorded with the corresponding time stamp, and another empty activity log to show how it looks at the start of the application. Basically, the activity log (Figure 3e) records all the activities that take place in the system. This log can prove to be highly effective, since each click made on the application is recorded and time-stamped using the stopwatch that was mentioned in the previous section.

Additionally, the activity log can also be saved in a database, which allows the complete log to be emailed to the user as a csv file. On the other hand, the paper-based version has no comparative feature, which means that real-time events cannot be documented automatically for later viewing.

NOTE: Since, the electronic clock and activity log are present on all the tabs of the application, they have been eliminated from some GUI screenshots below due to redundancy.



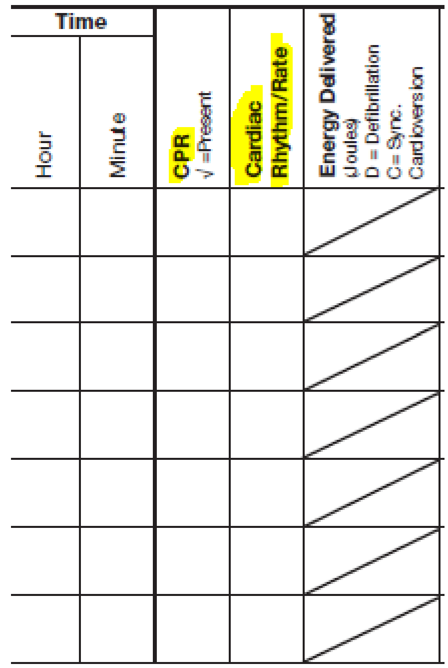
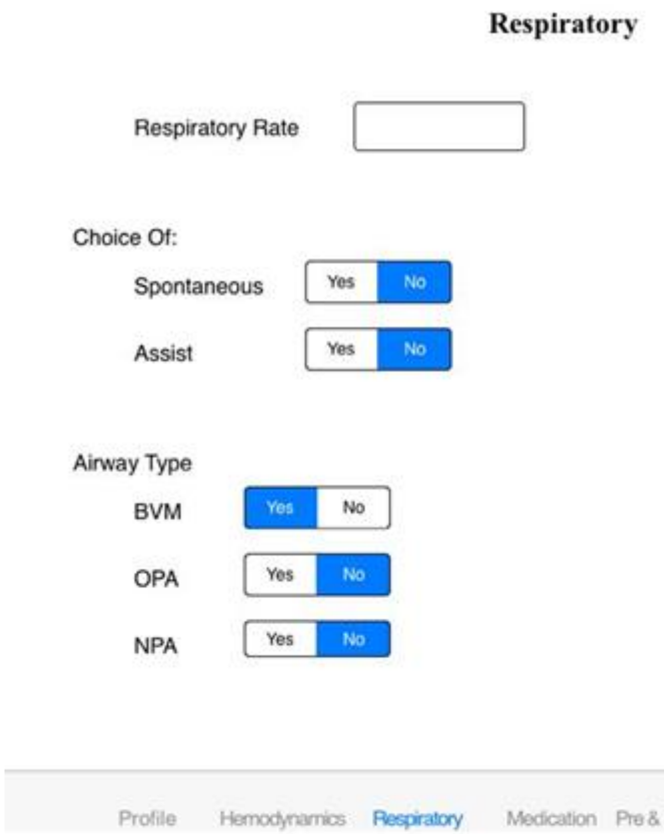


Figure 3f – Hemodynamics tab

Figure 3g - Paper based CPR

Figure 3f shows the hemodynamics tab, which is the most commonly used tab of the application. As far as the paper-based application is concerned, nurses have to keep entering time of CPR using a separate watch. This is reflected in the highlighted portion of figure 3g. On the other hand, the process that takes place through the electronic application is done automatically, using the electronic clock mentioned earlier. The user only has to select “Pause CPR” or “Restart CPR”, and the event, along with the current time is automatically logged into the activity log.

Furthermore, this tab also ensures that only one option for cardiac rhythm is true at one time. From a development perspective, this is achieved by using Boolean variables, which focuses on the idea that only one option can be true at any given time. This can be replicated for other paper-based applications that need similar functionality for multi selections.



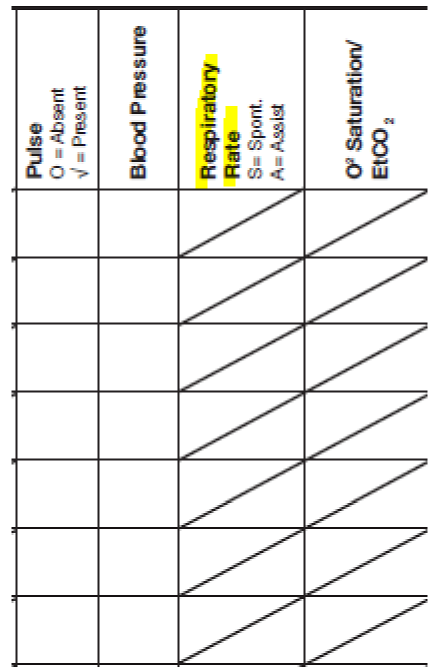


Figure 3h - Respiratory tab

Figure 3i - Paper respiratory rate

Similarly, the respiratory tab (shown in Figure 3h) can be comparable to the Hemodynamics tab, since this also allows only one airway type to be true at a given time. It can be seen from the paper-based version (shown in figure 3i) that the form consists of boxes, which are required to be utilized when choosing one of the two options, namely “spontaneous” and “assist”. However, the paper-based version appears crowded, and consists of confusing diagonal lines, which have been drawn in boxes that are already small in size. The iPad application, on the other hand, effectively counteracts this problem by developing clear “yes/no” bars representing the same two options (As shown in Figure 3h).

