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BladeShield 101: A Novel Prehospital Digital Wearable Combat Casualty Card

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ABSTRACT **Background:** The focus of the Israeli Defense Forces-Medical Corps (IDF-MC) is on reducing preventable death by improving prehospital trauma care. High-quality documentation of care can serve for casualty care and improve future care. Currently, paper casualty cards are used for documentation. Incomplete data acquisition and inadequate data handover are common. To resolve these deficits, the IDF-MC launched the BladeShield 101 project.

Objectives: To assess the quality of casualty care data acquired comparing standard paper casualty cards with the BladeShield 101.

Methods: The BladeShield 101 system consists of three components: a patient unit that records vital signs, medical care provided by a medical sensor that transmits to the patient unit and, a ruggedized mobile device that allows providers to access and document information. We compared all trauma registries of casualties treated between September 2019 and June 2020.

Results: The system was applied during the study period to 24 patients. All data were transferred to the military trauma registry within one day, compared to 72% (141/194) with a paper casualty card ($P < 0.01$). Information regarding treatment time was available in 100% vs. 43% ($P < 0.01$) of cases and 98% vs. 67% ($P < 0.01$) of treatments provided were documented comparing BladeShield 101 with paper cards, respectively.

Conclusions: The use of an autonomous system to record, view, deliver, and store casualty information may resolve most current information flow deficits. This solution will ultimately result in significant improvements to individual patient care and systematic learning and development processes.

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KEY WORDS: BladeShield 101, casualty card, medical record, monitoring, trauma registries

BladeShield 101 is a novel method for continuous monitoring and medical recording of vital signs and interventions performed during combat casualty care. The system consists of a sensor, a patient unit (black box), and a dedicated smartphone app, all of which were designed for the battlefield. The data can be retrieved during all echelons of care to improve decision making.

Saving lives on the battlefield has significant operational, strategic, and moral value. Combat casualty care is conducted under the harshest conditions by several echelons of care [1,2]. At the point of injury (POI), the medical care provider addresses four simultaneous efforts: triage and prioritized treatments, administration of critical care to the casualties, calls for help and arrangement of evacuation to the next echelon of care, and monitoring and documenting vital signs and treatments. Accurate assessment of the patient's status is essential to choosing the correct treatment for each casualty [3]. Data documentation allows for important information transfer between echelons of care and facilitates quality control and research intended to improve future treatments.

Most currently used clinical practice guidelines utilize a point measurement of vital signs to guide decision making. There are abundant data on the correlation between single measurements of vital signs and injury severity, patient outcomes, or the need for medical interventions [4]. Changes in vital signs have been described as prognostic predictors among non-trauma patients [5]. Medical decision-making based on trends and changes over time rather than an arbitrary sampling of vital signs will potentially allow for better assessment of the casualty's current physiological state and requirements.

The transfer of information among echelons of care is crucial to providing optimal medical treatment [6]. Studies show that military units that improved casualty care documentation reduced rates of preventable death [7]. Although monitoring and documentation alone will not eliminate preventable death rates, this process is a critical step forward [8]. Furthermore, the establishment of trauma registries in the past two decades has

allowed for unprecedented research, which, in turn, enabled many advances. Nonetheless, prehospital documentation is many times lacking or incomplete and thus prehospital trauma registries contain missing information. For example, only 18–25% of casualties from recent conflicts in Afghanistan (Operation Enduring Freedom) and Iraq (Operation Iraqi Freedom) had some form of prehospital data [9].

Until the introduction of the BladeShield 101 digital casualty card, the IDF's means of battlefield documentation was a standardized paper casualty card, similar to the Tactical Combat Casualty Care (TCCC) card. During Operation Protective Edge in 2014, only 12% of the casualties had a casualty card completed [10]. This number is similar to that described by Eastridge et al. [11] regarding the U.S army, with only 13% of patients receiving their completed TCCC card before moving to the next medical echelon. Low compliance to prehospital documentation is likely to be multifactorial. While a lack of awareness of the importance of documentation is a probable contributor, it is not the sole cause. POC medical providers are required to address several tasks simultaneously, at times under fire. These tasks require valuable time and workforce. Due to a lack of time and a shortage of human resources, one of the first tasks to be neglected is documentation.

The manually completed paper forms have many shortcomings. They are not durable, are easily lost, can be unreliable, and demand plenty of resources. To illustrate, documenting vital signs (blood pressure, heart rate, oxygen saturation, number of breaths, and a timestamp) at 2-minute intervals for two simultaneous casualties requires a dedicated provider who cannot assist with other tasks.

Currently, no commercially available system for autonomous monitoring and documentation is available. Therefore, in collaboration with the Design-Tech Lab, Faculty of Architecture, Technion–Institute of Technology, Haifa, Israel, the IDF launched the BladeShield 101 project.

In this study, we assessed the quality of casualty care data acquired and compared standard paper casualty cards with the BladeShield 101. We evaluated whether the BladeShield 101 system improved prehospital data acquisition.

