AUTOPULSE RESUSCITATION SYSTEM

Automatic CPR Machine

Abstract

The provision of cardiac chest compressions in the pre-hospital environment poses unique challenges to Paramedics and firefighters. Overcoming safety issues for both the providers and the patient while improving the quality and consistency of cardiac chest compressions are achievable, measurable outcomes realized with this product.

Cauthers, Chris
ccauthers@winnipeg.ca

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AutoPulse Resuscitation System

Executive Summary

The Winnipeg Fire Paramedic Service responds to approximately 1100 cardiac arrest patients every year. Each patient is assessed using specific criteria to determine if resuscitation is required, if resuscitation is discontinued at the scene or if transport to hospital while resuscitating is required. On average, 500 patients in cardiac arrest will require transport to hospital each year. Each of these involves egress from the scene and a lights and sirens transport to hospital. Both of these phases of patient care present challenges that are unique to the pre-hospital environment.

During egress to the ambulance, meeting the standards set for CPR is an often arduous task. The patient must be carried around corners, up and down stair cases, into elevators and down narrow hallways. Outside, Paramedics and firefighters contend with snow banks, ice, mud, river banks and uneven terrain. Often, CPR must be paused while obstacles are crossed to ensure the safety of all crew members. During transport to hospital, at least one Paramedic or firefighter is required to stand up while unrestrained in the patient compartment to provide chest compressions. Traffic conditions, cornering, braking, acceleration, deceleration and road conditions all affect the ability to provide consistent compressions for the patient and cause safety concerns for the provider who is standing.

The American Heart Association (AHA), the International Liaison Committee on Resuscitation (ILCOR) and the European Resuscitation Council (ERC) all stress the importance of high quality, uninterrupted chest compressions as being critically important for survival from sudden cardiac arrest. This statement has been reaffirmed by each of these committees for over a decade. Current data suggests that within the pre-hospital environment, and due to the previously mentioned barriers, it is difficult to perform adequate resuscitation to the levels specified by the AHA, ILCOR and ERC. As a result, survivability rates may be affected.

AutoPulse Resuscitation Systems are currently in use in multiple jurisdictions through Canada, the United States and overseas and the addition of this equipment to the Winnipeg Fire Paramedic Service (WFPS) will have the following benefits:

Improved Paramedic, Firefighter and Patient Safety

By implementing this product, the chances and opportunities for patient injury during egress from the scene to the ambulance can be lessened. By reducing the number of personnel in the patient compartment of the ambulance during transport, the overall risk of lost-time injury claims can be reduced. Finally, and perhaps most importantly, a seat-belted location for each Paramedic or firefighter in the patient compartment of the ambulance can be assured.

Increased Availability of Emergency Crews

During a cardiac arrest, Paramedics and firefighters work together to ensure appropriate patient care is provided. This method often reduces service capacity within WFPS as the firetruck needs to be out of service for medical and/or fire calls while the patient is being transported to hospital. The addition of the AutoPulse will reduce the frequency and duration of these out of service events by allowing personnel to be redeployed back to the firetruck and remain response ready.

Time Savings

The efficient use of time, devoted to issues that are strategic in nature, is vitally important to ensure success. Issues related to long term safety of employees and clients falls firmly into this category. The potential time savings that may be realized from the use of this new equipment will lead to increased efficiency for administrative officers and Return to Work Coordinators. The process to deal with this potential safety issue will be streamlined resulting in significant time savings.

Improved Patient Survivability

According to the research (see evidence section), consistent, high-quality chest compressions at the appropriate depth and rate and with minimal interruptions are critical for improved patient survivability. The compression rate of the AutoPulse Resuscitation System, which is set to 80 compressions per minute, is compliant with the 2015 AHA and ERC Guidelines. Its rate of 80 compressions per minute has been proven to improve blood flow to the heart and brain, increase aortic pressure, as well as coronary perfusion pressure when compared to manual CPR. By using the AutoPulse, WFPS will be able to improve compression quality dramatically and ensure that CPR fraction remains well above the recommended minimum of 60%.