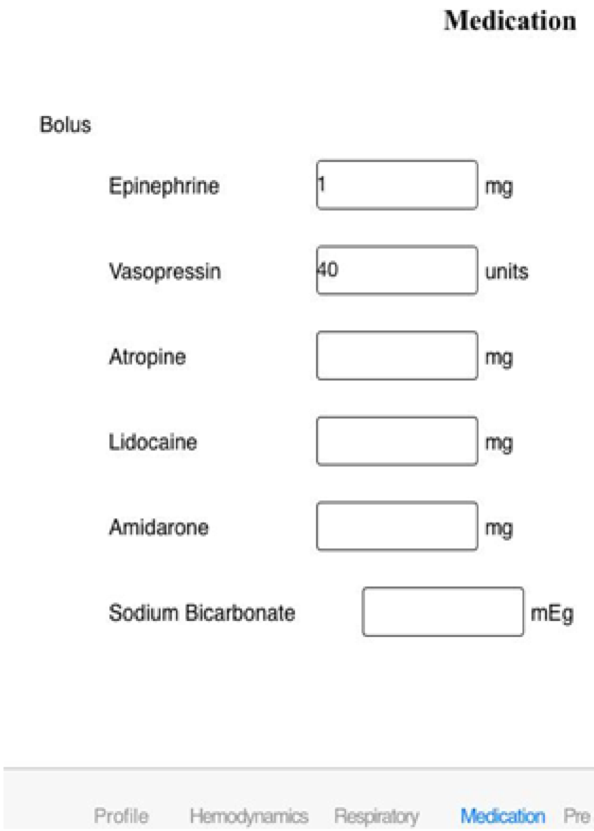


Figure 3j - Medication tab

IV Bolus Drugs						
Epinephrine	Vasopressin	Atropine	Lidocaine	Amiodarone	Sodium Bicarbonate	Calcium

Figure 3k - Paper based drugs

Moving on to the medication tab shown in figure 3j, we can see that it is a simple form, which the nurses can use to enter the quantity of each medicine administered to the patient. According to the discussion held with the staff of Mayo Clinic, the paper document (depicted in figure 3k) often results in recording incorrect units of the drugs being administered.

However, the iPad application has been developed aiming to overcome this problem. This has been achieved by the units that have already been entered into the tab. All these values are logged in the activity log, and can be reset to zero whenever the nurses have to enter a different value. Even though this is a beneficial feature, this aspect of the application cannot be replicated in the paper-based documentation due to limited space as shown in figure 3k.

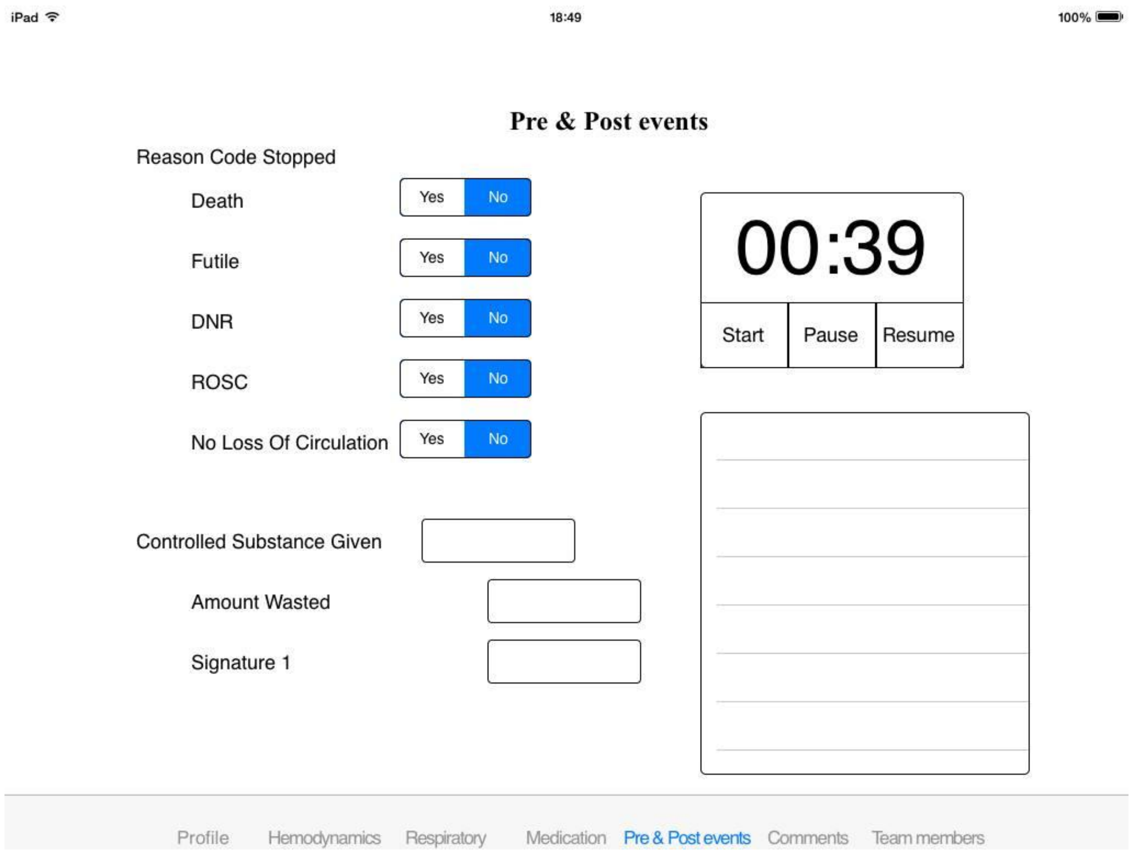
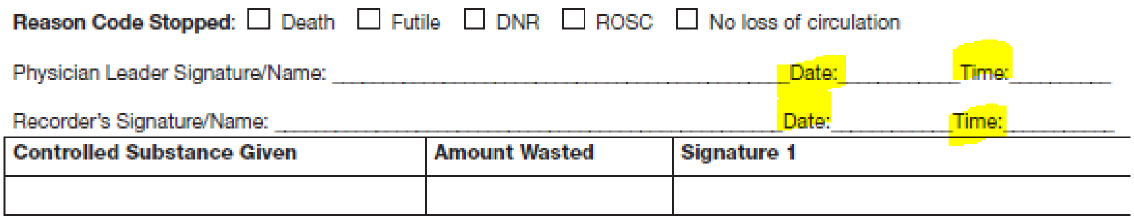


Figure 3l- Pre and Post events

The pre and post events tab (figure 3l) is one of the less critical tabs of the application, since the data is not required to be recorded in real-time. Conversely, figure 3m (displayed below) shows the paper version of this tab. Conversion of this tab was relatively easy, since the checkboxes were simply converted into yes/no toggle boxes, whereas the blank lines found in the paper version were changed to text boxes in the electronic application. This step is also easily generalizable for other paper applications with similar forms.



Reason Code Stopped: ☐ Death ☐ Futile ☐ DNR ☐ ROSC ☐ No loss of circulation

Physician Leader Signature/Name: ____________________ Date: __________ Time: __________

Recorder's Signature/Name: ____________________ Date: __________ Time: __________

Controlled Substance Given	Amount Wasted	Signature 1

Figure 3m – Paper Version of pre and post events

As we can see in figure 3m, the paper version consists of features that are similar to that of the electronic application. However, the date and time have to be manually entered into the form, whereas the electronic version automatically detects the date and time from the master clock. This particular 'master clock' is linked to a global clock that is situated in the time zone of the current location the user is in. This allows the time to be automatically entered into the relevant section of the application. Additionally, this method has been well documented in the code, so that it can easily be adopted for any paper form that requires the date and time to be automatically entered and recorded.

