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The Effect of Athletic Chest Protectors on the Performance of Manual and Mechanical CPR

A Simulation Study

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Objectives: Sudden cardiac arrest is a leading cause of death in athletes. Although athletes wear various athletic chest protectors (ACPs) to prevent commotio cordis (CC), cardiac arrest cases still occur. Although it is established that cardiopulmonary resuscitation (CPR) quality affects outcome, little research has evaluated the effect of ACPs on CPR compressions quality. This study aimed to observe whether: (1) ACPs impact depth, rate, and hand positioning of both bystander and LUCAS CPR. (2) LUCAS devices affect CPR performance compared with traditional compressions.

Methods: An observational, prospective, convenient sample of 26 emergency medicine residents performed CPR on a high-fidelity Laerdal mannequin, which recorded real-time performance data. Baseline CPR for 1- and 2-minute cycles, CPR on a mannequin wearing the ACP, and ACP removal time was recorded. LUCAS CPR performance was measured at baseline and over the ACP.

Results: Bystander CPR had a statistically significant difference in both hand placement and compression rate for baseline versus ACP compressions (85% vs 57%, $P < 0.05$; 138 vs 142, $P < 0.05$, respectively), but not in compression depth (51.08 vs 50.05 mm, $P = 0.39$). LUCAS CPR had no significant difference in CPR performance. Bystander versus LUCAS CPR had a significant difference in compression rate (138 vs 101, $P < 0.01$), but not in depth or hand placement.

Conclusions: Athletic chest protectors significantly impacted hand placement during bystander CPR, which may diminish CPR quality. Considering ACP removal required only 5.4 seconds, removing the ACP before standard CPR may improve quality.

Key Words: CPR, cardiac arrest, chest-protector, compressions

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Given the increasingly large number of Americans who are involved in athletic sports such as softball, lacrosse, and hockey from a young age, it is important that healthcare providers are aware of the risk of commotio cordis (CC) secondary to trauma during these athletic activities.¹ Furthermore, we must be prepared to initiate and perform high-quality cardiopulmonary resuscitation (CPR) and resuscitation on anyone presenting with such a clinical history.^{2,3} Thus far, only a few small-scale studies have aimed to determine whether the presence of athletic chest protectors (ACPs) would impact the performance of CPR during a cardiac arrest scenario. In addition, the few studies that have been done did not evaluate the performance of physicians but

rather evaluated the performance of athletic trainers and/or Basic Life Support/ Advanced Cardiac Life Support (BLS/ACLS) Emergency Medical Service (EMS) providers. Furthermore, in those studies, there was no definitive consensus on whether the performance of CPR over versus under chest protective equipment had an impact on the quality of CPR performance.^{4,5} Physicians are seldom available on the sidelines; therefore, our study results will guide the front-line bystanders, most often trained athletic coaches and EMS providers, on performing CPR with ACPs in place.

Although sudden cardiac arrest in athletes is a rare occurrence, it still remains one of the leading causes of death in athletes overall. In these cases, the time to initiation of CPR and the quality of CPR performance during these events can be directly linked to outcome. Numerous studies have indicated that the quality of CPR during a cardiac arrest is correlated to patient outcome and overall mortality. It has been shown that when adequate CPR and defibrillation are not performed during a cardiac arrest event, survival rates can drop up to 7% to 10% per minute.^{2,3}

In this study, we observed whether the presence of athletic chest protective equipment would impact the quality of CPR performance by emergency medicine physicians. Lastly, we assessed if the use of a LUCAS mechanical compression device (LUCAS Chest Compression System, Lund, Sweden) would lead to a significant variation in CPR performance as compared with manual compressions in the presence of athletic chest protective equipment.^{6–8}

METHODS

The observational study was conducted at an academic university setting, with a 3-year emergency medicine residency program with 96 residents. A total of 26 residents voluntarily chose to participate in the study. The study was performed during resident conference. The study was determined to be institutional review board exempt (no demographic information for residents regarding level of training, name, age, or sex was recorded).

We used American Heart Association (AHA)-approved CPR training mannequins that were autoprogrammed to measure compression rate, compression depth, hand placement, and percentage of compressions with correct depth. We used one of the most commercially available chest/heart guard protectors on the market—Heart-Gard (UNEQUAL Technologies Company, Concordville, Penn).