Reduced Task Loading

Paramedics and firefighters use a choreographed approach that accomplishes multiple steps and assessments simultaneously rather than sequentially. This product will remove the task load from two providers that rotate through providing

chest compressions allowing personnel to assist with other important tasks at the emergency.

Decreased Crew Fatigue

According to research (see evidence section), it is recommended that CPR providers change over about every two minutes to prevent a decrease in compression quality due to CPR provider fatigue. Changing positions in a moving ambulance is inherently risky and will result in an interruption in chest compressions. The AutoPulse will eliminate both the compression quality issue and the risk associated with changing positions.

Improved Working Conditions

The City of Winnipeg will benefit tremendously from the elimination of risk of injury since absenteeism, reduced productivity, corresponding WCB payments and other health-related costs are reduced. In addition, a decrease in reliance on overtime budgets is likely to follow.

Cost Effectiveness

WFPS currently recertifies its Paramedics and firefighters in manual CPR on a regular basis and this practice will continue regardless if the AutoPulse is purchased. The AutoPulse will provide consistent, quality compressions on all ambulances reducing the need for an expensive, time-consuming review and follow-up program for manual CPR. When looked at over time, an investment in the AutoPulse will be more cost-effective than an expensive, on-going CPR review and follow-up program where it will be difficult to achieve the same results.

Amount of Funding Requested

Item Description	# Required	Unit Cost	Total Cost
Auto Pulse	1	$11,280.87	$11,280.87
Battery	4	$846.45	$3,385.80
Battery Charger	1	$1,841.67	$1,841.67
Back Pack	1	$405.27	$405.27
Soft stretcher	1	$132.35	$132.35
		Total Per Ambulance:	$17,045.96
[24]		Total for fleet (24 ambulances):	$409,103.04
Central Battery Charger	2	$1,841.67	$3,683.34
Central Battery	4	$846.45	$3,385.80
Spare AutoPulse	2	$11,280.87	$22,561.74
		Total Proposal Cost:	$438,733.92

Cost/Benefit Analysis

Cost

The total cost of $438,733.92 will equip seventeen 24-hour ambulances and seven 12-hour ambulances for an expected life span of at least 5 years. The amount will also provide redundancy in the system with 2 spare AutoPulse systems. This equates to $87,744.58 per year. The yearly amount is roughly equivalent to the annual salary of a Paramedic or Firefighter-Paramedic provider.

Cost Recovery

In the event of an injury, self-insured employers like the City of Winnipeg pay 100 per cent of their actual costs of claims, as well as administration fees to the WCB for managing claims. At a minimum WFPS will pay the salary of the injured employee, but this amount does not take into consideration the staff required to cover the injured employee's shifts or other incidentals required for the injured employee's recovery. Often, overtime staff members are required to cover the absences which result from workplace injury.

After analyzing the injury statistics related to providing chest compressions, data indicates that from August 19, 2011- August 19, 2016 there have been 81 reports of injury or exposure during the provision of CPR. Implementation of the AutoPulse will reduce the potential for injuries related to providing chest compressions or from lifting/handling of the patient receiving chest compressions, so the reports not directly related to those criteria were eliminated. Of the 43 reports remaining, 12 were lost time injuries totaling 924.5 hours. Additionally, backfilling was required for 156 hours at double time for a total of 1236 hours. In monetary terms, this is approximately $50,000.

The risk of such injuries remains high as long as WFPS continues to perform CPR in the conventional manner. Paramedics and firefighters are obligated to provide appropriate care wherever it is required and this includes standing up in the patient compartment of a moving ambulance while providing chest compressions. The potential is that the City of Winnipeg could end up paying over three (3) hours for each one (1) hour of injury time.

Compared to an in-house manual CPR review and follow-up program for all WFPS providers, the purchase of the AutoPulse represents a cost-effective alternative with consistent, reproducible results for all Paramedics and firefighters.

