Evaluating Cardiac Monitoring Equipment on Columbus Division of Fire Engine and Rescue Companies

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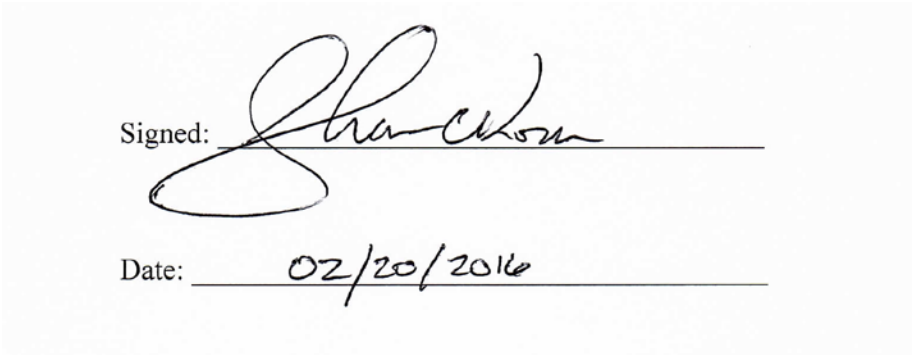

Abstract

The Columbus Division of Fire planned to purchase new LifePak cardiac monitors in the spring of 2016. The problem was there was no knowledge of how often and for what the monitors were used and therefore a lack of understanding as to whether or not they needed to purchase new monitors with the same capabilities. Evaluative research was performed. The purpose of this research was to evaluate the use of this equipment to determine whether or not they were needed on the apparatus on which they were carried. The research questions used to gather information on the subject were: (a) what cardiac monitoring equipment were carried on Columbus Division of Fire engine and rescue companies as well as in other cities across the country, (b) how often and in what capacity were the cardiac monitors used by Columbus Division of Fire engine and rescue companies, (c) how did the capabilities of a LifePak compare to those of an AED (d) what recommendations were made for cardiac monitoring equipment carried on Columbus Division of Fire engine and rescue companies? Procedures included surveying fire departments across the country, interviewing medical directors, company representatives, and EMS chiefs of other departments, performing Internet searches, inspecting cardiac monitoring equipment, and reviewing user manuals of each of the involved types of monitors. Results of the research determined that many departments around the country operate ALS engine companies, and the majority of those carry cardiac monitors. The research also revealed that Columbus, as most departments, primarily use their monitors for vital signs rhythm determination and not primarily for 12-lead ECG acquisition. It was recommended that the Columbus Division of Fire save money by either purchasing a monitor with lesser capabilities or purchase AEDs with rate and rhythm determination ability, with the goal to expand defibrillation capabilities.

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Introduction

Columbus Division of Fire has a rich history in EMS, having placed its first emergency squad in service in 1934. The system evolved to the all-ALS system that exists today, consisting of ALS transport vehicles and ALS-engine companies, each staffed with a paramedic and carrying ALS equipment and a cardiac monitor. The Columbus Division of Fire planned to purchase new LifePak cardiac monitors in the spring of 2016 to replace the aging LifePak 12s carried on engine and rescue companies. The problem was there was no understanding of how often and for what the monitors were used. This resulted in a lack of understanding as to whether or not the Division needed to purchase new monitors with the same capabilities. Evaluative research was conducted. The purpose of this evaluative research was to assess the use of the cardiac monitors carried on CDF engine and rescue companies and to determine whether or not they were actually needed on the apparatus. The research questions used included: (a) what cardiac monitoring equipment were carried on Columbus Division of Fire engine and rescue companies as well as in other cities across the country, (b) how often and in what capacity were the cardiac monitors used by Columbus Division of Fire engine and rescue companies, (c) how did the capabilities of a LifePak compare to those of an AED and (d) what recommendations were made for cardiac monitoring equipment carried on Columbus Division of Fire engine and rescue companies?

Background and Significance

Many consider the inception of Emergency Medical Services in the United States as the September 1966 report titled, *Accidental Death and Disability: The Neglected Disease of*

Modern Society. Among the many recommendations for investigation, research, and care of trauma patients from this report came the establishment of emergency medical services. The report called for a standard for ambulance design and construction, standards for the equipment and supplies carried on ambulances, and standards for the qualifications and supervision of ambulance personnel. It also called for states to each establish general policies and regulations pertaining to ambulance services. The report's recommendations also called for municipalities to establish the ways and means to deliver ambulance services to the public consistent with the federal and state standards. Finally, the report recommended active exploration of the feasibility of designing a single nationwide telephone number to summon an ambulance (National Research Council, 1966, p. 35).

Columbus, Ohio played an integral part in the development of EMS the way it is today, dating back over eighty years. Prior to the release of this report, emergency medical services performed by firefighters were largely reserved for saving their own. For instance, a Lyons pulmotor was placed on Columbus Fire Chiefs' vehicles in 1931 for the purpose of resuscitating firefighters overcome by smoke. It was first used outside of this reason in 1934, when then Chief Ed Welch and two firefighters responded to a scene of an electrocuted lineman (Key, 2013, p. 1). Although their resuscitation attempts were unsuccessful, their actions spawned demand from the public for development of this type of service for the citizens of Columbus. Later that same year the Columbus Division of Fire placed an old converted 1927 Seagrave hose wagon in service as its first emergency squad at engine house #6, equipped with supplies donated by the Red Cross and an H & H Inhalator to deliver emergency medical care to the public (W. Hall, personal communication, February 9, 2016).

The Ohio State University Disaster Research Center, established in 1963, had conducted research on the need for dedicating local resources to disaster response. They were also on the cutting edge of cardiac care, opening a Coronary Care Unit (CCU), one of the first units of its kind dedicated to the treatment of patients suffering myocardial infarction and other heart-related conditions (Hall, 2014, p. 1). In 1966, Dr. James Warren looked to take that level of care onto the streets of Columbus. Seeking to emulate the "flying squads" he observed during a visit to Belfast, Northern Ireland, he entered into discussions with the Columbus Division of Fire. Since the fire department had a well-established Emergency Medical Service, it was a logical step in providing emergency medical care to the public. By 1969, the Heartmobile program was off the ground. Staffed by three firefighters and a physician from OSU Medical Center, the mobile CCU responded on cardiac suspected calls when summoned by on scene squad crew (Key, 2013, app. A). At the time, the system served a population of approximately 650,000 at a cost of $5/person/year. Although the system was considered citizen-activated, about 15% of the calls originated from physicians. At that time, approximately 40% of the patients were transported to local hospitals, less than 10% of those had cardiopulmonary disease (Lewis, Stang, & Warren, 1984, p. 200). After a couple of years it was apparent to Dr. Richard Lewis, then Medical Director for the Columbus Division of Fire, and Dr. Warren that firefighters were skilled enough to interpret the ECG and respond without the resident assistance, and Columbus Fire took over operation of the Heartmobile (Key, 2013, app. A).