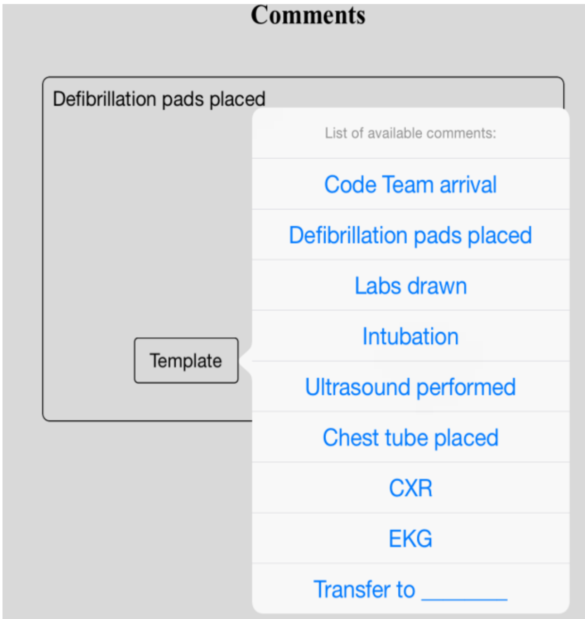


Figure 3n - Comments section electronic

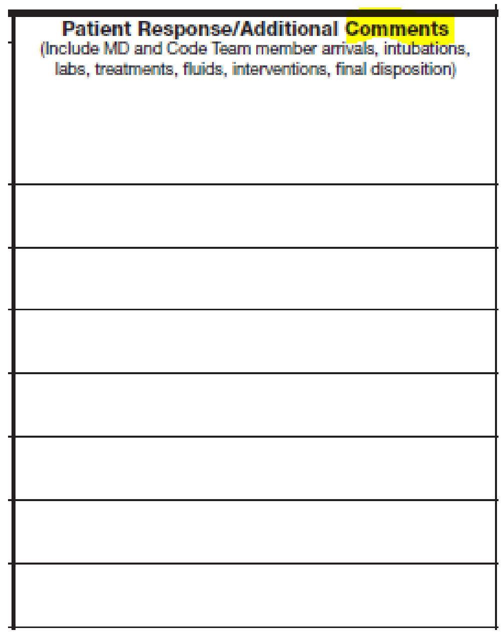


Figure 3p - Comments section Paper

Figures 3n and 3p facilitate us in making comparisons between the comments made on the electronic version, and the ‘comments’ section used in the paper-based version. The former has a ‘template’ button, which allows the users to choose from the pre-filled comments that are already entered in the system. The staff members at Mayo Clinic have selected a list of comments that are frequently used in the code-blue resuscitation procedures.

Additionally, the use of pre-existing comments allows these comments to be entered instantaneously rather than typing them from the beginning. Moreover, once the comments are submitted, they can also be saved in the activity log along with the corresponding timestamps.

On the other hand, the paper-based version only consists of an empty form, which has limited space for each comment. This makes the process relatively tiresome for the users. Furthermore, the development method of storing pre-filled comments using the electronic version can also be easily replicated and expanded for other paper to electronic conversions.

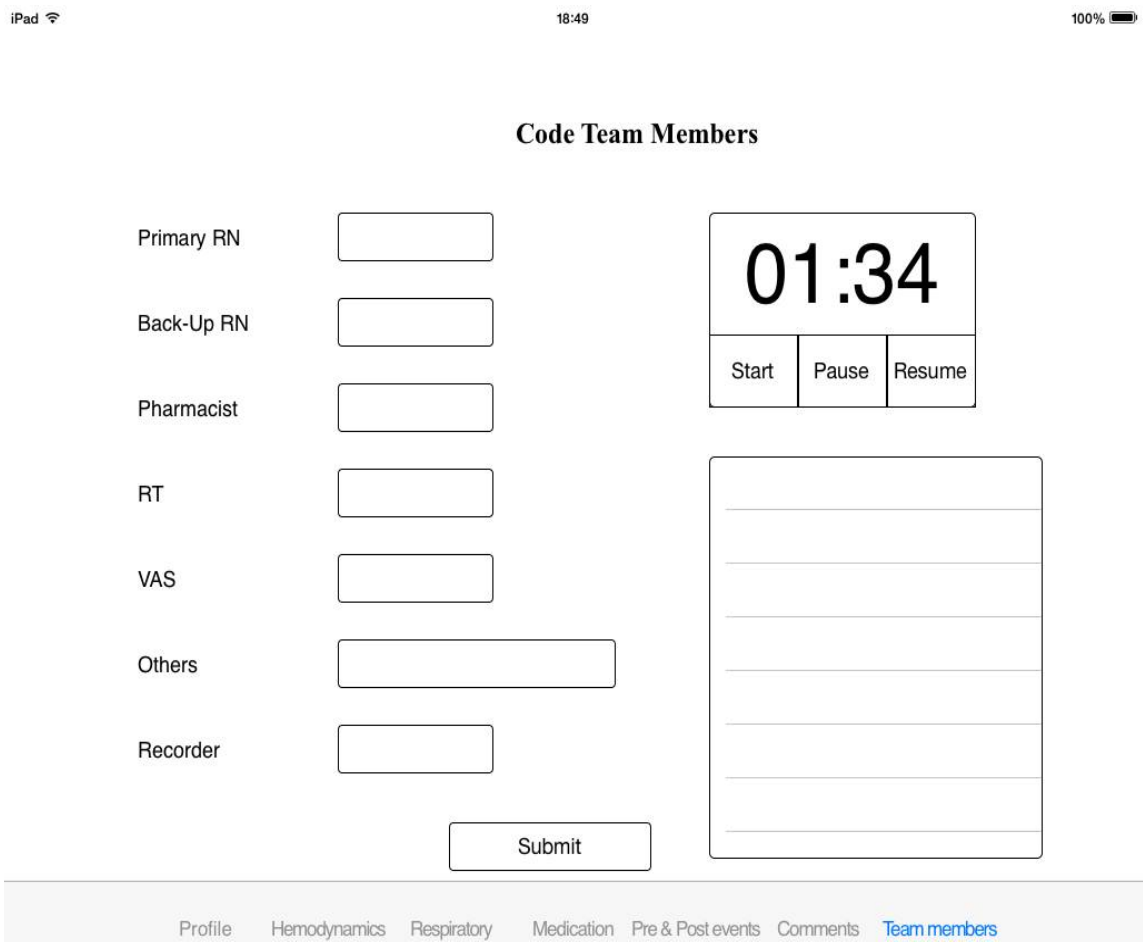
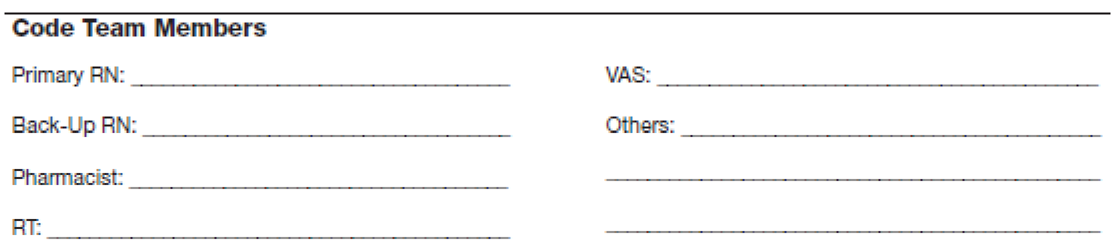


