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ORIGINAL ARTICLE

Skeletal and soft tissue injuries after manual and mechanical chest compressions

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Aims To determine the rate of injuries related to cardiopulmonary resuscitation (CPR) in cardiac arrest non-survivors, comparing manual CPR with CPR performed using the Lund University Cardiac Assist System (LUCAS).

Methods and results We prospectively evaluated 414 deceased adult patients using focused, standardized post-mortem investigation in years 2005 through 2013. Skeletal and soft tissue injuries were noted, and soft tissue injuries were evaluated with respect to degree of severity. We found sternal fracture in 38%, rib fracture in 77%, and severe soft tissue injury in 1.9% of cases treated with CPR with manual chest compressions ($n = 52$). Treatment with LUCAS CPR ($n = 362$) was associated with significantly higher rates of sternal fracture (80% of cases), rib fracture (96%), and severe soft tissue injury (10%), including several cases of potentially life-threatening injuries.

Conclusion LUCAS CPR causes significantly more CPR-related injuries than manual CPR, while providing no proven survival benefit on a population basis. We suggest judicious use of the LUCAS device for cardiac arrest.

Keywords Cardiac arrest • Cardiopulmonary resuscitation • Autopsy • Mechanical chest compressions • Injury • Complications

Introduction

Cardiopulmonary resuscitation (CPR) is a potentially life-saving treatment for cardiac arrest but puts the subject at risk for iatrogenic skeletal and soft tissue injuries.[1] The rates of rib and sternal fractures after CPR were 31% and 15%, respectively, in a pooled analysis of results from previous studies of both manual and mechanical CPR.[2] Furthermore, injuries to the heart, lungs, blood vessels, liver, and other soft tissues of the chest and abdomen are not uncommon.[3,4]

High quality chest compressions are an essential part of CPR after cardiac arrest.[5] Chest compressions of insufficient depth or rate are associated with worse outcomes,[6,7] as are prolonged interruptions of ongoing chest compressions.[8] A number of automated devices have been introduced to improve chest compressions during CPR, one of which is the Lund University Cardiac Assist System (LUCAS) Chest Compression System. The LUCAS consists of a suction cup attached to a piston driven by gas pressure or an electric motor. Two legs connect the motor and suction cup piston to a back plate placed beneath the patient. When running, the suction cup compresses the patient's chest in an anteroposterior direction against the back plate to a depth of approximately 5 cm at a rate of 100 compressions per minute. After each compression the suction cup returns to the starting position together with the chest wall. The first version of LUCAS (LUCAS 1) was powered by pressurized gas and was used in our regional medical system for out-of-hospital and in-hospital cardiac arrest from autumn 2003 and onwards. A neck strap was subsequently added to the device in order to prevent the suction cup from sliding caudally out of position. A second version (LUCAS 2) replaced the first in 2009 and differed mainly in that it was powered by a battery and electric motor. Later software updates have introduced a slightly altered depth and rate of compression.[9,10]

The benefit of such a device is apparent: guideline-adherent chest compressions limited only by the power source (pressurized gas or an electrical power outlet or battery). In pre-clinical studies, LUCAS chest compressions produced higher organ perfusion pressures and cerebral blood flow than manual compressions.[10–12] Furthermore, the LUCAS

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device allows CPR providers to focus on other tasks than compression of the chest and facilitates transportation of a patient with on-going CPR. This may be especially beneficial for out-of-hospital cardiac arrests, although some data suggest that using a mechanical device prolongs the time to the first defibrillation.[13] However, the two large randomized controlled trials available to date, the LINC trial and the PARAMEDIC trial, did not show any improvement in outcome with LUCAS CPR compared with manual CPR[14,15] and retrospective registry data have indicated worse outcomes with LUCAS CPR.[16,17]

We have previously voiced concern that the more vigorous mechanical chest compressions may cause more injury to the subject of CPR.[4,18,19] Therefore, we performed a study of CPR-related injuries in non-survivors, through post-mortem investigation. Our hypotheses were that patients treated with mechanical chest compressions during CPR (mechanical CPR) would present at autopsy with more injuries than those treated with manual chest compression CPR, and that we would find organ damage of such degree that it would be potentially lethal.