PATIENTS AND METHODS

BLADESHIELD 101

The BladeShield 101 project participants designed a system to monitor and store vital signs, documents, and medical treatment; allow for the accurate handover of information; process data in real-time; and provide decision support features for providers in an austere environment. The system was specifically designed to operate in military set-ups. Functionality, operational restrictions (durable, small, and light, muted and dimmed on demand), intuitiveness of software interface, user experience, pricing, and information security were addressed accordingly.

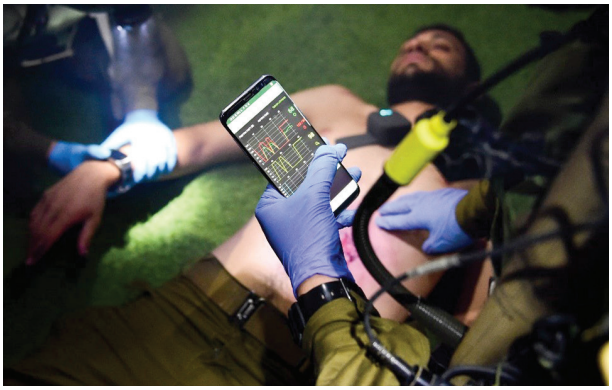
The system consists of three components, paired with near field communication (NFC) tags and synchronized via Bluetooth transmission:

- **Sensors:** Portable vital sign sensors
  These sensors provide continuous monitoring. All data is transmitted to the patient unit to be stored and processed. The currently used commercial sensors are the Nonin (Nonin Medical Inc., Plymouth, MN, USA) and the Masimo (Masimo Corp., Irvine, CA, USA). These sensors provide heart rate readings, respiratory rate, and oxygen saturation. In the future, the patient unit could be synchronized with any sensor with a Bluetooth transmitter thus allowing readings of additional vital signs and information such as blood pressure, estimated cardiac output, compensatory reserve measurement [12], estimated shock levels, and noninvasive blood tests.
- **Patient unit (black box):** A small box attached to the casualty using a quick strap
  This unit serves as the casualty digital card [Figure 1]. The box continuously records data collected from the sensors (every 30 seconds), records all medical procedures, and stores operational and medical data entered by the caregiver either through a dedicated smartphone application or directly to the patient unit using an NFC tag.
- **Dedicated application:** An app installed on a dedicated and rugged smartphone with no available communication protocols other than Bluetooth to maintain information security during operational use [Figure 2]
  All data entered via the application or sensors are recorded and stored on the patient unit and can be recovered by the mobile device throughout different echelons of care. For better patient monitoring, alarms can be set for the different metrics. Patient data are processed and presented to the caregiver using a graphic friendly user interface designed to promote accurate decision making.

In practice, the first medical provider tending to the patient, either a combat medic or an advanced life support provider, will attach the patient unit at the POI. The sensor is paired with the patient unit using an NFC tag by touching both devices. Once paired, the patient unit begins to record vital signs. Until an advanced life support provider arrives on the scene, the medic can document essential interventions (i.e., tourniquet application, analgesia) using a designated kit of NFC tags. Advanced life support providers carry a mobile device that is paired to the patient unit using NFC connectivity. Once paired, the provider can retrieve all previously recorded data and document all medical care performed. The caregiver can also add data regarding the mechanism of injury, body parts injured, initial assessment, evacuation tools, and relevant operational data. The patient unit remains with the casualty throughout all succeeding echelons of

Figure 1. Patient unit (black box)

Figure 2. Dedication smartphone application



care until he arrives at the hospital. Thus, providers throughout all echelons of care, including emergency department staff, can access the data from the moment the system is placed and view all interventions performed and vital signs records.

The system was deployed for evaluation in September 2019 and was first used on a patient four days after deployment [Figure 3]. All care providers underwent a 4-hour preparatory workshop regarding the use of the system, and they were instructed to train at least once a week with it.

STUDY DESIGN

In this study, we compared all trauma registries of casualties treated since introducing the BladeShield 101 system between September 2019 and June 2020. The trauma and combat branch at the IDF-Medical Corps contacted all care providers by phone for data quality assurance.

VARIABLES

Variables analyzed included time from injury to transfer of data to the trauma registry, vital signs (heart rate, oxygen saturation, pulse rate, and respiratory rate) documented, documentation of time (casualty assessment, treatment, and evacuation), and documentation of treatment provided.

STATISTICAL ANALYSIS

Categorical variables were analyzed using Fisher's exact test.

