

Heart Compression Resuscitation, LLC (HCR)

Frequency of Chest Injuries Associated with CPR

One of the most groundbreaking and significant features of HCR's new CPR manikin is the patented simulation of the **sound and feel** of rib fractures and other injuries to the chest as the result of CPR chest compressions. HCR's CPR manikin is the only manikin that provides this simulation. **Why is this so important?—because it will finally provide trainees with a training experience that more accurately matches a real-life CPR experience.**

The evidence shows that rib fractures and other chest injuries have always occurred with CPR, but that over time the reported frequency of such injuries has increased, primarily because of (1) the change in the American Heart Association (AHA) guideline for proper CPR chest compression depth from a range of 1.5 -2 inches to a minimum of 2 inches (AHA Guideline 2010; the AHA determined that chest compressions of less than 2 inches are too shallow to provide adequate circulation of blood flow to the heart and vital organs), and secondarily because of (2) the use of autopsy and computed tomography instead of X-ray to detect CPR injuries (X-ray falsely detects fewer injuries, which then go underreported).

**According to Dr. Michael Sayre, a spokesman for the
American Heart Association:
“Broken ribs can be expected when doing CPR”**

1. In 2014, the AHA journal, *Circulation*, included an article entitled “Rib and Sternum Fractures After Cardiopulmonary Resuscitation: An Autopsy Study”, which stated that “Chest compression during cardiopulmonary resuscitation (CPR) is associated with skeletal chest injury”. The article reported the results of a study completed in 2013, which assessed the incidence of rib and sternum fractures in 52 adult patients who did not survive after CPR. The patients were referred for clinical autopsy and examined by pathologists. Sternum fractures were found in 38% of the cases and rib fractures were found in 77% of the cases. The fracture of 3 ribs was found in 69% of the cases.¹
2. A recent 2015 article in *Resuscitation*, the official journal of the European Resuscitation Council, reported the incidence of chest injuries in 2,148 patients who had undergone resuscitation for cardiac arrest, did not survive, and were autopsied at the Institute of Forensic Medicine in the Republic of Slovenia from 2004-2013. Article title: “Frequency

and number of resuscitation related rib and sternum fractures are higher than generally considered". The autopsies of the 2,148 patients found that sternum fractures occurred in 59% of the males and 79% of the females, and rib fractures in 77% of the males and 85% of the females. The authors acknowledge that their study results highly exceed those reported in previously published studies. They concluded: "This difference is certainly due to multiple factors. Among them we attribute the greatest importance to changes in resuscitation guidelines".²

3. An article published in *Resuscitation* in September of 2014 discusses: "Both Manual and Mechanical CPR Commonly Cause Traumatic Injuries". Researchers in Sweden conducted a study of 83 adults who had autopsies following unsuccessful manually delivered CPR. The autopsies indicated that 76% of the 83 patients had CPR related injuries and most of the 83 had multiple fractures. The authors commented: "Although the injuries described in this study were in non-survivors, injuries are likely to be similar in patients who are successfully resuscitated. "'Push hard and fast" saves lives, but also causes injuries" (HCR note: such advice is frequently offered by the AHA and CPR trainers due to the current lack of realism of available CPR manikins).³
4. A March 2013 article in *Resuscitation* describes a "Comparison of computed tomography (CT) and autopsy in detection of injuries after unsuccessful cardiopulmonary resuscitation". The study involved submitting 31 patients to a CT and then to autopsy, using a radiologist and a pathologist who were blinded to each other's results. CT and autopsy revealed rib fractures in 22 (71%) and 24 (77%) respectively. The average patient showed a median of 9 such injuries.⁴
5. A March 2015 article in *Resuscitation* describes "Computed tomography findings of complications resulting from cardiopulmonary resuscitation". The authors' study involved 223 patients who had been admitted to their emergency room from 2008 to 2013, all of which then received CPR. The study included patients for which CPR had been both successful and unsuccessful. The CT images showed that 156 (70%) of the patients had rib fractures and 18 (8%) had sternum fractures. All sternal fractures occurred with rib fractures and were associated with a greater number of rib fractures.⁵
6. A March 2015 article in *Critical Care* reports the results of a "Comparison of complications secondary to cardiopulmonary resuscitation between out-of-hospital cardiac arrest and in-hospital cardiac arrest". Over a period from 2009 to 2014, the authors performed a study in two emergency rooms regarding 148 patients who had survived CPR, including 89 out-of-hospital and 59 in-hospital survivors. Using multi-

detector computed tomography to detect injuries in each group, they found rib fractures in 83% and 63% of the patients, respectively, and sternum fractures in 38% and 31% of the patients, respectively.⁶