Project Description

WFPS began a 6-month trial of this product on August 22, 2016 to test its ability to perform under Winnipeg conditions. WFPS is deploying the AutoPulse on four (4) Medical Supervisor units during the trial to ensure that appropriate and complete data is collected while incurring the least cost possible. The Medical Supervisors operate out of a chase car enabling them to assign to the cardiac arrest calls within their districts. WFPS dispatch procedures have been altered to include a mandatory notification to a Medical Supervisor for all cardiac arrest calls and all Medical Supervisors have received training from the project lead or from a subject matter expert brought in by Zoll Medical.

The intent of this trial is to prove viability in Winnipeg with the goal of placing one AutoPulse device on each ambulance deployed within the City of Winnipeg. Utilizing the AutoPulse on all ambulances in the system will ensure that every patient served by WFPS receives improved quality and consistency of the chest compressions provided and it will reduce the interruptions in effective chest compressions which together have been associated with improved patient survivability.

During the implementation trial, WFPS will track data through the Zoll X-Series cardiac monitors which are currently in use within the department. The same performance indicators that were used in the pre-trial phase will be tracked to ensure an accurate comparison of the different methodologies. The results are expected to be similar to other regions in Canada, the USA and abroad; specifically, improved safety for Paramedic and firefighter employees, a reduction in potential lost-time injuries, improved CPR fraction and quality, and improved adherence to AHA, ILCOR and ERC standards. Together, these may lead to improved patient outcomes.

Pre-Trial Data

The Winnipeg Fire Paramedic Service (WFPS) is committed to providing patient care and resuscitation to the standards of evidence based medicine. In the evaluation of cardiac arrest calls, the standards and guidelines of the American Heart Association (AHA), the International Liaison Committee on Resuscitation (ILCOR) and the European Resuscitation Council (ERC) were utilized.

Through the WFPS service quality department, and utilizing Zoll's "See-Thru" CPR technology, the effectiveness and adherence to the current performance indicators for manual chest compressions were reviewed.

Current data suggests that within the pre-hospital environment, it is difficult to perform to the levels specified by the AHA, ILCOR, and the ERC. Factors such as patient location within a residence, lifting/moving of a patient, provider fatigue, weather conditions, terrain, road and traffic conditions and others become a barrier to performing chest compressions at the rate, depth and consistency required to meet the current standards.

Using Zoll's Code Review Software, the WFPS Service Quality Department was able to review cardiac arrest data for all of 2015 and up to August 15, 2016 for patients (137 total) whose initial presenting rhythm was Coarse Ventricular Fibrillation or Fine Ventricular Fibrillation. This subset of cardiac arrest calls was chosen as these patients will respond most positively to CPR and defibrillation. The following performance indicators were assessed and the average results are below:

Total time in compressions	10 minutes and 31 seconds
Total time not in compressions	2 minutes and 54 seconds
CPR fraction (from above)	74.05%

Compressions within target depth (2-4”)	44.66%
Compressions below target depth (too shallow)	55.16%
Compressions above target depth (too deep)	0.18%
Compressions within target rate (99-110 cpm)	8.96%
Compressions below target rate (too slow)	13.59%
Compressions above target rate (too fast)	77.45%
Compressions in target range for depth and rate	5.27%

These statistics indicate that when Paramedics and firefighters manually perform chest compressions while at the scene and during transport, they are spending approximately 2 minutes and fifty four seconds during the event without providing chest compressions. When they are providing compressions, the appropriate compression depth is achieved only 44.66% of the time and the appropriate rate is being achieved only 8.96% of the time. Looking at both the rate and depth quality factors together gives an overall quality measure of 5.27% when both the rate and depth were within current standards. An argument could be made that a faster rate is beneficial to the patient based upon some recent studies, and the ERC 2015 guidelines now recommend that rates between 100 and120 are appropriate. Unfortunately, the data cannot be broken down to find out what the actual compression rates were for each call so to include the “compressions above target rate” data as being “within the target range” would not provide valid results.

