

CASE REPORT

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Autopsy Artifact Created by the Revivant AutoPulse™ Resuscitation Device*

ABSTRACT: In certain cases, the evaluation and correct identification of resuscitative artifacts is critical to the correct diagnosis and determination of the cause and manner of death. Resuscitative artifacts can resemble homicidal or accidental injury and thus possibly be misinterpreted. Occasionally, new technologies and/or medical procedures will create original and/or distinctive artifacts. In 2003, the San Francisco Fire Department emergency personnel began field-testing the Revivant AutoPulse™, an automated chest compression device. This device is currently being used in two other counties in the San Francisco Bay Area as well as regions of Florida, Virginia, and Ohio. We present three cases of resuscitative artifact that could be potentially confused with homicidal or accidental injury. These cases illustrate resuscitative artifacts, specifically lateral chest and horizontally oriented upper abdomen cutaneous abrasions created by this automated chest compression device.

KEYWORDS: forensic science, forensic pathology, resuscitative artifact, mechanical cardiopulmonary resuscitation, automated chest compression device, perimortem artifacts

Cardiopulmonary resuscitation (CPR) is a basic life support method intended to maintain perfusion of the internal organs in cases of apparent sudden cardiac arrest until advanced life support (ALS) can be instituted. Manual CPR has been widely used since 1960 (1). Resuscitative artifacts related to CPR have been previously well documented in the literature (2–4).

Myocardial blood flow is necessary to properly oxygenate the heart and brain in addition to reestablishing a normal pulse rate. Defibrillation alone has not been proven to have significant success rates outside of a three minute initial window in which CPR is begun (2). Previous studies have shown that CPR combined with early electrical defibrillation is the most effect method of supporting victims of sudden cardiac arrest where resuscitation proceeds past a few minutes (3,4). Manual CPR is approximately 30% effective in perfusion to the myocardial vessels (5). In animal trials, mechanical resuscitation has been shown to improve blood flow to the brain and heart to above normal pre-cardiac arrest levels in an ALS environment by improved compression depth, consistency and speed (6). Studies have shown that an individual cannot maintain a high level of CPR performance and only 24.9% of CPR compressions performed in the second minute were done effectively (5). The delivery of CPR by mechanical means could potentially improve the efficient and prolonged delivery of CPR and improve outcomes. Prospective studies could help clarify these issues.

The AutoPulse™ is a reusable, portable, automated chest compression device developed by the Revivant Corporation, a private

company, in Sunnyvale, California, just south of San Francisco. This is not the first attempt at an automated electronic CPR device. Numerous automatic and manual mechanical external chest compression devices have been designed and evaluated for supplementation of manual CPR and are summarized in a recent review (7). Many of these early devices were designed to be stationary requiring an electrical outlet and monitoring of pistons. The AutoPulse™ requires the technician to align the patient on the device, attach the latex-free plastic strip around the patient's chest, press start, and the compressions begin. This device consists of a backboard measuring 2 in. thick and 8 in. wide, weighing 20 lb. and carries two rechargeable batteries that have approximately 30 min of use time each. The batteries can be exchanged during resuscitation. The primary benefit of this portable automated chest compression device is that it delivers consistent cardiovascular compressions and improved cardiac output throughout its use during resuscitation. This includes periods of extrication and patient transport (stairs, elevators and/or ambulance). In addition, its use can free emergency personnel for other resuscitative or life saving efforts. In 2003, the San Francisco Fire Department emergency personnel began field-testing the Revivant AutoPulse™. This device is currently being used in two other counties in the San Francisco Bay Area as well as regions of Florida, Virginia, and Ohio.

In the spring of 2003, we observed unusual cutaneous abrasion patterns on the anterior and lateral torsos of three cases of apparent sudden cardiac arrest that came under the jurisdiction of the Office of the Chief Medical Examiner of San Francisco. Upon further investigation we determined that each of the three cases had undergone attempted field resuscitation using the Revivant AutoPulse™.