Methods

This study was approved by the Regional Ethical Review Board. We prospectively included cases referred for clinical autopsy at Skåne University Hospital, Lund, Sweden, from January 2005 through December 2013. Inclusion criteria were age >17 years and a history of CPR, either manual or mechanical CPR, within a few days before death. Inclusion also required that, out of a larger group of cases referred to our department, the autopsy be done by one of two pathologists with experience of CPR-related injuries (E.E., C.W.). We used register data to estimate the rate of cardiac arrest in our region and we reviewed all autopsies in our institution during one single year (2011) to estimate the rate of missed cases. Exclusion criteria were traumatic cardiac arrest, unknown method of CPR, incomplete autopsy or onward referral for forensic autopsy. Forensic autopsy is in Sweden performed in cases of suspected suicide, homicide, death by accident, ongoing drug/alcohol misuse, health care mistreatment, and when death is unexpected or when there is prolonged post-mortem delay, i.e. decomposition of the body, or otherwise difficulty identifying the deceased.[20] Ambulances in our regional emergency medical system are staffed by registered nurses and paramedics and dispatched to a suspected out-of-hospital cardiac arrest on the main basis of proximity.[21] During the study period, LUCAS devices were available in all ambulances within the hospital's catchment area for autopsies and regional guidelines enforced mechanical CPR as standard of care unless practically impossible (e.g. patient size). The decision to not apply the LUCAS device was in such cases made by the ambulance staff at their own discretion. Patient and CPR data were extracted from the autopsy referral document or the patient's medical records and included age, gender, type, and duration of CPR. Autopsy was performed with special attention given to CPR-related injuries using a standardized written protocol, introduced in the department during 2004 and subsequently also used by others.[22,23] The presence or absence of sternal and rib fractures was noted; fractures were counted and the position of rib fractures relative to the midline was noted. Soft tissue injuries and the presence and volume of any major internal haemorrhage were noted. Soft tissue injuries were evaluated for degree of caused damage and sorted into the following three categories, adapted from Krischer *et al.*[1]

(1) Life-threatening injuries: injuries with a probable lethal outcome regardless of the primary cause of cardiac arrest (e.g. rupture of the heart, rupture or significant laceration of the aorta, exsanguination >800 mL), had the patient survived the primary cause of cardiac arrest.
(2) Severe injuries: injuries likely to require intervention/therapy for repair, risk reduction or pain control, expected to prolong hospitalization (e.g. laceration of the liver, laceration of the aorta, haemothorax).
(3) Lesser injuries: injuries not likely to require specific intervention/therapy (e.g. minor visceral bleeding or lacerations) in a cardiac arrest survivor.

Cases with and without soft tissue injury were compared with regard to baseline characteristics and the extent of concurrent skeletal chest injuries. We approximated that LUCAS 2 replaced LUCAS 1 by mid-2009. Cases from before and after this time point were compared with regard to skeletal and soft tissue injuries to evaluate differences between the two versions of the device. Cases were divided into six groups according to duration of CPR, and the rib fracture counts and presence of sternal fracture were compared across the groups.

Data processing and analysis was performed using Microsoft Excel 365 and R.[24] Categorical data were compared using Pearson's χ^2 test or Fisher's exact test; numerical data were compared using Wilcoxon rank sum test or Kruskal–Wallis rank sum test. A *P*-value of <0.05 was considered statistically significant. All *P*-values were two-sided.