Initial Trial Data

Before the initial trial data is presented, a few points of clarification are required.

The AutoPulse does not compress to a standard depth as required in manual chest compressions. Rather, the AutoPulse measures the thickness of the chest and compresses to 20% of that depth. The AutoPulse also works its way up to the 20% over several compressions (i.e. 14%, 16%, 18%, and then 20%) instead of starting right at 20%. In other words, the chest compressions delivered by the AutoPulse are “tailored” to the individual. What this means is that a high compliance percentage within the depth criterion is expected.

In regards to rate, the AutoPulse compresses at a constant rate of 80 compressions per minute and works on a 50% duty cycle. This means that 50% of the time the chest is under compression and 50% of the time the chest is not under compression. Again, a high compliance percentage within the rate criterion is expected.

The data collected during resuscitation is facilitated through an accelerometer placed on the patient's chest which measures up and down movement. During manual CPR, the compression is at 90 degrees to the patient and the accelerometer yields very good data. During AutoPulse compressions, the compression is circumferential and this has caused some unexpected outlier data points to be included in the data (too fast and too slow). What is clear is that the issue is not with the AutoPulse – it is providing chest compressions at 80 per minute and at the appropriate depth for the patient. The AutoPulse is smart enough to know if the compression rate deviates from 80 or if the depth does not reach 20%. If either of these circumstances were to occur, the AutoPulse would automatically stop providing chest compressions and give a user advisory message. Undoubtedly, and this is confirmed with Zoll Medical, the issue is with the accelerometer data obtained through the software. Although WFPS is confident that the AutoPulse is providing the correct rate and depth for cardiac arrest patients close to 100% of the time, it would not be factual to exclude the actual data obtained. The inclusion of these outliers has negatively skewed the data and WFPS is working to rectify the issue with Zoll Medical on a go-forward basis. Despite the fact that the data includes unexpected outliers, the quality of chest compressions has still improved dramatically from 5.27% to 54.98%, and the CPR fraction has also improved from 74.05% to 79.0%

Total time in compressions	18 minutes and 36 seconds
Total time not in compressions	3 minutes and 49 seconds
CPR fraction (from above)	79.00%
Compressions within target depth (1-4")	97.69%
Compressions below target depth (too shallow)	2.30%
Compressions above target depth (too deep)	0.01%
Compressions within target rate (70-90 cpm)	56.00%
Compressions below target rate (too slow)	16.56%
Compressions above target rate (too fast)	27.45%
Compressions in target range for depth and rate	54.98%

It should also be noted that over the twelve (12) deployments of the AutoPulse during the trial; three (3) patients have had a return of spontaneous circulation (ROSC) in the field.

Benefits for the City of Winnipeg

Improved Paramedic, Firefighter and Patient Safety

By implementing the AutoPulse, Paramedic and firefighter safety can be improved in a few ways. By utilizing the soft stretcher included with this device, it will be easier for crews to carry the patient thereby substantially reducing the risk of Paramedic or firefighter injury. Multiple handles and carry points exist to ensure a good grip on the patient allowing the provider to focus more on personal safety issues as they arise (i.e. terrain, stairs etc.). Reducing the number of personnel in the patient compartment of the ambulance during transport will also improve safety. The ability to have fewer personnel in the patient compartment of the ambulance, subjected to increased risk of death or injury is a substantial benefit to the City of Winnipeg as it reduces the overall risk of lost-time injury claims. Finally, a seat-belted location for each provider in the patient compartment can be assured by utilizing the AutoPulse. The Paramedics and firefighters in the patient compartment are able to better secure themselves and still have adequate movement capabilities to provide patient care. The current reality is that the chest compressor is not able to utilize a seat belt restraint. Keeping employees safe by providing a safe work environment must be a high priority.