Figure 3q - Team Members Information Tab

This is the final tab (figure 3q) that allows the hospital's team members to enter their personal information. There is a 'submit' button at the bottom of this "Team Members" page. Once it is pressed, it stores all the data in an excel file (csv format), and automatically opens up the 'email' section with the file as an attachment. The data can then be sent to the email address that the user wants to send it to. This data includes all the information added in the activity log, as well as any other fields that have been filled. Furthermore, all this data comprises a timestamp, which records the exact time in seconds, if the user chooses that as an option. A portion of a sample data log is given in Appendix B.

Moving on, this data is saved on the user's device using the Core Data Framework. This framework allows the data to be stored natively with iOS applications. The data is organized into relational entities, which use SQLite in the background. Basically, SQLite in this scope is an abstraction to the developer, since it manages every command on its own from the backend. Hence, this feature of SQLite enables the developer to interact with the native data in a simplified way by providing an easier interface. Additionally, this method of data storage can also be used for every paper to electronic conversion.


Code Team Members

Primary RN: ____________ VAS: ____________

Back-Up RN: ____________ Others: ____________

Pharmacist: ____________ ____________

RT: ____________ ____________

Figure 3r- Paper-Based Team Member Form

As far as Figure 3r is concerned, we can see that it focuses on the paper version of the 'Team Members' tab. This is an uncomplicated form, consisting of blank spaces to enter the information. This form can be accommodated in the electronic version by using text boxes. Moreover, the electronic version would prove to be beneficial, since it would allow the names of the members to be saved in the system. This feature would allow the users to simply select the relevant names rather than typing them on their own.

To conclude this section, the design of the application might appear a little simplistic and basic. It might seem like it lacks the desired glamor and special effects. However, this sort of design is necessary for an application that deals with urgent patient care. The intent is to avoid any distractions on the screen, and hence, the design of the application should be kept as simplistic as possible.

This section aided by screenshots of the application, demonstrated how the design of certain features of the electronic application were generalizable for other paper to electronic versions. The methods mentioned in the conversion have a competitive advantage over the existing online conversion tools in terms of cost, licensing, privacy, flexibility and generalizability. The details have been mentioned in the existing work section of the literature review earlier in this thesis.

CHAPTER 4

USUABILITY TESTING

After the initial development of the application was complete using Nielsen's Metrics as guidelines for the design, the application was evaluated through usability testing. According to the definition from usability.gov official website, "Usability testing refers to evaluating a product or service by testing it with representative users. Typically, during a test, participants will try to complete typical tasks while observers watch, listen and takes notes. The goal is to identify any usability problems, collect qualitative and quantitative data and determine the participant's satisfaction with the product." (14). A similar process was followed for the usability testing of this application. Two rounds of testing were done for this application at Mayo Clinic. The details of these evaluations and their results are given below in this chapter.

4.1 First Iteration of Usability Testing

For the first round of testing, the application was tested using only two subjects. Subject 1 was a nurse whereas the Subject 2 was an emergency care physician. Both the subjects were employed at Mayo Clinic in Phoenix, Arizona. Real life resuscitation process was followed for a simulated (dummy) patient to test the documentation process. Subject 2 gave specific resuscitation orders to subject 1 just as they would have given in an actual resuscitation process. Subject 2 took the documentation using the iPad application rather than using the paper-based resuscitation sheet.

This process was audio recorded by the researcher and later converted to transcripts, which can be found in Appendix C. The main findings from this usability testing revolved around the screen design and color. The detailed findings about some minor features can also be found in the transcript. Moving on, the next page will discuss how the feedback from this usability testing was applied.