Results

A total of 414 deceased victims of cardiac arrest were included in this study, of which 362 cases had received mechanical CPR and 52 cases had received manual CPR only. The inclusion rate was relatively steady during the study period, with on average 40 cases/year (range 23–60 cases/year) in the mechanical CPR group and 5 cases/year (range 3–10 cases/year) in the manual CPR group. The reason for not applying the LUCAS device was discernible in some cases; the most commonly stated reason was irregular body size, primarily 'too big', followed by 'too thin'. In a few singular cases there was no LUCAS device available. There were approximately 150 out-of-hospital and 90 in-hospital cardiac arrests per year in our hospital's catchment area, with survival rates of roughly 10% and 40%, respectively.[25] This leaves an estimated 190 cardiac arrest non-survivors per year. In the year 2011, a total of 138 cases were referred to our department for autopsy after presumed cardiac arrest, with CPR having been performed in 82 of these. Thirty-two of those cases were included in the convenience sample used in this study.

Table 1 shows the presence of skeletal and soft tissue injuries after CPR. In summary, we found high rates of skeletal injuries of the chest in both study groups and most cases had multiple and bilateral rib fractures. There were significantly more skeletal and soft tissue injuries in the mechanical CPR group. Out of the cases with sternal fracture, 35/291 (12%) in the mechanical CPR group and 1/52 (1.9%) in the manual CPR group had more than one fracture of the sternum. An account of all identified soft tissue injuries is shown in *Table 2*. The cause of death established by full clinical autopsy of all cases from 2009 through 2013 is shown in *Table 3*. None of the cases in this study had a CPR-related injury established as the primary cause of death in the final autopsy report.

Cases with the shortest and longest duration of CPR (1–20 vs. 101–120 min) had median (interquartile range, IQR) numbers of rib fractures of 9.5 (7–12.75) vs. 11 (7.75–16), and rates of sternal

Table 1 Baseline and injury data

	mechanical CPR (*n* = 362)	manual CPR (*n* = 52)	*P*-value
Study population			
Age (years), median (IQR)	68 (58–75)	66 (59–77)	0.72
Male, *n* (%)	244 (67)	40 (77)	0.17
CPR duration (min), median (IQR)[a]	40 (25–60)	25 (18–35)	0.013
Skeletal injuries			
Any skeletal fracture of the chest, *n* (%)	354 (98)	42 (81)	<0.001
Sternal fracture, *n* (%)	291 (80)	20 (38)	<0.001
Rib fracture, *n* (%)	349 (96)	40 (77)	<0.001
≥4 rib fractures, *n* (%)	331 (91)	34 (65)	<0.001
≥4 bilateral rib fractures and sternal fracture, *n* (%)	190 (52)	10 (19)	<0.001
Number of rib fractures (fractures), median (IQR)[b]	10 (7–13)	9 (6–10)	0.0069
Soft tissue injuries, *n* (%)			
Life-threatening injuries[c]	9 (2.5)	0 (0)	0.0019[f]
Severe injuries[d]	29 (8.0)	1 (1.9)	
Lesser injuries[e]	62 (17)	3 (5.8)	
No injuries	262 (72)	48 (92)	

[a]CPR duration data were available for 111 cases (31%) and 13 cases (25%) in the mechanical CPR and manual CPR groups, respectively.
[b]Calculated for cases with rib fractures.
[c]That is, rupture of the heart, rupture or severe laceration of the aorta, exsanguination >800 mL.
[d]That is, likely to require intervention/therapy for repair, risk reduction or pain control, expected to prolong hospitalization.
[e]That is, minor visceral bleeding or laceration.
[f]*P*-value refers to Wilcoxon rank sum test across all soft tissue injury groups, $W = 7505.5$.

fractures of 85% vs. 75%. There were no statistically or clinically significant differences in rates of rib ($P = 0.15$) and sternal ($P = 0.77$) fractures between different durations of CPR.