Patient safety is also an important benefit to consider. By utilizing the soft stretcher included with this device, it is easier for crews to carry the patient thereby substantially reducing the risk of dropping the patient while providing continuous chest compressions. This will reduce the risk of litigation against the City of Winnipeg. The pre-trial data shows that chest compressions are only within target range 5.27% of the time – too deep risks injury to the patient; too shallow provides ineffective perfusion to the brain. Chest compressions have an inherent risk of injuring the patient - broken ribs and lacerated organs are known complications of manual chest compressions. To combat this, the squeezing pressure delivered by the AutoPulse's Load Distributing Band (LDB) during chest compressions was designed to be 50% lower than the reported threshold for chest compression related patient injuries. It is extremely difficult and possibly injurious to the patient to provide manual chest compressions during egress under non-ideal conditions. The AutoPulse will significantly improve the way that resuscitation is provided to the citizens of Winnipeg.

Increased Availability of Emergency Crews

Currently during a cardiac arrest, the Paramedic unit will require the services of two members of the responding firetruck to assist during transport to the hospital. This

will necessitate removing the firetruck from service for fire and medical calls until the ambulance transfers care to the hospital staff. By using the AutoPulse, the number of firefighter members committed to any specific cardiac arrest can be reduced and redeployed back to their apparatus to make it response ready for fire calls during the ambulance transport. In some cases, dependent upon which resources attend, such as training units, it is possible that both firefighters can be redeployed back to their apparatus to make it response ready for fire and medical calls. Ensuring capacity within WFPS is very important and both of these options will improve the level of service that can be provided to the citizens of Winnipeg without increasing staffing levels.

Time Savings

The efficient use of time, devoted to issues that are strategic in nature, is vitally important to ensure success. Issues related to long term safety of employees and clients falls firmly into this category. The potential time savings that may be realized from the use of this new equipment will lead to increased efficiency for administrative officers and Return to Work Coordinators. The process to deal with this potential safety issue will be streamlined resulting in significant time savings.

Improved Patient Survivability

According to the research (see evidence section), consistent, high-quality chest compressions at the appropriate depth and rate and with minimal interruptions are critically important for patient survival. By using the Zoll AutoPulse, WFPS will be able to improve CPR fraction. Currently manual chest compressions are provided 74.05% of the time, but only 5.27% of those compressions meet the rate and depth criteria recommended by the AHA, ILCOR and ERC. In short, the CPR provided by WFPS does not meet the current standards and there is much room for improvement. While CPR fraction is currently at an acceptable level, the quality of chest compressions is where the greatest improvement can be realized through the AutoPulse. The AutoPulse has been proven to improve blood flow to the heart and brain, increase aortic pressure, as well as coronary perfusion pressure when compared to manual CPR. All these factors contribute to increased patient survival.

Reduced Task Loading

Paramedics and firefighters use a choreographed approach that accomplishes multiple steps and assessments simultaneously rather than sequentially. The AutoPulse will remove the task load from two providers that rotate through delivering chest compressions and will provide for extra room around the patient to provide therapies and interventions critical for patient survival. The extra room allows those

interventions to be performed more easily and without disrupting the critically important provision of chest compressions.

Decreased Crew Fatigue

According to the ERC guidelines, “Several manikin studies have found that chest compression depth can decrease as soon as two minutes after starting chest compressions. An in-hospital patient study showed that, even while using real-time feedback, the mean depth of chest compressions deteriorated between 1.5 and 3 min after starting CPR. It is therefore recommended that CPR providers change over approximately every two minutes to prevent a decrease in compression quality due to CPR provider fatigue. Changing CPR providers should not interrupt chest compressions.” The pre-trial data shows that depth of compressions is an area that needs improvement even though WFPS rotates providers and uses the real-time feedback as suggested in the study.

Changing positions in a moving ambulance is inherently risky and will result in an interruption in chest compressions. This is due to the number of providers required in the patient compartment to perform manual chest compressions and with the constant movement occurring during ambulance transport. Space is at a premium in the patient compartment of the ambulance, making the change more difficult. The AutoPulse will eliminate this problem entirely.