To the best of our knowledge, artifacts related to this automated chest compression device have not been previously reported in the literature. We present three cases with resuscitative artifacts from the Revivant AutoPulse™ automated chest compression device that could be potentially confused with homicidal or accidental injury.

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Case 1

A 69-year old man and landlord of the residence with a history of hypertension was found dead on the floor of the bedroom/office in the home that he shared with his daughter and a downstairs tenant. On the evening of his death, his daughter was out with her fiancée. During the evening, the decedent reportedly engaged in a verbal altercation regarding the use of the oven in the kitchen with the downstairs tenant. The downstairs tenant reported that the decedent seemed very agitated, angry and tense, which was unusual for him. The downstairs tenant called the decedent's daughter, who returned with her fiancée to the residence. While the daughter's fiancée was speaking with the downstairs tenant he noted an abrasion on the back of the downstairs tenant's right hand, which the downstairs tenant claimed was from striking a wall after the verbal altercation with the decedent. The daughter went upstairs and found her father, the decedent, lying on the floor, unresponsive. Hearing the daughter scream, her fiancée went upstairs. The daughter called 911 while the fiancée started manual cardiopulmonary resuscitation on the decedent. When the paramedics arrived, they continued resuscitation using the Revivant AutoPulse™ automated chest compression device for approximately 35 min. The decedent's recorded terminal rhythm was a ventricular fibrillation. Despite all efforts, the decedent was pronounced dead at the scene. The decedent's primary care doctor was contacted and reported that he considered his death sudden and unexpected.

During autopsy, external examination revealed a well-developed man measuring 5'8" tall and weighing 185 lb. [Body Mass Index (BMI) = 28]. The decedent had truncal obesity and an increased anterior-posterior diameter of his chest. There was partially fixed, purple-red lividity of the anterior head and neck and posterior body surfaces except in areas exposed to pressure. There were petechial hemorrhages of the skin of the forehead, upper and lower eyelids and cheeks. There were focal confluent sclera hemorrhages. Evidence of medical therapy consisted of an endotracheal tube in the airway, a defibrillator pad on the anterior chest, a grounding pad on the upper central back, and an intravascular catheter in the right antecubital fossa. There were three dry, slightly depressed, irregular, red-yellow abrasions on the left side of the chest measuring up to 2 in. in greatest dimension and a horizontally oriented red-yellow abrasion on the upper abdomen measuring 4 in. in greatest dimension (see Figs. 1 and 2). There was a red abrasion on the left parietal scalp measuring 5/8 × 3/8 in. and a confluent 1 × 1/4 in. purple contusion. On the right side of the forehead and the right cheek over the right zygomatic arch were four separate red abrasions measuring up to 1 in. in greatest dimension. On the right side of the nose and medial aspect of the right eyelids were three separate red abrasions measuring no greater than 1/2 in. in greatest dimension. On the lateral aspects of the left eyelid were radiating purple-red contusions measuring no greater than 1 in. in greatest dimension. The nasal and facial bones and skull were palpably intact. There was a contusion of the left knee measuring 1–1/4 in. in greatest dimension.

Internally, there were minimally hemorrhagic, non-displaced fractures of the sternocostal regions of the right third and seventh and left sixth ribs. There were no hemorrhages of the thoracoabdominal soft tissue or injury of the underlying viscera or vessels. There were bilateral confluent paravertebral hemorrhages of the mid thoracic spine measuring up to 3 in. in greatest dimension. Examination of the neck was negative for hemorrhages or fractures. The heart weighed 520 g, and the cardiac contour was slightly globoid with dilated chambers. There was no evidence of myocardial scarring or acute infarcts. The proximal left anterior



FIG. 1—Left lateral view of chest of 69-year old man involved in a verbal altercation prior to terminal collapse. Manual CPR and chest compression device used.



FIG. 2—Anterior lateral view of chest of 69-year old man involved in a verbal altercation prior to terminal collapse. Manual CPR and chest compression device used.

descending and left circumflex coronary arteries showed up to 75% atherosclerotic stenosis. The distal right coronary artery showed up to 80% atherosclerotic stenosis. The remaining coronary arteries were unremarkable. The only other significant findings were bullous pulmonary emphysema and arteriolar nephrosclerosis.