Cases in the mechanical CPR group with 'potentially life-threatening' ($n = 9$), 'severe' ($n = 29$), 'lesser' ($n = 62$), or no soft tissue injuries ($n = 262$) did not differ significantly in age ($P = 0.44$), sex ($P = 0.53$) or duration of CPR ($P = 0.95$), and sternal fractures were present at similar rates ($P = 0.23$). The cases with soft tissue injury had on average 12 rib fractures, when compared with 10 rib fractures in cases without soft tissue injury (median difference 2 fractures, 95% confidence interval 1–3; $P = 0.0018$).

The four cases in the manual CPR group with at least one soft tissue injury had a higher median (IQR) number of skeletal chest injuries than the cases without soft tissue injury: 11 fractures (10–14 fractures) vs. 6.5 fractures (1–10 fractures). Two of the four cases in the former group had a sternal fracture, when compared with 18/48 cases (38%) in the latter group. Data on the duration of CPR was available for two of the four cases with soft tissue injury: the median duration in these cases was 40 min, which was longer than the median duration of CPR in the group without soft tissue injury (25 min).

Out of the cases treated with LUCAS 1, 203/228 (89%) had four or more rib fractures, and 159/228 (70%) had a sternal fracture; the median (IQR) number of rib fractures was 9 fractures (6–13 fractures). LUCAS 2 was associated with four or more rib fractures in 128/134 (96%) of cases, sternal fracture in 97/134 (72%) of cases and the average number of rib fractures was 12 (9–14) fractures. The prevalence of soft tissue injuries categorized as severe or potentially life-threatening was 25/228 (11%) in the LUCAS 1 group and 13/134 (9.7%) in the LUCAS 2 group.

We assumed that most of the patients in the mechanical CPR group had received a short course of manual CPR prior to application of the LUCAS device. The difference between the median time to start of manual CPR (excluding bystander CPR) and the median time to subsequent start of mechanical CPR was 3.5 min in the LINC trial.[14] In our study, there was a reported prolonged course of manual CPR in two cases: one case treated with manual CPR for 10 min followed by mechanical CPR for 35 min, the other case treated with manual CPR for 20 min followed by mechanical CPR for 20 min. Excluding these cases from the analysis did not affect the results (data not shown).

Discussion

In this study, we found that in cardiac arrest non-survivors, skeletal and soft tissue injuries were significantly more frequent after mechanical CPR than after manual CPR and were judged as potentially life-threatening in some cases. This was consistent with our hypothesis that mechanical chest compressions may cause more harm than manual chest compressions.

Skeletal injuries after manual vs. mechanical cardiopulmonary resuscitation

We found rib fracture in 77% and sternal fracture in 38% of manual CPR cases with an average number of nine rib fractures per individual case. These numbers are similar to or higher than those reported in earlier studies. Reported rates of CPR-related rib fractures in other

Table 2 **Frequency of soft tissue injuries**

	mechanical CPR (*n* = 362)		manual CPR (*n* = 52)	
	n	Percentage	*n*	Percentage
Pericostal bleeding	19	5.2	1	1.9
Liver laceration or rupture	15	4.1	1	1.9
Retrosternal bleeding	14	3.9	1	1.9
Mediastinal bleeding	14	3.9	1	1.9
Haemopericardium	10	2.8	0	0
Aorta laceration or rupture	9	2.5	0	0
Liver haemorrhage, subcapsular	9	2.5	0	0
Cardiac petechiae	8	2.2	0	0
Haemothorax	7	1.9	0	0
Perirenal bleeding	7	1.9	0	0
Epicardial haemorrhage	4	1.1	0	0
Myocardial rupture	3	0.83	0	0
Lung bleeding	3	0.83	0	0
Liver haemorrhage, other	3	0.83	1	1.9
Pneumothorax	2	0.55	0	0
Laceration of oesophageal and tracheal mucosa	1	0.28	0	0
Laceration of gastric mucosa	1	0.28	0	0
Right coronary artery rupture	1	0.28	0	0
Pancreatic bleeding	1	0.28	0	0

Numbers and percentages of soft tissue injuries. Some individual cases had several simultaneous soft tissue injuries.