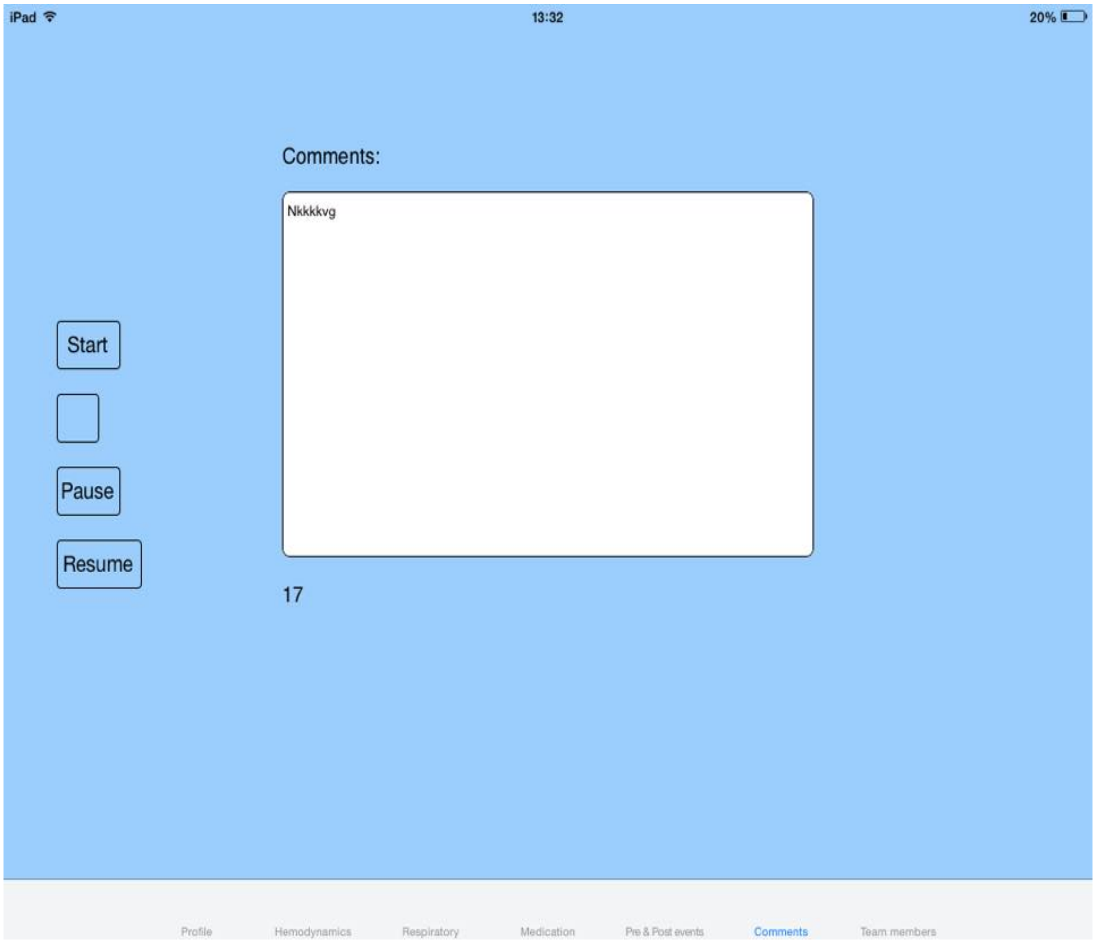


Figure 4a - Comments section that was present for this usability study

Figure 4a shows the comments section as well as how the layout looked like in this iteration. It was discovered through this usability testing that the blue background was not very pleasing on the eye so a white background replaced it. Also, it can be noticed that the stopwatch is not very good looking. The text on the bottom bar is also very small. These changes were addressed using the design principles as shown in the next figure.

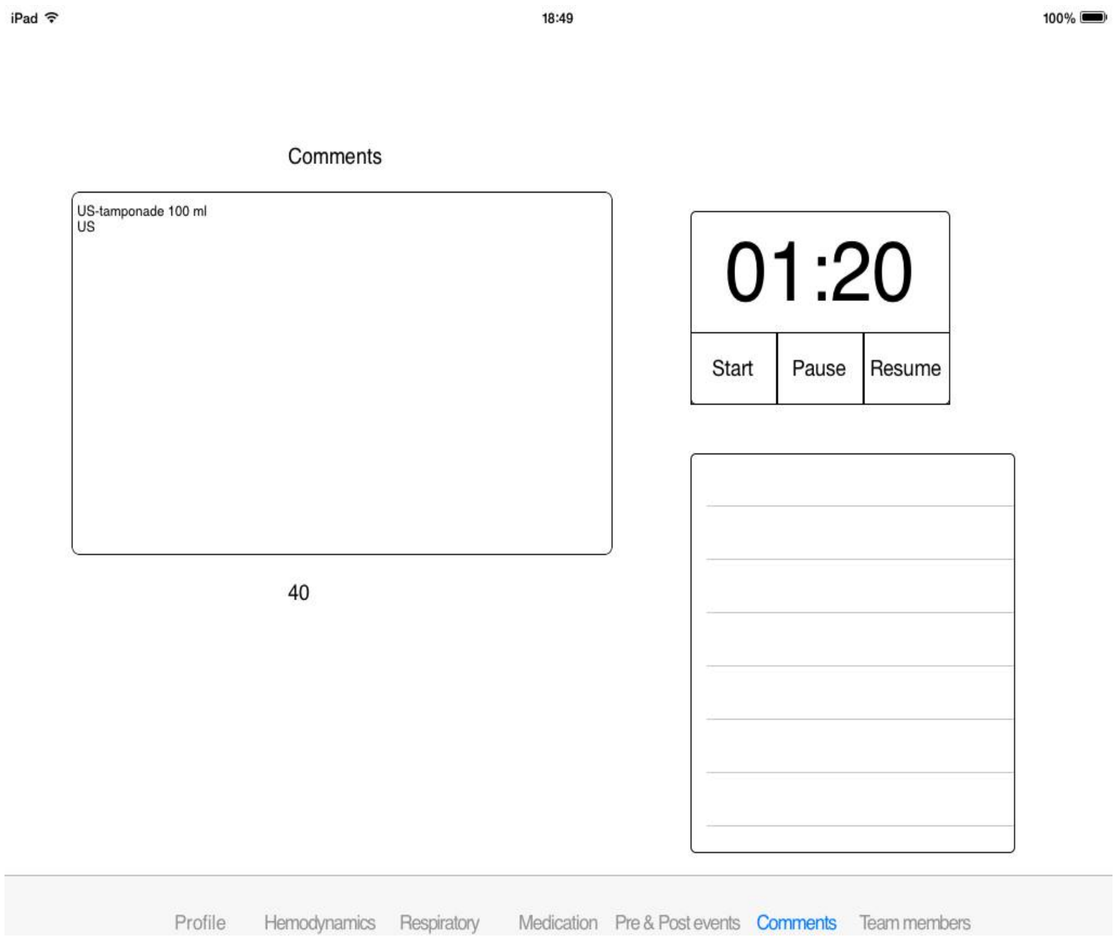


Figure 4b - Comments section after this usability study

Figure 4b shows that the stopwatch is larger than the previous version. Additionally, the 'contrast' is sharper, which makes it more readable. Moreover, according to the researcher's observation, the white background is easier on the eye, and the larger text on the bottom bar makes the application more user-friendly.

As far as the activity log is concerned, this particular feature was discovered during the usability testing, and it was considered to be a remarkably valuable component to add in the application. The addition of the activity log to the previous figure ensures the logging of all critical events, which is a highly beneficial feature for the user. Apart from that, the beauty of the application lies in its simplicity. For this reason, the interface is kept simple and concise, rather than making it flashy, and too fancy.

The test results were very promising, since subject 2 found using the iPad application much easier, as compared to using paper-based version for the documentation. After getting positive feedback from the subjects, and making the required design changes, the next step was to move to a survey with a larger number of end-users.

4.2 Second Iteration of Usability Testing

For the second round of testing, twenty nurses from Mayo Clinic in Phoenix, Arizona tested the iPad application. Nurses were chosen, as they will be the end users of the application, once this application goes in production. Once again, mock resuscitation event commands were simulated so that the survey results are comparable to actual results. Nurses with varying level of technical competency and experience were recruited to keep our data set unbiased. The physician directing the resuscitation was the one giving the instructions, while the nurses used the iPad application to document the variables.