The findings of the external examination on this case were suggestive of possible blunt trauma/stomping or mechanical asphyxia and possible homicidal or accidental manners of death. Additional investigation revealed that the decedent was originally found on the floor lying on his right side with his head resting against the edge of the mattress box spring corresponding to the abrasion and contusion on his scalp. His head was not reported to be in a position that would have obstructed his airway. No horizontal objects were present on, below or about the upper abdomen. The decedent's glasses were located on the floor next to the bed where he was found with the right temple piece bent and a small amount of apparent human tissue in the right hinge corresponding to the abrasions, contusions, and confluent hemorrhages on and about the eyes and nose. There were no signs of a struggle in the room or house where he was

found. The downstairs tenant showed police officers responding to the scene a mark on the downstairs wall consistent with his history of striking the downstairs wall after the reported verbal altercation with the decedent.

The cutaneous petechial hemorrhages of the forehead, upper and lower eyelids and cheeks are suggestive of an asphyxial death such as a manual strangulation or neck compression; however, the external and internal examination of the neck showed no evidence of injury or hemorrhage to support those diagnoses. Based on the investigative and autopsy findings in this case, the petechial hemorrhages and focal confluent hemorrhages are most likely associated with a terminal cardiac event and/or CPR.

The minimally hemorrhagic, non-displaced fractures of the anterior right third and seventh and anterior left sixth ribs of this case are consistent with well-recognized findings associated with manual CPR and were only present in this case in which manual CPR was known to be performed. Personal observation by one of the authors (A.H.) of the Revivant AutoPulse™ automated chest compression device showed no focal concentrated application of force by the chest belt to the anterior chest wall where these fractures were located.

The toxicology studies of the peripheral blood were positive for lidocaine that had been administered during resuscitation. There were no other drugs or chemicals present. Based on the investigative, toxicology and autopsy findings, the cause of death in this case was determined to be atherosclerotic hypertensive cardiovascular disease with chronic obstructive pulmonary disease as a significant contributing condition. The manner of death was determined to be natural.

Case 2

A 58-year old Asian woman with a 2–3 day history of “feeling bad” and indigestion was sitting up in bed watching television. Her husband witnessed her suddenly slumping to her left and becoming unresponsive. No bystander CPR was performed. Emergency medical personnel responded, however she was pronounced dead at the scene after approximately 30 min of resuscitation using the automated chest compression device. Her recorded terminal cardiac rhythm was asystole. Approximately one hour before her death she had taken 2 teaspoons of Mylanta. She had no significant previous medical history and was not taking prescription or over the counter medications. She had no history of alcohol, tobacco or illicit drug use.

The external examination revealed a well-developed woman measuring 5'0" tall and weighing 134 lb (BMI = 26). There was pink-purple lividity of the posterior body surfaces and congestion of the face. There were petechial hemorrhages of the conjunctivae and sclerae. Evidence of medical therapy consisted of an endotracheal tube in the airway, cardiac monitoring electrodes on the anterior torso, a defibrillator pad on the chest, and a grounding pad on the left side of the back. There were two blue contusions on the posterior aspect of the left upper arm measuring 3/4 and 1/2 in. in greatest dimension. In addition, on the lateral aspect of the left breast were four dry, slightly depressed, irregular, red-yellow abrasions ranging from 1/2 × 1/8 in. and 2 × 3/4 in. in greatest dimension (see Fig. 3).

The internal examination revealed a 380 g heart showing mild left ventricular hypertrophy with a left free wall concentric thickness of approximately 1.6 cm. There was no evidence of myocardial scarring or acute infarcts. The left anterior descending coronary artery showed an occlusive dark red-brown thrombus superimposed on a



FIG. 3—Lateral view of left breast of 58-year old woman. Automated chest compression device used for CPR.

severely atherosclerotic segment located approximately 2 cm from the origin of the vessel. The right coronary artery had atherosclerotic narrowing up to 75% of the luminal diameter. The remaining coronary arteries were unremarkable. The only other significant findings were pulmonary congestion and edema. The cause of death was determined to be acute coronary thrombosis due to arteriosclerotic cardiovascular disease and the manner of death was determined to be natural.