Katy Sampson, a CCU nurse at OSU, developed and taught a 96-hour paramedic education program to firefighters from Columbus and surrounding agencies. These paramedics had better short-term and long-term survival rates from cardiac arrest and a better successful endotracheal intubation rate than did the physicians who had staffed the Heartmobile (Lewis et

al., 1984, p. 202). The program continued to be administered by The Ohio State University Department of Emergency Medicine until 1980, when the Division of Fire took over the education of its paramedics teaching the Ohio Department of Transportation course.

Equipment carried on emergency medical service vehicles has evolved since those early days of the pulmotor, a gas-powered machine ventilator designed by Dräger. In the mid-seventies, the four ALS units in Columbus with paramedics carried portable defibrillators, electrocardiographic equipment, and standard resuscitative drugs and devices (Lewis et al., 1984, p. 201). They followed protocols established by a Medical Advisory Board to obtain electrocardiograms, start intravenous lines and deliver medications when needed. At the time there were seven standard emergency medical transport units, staffed by EMTs that carried basic medical equipment. The cardiac monitoring equipment carried on ALS vehicles was heavy with unreliable telemetry capabilities. The LifePak 5 from Physio-Control was introduced in 1976, and weighed approximately 19 pounds ("LifePak 5," n.d., p. 1). The two-piece cardiac monitor/defibrillator had a selector switch to view the leads I, II, and III. To view the unipolar ECG leads, the ECG patched needed to be moved.

As technology advanced, so did the equipment carried on ALS and BLS ambulances. The two-tiered response remained in effect until 1995, when the Division of Fire implemented an all-ALS system. At that time, every transport vehicle was called a ‘Medic’, and was staffed with two paramedics. Every engine company was eventually staffed with one paramedic. This system remains in place today in Columbus. An engine company and medic are dispatched on all ALS1 and ALS2 calls. An EMS Field Supervisor is also dispatched on ALS2 calls. An ALS1 call is considered any transportation by ground ambulance and the provision of medically necessary supplies and services including the provision of an ALS assessment or at least one

ALS intervention. An advanced life support (ALS) assessment is an assessment performed by an ALS crew as part of an emergency response that was necessary because the patient's reported condition at the time of dispatch was such that only an ALS crew was qualified to perform the assessment. An ALS assessment does not necessarily result in a determination that the patient requires an ALS level of service (Centers for Medicare and Medicaid Services [CMS], 2010, p. 5). An ALS intervention is considered a procedure that, in accordance with State and local laws, must be performed by an emergency medical technician-intermediate (EMT-Intermediate) or EMT-Paramedic. An ALS2 call is characterized by at least three separate administrations of one or more medications by intravenous push/bolus or by continuous infusion (excluding crystalloid fluids) or at least one ALS2 intervention, the most common being defibrillation or endotracheal intubation (CMS, 2010, p. 7).

Upon its creation in 1992, the State of Ohio tasked the state board of emergency medical services with determining the design, equipment, and supplies for ambulances and medical aircraft, including special equipment, supplies, training, and staffing required to assist pediatric and geriatric emergency victims (Recommendations for operation of ambulance and emergency medical service organizations, 2000). The state medical board published the list of ambulance recommendations on its ambulance inspection form ("EMS 4016," 2013, p. 1). The state also released recommendations for a non-transport EMS vehicle, specifically an EMSO (EMS Field Supervisor) vehicle ("EMS 4026," 2013, p. 1). Minimal EMS equipment is included in the checklist, and the equipment does not include cardiac monitoring equipment or an automated external defibrillator (AED). There are no equipment recommendations for fire apparatus from the state EMS board.

The National Fire Protection Association (NFPA) 1901 is the standard for automotive fire apparatus. Within the recommendations for miscellaneous equipment to be carried on all initial attack fire apparatus are one first aid kit and one automated external defibrillator (AED) (National Fire Protection Association [NFPA], 2016). The Division of Fire just began getting new aerial apparatus with an AED as standard equipment consistent with NFPA recommendations within the past couple years.

Currently, Columbus Division of Fire engine and heavy rescue companies carry ALS equipment, including an airway kit to administer oxygen and the tools to perform endotracheal intubation. The drug box carried on those companies consists of equipment to establish intravenous lines and deliver medications via the intranasal, IV, or intraosseous (IO) route. In the state of Ohio, advanced EMTs (AEMT) can administer most of the medications that a paramedic can, with the exception of cardiac medications, including epinephrine IV (State Board of Emergency Medical, Fire and Transportation Services [EMFTS Board], 2014, p. 3). They also carry Physio-Control LifePak 12 units that are capable of performing defibrillation and obtaining a 12-lead ECG. Columbus Fire currently has approximately 25 front line emergency response vehicles that do not have the ability to defibrillate a patient in cardiac arrest, including battalion chiefs and EMS field supervisors.

This ARP was intended to identify a standard for equipment on ALS fire apparatus and make a recommendation on the purchase of cardiac monitoring equipment. This ARP directly relates to the U.S. Fire Administration's strategic goal #2, "Improve local planning and preparedness" and goal #3, "Improve the fire and emergency services' capability for response to and recover from all hazards" (United State Fire Administration [USFA], 2010-2014, p. 14). According to the U.S. Fire Administration, fire and emergency medical services (EMS)

personnel are part of the foundation of our Nation's local first response capability and have a critical role to play in local planning and preparedness. The effectiveness an incident is handled at the local level is a direct result of the preparedness of the local responders and the communities they serve (USFA, 2010-2014, p. 14). Being prepared with the proper EMS equipment is critical in the response to calls for emergency medical service.

