Evaluation of the Zynex Cardiac Monitor, Model 1500 (CM-1500) in Healthy Adult Subjects.

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Abstract

Background. Internal Hemorrhagic events, such as internal bleeding, blood or fluid loss, are not only challenging to detect but can lead to severe complications compromising patient outcomes during surgical procedures, treatment of traumatic injury, and post-op recovery. Depending on the type of surgery, patient hemorrhaging can lead to clinical complications ranging from mild anemia to fatal hemorrhagic shock. Currently, the standard of care for monitoring hemorrhagic events is by visually estimating simultaneous or sudden changes in the patient's vital signs. More advanced and accurate methods are needed to ensure optimal fluid management and quality care for patients at risk for Hemorrhagic events.

Purpose. The purpose of this study was to evaluate the effectiveness of an innovative, non-invasive monitoring device, the Zynex® Cardiac Monitor Model 1500 ("CM-1500") in detecting fluid volume changes as well as absence of fluid volume changes among healthy adult subjects.

Methods. During this controlled, single-center study, 12 healthy adult subjects underwent a manual blood loss of 500mL. Control verification testing was also completed with 16 healthy adult "control" subjects and data was used comparatively to our 12 feasibility subjects. All subjects laid in a supine position for 30 minutes while connected to the non-invasive CM-1500 while data was electronically recorded.

Results. Eleven of the 12 subjects completed the 500mL blood draw. The results showed the average Relative Index (RI) value decreased from the baseline (100) by 7.8 over the course of time that 500 mL of blood was manually withdrawn. Comparatively, the control subjects (no blood loss event) maintained a near-constant Relative Index (RI) of the baseline 100.

Conclusion. The outcomes demonstrate that decreases in the CM-1500's Relative Index (RI) is directly correlated with a decrease in bodily fluid volume, in this case, a manual blood loss of 500mL, lending support to the hypothesis that non-invasive, accurate real-time measurement of blood loss is achievable with the CM-1500. The control study also demonstrates the accuracy of the CM-1500 when no changes in fluid volume (blood or other fluid) occurs while being monitored, as subject's physiological parameters were maintained (RI baseline values avg = 99.1). Further evaluation is recommended to assess the clinical utility of the CM-1500 among patients at risk for hemorrhagic events.

Introduction

Hemorrhagic events, such as internal bleeding, blood or fluid loss, are not only challenging to detect but can lead to severe complications or compromised patient outcomes during surgical procedures and during post-op recovery. Depending on the type of surgery, patient hemorrhaging can lead to clinical complications ranging from mild anemia to fatal hemorrhagic shock which is the leading cause of death among trauma patients[1]. Numerous studies reveal that post-operative hemorrhagic events are also quite frequent, occurring in as many as 13 to 19% of patients following various type of surgeries (i.e., major pancreatic resections, transoral robotic surgery (TORS) for oropharyngeal squamous cell carcinoma, and living-donor transplants) [2,3,4].

Identifying and monitoring indicators of hemorrhagic events in real-time is needed to initiate effective interventions that mitigate blood or fluid loss and stabilize at-risk patients. Various impractical monitoring solutions have been explored, such as gravimetric measurements (e.g., weighing soaked laparotomy sponges intraoperative), but these unusual methods can be highly sensitive to error[5,6,7]. Currently, the standard of care for monitoring hemorrhagic events, such as blood or fluid loss, is by visually estimating simultaneous or ongoing changes in the patient's vital signs such as heart rate, body temperature or noticeable signs of uncontrolled bleeding[8]. When visual estimates of blood loss are used, clinicians tend to underestimate blood loss during high blood loss volumes and overestimate during low blood loss volumes, thus leading clinicians to under- or over- transfuse to mitigate the event[5]. Simulation training as well as didactic training purportedly improve providers' blood loss

estimation skills, however retention lessens with time and simulation training is not always readily available.[6]

Relying on visual assessment methods can lead to inaccuracy, delayed intervention decisions, or may result in unnecessary invasive techniques to confirm hemorrhaging if the clinical signs are unclear. Studies[2,3,4] substantiate that there is no real 'standard' method of monitoring, as a variety of different postoperative procedures are used by clinicians to identify fluid changes. Innovative and more precise methods are needed to ensure optimal fluid management and quality care for at-risk patients.