Improved Working Conditions

Improving the conditions in which Paramedics and firefighters are required to work will lead to improvements in employee morale and happiness. The City of Winnipeg will benefit tremendously from having healthy and happy employees since absenteeism, reduced productivity and other health-related costs are reduced. In addition, a decrease in overtime usage is likely to follow.

Cost Effectiveness

WFPS currently recertifies its Paramedics and firefighters in manual CPR on a regular basis and this practice will continue regardless if the AutoPulse is purchased. Clearly there is an identified need to improve the quality of the manual CPR (pre-trial data) delivered by WFPS staff and, in addition to the training received, this should involve a review and follow-up program to ensure that providers are meeting standards. This type of program would involve retrieving and analyzing data for each cardiac arrest, determining where the issues lie and addressing them with the provider. The AutoPulse will provide consistent, quality compressions on all cardiac arrests reducing the need for a review and follow-up program for manual CPR. When looked at over time, an investment in the AutoPulse will be more cost-effective

than a time consuming, on-going CPR review and follow-up program where it will be difficult to achieve the same results.

Conclusion

In conclusion, the AutoPulse is a device that provides consistent chest compressions in all circumstances encountered within the pre-hospital environment while maintaining compliance with the current standards of care. The Auto Pulse will provide the consistency that the citizens need, and will contribute to improved patient survivability while reducing the potential for and actual lost-time injuries sustained by Paramedics and firefighters during the provision of chest compressions. The AutoPulse will significantly enhance the service provided to the community and the customers that are served. This will also be a huge step forward to improve the way in which City services are delivered.

Evidence

To provide a better understanding of how the AutoPulse will improve the provision of chest compressions, the following three-minute video shows a side-by-side comparison of manual chest compressions and the AutoPulse in a moving ambulance.

https://www.youtube.com/watch?v=6kwr6tqzcfA

The 2015 AHA, ERC and ILCOR guidelines suggest that mechanical compressions are a reasonable option in situations where it might be difficult, dangerous, or impossible to sustain high quality manual CPR. As described, these are the situations WFPS works in.

The evidence that informs these guidelines varies widely. Individual studies cover a range of design, purpose, quality, and applicability to the prehospital context in general, and to Winnipeg in particular. Because of the inherent difficulties of conducting research outside of hospitals, few studies can be rated as high quality; some assess a different style of device than the one under consideration. The selection of evidence cited below represents some of this diversity and includes

contradictory results. This selection highlights the difficulty that guideline authors face when reducing a heterogeneous body of research to blanket recommendations. Although the existing research has limitations, and although more studies are suggested, the consensus of experts in the field supports the use of these devices in prehospital environments.

- AutoPulse Guideline Compliant Letter: *A growing body of evidence suggests that the AutoPulse Resuscitation System improves blood flow as well as short and long term survival. When the AutoPulse was designed, the 80 compressions per minute rate that the device is currently set to was **targeted to achieve improvements in multiple clinical outcomes (i.e. hemodynamics, ROSC, etc.)** when compared to manual CPR and piston-driven mechanical CPR devices, which have since been **clinically proven** with the AutoPulse. The 2015 AHA Guidelines also gives the AutoPulse a Class IIb rating (benefit > risk), which is the same rating given to all mechanical chest compression devices in the Guidelines; its rate of 80 compressions per minute has been **proven to improve myocardial flow, cerebral flow, aortic pressure, as well as coronary perfusion pressure when compared to manual CPR.***

- Summary of Mechanical CPR Research (2013):

  - *Compared with resuscitation using manual CPR, a resuscitation strategy using Load Distributing Band (LDB)-CPR on EMS ambulances is associated with **improved survival to hospital discharge** in adults with out-of-hospital non-traumatic cardiac arrest.*