Case 3

A 54-year old Caucasian woman was eating dinner with her daughter at a restaurant when she stated, “Here is that feeling again,” and she suddenly fell from her chair to the floor and became unresponsive. The daughter reported that her mother did not choke on anything prior to the event. No bystander CPR was performed. Emergency medical personnel responded, however she was pronounced dead at the scene after approximately 40 min of resuscitation including using the automated chest compression device. Her recorded terminal rhythms were ventricular fibrillation and pulseless electrical activity. Approximately two weeks before her death, she had been seen in an Emergency Room for chest discomfort, where she was told it was probably indigestion, but she should have follow up studies. She had no additional significant previous medical history and was not taking prescription or over the counter medications. She had no history of alcohol, tobacco or illicit drug use.

The external examination revealed a well-developed, obese woman measuring 5'2" tall and weighing 240 lb (BMI = 44). There is pink-purple lividity of the posterior body surfaces and congestion of the face. Evidence of medical therapy consisted of an endotracheal tube in the airway, cardiac monitoring electrodes on the anterior torso, a defibrillator pad on the chest, a grounding pad on the left side of the back and an intravascular catheter in the right antecubital fossa. On the upper outer quadrant of the right breast was a 1 × 1/2 in. blue contusion. On the right side of the chest at approximately the anterior axillary line was a dry, sharply demarcated, slightly depressed, red-yellow abrasion measuring 2–1/2 in. anterior to posterior dimension and 1/8 to 5/16 in. superior to inferior



FIG. 4—Right lateral view of chest of 54-year old woman. Automated chest compression device used for CPR.

dimension (see Fig. 4). The only other evidence of trauma was a $1 \times 3/4$ in. blue contusion on the anteromedial right lower leg.

The internal examination revealed 280 mL of liquid and clotted blood in the pericardial sac. The 460 g heart showed concentric left ventricular hypertrophy with a free left wall thickness of 2.0 cm and a ruptured, tan-yellow, hemorrhagic infarct of the base of the posterior free wall of the left ventricle. No areas of myocardial scarring were identified. The left anterior descending coronary artery had a pinpoint lumen located approximately 1.5 cm from the origin of the vessel. There was a dark-brown thrombus superimposed upon this atheromatous plaque. The right and left circumflex coronary arteries showed multifocal approximately 50% atherosclerotic narrowing. The airways were free of obstructions. Other findings included pulmonary congestion and edema and arteriolar nephrosclerosis. The cause of death was determined to be hemopericardium due to ruptured acute myocardial infarct due to coronary thrombosis due to arteriosclerotic cardiovascular disease. The manner of death was determined to be natural.

Discussion

The autopsy findings of fatal stomping, stamping, punching, kicking or mechanical (traumatic or compressive) asphyxia reported in the recent English literature are sparse. Classic forensic textbooks describe external blunt force injury (sometimes patterned), fractures (primarily of the ribs), internal soft tissue hemorrhages, and lacerations of internal organs and vessels associated with hemorrhage or air in the thoracoabdominal cavities associated with fatal stomping, stamping, punching, and kicking. Fatal mechanical asphyxia in these same textbooks is described with a paucity of autopsy findings but can include congestion, swelling, petechial hemorrhages, retinal hemorrhages, small hemorrhages near bony attachments, and sometimes patterned or non-patterned external blunt force injuries. Mechanical asphyxia can often only be diagnosed by careful assessment of the history and circumstances surrounding the death and exclusion of other causes of death (8–10).