RESULTS

During the study period, 24 casualties were monitored and documented using the BladeShield 101 system, and 197 casualties were documented using a standard paper casualty card. All data were uploaded to the Israel Defense Forces-Trauma Registry. In its first 8 months of use, the BladeShield 101 system had been used only in non-combat scenarios. Among the 24 casualties monitored by the BladeShield 101 system, 21 cases comprised a single casualty, and 3 cases had 2-3 casualties; 100% of the data was transferred to the military trauma registry within a day, compared to 72% (141/194) with a paper casualty card ($P < 0.01$). The number of documented vital signs rose from a median of 4 (IQR 3–4) measurements per hour to 120 (IQR 100–125) per hour. Information regarding treatment time increased from 43% to 100% ($P < 0.01$), while data regarding treatment given changed from 67% to 98% ($P < 0.01$). Mean treatment time on the ground (before starting evacuation) did not differ (14 minutes). Medical teams using the system reported that continuous measurement of vitals helped them in treatment decisions, while fewer human resources were needed to receive these data. Although not tested yet in a combat scenario, the use of the BladeShield 101 system did not increase the treatment time prior to evacuation.

DISCUSSION

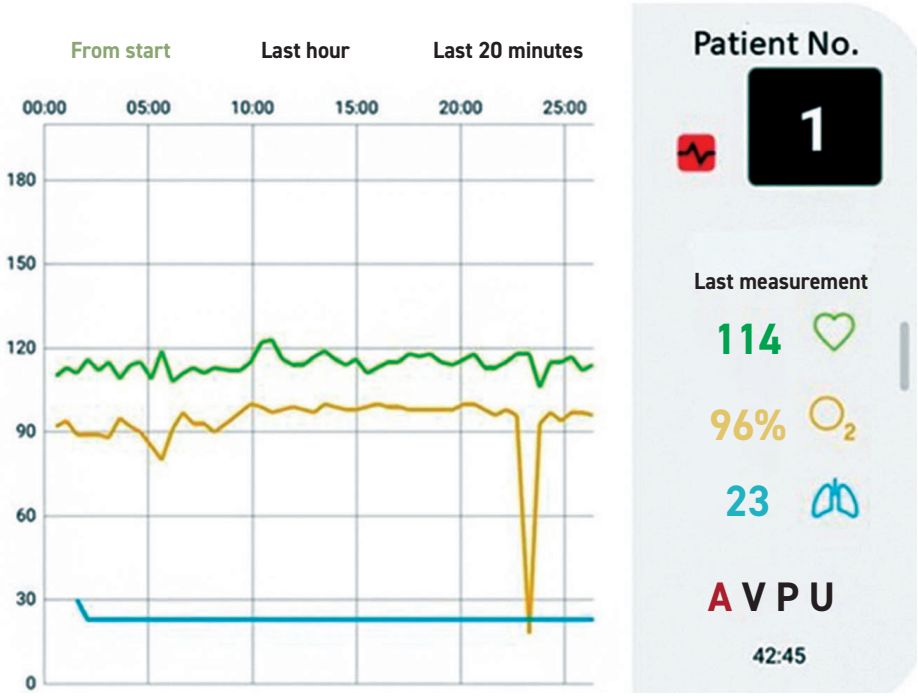
In this study, we examined the recent experience using the BladeShield 101 system and found that data quality using the system was superior to that acquired using conventional paper cards. The information acquired by the BladeShield 101 system had almost no missing data regarding variables assessed, was available for further analysis faster, and was of higher resolution.

During casualty care, constant assessment and decision making are necessary. Appropriate automatic data acquisition and presentation may assist in better decision making. In this study, we did not analyze casualty outcomes. Future studies should assess whether the use of the BladeShield 101 improves outcomes.

Continuity of treatment is crucial in providing optimal casualty care. In this study, we demonstrated how using paper casualty cards resulted in loss of data and inadequate documentation. In contrast, using the BladeShield 101 system data reached its final destination (IDF-TR) nearly devoid of missing data, implying it was fully available for all echelons of care.

High-quality research regarding prehospital trauma care is difficult to perform. Much of the research performed is retrospective. High quality databases are thus crucial for research in this field to optimize care. Our results show how the BladeShield 101 system can serve to form such a database, including

Figure 3. Vital signs recordings of the first casualty care using the BladeShield 101 system



frequent vital sign documentation and full documentation of various aspects of treatment (time of treatments and treatments provided).

Widespread deployment of the BladeShield 101 system is currently underway in the IDF, thus alleviating the need for paper casualty cards, which are gradually being replaced. We plan to start using the system in combat scenarios and synchronize it with digital tactical control systems, allowing for relevant information to reach medical personnel in higher echelons and line commanders in real-time. In the future, these accumulated big data, using machine learning algorithms, will help deliver a decision support system that will improve medical care in these challenging combat scenarios.

CONCLUSIONS

Data are essential to improve medical care quality. Improvement is needed both for treating a single casualty and designing enhanced medical systems. Currently, available data techniques for documentation, handover, storage, and analysis are insufficient and result in a high proportion of data loss. The digital BladeShield 101 system allows for real-time, autonomous, and continuous recording and handover of data. This solution may result in better individual patient care and better trauma registries.

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