7. A study reported in the July 2013 issue of the *Journal of Forensic Sciences* states that “The manual-only CPR fractures observed in this study are consistent with previous studies, demonstrating a high percentage of cases with rib fractures and approximately half of the cases with sternal fractures”. “The cause of this rib and sternum fracture pattern is twofold. First, in a study of end-loaded isolated ribs, it was found that the interior rib shaft is weaker compared with the posterior region of the rib. Therefore, loading of the ribs at or near the ends as is performed in manual CPR, applies the greatest force to the weakest point of the rib thus increasing the risk of fracture. Second, during manual chest compressions, both hands are placed at the mid-chest where the maximum biomechanical force is routed through the hypothenar regions surrounding the fifth metacarpal. The close proximity of these regions results in a large force over the sternal area, therefore resulting in sternal and anterior rib fractures.”⁷
8. **During the design phase of HCR’s CPR manikin, a series of prototypes in various stages of development were beta tested by a large audience (105 professionals), including AHA personnel, American Red Cross directors and trainers, fire department captains and personnel, private training companies, and many others with over 1000 years of experience. The beta test participants consistently reported to HCR that the performance of CPR on actual victims of cardiac arrest very commonly involves the tearing of cartilage, sternum injuries, and broken ribs. This was a key reason why they so enthusiastically received, praised, and support HCR’s new manikin. A fire department medical director offered “That’s just how it should feel. You guys have a winner here”.**
9. It is not atypical to review web sites like EMTLife.com and allnurses.com where someone new to the profession poses a question about the incidence of broken ribs etc. encountered while delivering CPR. Inevitably, their fellow bloggers respond that these results are just a natural part of the experience.
10. A 2009 article reported by the *Netherlands Heart Journal* states that “Cardiopulmonary resuscitation is a life-saving procedure but can be associated with various complications. The most frequently reported complications are fractures of ribs and sternum”.⁸

11. A recent article on cardiopulmonary resuscitation published by the University of Arizona (Lowe on CPR) lists broken ribs at the top of a list of CPR hazards with the comment “(this is almost certain to happen)”.⁹
12. The National Institutes of Health states that “Fractured ribs and sternum are frequent complications of thoracic compression during CPR in adults”. Their conclusion: “rib cracking etc. (which occurred in 94% of their test sample by autopsy) is commonly under investigated and, therefore, not reported”.¹⁰
13. An October 2011 article published in *Resuscitation* analyzed “Multi-detector CT findings of skeletal chest injuries secondary to cardiopulmonary resuscitation.” The authors submitted 40 patients who had undergone CPR to both multi-detector computed tomography (MDCT) and X-ray. MDCT revealed that 26 patients (65%) had rib fractures and 12 patients (30%) had sternal fractures. However, X-ray detected only 10 patients who had rib fractures. In 25 of the 26 cases, multiple ribs were fractured (ranging up to 13 rib fractures).¹¹
14. The AHA’s Guidelines 2005 stated that “Rib fractures and other injuries are common but acceptable consequences of CPR given the alternative of death from cardiac arrest”.¹²
15. An article in *Resuscitation* in May 2014 is titled “Chest injuries during resuscitation following the current guidelines: First results of the RECAPTA study”. The authors analyzed the autopsy reports of 20 patients and determined that 56% had at least one rib fracture and 18% had fractures of the sternum. The mean number of rib fractures was 5.5. Their conclusion: “Chest injuries by chest compressions are common. Their high frequency is surprising, compared to other studies which may be increased by the application of the current guidelines (referring to AHA Guideline 2010); (HCR note: The “other studies” referenced were completed in 1999 and 2004).¹³
16. A December 2004 article in *Resuscitation* dealt with a review of 1823 deaths referred to Edinburgh City Mortuary for autopsy from 2000-2001. 499 cases were studied that had received either in or out-of-hospital CPR prior to death. Rib fractures were found in 29% and sternal fracture in 14% of the cases.¹⁴
17. A 2004 *Forensic Pathology Review* article titled “Injuries Resulting From Resuscitation Procedures” stated that “The most common cardiac resuscitation-related injuries are fractures of the ribs and sternum in 40-70% of cases.”¹⁵