The Zynex® Cardiac Monitor Model 1500 (CM-1500) is an innovative, non-invasive monitoring device, designed to detect and monitor fluid volume changes in pre-, intra- and post-operative environments. The volume changes are calculated using real-time data on multiple key physiological parameters, that have been shown to be associated with fluid status and blood loss[10-16]. Individual parameters, which often remain stable despite fluid loss, do not provide sufficient information for early intervention and prevention of negative patient outcomes[1,9], therefore the CM-1500's design combines information from multiple parameters. Using a complex algorithm that considers artifacts, such as patient movement, and weights each parameter by its hypothesized relative importance, the CM-1500 establishes an initial fluid volume baseline, called the Relative Index (RI), of 100, displayed on the monitor. The RI is a clear indicator of the patient's blood or fluid volume status at any given time and will begin to fall below 100 as fluid loss is detected.

Purpose

This purpose of this study was to perform a preliminary evaluation of the effectiveness of a novel, non-invasive monitoring device, the Zynex® CM-1500. The CM-1500, is an FDA cleared, non-invasive fluid monitoring device that simultaneously monitors five (5) parameters in real time. This device is designed to detect slight changes in fluid volume, signaling fluid loss (i.e., blood loss) through continuous monitoring of several cardiac-related parameters including Bioelectrical Impedance, Heart Rate, ECG Amplitude, PPG Amplitude, and Skin Temperature. Based on these measurements, the CM-1500 establishes an individual's baseline Relative Index (RI) (Baseline RI=100), displayed as a single value on the monitor, then allows real-time monitoring of RI changes using a built-in algorithmic processor to alert clinical staff of changes that are indicative of a hemorrhagic event. The RI is a unique functionality of the Zynex CM-1500. The observed changes in these parameters and thus that individual's fluid volume is represented by change in the Relative Index (RI). A RI value less than 100 denotes that at least one parameter has changed in the direction indicative that blood or fluid loss is occurring.

Methods

This feasibility study evaluated twelve (12) healthy adult subjects undergoing a manual blood loss of 500mL. This IRB-approved study was a prospective, single-arm, non-randomized, non-controlled, single-center study. The primary objective was to verify that the event of fluid volume change can be identified by the CM-1500, during a manual blood loss event. Baseline data for each subject was recorded by the CM-1500 while the subject laid in a supine position.

500mL of blood was drawn manually by a trained phlebotomist from each subject. The subject was observed for 30 minutes post-blood draw, all while still being connected to the CM-1500. When the blood draw event began, the trial operator pressed the “mark event” button on the CM-1500, which created a timestamp to be used as a reference during data analysis; utilizing timestamps allowed data sets to be normalized. Data was continuously recorded electronically, and additional clinic notes were recorded for protocol deviations and adverse events.