  - *Patients treated with mechanical chest compressions during transport are **more likely to be resuscitated** during transport compared with patients receiving manual chest compressions presumably due to improved chest compression quality during transport.*

  - *The AutoPulse may **improve the overall likelihood of sustained ROSC (RETURN OF SPONTANEOUS CIRCULATION)** and may particularly benefit patients with non-shockable rhythms.*

- *In patients with out-of-hospital CA, the use of AutoPulse is associated with an increased diastolic BP compared to manual chest compressions.* ***While its benefit to survival has yet to be demonstrated, the increase in diastolic and mean BP is a promising outcome for AutoPulse use.***

- *Use of an automated LDB-CPR device as implemented in this study was* ***associated with worse neurological outcomes and a trend toward worse survival than manual CPR.*** *Device design or implementation strategies require further evaluation.*

- AHA Journal 2002: *Mouth-to-mouth ventilation performed by single layperson rescuers produces substantial interruptions in chest compression–supported circulation.* ***Continuous chest compression CPR produces greater neurologically normal 24-hour survival than standard ABC CPR when performed in a clinically realistic fashion.*** *Any technique that minimizes lengthy interruptions of chest compressions during the first 10 to 15 minutes of basic life support* ***should be given serious consideration*** *in future efforts to improve outcome results from cardiac arrest*

- *In their respective guidelines for 2005, for CPR in emergency cardiac care, both the American Heart Association (AHA) and European Resuscitation Council (ERC) stress the importance of* ***high quality, uninterrupted chest compressions as being critically important for survival from sudden cardiac arrest****. The AHA document specifically states "simply put push hard, push fast, allow full chest recoil, and minimize interruptions in compressions.* ***LDB may be considered for use by properly trained personnel as an adjunct to CPR for patients with cardiac arrest in the out of hospital setting or in hospital setting.***

- The 2010 AHA and ERC Guidelines *for CPR once again* ***emphasize the need for high-quality CPR,*** *including a compression rate of at least 100/min (a change from "approximately" 100/min) • A compression depth of at least 2 inches (5 cm) in adults and a compression depth of at least one third of the anterior-posterior diameter of the chest in infants and children (approximately 1.5 inches [4 cm] in infants and 2 inches [5 cm] in children). • Allowing for complete chest recoil after each compression •* ***Minimizing interruptions*** *in*

*chest compressions • Avoiding excessive ventilation. There is also a **new emphasis placed on the importance of chest compressions***

- 2015 AHA guidelines *reaffirm 2010 guidelines for the characteristics of high-quality CPR: compressing the chest at an **adequate rate and depth, allowing complete chest recoil after each compression, minimizing interruptions in compressions**, and avoiding excessive ventilation.*

- 2015 AHA (Reaffirmation of 2010): *Rescuers should **attempt to minimize the frequency and duration of interruptions in compressions to maximize the number of compressions delivered per minute.** 2015 (New): For adults in cardiac arrest who receive CPR without an advanced airway, it may be reasonable to perform CPR with the goal of a chest compression fraction as high as possible, with a target of at least 60%. Why: Interruptions in chest compressions can be intended as part of required care (i.e., rhythm analysis and ventilation) or unintended (i.e., rescuer distraction). Chest compression fraction is a measurement of the proportion of total resuscitation time that compressions are performed. An increase in chest compression fraction can be achieved by minimizing pauses in chest compressions. The optimal goal for chest compression fraction has not been defined. The addition of a target compression fraction is intended to limit interruptions in compressions and to maximize coronary perfusion and blood flow during CPR.*

- 2015 AHA Guidelines state *"The evidence does not demonstrate a benefit with the use of mechanical piston devices for chest compressions versus manual chest compressions in patients with cardiac arrest. Manual chest compressions remain the standard of care for the treatment of cardiac arrest. However, such a device may be a **reasonable alternative to conventional CPR in specific settings where the delivery of high-quality manual compressions may be challenging or dangerous for the provider** (e.g., limited rescuers available, prolonged CPR, CPR during hypothermic cardiac arrest, **CPR in a moving ambulance**, CPR in the angiography suite, CPR during preparation for extracorporeal CPR [ECPR]), provided that rescuers strictly limit interruptions in CPR during deployment and removal of the devices."*