While performing the usability study, the behavior of the users was observed by the researcher to see how the users are interacting with the system. The researcher made notes for each of the twenty subjects. A key change to the application occurred from these observations. It was noted that some users were struggling to type quickly in general comments section as they were more used to hand writing than typing. However, it was also noted that a lot of the comments to be added were the same for a resuscitation process. So based on this observation from the usability study, a dropdown menu was added to the comments tab as seen in figure 4c. This drop down has the most common comments already added so users can just click on them to add them to the comments box. This way recording comments can be faster using the interface as compared to paper, even for users who prefer hand writing to typing.

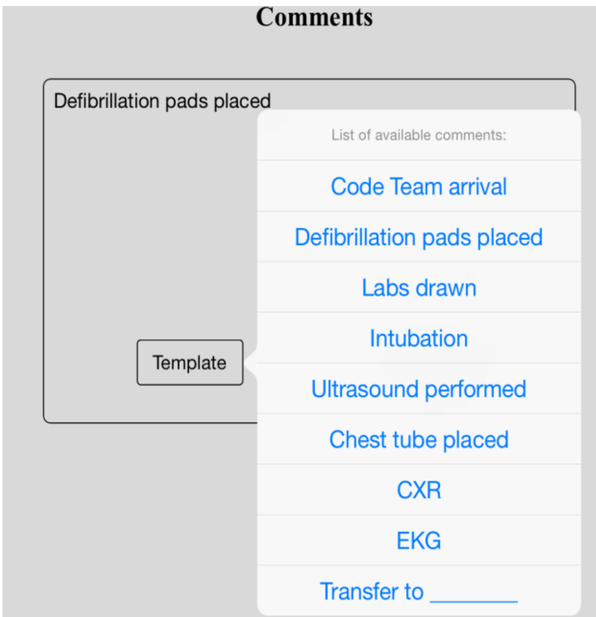


Figure 4c – Comments with drop down

Once the resuscitation process was completed, the nurses were given a survey to record their experience of using the iPad application. The survey, shown in Appendix D, was selected by a member of the thesis committee and finalized by the critical care physician, who directs resuscitation, at Mayo Clinic. It can be seen that survey was kept brief with only ten questions with simple checkmarks to show if users agreed or disagreed. Four follow up questions were asked to see if previous experience using electronic health application affected the results. The results are discussed in the following section.

4.3 Results

The results from the survey are given in Appendix E below. It shows the percentage of users who selected a given option. The total number of users was twenty so 5 percent implies one tester. All the testers were nurses who will also be the end users of the application after it is released.

For the first two questions in the survey, all the testers agreed that the materials presented in iPad were intuitive and the messages and prompts displayed by the tool were understandable. Only 1 out of 20 nurses disagreed in the third question as she felt that it is not easy to move between screens. Interestingly, she was the only who had never used a tablet before which might have led to her judgement. 3 (15 Percent) of the testers felt that tasks took longer to execute using iPad than expected. When probed further, these subjects had very high expectations, which are not realistic for an application that has to store data dynamically. They were expecting all features on one screen, which is not possible for this application as there is loads of content and limited screen size. Question 5 from the survey had a 100% positive response as no user reported the tool crashing.

For questions 6 and 7, nineteen out of twenty users felt that iPad was easier to navigate and also to document critical events compared to the paper-based version. This overwhelmingly positive response from the testers augurs well for the future of the application, as these two features are critical part of the resuscitation process. The one person who disagreed to these questions was the same tester who had never used a tablet before. This brings out an interesting development that some basic tablet or smartphone experience is needed to make best use of the application. Alternatively, some form of training on using the application and tablet can be provided for users with no prior experience.

However, not even a single user disagreed for question 8 which stated, “It was easy to look at the timestamps of different interventions post hoc/post data entry”. This is also an essential part of the application. Users do not have to manage different clocks, as the clock built into the application is handling everything. Question 9 was a point of concern as 8 (40 Percent) of the testers felt that there are too many data points on one screen. This screen was identified as the hemodynamics tab and a cheat menu was proposed which will further divide that screen into sub sections. This has been included in future work as it is not a critical issue for the current iteration.

The final question asked whether the users preferred the iPad application over paper-based for the documentation. 15 (75 Percent) of the users agreed whereas 3 (15 Percent) remained neutral. Two users disagreed, as they still preferred the paper-based documentation. These results show that an overwhelming majority of the participating nurses preferred the electronic version. To make this result more meaningful, it should be noted that the testers have been using the paper-based version for years whereas it was the first time they were using the developed application. Despite this, a good majority preferred the iPad application, showing a great future for the application.

4.4 Clickstream Analysis

To provide quantitative depth to the results as well as providing additonal measures from a usability standpoint, clickstream analysis was performed. Clickstream analysis is the process of collecting, analyzing, and reporting aggregate data about which pages users visit in what order - which are the result of the succession of mouse clicks each user makes. (17)

As part of their usability testing, the actions that the twenty nurses performed on the iOS application were logged into the database. Once the nurses completed their survey, they emailed the logs to the developer (who is also the author of this thesis). The logs contain every click that the nurses performed with time stamps. Using this data, the screen flow of the application can be emulated, which provides the ordering of clicks that the users performed. This data mainly provides a representation of the user's navigation through the application, and also demonstrates their path before they abandoned a particular task.

Furthermore, after careful consultation with the emergency care physician at Mayo Clinic, the researcher identified certain tasks as 'critical' for the success of the application. These particular 'critical' tasks have been listed in table 4 below. The completion rate, also given in the table, shows the percentage of nurses who were able to complete the task successfully. Using this data, the researcher came up with the following click-stream analysis presented in table 4 below.

Task	**Completion Rate (%)**
Logging Patient Information	100%
CPR Start and Pause clock automatically	95%
Logging Respiratory Rates and Airway Types	95%
Logging Medication Dosages	100%
Logging Pre and Post Resuscitation Events	100%
Entering Comments	90%
Submitting Report and Activity Log	70%

Table 4: Clickstream Analysis

The results show a high percentage of completion rate, which indicates that most of the users were able to complete the task assigned to them. Moreover, a 100% completion rate also implies that all twenty nurses were able to complete the task without navingating to the wrong screen, or clicking the wrong buttons. Additionally, the only task that has a completion rate of less than 90% is the submission of final report and the activity log. The reason for the lower completion rate for this task is that users usually navigate to the earlier tabs before they submit the report. The users want to be sure that all the required information has been filled out. Therefore, they navigate away from the 'submit' screen, which in turn leads to a lower completeion rate.

Overall, the clickstream analysis provides quantative depth to the earlier usability testing by depicting that most of the critical tasks were completed by majority of users with a high success rate.