Literature Review

In order to understand where fire-based EMS is today, it is important to know its origins. The first medical equipment carried on a Columbus Division of Fire vehicle was a Lyons pulmotor. This device was donated to the department in 1931 for the purpose of resuscitating firefighters overcome with smoke. The device was carried on the Fire Chief's car (Key, 2013, p. 5). Fire Chief Edward Welch, recognizing the opportunity and need for firefighters to deliver emergency medical care to the public, recommended the formation of emergency squads in his annual report in 1933. The following year Chief Welch, along with two firefighters, responded to the scene of an electrocuted lineman. Although their efforts were unsuccessful, the newspaper coverage of the efforts inspired citizens to call for the fire department to deliver emergency medical care to the citizens of Columbus (Hall, 2014, p. 1). The primary cause of death in victims of electrocution or lightning strike is the fatal cardiac rhythm of ventricular fibrillation, leading to cardiac arrest (American Heart Association [AHA], 2005, para. 3).

Ventricular fibrillation was known as early as 1850 (Bakalar, 2010, para. 1), although some scholars believe that ventricular fib could have actually been observed by the ancient Egyptians. A passage of Ebers Papyrus dated back to around 3500 B.C. contains a possible description of ventricular fibrillation: "When the heart is diseased its work is imperfectly performed: the vessels proceeding from the heart become inactive, so that you cannot feel them .

. . If the heart trembles, has little power and sinks, the disease is advancing and death is near." The trembling of the heart and the lack of pulsation of the vessels leading from the heart are indeed quite characteristic of ventricular fibrillation (Brewer, 1983, p. 698).

Until the 1950s, defibrillation of the quivering heart could only be done when the chest cavity was open. Early 'external' defibrillators used alternating current (AC) and caused quite a bit of collateral damage (Abhilash & Namboodiri, 2014, p. S6). Although many people are credited with inventing the first defibrillator, portable units operating on direct current (DC) power began to become available in the mid-1950s.

By the early 1960's, emergency medical care began to be a topic of national discussion. In 1965, an estimated 107,000 people were killed in accidental injures, another 400,000 were permanently impaired, and over 10 million were temporarily disabled. This came at a cost to the American taxpayer of more than $18 billion. 49,000 of these accidental deaths were due to motor-vehicle accidents (National Research Council, 1966, p. 5). Political activist and attorney Ralph Nader published in 1965 a book titled, *Unsafe at Any Speed: The Designed-in Dangers of the American Automobile*. The book shed light on the lack of efforts to increase passenger safety from the automotive industry and was a factor in the passage of the 1966 National Traffic and Motor Vehicle Safety Act (Branch, 2016, p. 1).

At the time, pre-hospital care varied widely across the United States. Mortuaries provided nearly half of the nation's ambulance services. Hearses were the most efficient vehicle for transporting stretchers, but allowed no room for the patient to receive medical treatment en route to the hospital (Jensen, Decker, & Rousseau, n.d., p. 1). Although the 1966 *EMS White Paper* stated that local political authorities have neglected their responsibility to provide optimal emergency medical services (National Research Council, 1966, p. 6), by this time Columbus had

a highly trained fire department emergency squad that arrived at the scene on an average of four minutes after a call for help (Hall, 2014, p. 1). Another leading cause of death at the time was from cardiac emergencies. The Ohio State University Medical Center was at the forefront of cardiac care in the 1960s, having been among the first hospitals in the nation to perform cardiac catheterization ("Cardiovascular medicine history," n.d., p. 1) and opening its first coronary care unit in 1964 (Hall, 2014, p. 1).

Dr. James Warren was a cardiologist and Chairman of the Department of Emergency Medicine at Ohio State from 1961 to 1979. Dr. Warren was world-renowned in cardiovascular care and research (Rodgers, 2014, para. 1). While traveling in the United Kingdom, Dr. Warren met Dr. Frank Pantridge, who had begun operating “flying squads” in Belfast, Northern Ireland. Dr. Pantridge is often referred to as the ‘Father of Emergency Medicine’ and, along with his colleague Dr. John Geddes, credited with producing the first portable defibrillator and pioneering the modern method of performing cardiopulmonary resuscitation (CPR) (Peck, 2011, para. 1). Doctors and nurses staffed Dr. Pantridge’s ambulance No. 331, which was specifically built to respond to cardiac victims at the scene, stabilize and treat them, and transport them to The Royal Victoria Hospital.

Dr. Warren brought those successful practices back to the United States and The Ohio State University, where he entered into discussions with the Columbus Division of Fire. Columbus’ successful squad program made it the perfect delivery system for coronary care in the field. Thanks to funding from a federal highway grant, as well as donations from the local chapter of the American Red Cross and other local entrepreneurs, the Heartmobile program was born. The Heartmobile was the first vehicle of its kind in the United States. Built specifically as

a mobile coronary care unit (CCU), the Heartmobile was staffed with the Columbus Firefighters and a physician from Ohio State.

The equipment carried on the original Heartmobile was as state of the art as the concept itself. It carried an early model defibrillator cardioscope Physio-Control introduced its LifePak 33 cardiac monitor/defibrillator at the American Heart Association conference in Miami, Florida in 1968. The device became instantly popular, going on sale commercially in 1969. The Columbus Fire Department was among the first users of the device, along with Miami and Jacksonville Fire Departments and Seattle's "Medic One" program in King County, Washington (Barlett, 2008, para. 5). A large tackle box housed intravenous line supplies and medications, including cardiac and respiratory medications. At the time, Columbus Fire engine companies did not carry EMS equipment other than a small first aid box (W. Hall, personal communication, February 9, 2016).

Today Columbus Division of Fire operates an all-ALS system consisting of two paramedics on every transport vehicle and at least one paramedic on every engine company (Columbus Division of Fire, 2008, p. 4). The Division determines the equipment carried on the engine and heavy rescue companies. The State Board of Emergency Medical, Fire, and Transportation Services regulates the equipment that is required to be carried on board the ALS transport vehicles. An ALS transport vehicle must carry a cardiac monitor/defibrillator with external cardiac pacing and ECG trace capability ("EMS 4016," 2013, p. 1). This is consistent with the recommendations in the joint policy statement released by the American College of Emergency Physicians, et. al (American Academy of Pediatrics, American College of Emergency Physicians, American College of Surgeons Committee on Trauma, Emergency

Medical Services for Children, Emergency Nurses Association, National Association of EMS Physicians & National Association of State EMS Officials, 2014, p. 95).

EMS equipment is expensive and, since it is mandated by the state, cities have little room to cut costs. The Zoll X series cardiac monitor/defibrillator is standard equipment on Oneonta EMS ambulances in Oneonta, New York. The city spent $100,000 to purchase three of them. One of these monitors with all of the available options is normally $42,000, but Oneonta saved money by buying multiple monitors and trading in old equipment (Richardson, 2016, para. 7).