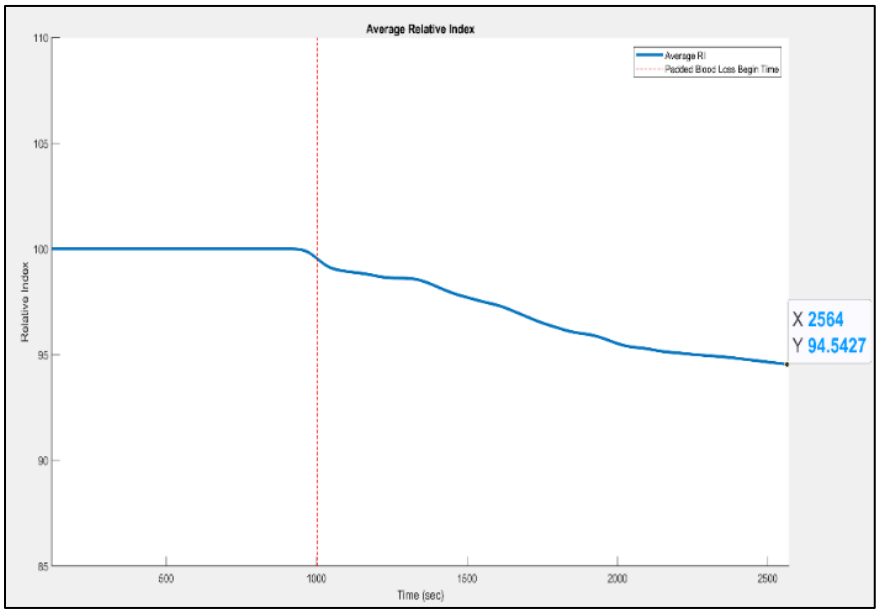
Control verification testing was also completed under an in-house verification protocol in the Zynex Engineering Lab using sixteen (16) healthy adult subjects known as “Controls.” The control verification testing was a prospective, single-arm, non-randomized test and data was used comparatively to our feasibility subjects. Like feasibility subjects, the control subjects laid in a supine position for 30 minutes while connected to the non-invasive CM-1500 while data was electronically recorded. The control subjects had no interaction while being connected to the device and laid in a relaxed state for the entire test.

Results

This feasibility study included seven (7) females and five (5) males. All subjects were in good health as evaluated by a health screening and self-reported medical history. All subjects were over the age of 18 years old, with a median age of 32. Feasibility subjects had an average Body Mass Index (BMI) of 25.82 kg/m^2 with a median of 25.5 kg/m^2. A few subjects participated in the study more than once.

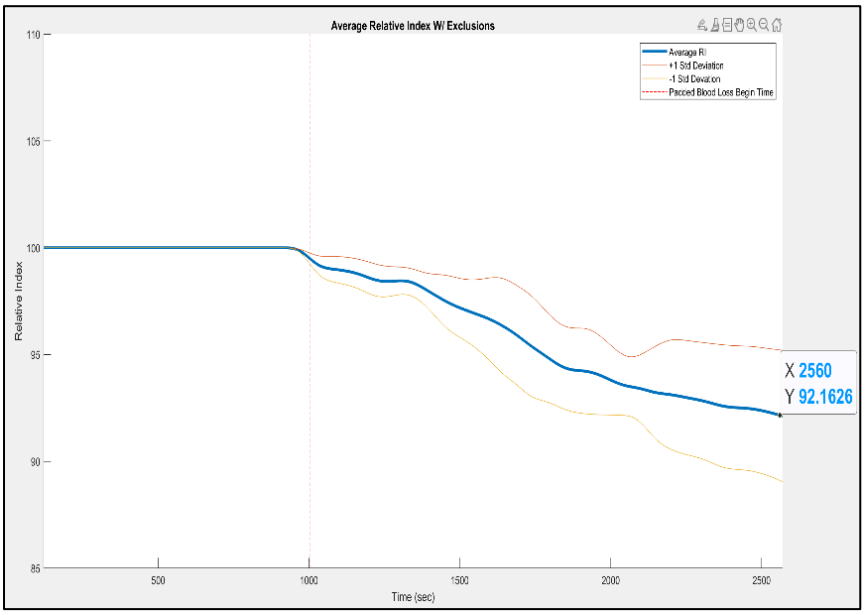
Eleven of the 12 subjects completed the 500mL blood draw. One (1) subject was stopped prematurely due to clotting and only completed a manual blood loss of 289mL. Manual blood loss was completed, on average, within 7 minutes and 37 seconds.

After completing the feasibility study, the data sets were analyzed to better understand the response of the Relative Index (RI) to the event of losing 500mL of blood. The data was analyzed by calculating an average RI value and the RI standard deviation. The results showed the Average RI value decreased by 5.0 (from 100 to 95.0) over the course of the manual blood loss event (Graph 1). The Average RI had a standard deviation of 4.3 RI points at the end of the manual blood loss event.