CHAPTER 5

DISCUSSION AND FUTURE WORK

The iPad application developed for this thesis can be expanded to include new features and modify the existing ones, depending on the needs of the users. All the source code has been passed on to another developer at Mayo Clinic, who is integrating the application with Mayo Clinic's database. Additionally, the developer is using the documentation provided in this thesis to incorporate additional features in the application. Furthermore, the developer will eventually push the application to production, and also release it onto the apple store.

This application was developed specifically for use at Mayo Clinic. However, this application can be used in hospitals across the world to document the resuscitation process. Another benefit of this application is that it covers processes that are not code-blue as well, which gives it greater generalizability for large-scale use. Moreover, at present, there is no generalizable code-blue application that is in large-scale use.

The methods described in this thesis can be used to develop more electronic applications from paper-based documentations. The developers would have to download the source code and run it from their local machine to have the code-blue application running on their computers. After this is done, they can view the screen design, along with the documentation found in this thesis. Additionally, once they understand the rationale behind the conversion steps, the developers can simply copy and paste the various segments of the code to fit their needs. For instance, they can swap radio buttons with text boxes. The labels or written text used in the application can simply be overwritten to represent the new application.

Furthermore, this process could have potentially massive implications for the future as there are numerous paper-based documentations existing in the medical field at present and converting these documents into electric form could prove to be vastly beneficial for the users. The methods discovered in this thesis can potentially be used for most of these conversions. Similarly, a working activity log, and a ‘master’ stopwatch (to record the timestamps) are already present in the code. These features will help developers in saving significant time, since they will find these features already working in the existing tabs. Moreover, these features also hold special importance, since they are needed for most of the medical applications in hospitals around the world.

In addition to that, these overall methods can be applied to the non-medical world as well. Basically, any paper-based form that needs to be converted to an electronic form can benefit from this thesis.

CHAPTER 6

CONCLUSIONS

This thesis addresses the problems with data capture, as it exists during Code Blue events at the Mayo Clinic. The researcher developed an iOS application primarily designed for iPads that hopefully will improve transcription of resuscitation variables for patients who undergo a Code Blue event. This application aims to replace the conventional, paper-based resuscitation transcripts that nurses currently use to an electronic form. Based on a literature review, a high quality electronic application was noted to be preferable to a paper-based version. Usability testing of the electronic resuscitation documentation application done at Mayo Clinic corroborated that physicians and nurses strongly prefer the electronic version of Code Blue resuscitation sheet.

The iPad application developed as part of this research meets the basic standards required as it was tested based on the usability principles covered in a heuristic evaluation. Moreover, a number of healthcare providers at the Mayo Clinic indicated a strong desire to use this application, and support the future work that would involve synchronizing the application based-data with Mayo Clinic's patient database (electronic medical record) as well as adding more functionality to the application.

To conclude, this research, lead to the development of an iPad-based application that is expected to meet the needs of the frontline healthcare providers and has shown that this electronic form of code-blue documentation is preferable to a paper-based form. This could lead to improved resuscitation data transcription, and enable clinicians to address deficiencies in quality of care. Further field-testing in the clinical environment is warranted in future studies, to update the next generation of the application.

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APPENDIX A

MAYO CLINIC PAPER RESUSCITATION DOCUMENT

MAYO CLINIC

Cardiopulmonary Resuscitation Flowsheet

Number (above) and Name

Date: ______________

Witnessed Arrest? ☐ Yes ☐ No

Estimated time of Arrest: ______

Site of Arrest: ______________

Patient Found By: ______________

Time of EMS Handoff: __________

Monitoring at onset **Weight:** __________

☐ Arterial Line ☐ NIBP

Telemetry? ☐ Yes ☐ No

Pulse Oximetry? ☐ Yes ☐ No

Initial Assessment

Conscious? ☐ Yes ☐ No

Breathing? ☐ Yes ☐ No

If Yes: ☐ Spontaneous ☐ Agonal ☐ Assisted

Circulation	**Per EMS**	**Prior to Code Team Arrival**
Time Chest Compressions Started: ________	☐	☐
Epinephrine/Vasopressin Dose(s): ________	☐	☐
Defibrillator Shock: ________________	☐	☐

Significant Events Prior to Arrest:

Time									IV Bolus Drugs								IVF/Drips				Patient Response/Additional Comments (Include MD and Code Team member arrivals, intubations, labs, treatments, fluids, interventions, final disposition)
Hour	Minute	**CPR** √ =Present	**Cardiac Rhythm/Rate**	**Energy Delivered** (Joules) D = Defibrillation C= Sync. Cardioversion	**Pulse** O = Absent √ = Present	**Blood Pressure**	**Respiratory Rate** S= Spont. A= Assist	**O² Saturation/ EtCO₂**	Epinephrine	Vasopressin	Atropine	Lidocaine	Amiodarone	Sodium Bicarbonate	Calcium	(Additional Bolus or Drip)________	Levophed	Epinephrine	Vasopressin	Amiodarone	

Initial Vascular Access: ______________________________

ET Tube Placement Confirmed by: ☐ Colorimetric ☐ Capnography ☐ Capnometry **Temp** ______

Reason Code Stopped: ☐ Death ☐ Futile ☐ DNR ☐ ROSC ☐ No loss of circulation

Physician Leader Signature/Name: ______________________ Date: ________ Time: ________

Recorder's Signature/Name: ______________________ Date: ________ Time: ________

Code Team Members

Primary RN: ______________________

Back-Up RN: ______________________

Pharmacist: ______________________

RT: ______________________

VAS: ______________________

Others: ______________________

____

____

Controlled Substance Given	**Amount Wasted**	**Signature 1**	**Signature 2**

Page ________ of ________

MCS6790rev0515

Place Origional in Chart   Copy to Pharmacy

APPENDIX B

SAMPLE DATA LOG FROM USABILITY TESTING

1	
2	Time Taken In Seconds
3	39
4	
5	Profile
6	Name : Wasif
7	Age : 22
8	MRN : 14366
9	Gender : Male
10	Weight22
11	
12	Hemodynamics
13	CPR
14	CPR Status : Yes
15	Pause CPR : No
16	Restart CPR : No
17	Cardiac Rhythm/Rate
18	SR : No
19	ST : No
20	SB : No
21	A-Flutter : No
22	A-Fib : No
23	SVT : No
24	VT : No
25	VF : No
26	PEA : No
27	Asystole : No
28	Other : No
29	Energy Delivered :
30	Choice Of
31	Sync. Cardioverison : No
32	Defibrillation : No
33	Pulse : No

Data log of dummy patient resusciation proces

APPENDIX C

TRANSCRIPTS FROM USABILITY TESTING

a, Coded transcripts

Given below are the transcripts from the two rounds of usability testing done for this application.