Springfield Fire/Rescue Division in Springfield, Ohio spent $163,000 in December, 2015 on nine of the Zoll X Series cardiac monitors, a cost of about $18,000/each. They got the low price because the units had previously been demo models by the vendor (Cooper, 2015, para. 4). They previously used LifePak 12 units from Physio-Control.

Western Alliance Emergency Services in Troy, Pennsylvania recently received a $7,444.80 grant mandated for monitor equipment purchase but it only covers about six percent of the cost of four new 12-lead cardiac monitors (Hrin, 2015, para. 1). Although cardiac monitors and other equipment are expensive, there's no doubt that its worth the price to save a life. Greg Wolpert, 60, collapsed while running the Naples half marathon in 2015. He had no pulse and was not breathing when bystanders stopped the race and began administering life-saving CPR. His heart was in ventricular fibrillation, and was shocked by a $25,000 LifePak monitor only eight minutes after he collapsed (Handel, 2016, para. 6).

Thirty-five year old Matt O'Brien suffered a similar incident in downtown Columbus during the Cap City Half Marathon in May of 2011. He was running down 'the chute' toward the finish line when he put his hand to his chest and collapsed face down on the road. Luckily for Matt, Columbus paramedics were close by to perform CPR and administer defibrillation. He

unknowingly suffered from a hereditary electrical condition called Brugada Syndrome, which causes sudden death in otherwise healthy people because of disturbances in the heart's electrical rhythm (Jones, 2012, para. 13).

The preceding cases focused on the condition of cardiac arrest, the abrupt loss of heart function in a person who may or may not have diagnosed heart disease (American Heart Association [AHA], 2014, para. 1). Cardiac arrest calls are probably one of the most serious calls any firefighter can answer, but fortunately they don't happen frequently. Other types of medical calls include heart attacks, strokes, and respiratory difficulty, to name a few. Often these calls are answered by one of Columbus' ALS engine companies. There are currently no standards established by the state of Ohio for equipment carried on engine companies. National Fire Protection Association (NFPA) 1901 is the standard for automotive fire apparatus. The standard recommends one first aid kit and one automated external defibrillator (AED) are carried on all initial attack fire apparatus (National Fire Protection Association [NFPA], 2016). Columbus Division of Fire engine companies carry a full compliment of ALS equipment, including a cardiac monitor (LifePak 12), airway kit with intubation supplies, and medical kit with intravenous (IV) line supplies and a variety of cardiac medications.

A LifePak 12 cardiac monitor can defibrillate a patient in ventricular fibrillation, and much more. A paramedic using one can also monitor continuous electrocardiogram (ECG), perform noninvasive pacing, obtain a 12-lead ECG, monitor SpO2, obtain a patient's blood pressure, monitor end-tidal CO2, and perform a synchronized cardioversion (Physio-Control, 2008, p. iii). A LifePak 1000 defibrillator can obviously deliver a direct-current defibrillation either automated (in AED mode) or manually (manual mode) as well as provide a non-diagnostic

display of the patient's ECG rhythm. Both manual defibrillation and ECG rhythm identification require ECG display option (Physio-Control, 2008, p. 3-2).

Some police agencies even have the ability to defibrillate a patient in cardiac arrest, carrying an AED with them. In Bexley, Ohio the police department just received new AEDs thanks to a grant from the Bexley Community Foundation (The city of Bexley, Ohio [Bexley], 2015, para. 2).

Procedures

The purpose of the procedures was to answer research questions by gathering information about the types of cardiac monitors on apparatus in other cites. To summarize the history of EMS in the United States, an Internet search was performed to determine the origin of emergency medical services both in Columbus, and in the United States. Division of Fire historian William Hall was interviewed. The types of cardiac monitors carried by fire companies and their cost was researched. A survey was developed and sent to fire departments in Ohio as well as EFO students to determine if their departments staffed ALS engine companies and if so, what types of cardiac monitoring equipment they carried. Questions also sought to reveal if the departments surveyed tracked how often cardiac monitors were used and in what capacity. Next, every LifePak 12 carried on Columbus Division of Fire engine and rescue companies were examined to determine how often they were used and in what capacity. Ultimately the goal was to determine the number of times crews used the monitors on their fire apparatus to obtain 12-lead ECG or other ALS procedures that could not be performed by an automated external defibrillator. Discussions were had with EMS Chiefs from several departments to determine what they considered an ALS engine company. The Medical Director and Associate Medical Director of the Columbus Division of Fire as well as the former Medical Director of Wake

County, NC EMS were interviewed. Response times for the run type of chest pain were requested from Quality Improvement Captain. The Fire Chief of Columbus Fire was also interviewed. The local sales representatives of both Physio-Control and Zoll Medical were interviewed. External resources, including NFPA 1901 were used to gain an understanding of to what standard fire departments are held. Following the completion of the research, a recommendation letter was submitted to the Fire Chief.

For the first research question, the cardiac monitoring equipment carried on Columbus Division of Fire engine and rescue companies was well known to the researcher. The equipment was verified by direct visualization. A survey was constructed on the Survey Monkey website and distributed to 30 fire departments around the nation. A limitation of the initial survey distribution was that like sized departments and geographically proximal departments were not targeted. Research was conducted to determine the 20 largest fire departments in the country. An Internet search was conducted to determine if the departments in the top 20 operated paramedic (or ALS) engine companies. Similarly sized departments and departments in Ohio were identified and contacted by telephone for information regarding the equipment carried on their engine companies. The survey questions asked for city name, population, type of department (career, combination, volunteer, or other), and size of department (authorized strength). Then the following questions sought to determine what equipment was carried on their respective engine companies: 1) does your department have paramedic (ALS) engine companies, 2) what type of monitor is carried on your engine companies, 3) If a 12-lead capable monitor is carried, what brand do you use. After these questions, these three follow-up questions sought to determine for what the monitors carried on engine companies are primarily used: 1) if a 12-lead capable monitor is carried, do you track how often it is used to perform 12-lead ECGs, 2)

if yes, how often are 12-leads performed by engine companies, 3) for what are your cardiac monitors on engine companies primarily used.