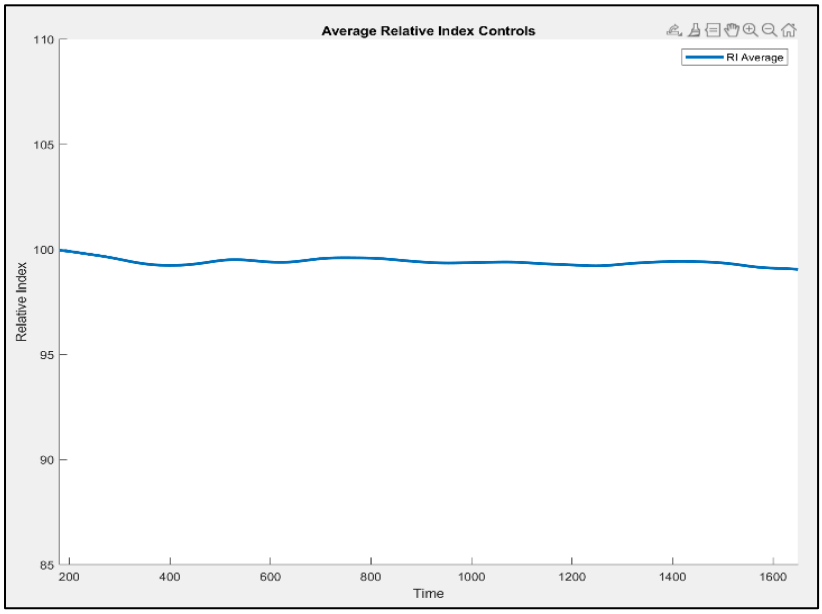
Graph 1: Average Relative Index During a Manual Blood Loss Event

Subjects in the feasibility study were allowed to participate more than once (notated as “repeat subjects”). Although the study’s few repeat subjects did not provide additional diversity, their data provided consistency, which further reinforced the accuracy of the CM-1500. Graph 2 presents the average RI, excluding the repeat subjects and the one (1) subject who did not complete the 500 mL manual blood draw. The exclusion of the aforementioned subjects from the aggregate results demonstrates the largest decrease in the RI for the event of manual blood loss. The adjusted average RI decreased by 7.8 RI points (from 100 to 92.2) with a standard deviation of 3.1.



Graph 2: Average Relative Index During a Manual Blood Loss Event with Exclusions Removed

Comparatively, the control subjects (no blood loss event) maintained a near-constant Relative Index (RI) of 100. The minimum average RI was 99.1, with a standard deviation of 1.7 RI points (Graph 3). The control subject's data confirmed that the CM-1500 could measure a subject's parameters while the RI value maintains values near 100.



Graph 3: Average Relative Index for Control Subjects

Conclusion

The results from the feasibility and control study demonstrate that the decrease in bodily fluid volume, in the form of a manual blood loss, has a direct correlation with a decrease in the CM-1500s Relative Index (RI). By using several clear physiological parameters and combining them through a complex algorithm into a Relative Index (RI), the CM- 1500 effectively detected blood loss in healthy adults during a controlled blood draw. The average RI decreased by 7.8 points for the aggregate set of feasibility subjects over the course of a 500mL manual blood loss. These results demonstrate the capability of the CM-1500 to detect fluid changes in the form of a blood

loss. The control study also demonstrated the accuracy of the CM-1500 when no changes in fluid volume (blood or other fluid) have occurred.

The results establish the utility of the algorithmic real-time monitoring provided by the Zynex® CM-1500. The findings suggest that the CM-1500 provides an effective, low-risk and non-invasive method for monitoring blood loss, as its intended to do. The CM-1500 could provide a simple and effective method for monitoring of blood loss in clinical settings, thus further testing in a clinical setting is needed.

With the absence of viable monitoring methods and the risks associated with hemorrhagic events, the CM-1500 provides an innovative and scientifically proven solution. Reliance on gravimetric measures and visual estimation of blood loss remain an imprecise, yet widely practiced solution for monitoring fluid changes among anesthesilogists[17]. Incorrect estimation of a potential hemorrhagic events poses unnecessary risk for patients as well as potential malpractice concerns for clinicians. The findings from this preliminary evaluation are promising and further testing of CM-1500 device should be undertaken in clinic settings with at-risk patients.

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