A. STUDY DESIGN

Observational, prospective design using emergency medicine residents to perform CPR in simulated cardiac arrest scenarios.

Each participant performed CPR in 4 situations with a 5-minute break in between sessions:

- Baseline CPR on mannequin
- CPR performed with chest guard protector remaining on mannequin

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TABLE 1. Comparison of Quality of CPR In Different Groups

	Regular CPR	CPR Over ACP	Removal of ACP (2 min CPR)	LUCAS	Lucas With ACP
n	26	26	26	5.00	5.00
Average depth	51.08	50.08	49.81	52.60	50.60
Average rate	138.54	142.69	145.42	101.00	101.00
Compressions with correct depth %	58.35	60.42	55.58	94.40	87.40
Compressions with correct rate %	5.23	1.08	0.08	92.40	95.20
Correct hand/piston placement %	85.27	57.19	91.85	100.00	100.00
Time to removal of ACP	NA	NA	5.38	NA	NA

NA, not available.

- c. CPR performed with chest guard protector initially on mannequin then removed before initiating CPR
 d. CPR performed by LUCAS device with chest guard protector on mannequin

b. Measured Outcomes

During these sessions, we aimed to measure:

- Time to initiation of CPR
- Average depth of CPR compressions
- Average rate of CPR compressions
- Average time required for removal chest guard protector

c. Inclusion Criteria

All current categorical emergency medicine residents present on the day of the conference and who were initially trained in CPR.

d. Exclusion Criteria

Participants who did not consent to participate in the study. Consent was verbally obtained.

e. Statistical Analysis

Wilcoxon signed ranks test or Mann-Whitney test was used to test for differences between continuous nonparametric data. χ^2 was used for categorical nonparametric data. Two-tailed significance was set at $P \leq 0.05$. STATA/IC 13.0 was used for statistical analysis.

RESULTS

A total of 26 residents participated in this study. The regular baseline CPR mean (SD) depth was 51.08 (6.36) mm. The mean

(SD) compression depth with ACP in place was 50.08 (5.63) mm and after ACP removal was 49.81 (7.65) mm. The LUCAS device was used for 26 sessions with and without ACP in place, and the mean (SD) compression depth without guard was 52.04 (0.87) and with ACP was 51.85 (1.29).

In our study, the average compression rate per minute with regular CPR was 138.54 (7.07). Compression rate for CPR over the ACP was 142.69 (7.09), and CPR for 2 minutes after removal of ACP was 145.42 (9.01). The average rate with the LUCAS device was not affected by the presence of the ACP device and was 101 per minute with or without the ACP in place (0).

The percentage of correct hand placement in regular CPR was 85.27% (32.83). During CPR with the ACP in place, the percent of correct hand placement was only 57.19% (48.65). During CPR for 2 minutes after removal of ACP, the correct hand placement was 91.85% (24.79). Compression piston placement while using the LUCAS device was unchanged whether or not the ACP was in place, with mean of 100% accurate placement in all cases (0).

The mean (SD) time to remove the ACP was 5.38 (3.32) seconds.

DISCUSSION

In our study, we found a significant deterioration in hand/piston placement while the depth was not affected when the ACP was used during manual CPR. When viewed from the perspective of AHA 2015 guidelines, the recommended chest compression depth for adults is at least 2 inches (5 cm) but not greater than 2.4 inches (6 cm). Our data suggest that the average depth of CPR remains within the recommended guidelines, except when the ACP was removed, and the depth was marginally below the recommendations. The results from this study do not indicate any statistically significant difference in compression depth with or without the presence of an ACP device in place. Furthermore, when the LUCAS device was used with or without chest protector in place, there was minimal deviation in the depth as compared with manual baseline CPR performance. Therefore, there is no

TABLE 2. Statistical Analysis of Quality of CPR In Different Groups

	<i>T</i> Tests and <i>P</i>			
	Manual CPR 1 min vs Manual CPR w/ HG	Manual CPR 1 min vs Manual CPR 2 min	Manual CPR 1 min vs Lucas CPR	Manual CPR w/ HG vs Lucas w/ HG
Average depth, mm	0.38742	0.23047	0.60171	0.33191
Compressions w/ correct depth, %	0.82843	0.75186	0.06011	0.07424
Avg. rate	0.00276	0.00041	0.00000	0.00000
Compressions w/ correct rate, %	0.28600	0.18830	0.00000	0.00000
Hand/piston Placement %	0.00421	0.40216	0.33057	0.06207

apparent added benefit for removing the chest protector with regard to compression depth alone.