To answer the second research question, every LifePak 12 on engine and rescue companies were examined. The unit was turned on and the 'options' button was pressed. Then the 'archive' button was pressed, taking the unit out of monitoring mode. This allowed the history to be viewed. The month of November was the focus of the review; although the dates could not all be viewed because of the way events fall off the archive list. For each monitor, approximately 30 days were reviewed. Code summaries, 12-lead ECGs, vital signs summaries, and trend summaries can be printed in report retrieval mode on the LifePak 12. Events were listed for each unit, and then summarized in a report.

The third research question sought to differentiate between the capabilities of an AED and those of a LifePak 12 or other comparable cardiac monitor carried on fire apparatus. Although these capabilities are well known to the researcher, a literature review was completed to define specific capabilities of each unit. For the capabilities of a cardiac monitor, the LifePak 12 and 15 were specifically researched, while the LifePak 1000 was researched for AED capabilities. Additionally, the local sales reps for both Physio-Control and Zoll Medical were interviewed. The purpose of these interviews were to determine what other options existed for equipment carried on ALS engine and rescue companies and the estimated cost of these options.

For the fourth research question, the information obtained about what equipment engine companies in other cities carry, how often the cardiac monitors carried on Columbus Fire engine and rescue companies are used and in what capacity, the financial comparison, and capability summary was compiled and presented to the Fire Chief and included in this paper.

Results

The literature review revealed that Columbus Division of Fire has a rich history in EMS, putting the first emergency squad in service in 1934. After the 1966 publication of the paper *Accidental Death and Disability: The Neglected Disease of Modern Society*, standards for ambulance services were established in the United States. The paper recommended that municipalities serve their communities by adopting ways and means of providing ambulance services consistent with the recommendations at the federal and state level (National Research Council, 1966, p. 35). The Columbus Division of Fire was one of the first EMS systems in the country, cooperating with the Ohio State University Medical Center to implement the Heartmobile in 1969. The Columbus Division of Fire operated a two-tiered EMS system until 1996, when they adopted an all ALS-system.

The all-ALS system necessitates a paramedic staff every engine company with ALS equipment and a cardiac monitor. Staffing for an ALS-engine seems fairly consistent across the country, meaning that it will at least have one paramedic. In Miami-Dade County, Florida an ALS-engine will have two paramedics (O. Fromata, personal communication, February 8, 2016).

An ALS-engine should have a paramedic and be capable of delivering ALS care, according to Dr. David Keseg, Medical Director for the Columbus Division of Fire. He stated procedures like intubation, defibrillation, and delivery of ALS medications was a must (D. Keseg, personal communication, February 12, 2016). At a recent staff retreat, the Fire Chief expressed concern about the engine companies losing the ability to perform synchronized cardioversion and pacing (K. O'Connor, personal communication, February 17, 2016). The American Heart Association (AHA) removed transcutaneous pacing from the asystole algorithm, and is only indicated for symptomatic bradycardia (ACLS Training Center, 2016, expression 5).

Dr. Brent Myers, former Medical Director for Wake County EMS agreed that ALS engines should have a paramedic and be able to deliver ALS care. He also pointed out that the ability to verify tube placement via EtCO2 should not be discounted.

The cardiac monitor carried on Columbus Division of Fire engine and rescue companies is the LifePak 12 cardiac monitor/defibrillator made by Physio-Control. Previously, engines and rescues carried LikePak 11s. The monitors on the engines and rescues are handed down from the ALS transport vehicles when new monitors are purchased. The transport vehicles carry LifePak 15s.

A survey was created using the SurveyMonkey website and sent to EFO students because they represent a diverse group of departments from all over the country. It was recognized that it would be beneficial to query similarly sized departments and those in close proximity to Columbus for comparison. Twenty responses were received. The first question following the demographic information asked the respondents if their departments operated paramedic (ALS) engine companies. Exactly half of the respondents answered ‘yes’, they did operate ALS-engine companies. Of the 10 cities who operated an ALS engine company, nine of the ten stated they have 12-lead capable monitors. Interestingly, two of the cities that do not have ALS engines carry 12-lead capable cardiac monitors. Eight of the twelve respondents carried Physio-Control LifePak cardiac monitors on their engine companies. The three follow-up questions sought to determine for what the monitors carried on engine companies are primarily used. Five of the ten ALS engine respondents stated their cardiac monitors were primarily used for obtaining vital signs. Two stated they were used to determine rate and rhythm. Two answered to obtain 12-lead ECG. One answered defibrillation was the primary use for their cardiac monitors.

After determining what was happening around the country, the history of the cardiac monitors carried on Columbus Division of Fire engine and heavy rescue companies were examined to determine how often and for what they were used. The original hypothesis was that the monitors are not used as often as they could be. The cardiac monitor on each of the 34 engine companies and five heavy rescue companies was examined to answer the second research question. Due to the way events drop out of the cardiac monitor's history, often the whole month of November could not be viewed. In most cases, 30 days worth of data was pulled from each monitor. In all, 39 monitors were examined for a total of 1176 days of accumulated data. Crews are required to perform a daily check on their equipment, including the cardiac monitor. Of the 1176 days, the monitor was checked by crews 1058 days, or 89 percent of the time. Crews ran seven cardiac arrests during the study period. A patient's vital signs were obtained using the LifePak 12, 250 times. The monitor was used 132 times to check a patient's heart rate and cardiac rhythm. Only twenty 12-lead ECGs were performed. Often times, crews will attach only the limb leads to take a look at a patient's ECG, viewing the heart basically in the vertical plane. Columbus Fire crews refer to this as a 'quick six'. It is a non-diagnostic view of the heart leads I, II, and III, as well as aVR, aVL, and aVF. Crews obtained a 'quick six' 22 times. The research conducted confirmed the hypothesis that crews do not use the cardiac monitors routinely.

Of the twenty 12-lead ECGs obtained by crews during the study period, two were found to be abnormal. This is of significance depending on how far behind the engine company's arrival the medic unit was. The first one was from Engine 21, who arrived at 12:05:49. The medic arrived on the run at 12:09:01. Assuming the time was correct on the cardiac monitor, the 12-lead was obtained at 12:11:21, after arrival of the medic. The second abnormal ECG was

from Engine 22. They arrived on their run at 10:52:13. A township medic arrived on the run at 10:54:55. The 12-lead ECG was obtained at 10:58:22, again assuming the time was correct on the cardiac monitor and again after arrival of the medic (A. Renner, personal communication, February 22, 2016).