Investigation of the abrasions on the anterior and lateral torso on these three cases included a physical examination of the Revivant AutoPulse™ automated chest compression device (see Figs. 5A and 5B). Direct observation and examination of the automated chest compression device showed that the short rigid backboard had attached front closing, synthetic cloth covered, and Velcro®-like secured chest belt. When activated, the synthetic cloth covered

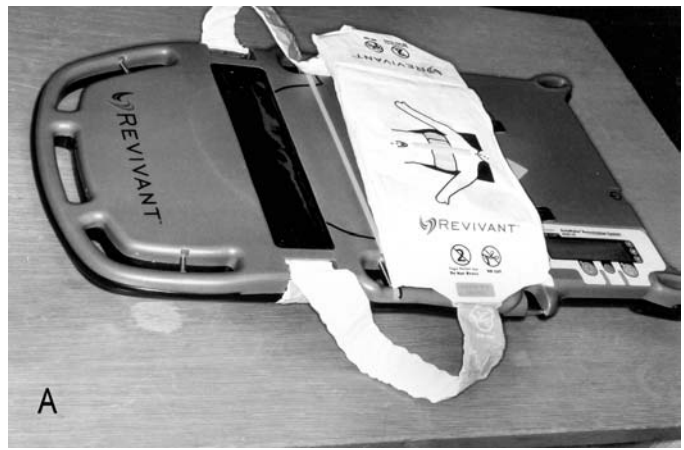


FIG. 5—Portable automated chest compression device (A). Portable automated chest compression device with torso manikin in place (B).

side straps of the chest belt automatically adjust to the depth of the patient's chest before beginning rhythmic compressions at a computer-calculated depth. When placing a hand under the chest belt during compressions on a resuscitation manikin (personal observation of author A.H.), it was noted that the chest belt embraced the chest with even anterior and lateral pressure. No focal concentrated areas of pressure were noted except for the areas over the anterior-lateral chest directly below the synthetic cloth covered metal safety release devices corresponding to the abrasions noted on the lateral chest walls of all three cases. The rough horizontal anterior-inferior edge of the Velcro®-like chest belt corresponds to the horizontal abrasion on the upper abdomen of the decedent in Case 1.

To the best of our knowledge, the presence of symmetrical paravertebral hemorrhages in the mid thoracic region have not been previously described in the literature in association with manual or assisted CPR. Symmetrical paravertebral hemorrhages were only present in Case 1 in which manual and assisted CPR were both known to be performed.

There were no overlying cutaneous lesions or investigational or scene information to determine the nature of these hemorrhages. Symmetrical paravertebral hemorrhages were not present in Cases 2 or 3. Examination of the automated chest compression device showed no unequal pressure applied to the back, however the symmetrical paravertebral hemorrhages may present dynamic movement of the posterior aspects of the ribs related to the equal and diffuse chest pressure exerted by the automated chest compression

TABLE 1—Summary of cases.

	Age	Sex	BMI*	External Finding	Internal Finding	Manual CPR**	ACCD*** Minutes
Case 1	69	M	28	Anterior and Left Lateral Chest Abrasions	Minimally Hemorrhagic Non-displaced Anterior Sternocostal Rib Fractures (3) and Mid Thoracic Paravertebral Hemorrhages	Yes	35
Case 2	58	F	26	Left Lateral Chest Abrasions	None	No	30
Case 3	54	F	44	Right Lateral Chest Abrasion	None	No	40

* BMI is the Body Mass Index = (weight in lb./height in inches²) × 703.

** CPR is Cardiopulmonary Resuscitation.

*** ACCD is the Automated Chest Compression Device.

device in the presence of anterior rib fractures from previously performed manual CPR. The source of these hemorrhages appears to be associated with the use of the automated chest compression device after manual CPR has been initiated.

Based on the investigative information, autopsy findings, and direct observation of the automated chest compression device, we concluded that the lateral and anterior abrasions on the chest corresponded in size and location to the chest belt of the automated chest compression device, the anterior ribs fractures were due to manual CPR (see Table 1) and the source of the symmetrical paravertebral hemorrhages was undetermined.

Further prospective studies may better determine the frequency and distribution of resuscitative artifacts related to the use of this automated chest compression device and any relationship they have to the medical conditions and physical characteristics of individual patients. Because it is unlikely that this reusable automated chest compression device will be left in place, it is imperative that forensic pathologists, medical examiners, coroners and medicolegal investigators become aware of this new technology in cardiopulmonary resuscitation.

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