- ILCOR (2015): *Mechanical chest compressions are not recommended. Not routinely at least. "The evidence does not demonstrate a benefit with the use of mechanical piston devices for chest compressions versus manual chest compressions in patients with cardiac arrest." They state that mechanical compression is a* ***reasonable alternative if sustained high quality compressions are impractical or compromise provider safety***

- ERC 2015: *Two studies, with a total of 13,469 patients, found higher survival among patients who received chest compressions at a rate of 100–120 min, compared to >140, 120–139, <80 and 80–99 min. Very high chest compression rates were associated with declining chest compression depths. The ERC recommends, therefore, that chest compressions should be performed at a rate of 100–120 min.*

- *Delivery of rescue breaths, shocks, ventilations and rhythm analysis lead to pauses in chest compressions. Pre- and post-shock pauses of less than 10 s, and* ***chest compression fractions >60% are associated with improved outcomes.*** *Pauses in chest compressions should be minimized, by ensuring CPR providers work effectively together.*

- Technical Report 2 – Chest Compression Injuries: *The pressure delivered by the load-distributing band system is* ***50% lower*** *than the reported threshold for chest compression injuries.*

- http://www.resuscitationjournal.com/article/S0300-9572(14)00751-5/abstract

  A protocol including E-CPR instituted by critical care physicians for refractory cardiac arrest which includes mechanical CPR, peri-arrest therapeutic hypothermia and ECMO is feasible and associated with a relatively high survival rate.

- https://sjtrem.biomedcentral.com/articles/10.1186/1757-7241-20-39

  In this review, we found insufficient evidence to support or refute the use of mechanical CPR devices in settings of out-of-hospital cardiac arrest and

during ambulance transport. While there is some low quality evidence suggesting that mechanical CPR can improve consistency and reduce interruptions in chest compressions, there is no evidence that mechanical CPR devices improve survival, to the contrary they may worsen neurological outcome.

- http://www.ncbi.nlm.nih.gov/pubmed/12971929

  "*Restrained ambulance occupants involved in a crash were significantly less likely to be killed or seriously injured than unrestrained occupants."* *; "Unrestrained ambulance occupants, occupants riding in the patient compartment and especially unrestrained occupants riding in the patient compartment were at substantially increased risk of injury and death when involved in a crash"; "Relative to police cars and fire trucks, ambulances experienced the highest percentage of fatal crashes where occupants are killed and the highest percentage of crashes where occupants are injured."*

- http://www.jems.com/articles/2012/08/merits-mechanical-cpr.html

  The study of adult patients from the Resuscitation Outcomes Consortium Cardiac Arrest Epistry with confirmed ventricular fibrillation (VF) or ventricular tachycardia (VT) has shown that increasing chest compression fraction (hands-on time) during out-of-hospital resuscitation of patients with VF/VT is an independent determinant of survival to hospital discharge.(7) However, three human observational studies showed that interruptions of chest compressions were common, averaging 24% to 57% of the total arrest time

- https://www.jstage.jst.go.jp/article/circj/80/6/80_CJ-16-0330/_pdf

  The quality of prehospital resuscitation is thought to be a key factor in determining outcome from out of hospital cardiac arrest (OHCA). High-quality CPR in adult patients with OHCA of presumed primary cardiac origin has been shown to improve rates of ROSC and survival to discharge.

- http://rebelem.com/cpr-in-out-of-hospital-cardiac-arrest-man-vs-machine/

  In cardiac arrest, high quality, uninterrupted CPR is essential to help improve survival rates. In theory, mechanical CPR should provide CPR at a standard depth and rate for prolonged periods without a decline in quality, which should help improve survival and survival with good neurologic outcomes.