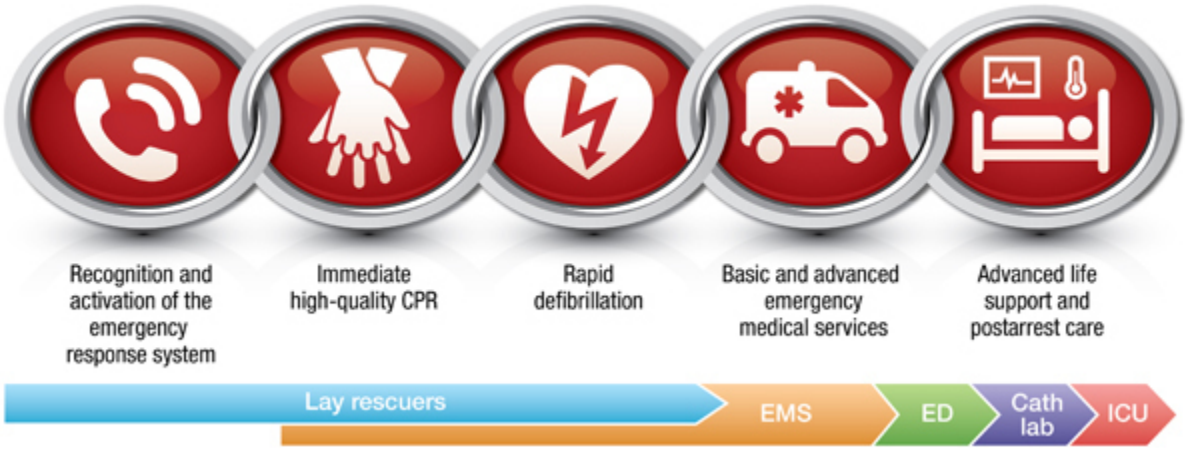
To answer the third research question, what are the capabilities of an AED compared to those of a LifePak 12 or other comparable cardiac monitor carried on fire apparatus, the user manuals of both products was researched. The LifePak 12 was emphasized because it was the one carried by CDF companies; no monitor brand preference was implied. Although those capabilities were well known to the researcher, a detailed description of both was included.

The LifePak 12 monitor/defibrillator is was first manufactured by Physio-Control in 1998. At the time of its release, it was a state-of-the-art piece of cardiac monitoring for use in the emergency or acute care setting. The monitor has five basic operating modes, two of them diagnostic or treatment modes and three service or training modes. The unit weighs approximately 18 pounds, including the batteries and is approximately 12.5in x 15.6in x 9.1in (Physio-Control, 2008, p. 8).

When the monitor is in AED mode, it is intended for use by providers with CPR and AED training on patients in cardiac arrest and the monitor has a manual mode, which provides normal operating capabilities for ALS users. Nine capabilities are at the disposal of the ALS user in the LifePak 12 in manual (normal) mode. Those capabilities are: defibrillation therapy, noninvasive pacing, 12-lead electrocardiography, SpO2 monitoring, NIBP monitoring, end-tidal CO2 (EtCO2) monitoring, invasive pressure monitoring, vital signs and ST monitoring, and ECG monitoring (Physio-Control, 2008, p. ix). Invasive pressure monitoring requires an invasive catheter system with a compatible transducer and is not an option on the monitors carried by

Columbus Division of Fire engine and rescue companies. The monitors do possess all other capabilities.

Defibrillation is the delivery of a brief, intense pulse of direct current to the heart muscle in an effort to terminate the potentially fatal dysrhythmias of ventricular fibrillation (v-fib) or symptomatic ventricular tachycardia (v-tach). When a patient is in cardiac arrest, defibrillation is a key component to increasing the chances of survival. According to the American Heart Association, defibrillation is one of the five links in the out-of-hospital chain of survival. Links in order are depicted below:



(AHA, 2015)

The monitor can be placed in synchronized mode, which time the electricity with the QRS complex for treatment of Atrial fibrillation, Atrial flutter, paroxysmal supraventricular tachycardia, and stable ventricular tachycardia (Physio-Control, 2008, p. xi).

Noninvasive pacing is the process of delivering electrical stimulus to the heart to cause cardiac depolarization and myocardial contraction (heart beat). It is typically initiated for a patient with symptomatic bradycardia (slow heartbeat) with a pulse (Physio-Control, 2008, p. xi).

A 12-lead electrocardiogram is a view of the heart's electrical impulses and their path through the myocardium used to identify, diagnose, and treat cardiac disorders including patients suffering acute myocardial infarction (Physio-Control, 2008, p. xi). It looks at the heart's electrical potential from 12 different angles through two planes, the frontal plane and horizontal plane.

SpO2 monitoring, also known as a pulse oximeter, is a noninvasive optical sensor that directs light through the patient's finger and measures the light received on the other side. This measures the saturation of oxygen in arterial blood. This can indicate if a patient is experiencing hypoxemia (Physio-Control, 2008, p. xii).

NIBP monitoring measures the blood pressure in the patient, and can be measured manually or can be set to recur at a predetermined interval (Physio-Control, 2008, p. xii). EtCO2 monitoring uses non-dispersive infrared spectroscopy to continuously measure the amount of carbon dioxide (CO2) exhaled with each breath (Physio-Control, 2008, p. xiii). The most common reason in the pre-hospital emergency setting to use capnography is to ensure that endotracheal tubes are correctly placed (Masimo, n.d., p. 2). Carbon monoxide levels can predict survivability in cardiac arrest as well as indicate severity of other health issues. A high EtCO2 level is referred to as hypercapnia and can indicate hypoventilation or acidosis. Hypercapnia along with low oxygen levels can indicate the potential for respiratory failure. A low EtCO2 level is referred to as hypocapnia, and can indicate hyperventilation, hypoperfusion, or hypothermia (Page, 2010, para. 13).

Finally, the LifePak12 allows the provider to track the patient's vital signs and ST segment measurements over a period of time. It also allows for recording of the ECG (Physio-Control, 2008, p. xiii).

Additional features on the LifePak 15 not included in the LifePak 12 are the ability to measure SpCO and SpMet. SpCO is the measurement of carbon monoxide present in the blood. CO is a colorless, odorless, poisonous gas contained in the fumes of equipment that burn fossil fuels (Centers for Disease Control and Prevention [CDC], 2015, para. 1). SpMet is the measurement of methemoglobin present in the blood. Methemoglobin results from the presence of iron in the ferric form instead of the usual ferrous form, which can result in a decreased availability of oxygen to the tissues (Denshaw-Burke, Kumar, Savior, Curran, & DelGiacco, 2016, para. 1). The LifePak 15 also has a CPR metronome, which produces audible ticks for timing CPR delivery.