The process was begin by Dr Ayan Sen taking command and directing orders to the Nurse named Amanda. For this testing, there was not a real patient, but the process followed by Dr Sen was just the way the resuscitation would be done with an actual patient.

Dr Ayan Sen: " arrive on scene - start compressions. - Continue compressions - get somebody to bag the patient - continue bagging at 12 per minute - check rhythm - lets do vf as rhythm , lets continue compressions. we can give 1 mg of cont after 2 mins of cpr, we will check rhythm. Meantime, keep pushing IV, go to central line. and give a dose of calcium , a dose of bicarbonate, 1 mg. give epihnhidrble. 50 meq defibrillation.

Nurse Amanda: "doses given and recorded"

Dr Ayan Sen: " continue compression. history of cardiac surgery, chest tubes taken out. ultrasound in, check if we need to put cardio tube.

Nurse Amanda: "2 mins are up for the CPR"

Dr Ayan Sen: "lets check rhythm. stop cpr now , check rhythm at this time. rhythm is at normal. continue compressions, chest compressions. good chest wall movements, ensure that patient has one fluid in. NO hype dynamin, put needle,input preciado needle,put blood, blood has drained. 100 mg of blood. when another 2 mins are up, we will figure out what the rhythm is. at this time, patient started to move around. stop compressions again, and ah , check pulse, it is going into sinus rhythm, lets do blood pressure again. lets stop the code now."

Findings from this transcript

By observing Amanda interact with the application and by Amanda thinking out loud as she filled out the application, we came up with the following findings from this usability testing.

Amanda: "the typing issue, when you are typing at bottom of page, the keypad comes on top of the text field,
for quality issue, have running activity log so we need that
when we are choosing intervention, we have a range of cardiac rhythms, it gets a little confusing, so if we set one, we should have a system that all others become no. just because now , it seems we have all 4 rhythms running at one time.
only one can be active at one time.
if comment section could clear after every comment.
have post button which logs current post.
and then change wording to cpr code team arrival from cpr. we want to know if they have already started compression.
we shouldn't be pausing this
medications are fine
medications should also default to zero once we enter some value
controlled substance given is a box
amount wasted is a box
signatures needs to be boxes
go back to airway
basically everything has to be reset after clicking.

under ETT , we need yes no and box for size on the side.
hemodynamics, lucas and have yes or no with it
this should all be recorded on the timeline.
comments section is good. but we can have common lines for comments. I can give a test that you can use. And you can feed into it. and if we could use a log that post each comment.
check how the results are coming out. lets enter email address.
And we are getting them."

These findings were very useful as there is no way I could have figured out these usability issues on my own. For these fixes, it was essential to get the testing done by the actual user. After the feedback, I made the changes and two weeks later went to Mayo clinic for another usability testing with Dr Sen and Amanda.

Dr Ayan Sen: "Lets start. You have a patient who is having chest compressions, continue chest compressions get one dose of ephiniirdine and continue 2 mins of cpr.

Bag and mask circulation. get one dose of Mg, check vf, continue cpr. shock the patient. give another dose of ephinhpire, and another dose of calcium. and get some iv bolus going. CO2 is about 14. continue cpr , pause cpr , check for pulse,

give 500 of albumin, give another round of ephinire and give oppression as well 40 units. check the 4 hs. There is no tension in the ultra sound. inject needle , 100 blood went out. 2 mins of cpr are done, check cpr again. blood pressure is 87 / 46."

Findings from this transcript

Nurse Amanda: "so I notice, there are all checked yes in airways. they should all default to no. it was a lot easy than last time. clear the value, comments section with the dropdown. all these things default to no, even the lucas. and then on airway type,

ETT should be another yes no and with a blank space. design is pretty decent, it is functional. a lot to scroll down, can we have cheat menu on the side which makes it easy to scroll up and down.

lucas should be near cpr.
have text fields next to boxes. yes no except for vfib and asystole.

Have other option in cardic rhtyms. scroll down is different. putting in the data was easier than paper..
put a heading on there like code blue. if clock can be moved a little upwards."

Once again, the finding from the usability testing was extremely useful and helpful. Both the doctor and the nurse noticed that even with some minor fixes required, the process of entering data using an iPad was much easier than using paper based documentation.

APPENDIX D

QUALITATIVE SURVEY

Survey questions

ID	Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	The materials presented in iPad form was intuitive					
2	I understand the messages and prompts displayed by the tool					
3	It's easy to move back and forth between screens					
4	Tasks took longer to execute using iPad than expected					
5	The tool crashed or throws up error messages when attempting to use it					
6	Compared to paper, the iPad was easier to navigate					
7	Compared to paper, critical events were easier to document using iPad					
8	It was easy to look at the timestamps of different interventions posthoc/post data entry					
9	There are too many data points on one screen					
10	Overall, I prefer using this tool compared to paper based documentation					

How long have you been working at Mayo?
Have you used an electronic health application before on a tablet?
If yes, on a scale of 1(beginner) to 5 (expert), what is your experience level?

On a scale of 1(beginner) to 5 (expert), what is your competency level of using an iPad?

Usability Study Survey

APPENDIX E

SURVEY RESULTS

ID	Question	Strongly Agree #(Percent)	Agree #(Percent)	Neutral #(Percent)	Disagree #(Percent)	Strongly Disagree #(Percent)
1	The materials presented in iPad form was intuitive	5 (25%)	15 (75%)	0 (0%)	0 (0%)	0 (0%)
2	I understand the messages and prompts displayed by the tool	7 (35%)	13 (65%)	0 (0%)	0 (0%)	0 (0%)
3	It's easy to move back and forth between screens	3 (15%)	14 (70%)	2 (10%)	1 (5%)	0 (0%)
4	Tasks took longer to execute using iPad than expected	1 (5%)	2 (10%)	7 (35%)	9 (45%)	1 (5%)
5	The tool crashed or throws up error messages when attempting to use it	0 (0%)	0 (0%)	0 (0%)	7 (35%)	13 (65%)
6	Compared to paper, the iPad was easier to navigate	5 (25%)	6 (30%)	8 (40%)	1 (5%)	0 (0%)
7	Compared to paper, critical events were easier to document using iPad	2 (10%)	11 (55%)	6 (30%)	1 (5%)	0 (0%)
8	It was easy to look at the timestamps of different interventions post hoc/post data entry	7 (35%)	10 (50%)	3 (15%)	0 (0%)	0 (0%)

9	There are too many data points on one screen	1 (5%)	7 (35%)	2 (10%)	9 (45%)	1 (5%)
10	Overall, I prefer using this tool compared to paper based documentation	7 (35%)	8 (40%)	3 (15%)	2 (10%)	0 (0%)

Results from a survey on usability of the developed application