Table 3 **Causes of death (2009–2013)**

	mechanical CPR (*n* = 157)		manual CPR (*n* = 24)	
	n	Percentage	*n*	Percentage
Acute myocardial infarction	102	65	13	54
Aortic dissection	11	7.0	0	0
Pulmonary embolism	9	5.7	2	8.3
Other cardiac disease	7	4.5	0	0
Pneumonia	6	3.8	2	8.3
Cancer	5	3.2	1	4.2
Rupture of aortic aneurysm	4	2.5	2	8.3
Stroke	3	1.9	0	0
Sepsis/enterocolitis	2	1.3	0	0
Other	8	5.1	4	17
Total	157	100	24	100

Overview of the causes of death in a part of the sample.

prospectively recruited autopsy cohorts range from 32% to 74%. In the same cohorts, sternal fractures were reported in 15–66%.[1,23,26–29] There seems to be agreement that rib fractures, when present, are usually multiple.[26] The average number (median or mean) of rib fractures range between 3 and 8 fractures/patient in other studies reporting actual counts.[28–32]

There is great variability in the reported rates of CPR-related injuries in the literature, likely resulting from heterogeneity of inclusion criteria, population characteristics, CPR performance, and how injuries were evaluated (clinically; radiographically; clinical or forensic autopsy). Here, we included deceased victims of cardiac arrest. It is possible that survivors after CPR may suffer from a different spectrum and load of CPR-related injuries than non-survivors. However, comparing the two groups is difficult. For example, there are many ethical, practical and economical limits to what types of investigations patients may be subjected to post-CPR. Using plain X-ray to evaluate

CPR-related injuries is likely to underestimate their incidence.[30,33] With regard to skeletal injuries there may be reasonable concordance between post-mortem computed tomography and autopsy results, while soft tissue injuries may be both under- and overestimated.[34–36] Evaluation of chest injuries through prospective autopsy focused on CPR-related injuries allegedly has the highest sensitivity compared with other methods but is not applicable to the surviving population.[26,37]

In this investigation, treatment with mechanical chest compressions was more often associated with rib fractures (96% of cases) and sternal fractures (80% of cases) than manual chest compressions. A few authors have previously compared CPR-related skeletal fractures after mechanical and manual CPR. In a randomized controlled trial, Koster *et al.*[31] compared the incidence of injuries in CPR survivors and non-survivors randomized to chest compressions with the LUCAS device, the AutoPulse load-distributing band device or control (manual chest compressions). They found that more than half of patients treated with LUCAS had no CPR-related skeletal fractures and only 6.5% had a sternal fracture, rates not statistically different from those of the manual CPR group. In a retrospective analysis of an autopsy cohort of more than 2000 non-survivors after CPR, Kralj *et al.*[38] found rib and sternal fractures in approximately 79% and 65%, respectively, but no increased incidences in the subgroup of patients treated with LUCAS. Rib fracture was more common in the LUCAS group (79% of cases) than in the manual CPR group (65%) in a study by Smekal *et al.*,[23] while there were similar rates of sternal fractures. One smaller observational study reported sternal fractures in 35% and 22% of cases in the LUCAS CPR group and manual CPR group, respectively, and significantly more rib fractures in the LUCAS CPR group.[32] We believe that the large differences in injury rates in these studies can be explained to a great extent by differing methods of injury evaluation. For example, in the Koster *et al.*[31] study, only approximately one-fifth of cases were evaluated by autopsy, while the rest were evaluated by either post-mortem imaging or clinical assessment.