In comparison, the LifePak 1000 can defibrillate in AED mode and can allow the provider to monitor the ECG of patients for the purpose of rhythm recognition and rate determination (Physio-Control, 2008, p. vi).

Linda Gleaves has been the Senior Sales Rep for Physio-Control for pre-hospital sales in the central Ohio area for more than 36 years. She stated new cardiac monitors, with trade-in allowance for old ones, would fall somewhere between $23 and $25,000 each. The cost of a new LifePak 1000 would be about $2,000/each. The Division of Fire would not be eligible to trade in LifePak 12s for LifePak 1000s (L. Gleaves, personal communication, February 7, 2016). The Division could also purchase new LifePak 15s for the engines without the ability to obtain a 12-lead ECG, but having most of the other features, for about $14,000/each.

There is no contract requiring the city to purchase cardiac monitors from Physio-Control. Zoll Medical sells a variety of different monitors, including the X Series, Propaq M and MD, and different AEDs. The Zoll X Series cardiac monitor/defibrillator has the ability to do the following: defibrillation therapy, noninvasive pacing, 12-lead electrocardiography, SpO2

SpCO2, and SpMet monitoring, NIBP monitoring, end-tidal CO2 (EtCO2) monitoring, invasive pressure monitoring, vital signs and ST monitoring, temperature monitoring, and ECG monitoring. The X series also provides real-time feedback on the quality of CPR, encouraging users to increase depth of compressions or adjust rate of compressions as necessary (Zoll Medical Corporation [Zoll Medical], 2015, p. 1-9). Zoll Medical could also provide X Series monitors without the ability to obtain a 12-lead ECG, but contain the other desired abilities, for approximately $10,000/each with trade-in of the LifePak 12s. A Zoll AED is approximately $2000/each (B. Van Bourgondien, personal communication, February 19, 2016).

Discussion

The Columbus Division of Fire was one of the first EMS systems in the United States, even prior to the publication *Accidental Death and Disability: The Neglected Disease of Modern Society*. This rich history started with Heartmobile in 1969 and continues to today. The current all-ALS EMS system was adopted in 1996, placing a paramedic on every engine company and two on every EMS transport vehicle. To answer the first research question, the engines and rescues in Columbus carry a compliment of ALS equipment, including a LifePak 12. The transport vehicles carry LifePak 15s. Battalion chiefs, the deputy chief, and even EMS field supervisors do not carry a defibrillator of any kind. New cardiac monitors are being considered for purchase at an estimated cost of $23 and $25,000 each. Ten new LifePak 1000s could be purchased for the cost of just one LifePak 15. The survey distributed revealed that ALS engines, although commonplace around central Ohio, are not necessarily the standard across the country. Ten of the twenty respondents stated they also operate ALS-engine companies. The majority of cities who operate ALS engines carry 12-lead capable monitors. Physio-Control supplies the share of those; about 66% of respondents carry their brand of monitor.

The second research questions revealed that Columbus Division of Fire does not routinely track how often, or for what, the monitors on its engine and rescue companies are used. After performing a review, it was discovered they are not used much. During an approximately 30-day period between November 30 and December 8, a total of 1176 days of accumulated data were reviewed. Crews failed to even perform a daily check on the monitor eleven percent of the time. The monitor was used on a patient in cardiac arrest seven times. It was used to take vital signs 250 times. A patient's rate and rhythm were checked just 132 times. Crews only ran 20 12-lead ECGs, two of which showed a possible ST-elevation MI. During the month of November, Columbus Division of Fire took an average of 130 ALS run calls per day. Depending on if a medic was dispatched with the engine, which arrived first, and how long the engine might have been on the scene without the medic there could be a lot of opportunity to use a cardiac monitor.

Many of the respondents surveyed also did not know how often their cardiac monitors were used. Results from the survey mirrored Columbus Fire's use of the monitors. Five of them answered that they believed that their cardiac monitors were primarily used for obtaining vital signs. Two stated they were used to determine rate and rhythm. Two answered to obtain 12-lead ECG. One answered defibrillation was the primary use for their cardiac monitors.

The third research question revealed that LifePak 12 monitor/defibrillator carried by CFD engines and rescues has many capabilities including, defibrillation, pacing, 12-lead ECG, SpO2, NIBP, and EtCO2 monitoring, vital signs, ST segment, and ECG monitoring. One of the most critical capabilities of the monitor is defibrillation, the delivery of an intense shock to the heart muscle in an effort to terminate v-fib or v-tach. This is the AED's primary function, and no difference in ability or additional benefit exists by carrying a LifePak 12 over an AED. The

LifePak12 displays the patient's rate and rhythm on the screen, also an ability included on the LifePak 1000 with ECG display. Crews used the LifePak 12 approximately 250 times to check the vital signs of a patient. Although it can obtain an accurate pulse rate and blood pressure, crews should be obtaining a set of vital signs manually per Division Standard Operating Procedures (Columbus Fire, SOP 07-01-01).

The LifePak 12 does have capabilities that the LifePak 1000 does not, many of which could be of benefit to a patient. Eighteen times the LifePak 12 was used to obtain a 12-lead ECG of a patient experiencing cardiac symptoms. Two of these times the cardiac monitor revealed a potential heart attack. There's a common saying in EMS, "treat the patient, not the monitor". However, several studies have shown that pre-hospital recognition of STEMI can significantly reduce (first medical contact) FMC-to-balloon times, or the time from STEMI recognition to reperfusion therapy (Mumma, Kontos, Peng, & Diercks, 2014, p. 915). Transmission of the ECG to the hospital is a significant component of that success, however the engines and rescues do not have the capability to transmit the ECG from their LifePak 12s. A review of chest pain runs for October through December 2015 for the Division of Fire revealed the engine and medic arrived virtually simultaneously. The dispatch to arrival time was 5:14 for engine companies and the 5:33 for medic crews (A. Renner, personal communication, February 19, 2016). When the time is longer, options exist to reduce the time to treatment.

One option to cut the time down from engine company arrival to 12-lead ECG is being explored in Wake County, NC. There the countywide EMS service often runs with engine companies from multiple fire departments. In one district, engine companies were given just the ECG cables to apply to the patient, and upon arrival of the medic vehicle the cables simply had to be plugged in. The experiment showed some promise, according to Brent Myers. He stated

arrival to 12-lead acquisition times improved from 12 minutes for those companies without the cables to 6.5 minutes with cables (B. Myers, personal communication, February 12, 2016).