There are a large number of reports, including the two previous studies, of chest injuries resulting from CPR beginning in the 1960s and carrying through 2005 and beyond. In 2006, Zoll Medical Corporation published an article written by Dr. Howard Michaels, which summarized eleven different published reports on the incidence of injury to skeletal and soft tissue with standard manual CPR (ranging in dates from the 1960s through 1987). These reports included 2,194 patients. The incidence of rib fracture in this group was 33% and sternum fracture was 19%. According to the article, “These results formed the basis of the AHA Guidelines 2000 and 2005 position – prompt and energetic CPR was performed on these patients because the mortality rate from cardiac arrest is high. This level of injury has been deemed acceptable because external chest compression is the only technique that can restore circulation to a patient with cardiac arrest – a patient who will very quickly expire without circulation.”¹²

Conclusion: As stated by the authors of the 2015 *Resuscitation* article discussed in item 2 above, the frequency of chest related injuries reported in their study greatly exceeded previously reported results (including the Zoll Medical Corporation report and many others), which were based upon the AHA resuscitation guidelines of 2005 and earlier. Studies completed since the implementation of Guideline 2010 (the minimum recommended chest compression depth increased from not less than 1.5 inches to not less than 2 inches.) indicate that the frequency of reported CPR chest compression injuries has increased substantially from approximately 30% and above to as high as 70 to 90%.

It is critical that CPR trainees are aware of the **sound and feel** of these potential injuries so that they will not become alarmed if and when they have to perform CPR on a live human being. It is not uncommon for bystanders to cardiac arrest to stop performing chest compressions when fractures occur, because they think they have wrongly and unnecessarily harmed the patient. HCR’s CPR manikin will provide this valuable **sound and feel** experience (in addition to other unique features and benefits), and give professionals and potential bystanders more confidence that they can save lives-- and more lives will be saved.

References

1. Friberg, Walther and Englund. Abstract 103: Rib and Sternum Fractures After Cardiopulmonary Resuscitation: An Autopsy Study. **Circulation**, 2014
2. Kralj, Podbregar, Kelzar and Balazic. Frequency and number of resuscitation related rib and sternum fractures are higher than generally considered. **Resuscitation**, August 2015
3. Koenig. Both Manual and Mechanical CPR Commonly Cause Traumatic Injuries. **Resuscitation**, September 2014
4. Smekal, Hansen, Sandler and Rubertson. Comparison of computed tomography and autopsy in detection of injuries after unsuccessful cardiopulmonary resuscitation. **Resuscitation**, March 2013

5. Kashiwag, Sasakawa, Tampo, Kawata, Nishiura, Kokita, Iwasaki, and Fujita. Computed tomography findings of complications resulting from cardiopulmonary resuscitation. **Resuscitation**, March 2015.
6. Seung and Park. Comparison of complications secondary to cardiopulmonary resuscitation between out-of-hospital cardiac arrest and in-hospital cardiac arrest. **Critical Care**, 2015
7. Pinto, Haden-Pinneri, and Love. Manual and Automated Cardiopulmonary Resuscitation (CPR): A Comparison of Associated Injury Patterns. **Journal of Forensic Sciences**, July 2013
8. De Weerd, Kraaier, Logenberg, Huisman, and von Birgelen. Successful bystander cardiopulmonary resuscitation complicated by liver rupture. **Netherlands Heart Journal**, Jan 2009.
9. Lowe, University of Arizona, date unknown
10. Lederer, Mair, Rabl, and Baubin. Frequency of rib and sternum fractures associated with out-of-hospital cardiopulmonary resuscitation is underestimated by conventional chest X-ray. **Resuscitation**, Feb 2004.
11. Kim, Yang, Sung, Cho etal. Multi-detector CT findings of skeletal chest injuries secondary to cardiopulmonary resuscitation. **Resuscitation**, October 2011
12. Howard Michaels, M.D. Injuries Associated with Delivery of Manual CPR and AutoPulse CPR: A Literature Review. **Zoll Medical Corporation**, 2006
13. Azeli, Landin, Jiminez-Herrera, Lucas-Guarque, Fortuny, Guillen-Lopez, Barberia, and Bardaji. Chest Injuries during resuscitation following the current guidelines: First results of the RECAPTA study. **Resuscitation**, May 2014.
14. Black, Busutil, and Robertson. **Resuscitation**, December 2004..
15. Michael Tsokos, M.D. Injuries Resulting From Resuscitation Procedures. **Forensic Pathology Reviews**, Volume 1, 2004.

Author: Robert C. Fick

July 26, 2015