Soft tissue injuries after cardiopulmonary resuscitation

The higher incidence of skeletal injuries after mechanical chest compressions is concerning. Skeletal fractures of the chest would likely have increased pain, the risk for post-arrest complications such as pneumonia, and potentially necessitated prolonged hospital stay, had the patient survived. Furthermore, the fractures correlated with a likewise higher incidence of soft tissue injuries in this study. The most common such findings were bleeding or haematomas of the chest wall and mediastinum. These injuries were always associated with concurrent rib fracture; sternal fracture was present in all cases of mediastinal/retrosternal bleeding. The incidence of mediastinal bleeding after CPR was 10% in a pooled analysis of 1220 previously reported cases,[2] similar to our findings of mediastinal/retrosternal bleeding in 8%. Mediastinal and pericostal bleeding probably seldom causes severe morbidity on its own, although, in this study, we did identify one case with life-threatening haemothorax exsanguination associated with mediastinal bleeding, double sternal fractures and multiple bilateral rib fractures.

Previous studies have reported serious or life-threatening injuries in 0–6% of cases after manual CPR and in 1–7% of cases after LUCAS CPR.[2,23,31] In the Kralj *et al.*[38] study, 30/2148 (1.4%) of non-survivors autopsied after CPR were judged to have iatrogenic CPR-related injuries that had contributed to death, including exsanguination of >500 mL. This contrasts to our finding of potentially life-threatening injuries in 9/362 (2.5%) cases treated with LUCAS CPR and severe injuries in another 29/362 (8%).

The presence or absence of soft tissue injury in cases treated with LUCAS CPR did not correlate with age or duration of CPR and was not associated with sex or the presence of skeletal injuries. The difference in median number of rib fractures of 12 fractures vs. 10 fractures in the soft tissue injury and non-soft tissue injury groups, respectively, was judged statistically but not clinically significant. In contrast, in the manual CPR group there were more skeletal injuries and longer durations of CPR in the cases that had soft tissue injuries. Our interpretation is that the indiscriminate guideline-adherent chest compressions of the LUCAS confers a rather constant risk of causing CPR-related injuries, while a manual CPR performer may (for better or worse) adjust compressions according to the properties of the receiving patient. Skeletal and soft tissue injury rates were similar in the early (LUCAS 1) and late (LUCAS 2) stage of the study with a tendency towards more rib fractures in the latter group.

In our study, 18 of the 38 cases with severe or presumably life-threatening soft tissue injuries presented with damage to the cardiovascular system, e.g. myocardial rupture, aortic rupture or laceration, and haemopericardium. For comparison, recent autopsy data indicate rates of myocardial rupture or laceration of 1.1–2.7%, aortic rupture or laceration of 0.67–1.1%, and haemopericardium of 2.7–3.3% after unsuccessful manual CPR.[29,36] In our present study, these injuries were all in the LUCAS CPR group; none such injuries were present following manual chest compressions. Based on our data, we believe that the repeated indefatigable chest compressions of the LUCAS may contribute to such injuries to a greater extent than manual chest compressions do. This needs to be considered, especially in the era of declining autopsy rates worldwide, since myocardial and especially aortic injuries are often overlooked using post-mortem imaging.[35]

The high incidence of liver injuries in the LUCAS group is another cause for concern. Liver laceration or rupture was found in 4.1% of cases, which compares to 1.9% in the manual CPR group and 0–1.1% reported earlier.[29,36,37] We also found lesser, subcapsular, liver injuries in another 2.5%.

The LUCAS has not been shown to improve outcome after out-of-hospital cardiac arrest, despite delivering more efficient chest compressions.[14,15] We believe that the increased rates of CPR-related injury with LUCAS CPR is possibly a contributing factor. It is possible that the LUCAS is of particular benefit for the subgroup of cardiac arrest victims eligible for definite in-hospital treatment, such as percutaneous coronary intervention. Identifying those patients is difficult. It may be the wrong approach to indiscriminately treat the large, assorted group of patients with out-of-hospital cardiac arrest with LUCAS, since this may result in prolonged emergency care and intolerably high risk of traumatic CPR-related injury.