The pulse oximeter is part of a complete assessment of a patient's oxygenation, and LifePak 12s have the ability to measure the SpO2, or pulse oxygenation level. Obviously if the engines and rescues no longer carry a LifePak, they will not be able to obtain this measurement without additional expense of purchasing hand-held unit. Hand-held pulse oximeters cost anywhere from $40 to $600 depending on the model chosen.

Other capabilities, such as cardioversion, pacing, and EtCO2 monitoring will also not be available without a 12-lead ECG. The Fire Chief expressed concern over losing these abilities. As show by the research, an ALS transport vehicle is on average only 20 seconds behind the engine when arriving first.

Recommendations

The purpose of this evaluative research was to determine what cardiac monitoring equipment was carried on Columbus Division of Fire engine and rescue companies as well as determine how often and in what capacity that equipment was used. It was also necessary to determine how other departments around the country staffed their engine companies and what those departments carry. After review, the cardiac monitors on engine and rescue companies are not used frequently and they are not used to their full potential. This is probably because of proximity of ALS transport vehicles. The information collected was given to the Fire Chief in a recent staff retreat, along with the suggestion that, instead of new LifePak 15s for engines and rescues, the Division would get more mileage out of giving all marked Division vehicles defibrillation capabilities. Purchasing 60 LifePak 1000 AEDs or similar device with the optional ECG display would cost the Division approximately $132,000 compared to $700,000 for 29 new

LifePak 15s for the engines and rescues and give approximately 30 more vehicles defibrillation capability and save the city $568,000. This would improve the Division's capability to save lives consistent with the U.S. Fire Administration's strategic goal #2, "Improve local planning and preparedness" and goal #3, "Improve the fire and emergency services' capability for response to and recover from all hazards" (USFA, 2010-2014, p. 14) and the mission of the Division of Fire, "minimizing injury, death, and suffering by providing timely and effective emergency medical service" (Columbus Division of Fire, 2005, p. 3). The recommendation is contingent on the current apparatus placement and staffing model. It was recommended that the Fire Chief approve the proposal and forward up to Finance and the Safety Director's office for consideration.

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Appendix A

Engine Company Cardiac Monitor Use

Apparatus	Days checked	Days not checked	Cardiac arrests	V/S	Rate and Rhythm	12-lead ECG	Quick 6
Engine 1	27	3	0	2	3	0	1
Engine 2	29	1	0	21	13	2	2
Engine 3	27	3	0	13	3	0	1
Engine 4	28	2	0	6	4	0	1
Engine 5	29	1	1	11	8	1	0
Engine 6	29	1	0	21	13	2	2
Engine 7	25	6	0	4	3	0	0
Engine 8	28	2	1	11	7	0	2
Engine 9	29	2	0	4	2	0	1
Engine 10	30	0	0	15	3	0	0
Engine 11	28	2	0	4	3	0	0
Engine 12	25	5	1	10	6	2	2
Engine 13	26	4	0	4	2	0	0
Engine 14	27	4	0	4	5	1	1
Engine 15	28	2	0	17	7	0	1
Engine 16	28	2	0	13	10	0	0
Engine 17	28	1	1	15	6	1	1
Engine 18	26	4	1	7	4	0	0
Engine 19	29	1	0	3	1	0	0
Engine 20	27	3	0	3	1	0	0
Engine 21	24	7	0	2	1	2	0
Engine 22	27	3	0	6	1	3	0
Engine 23	28	2	0	11	4	0	0
Engine 24	24	0	0	10	7	1	3
Engine 25	25	5	0	1	0	0	0
Engine 26	30	1	1	3	2	0	0
Engine 27	28	3	0	3	1	1	0
Engine 28	25	5	0	4	3	0	0
Engine 29	26	4	0	3	1	1	1
Engine 30	23	7	0	0	0	1	0
Engine 31	30	4	0	5	1	1	0
Engine 32	28	2	1	7	4	0	1
Engine 33	29	1	0	2	1	1	1
Engine 34	30	0	0	1	0	0	0
	Days checked	**Days not checked**	**Cardiac arrests**	**V/S**	**Rate and Rhythm**	**12-lead ECG**	**Quick 6**
Totals	930	93	7	246	130	20	21

Appendix B

Rescue Company Cardiac Monitor Use

Apparatus	Days checked	Days not checked	Cardiac arrests	V/S	Rate and Rhythm	12-lead ECG	Quick 6
Rescue 2	21	9	0	0	1	0	0
Rescue 4	26	5	0	1	1	0	0
Rescue 11	27	4	0	1	0	0	0
Rescue 16	26	5	0	0	0	0	1
Rescue 17	28	2	0	2	0	0	0
	Days checked	**Days not checked**	**Cardiac arrests**	**V/S**	**Rate and Rhythm**	**12-lead ECG**	**Quick 6**
Totals	128	25	0	4	2	0	1

Appendix C

Survey Results (ALS engine companies)

City	Type of monitor	Brand of 12-lead ECG	Tracked?	How Often?	Primary Use
Burnsville, MN	12-lead capable	Physio-Control	No	Several/month	Obtaining VS
Albuquerque	12-lead capable	Physio-Control	Yes	Several/week	Obtaining VS
Columbia	12-lead capable	Physio-Control	Yes	Unknown	Defibrillation
Norfolk	12-lead capable	Phillips MRx	Yes	Unknown	See note
Amerst, MA	12-lead capable	Physio-Control	Yes	Once/month	12-lead ECG
Newark, OH	12-lead capable	Physio-Control	Yes	Several/week	Rate and rhythm
HENRICO County	12-lead capable	Phillips MRx	Yes	Several/week	Obtaining VS
Eugene/Springfield	Monitoring only	Zoll E-Series	Yes	Several/week	Obtaining VS
Ventura	12-lead capable	Physio-Control	No	Unknown	Rate and rhythm
Cincinnati	12-lead capable	Physio-Control	No	Several/week	12-lead ECG

Appendix D

Engine and Medic Dispatch to Arrival Times

Per Month		
Month	Unit Type	Average Disp to Arv
Oct	E	0:05:12
Oct	M	0:05:36
Nov	E	0:05:18
Nov	M	0:05:35
Dec	E	0:05:11
Dec	M	0:05:29

Oct 1 - Dec 31	
Unit Type	Average Disp to Arv
E	0:05:14
M	0:05:33