As prior research has shown that automated/mechanical compression devices lead to sustained high-quality adequate depth of CPR (AHA, 2015), it can be recommended from our study that the use of a LUCAS device either with or without an ACP in place would be acceptable as compared with traditional CPR.

Per the AHA, the current recommended chest compression rate during CPR is 100 to 120 per minute. In this study, the average manual compression rate with or without the chest protector in place was approximately 20% to 30% higher than the recommended rate. However, the LUCAS device maintained the appropriate programmed compression rate during all cases. Elevated compression rates can lead to decreased filling of the ventricles during the CPR and hence decreased cardiac output. There are numerous studies that have demonstrated that physicians tend to hyperventilate during periods of stress while bagging, and we believe that this phenomenon is very similar to the increased compression rates seen during stressful conditions.^{9,10} It is interesting to note, however, that when manual CPR was performed over the ACP, there was a 4% to 5% increase in the compression rate. This may be due to the fact that it was viewed as an obstruction, which would require faster compressions, and even after removing the guard, participants were still overcompensating and performing compressions at a higher rate as compared with their baseline.

Hand placement is a vital prognostic factor for appropriate and effective CPR. In this study, hand placement during manual CPR was accurate 85.27% of the time when no ACP was in place, versus 57.19% of the time when there was an ACP in place ($P = 0.004$). The significant difference 7 in proper hand/piston placement can potentially lead to a significant difference in the quality of CPR performance. However, in cases when the ACP was removed before initiating CPR, more attention was noted for hand placement, and the percentage of hand placement was 91.85% versus 85.27% during baseline manual CPR. However, the difference was not found to be statistically significant ($P = 0.419$).

During cases when participants removed the ACP before initiating CPR, the mean time to remove the guard was 5.4 seconds. This time delay is likely minor, as compared with the significant impact in proper hand placement when the ACP is no longer in place. Therefore, when feasible, we believe that the ACP should be removed before initiating CPR. However, some models of athletic protective chest equipment are embedded within the clothing and may require a scissor or a cutting device for removal, which could increase the time it takes to remove leading to a delay in compressions. Therefore, further discussion would be required to determine whether athletic chest gear should be routinely removed before initiating CPR. It would be valuable to educate the school and college teams regarding CPR and differences in CPR with the ACP.¹¹

Of the incidents of sudden cardiac death in athletes, a small percent is due to CC, which can occur with direct striking trauma to the chest during sports such as lacrosse, softball, and hockey.² During these sports, athletes often wear protective equipment, which covers their shoulders and chests. In recent years, more manufacturers have been marketing protective equipment with the specific goal of reducing chest trauma and the possibility of cardiac arrest secondary to CC.

However, despite the use of such chest protectors, there have still been documented cases of sudden cardiac arrest because of commotion cordis.³ One study, which evaluated data from the US CC Registry, determined that close to 40% of sudden deaths reported in young athletes that occurred because of CC had

occurred despite the use of commercially marketed chest protectors. Additional research performed on animal models indicated that a wide variety of commercially available athletic chest wall protectors were ineffective in preventing CC caused by chest blows.^{5,12}

CONCLUSIONS

The use of an ACP had a significant impact on hand placement during bystander CPR. This may have a detrimental effect on bystander CPR quality. Considering ACP removal required only 5.4 seconds, it may be beneficial to remove the ACP before starting of bystander CPR. However, ACP equipment was shown to have no significant impact when a LUCAS device is used for mechanical CPR. In addition, there was significant difference between resident and LUCAS CPR in rate of compressions, which plays a critical role in CPR quality. Hence, access to LUCAS device and training of the healthcare workers on the field for LUCAS can be considered in addition to CPR training.

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