Limitations and strengths of this study

This study was limited by the typical issues of observational cohort studies. There was a significant risk of selection bias since we had no influence on which type of CPR was chosen for each individual patient or on which patients were subsequently referred for clinical autopsy. As mentioned, mechanical CPR was considered standard of care for out-of-hospital cardiac arrest during the study period, while the ambulance crew could make the active decision not to apply the LUCAS device. A third level of potential bias was inferred because our inclusion criteria required that autopsies be performed by either of two dedicated pathologists (E.E. and C.W.). This led to the loss of a number of cases at random. We believe, however, that this was more than compensated by the benefits of having the same two pathologists evaluating all cases. In other studies on autopsy-found injuries here discussed,[22,23,38] we did not see a similarly homogenous method of evaluation. In some studies, the number of evaluating pathologists was larger, in others the actual set-up was not declared. In the studies where autopsies were performed in several hospitals, few cases were investigated in each department, and as such leaving as little as singular cases per year to the individual pathologist.

We included fewer manual CPR cases than mechanical CPR cases. The main reason was that few deceased non-survivors after manual CPR were referred for clinical autopsy, likely because the LUCAS device was thoroughly implemented in the ambulances in our hospital's catchment area and was the recommended default method of chest compressions for out-of-hospital cardiac arrest. Few cardiac arrest victims thus received treatment with manual CPR. The main reason for ambulance crews not to apply the LUCAS device was that the patient's body was too large or too thin to fit the device. This may have affected our results, as a larger body may have greater resilience to CPR-related injuries, while the opposite is possibly true for a thin cachectic body. Another reason for the group size difference may be that because the LUCAS device often leaves typical round suction cup skin markings on the chest of the deceased, these cases were automatically identified by all personnel involved, while manual CPR cases may have gone unnoticed with autopsy initiated before study inclusion. These factors certainly may affect the generalizability of our findings, and the data should be interpreted judiciously.

While the CPR duration in the manual CPR group (median 25 min) was in line with earlier reports,[39] LUCAS CPR was performed for considerably longer (median 40 min), which may have contributed to increased damage. One explanation may be that termination of ongoing CPR is difficult, particularly with mechanical CPR devices, which are both immune to fatigue and able to work during prolonged patient transportation. Although it seems plausible that longer CPR duration causes more CPR-related injury, the evidence is conflicting. Two studies evaluating CPR-related injuries by autopsy found no correlation between CPR duration and the presence of CPR-related injury,[28,29] while another study with a different methodology disagreed.[40] It has been suggested that most skeletal fractures occur during the first seconds or minutes of CPR.[27] In this study, we did not find any statistically significant association between the presence of skeletal or soft tissue injury and the duration of CPR in the LUCAS CPR group. It should be noted, however, that data on CPR duration were available for only a subset of cases in our study. It is possible that physicians were more likely to report the actual duration of CPR in prolonged resuscitation situations, possibly deeming shorter durations of CPR as less significant and less important to report to the pathology department.

Finally, it is not clear if results from cardiac arrest non-survivors are generalizable to the population surviving cardiac arrest and CPR, since there are several potential confounding factors. In any way, the deceased or likely terminal victims of cardiac arrest must be granted a worthy and medically correct treatment and handling. The dramatic increase in CPR-related injuries presented here is certainly not acceptable even if confined to the non-surviving population.

Based on the reported data, we suggest that LUCAS chest compressions during CPR cause significantly more damage to the victim's body than manual chest compressions, and that this damage may sometimes contribute to death or severe morbidity. We do acknowledge that some degree of CPR-related injury is expected and acceptable since the alternative to CPR is usually the certain death of the patient. We also acknowledge that unwarranted fear of doing harm may prevent layperson and health care cardiac arrest responders to perform the crucial resuscitative manoeuvres. Until further, however, we suggest that the use of mechanical chest compression devices be limited to selected cases.

Conflict of interest: none declared.

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