



## Review

## Injuries associated with resuscitation – An overview

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## ABSTRACT

External cardiopulmonary resuscitation is a potentially lifesaving intervention aimed at preserving the cerebral function of a person in cardiac arrest. However, certain injuries can be caused by the various techniques employed. Although these are seldom consequential, they may complicate the forensic evaluation of cases. Fractures of the ribs and sternum are the most common internal injuries and are frequently acknowledged as a consequence of resuscitation. Nonetheless, the recognition that less common fractures such as of the larynx or injuries involving the stomach, spleen, heart and liver can occur due to resuscitation will assist the forensic examiner assess the significance of these findings when they present in cases of sudden death.

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## 1. Introduction

Cardiopulmonary resuscitation is an emergency procedure involving external chest compression and artificial ventilation that aims to restore the flow of oxygenated blood to the brain and heart in individuals in cardiac arrest.<sup>1</sup> In 1960, Kouwenhoven et al. developed a method of external cardiac massage that did not require thoracotomy, which is now known as cardiopulmonary resuscitation.<sup>2</sup> Its relative simplicity allowed resuscitation to be performed both in and out of hospital, by bystanders, as well as by trained medical personnel. The method has remained fundamentally unchanged.<sup>3,4</sup> Whilst potentially lifesaving, it was recognised from the early days that injuries or complications may arise.<sup>5</sup> Complications from resuscitation may create unusual lesions or injuries<sup>6,7</sup> of which the pathologist should be aware to prevent findings being misinterpreted; a rare example being a 9 mm circular defect resembling a gunshot wound of the chest.<sup>8</sup> In this paper the literature is reviewed to demonstrate the range injuries that may be encountered during the medicolegal autopsy when death has been declared following a period of resuscitation that

may complicate the forensic evaluation of cases due to their rarity or potential significance in terms of determining the cause of death.

## 1.1. Head and neck

Injuries related to resuscitation may be observed on external examination. Bruises and abrasions may be seen on the scalp and face.<sup>9–11</sup> Use of a mask for resuscitation can cause soft tissue damage.<sup>12</sup> Pinching of the nose can result in injuries when mouth-to-mouth resuscitation has been performed and the action of maintaining an airway may result in fingernails causing abrasions under the jaw; the distribution and pattern is generally different to that encountered in cases of throttling, except for abrasions produced by forcefully feeling for a carotid pulse.<sup>9</sup> Injuries to the face can follow the removal of vomit.<sup>9</sup>

Within the mouth mucosal injuries can occur involving the lips<sup>13</sup> including necrosis reported from use of a Guedel airway.<sup>14</sup> There may be damage to the teeth and lips from intubation<sup>10,13</sup> or insertion of an oropharyngeal airway.<sup>12</sup> Use of nasopharyngeal airways have been associated with damage to the nasal passages, including damage to turbinates<sup>15</sup> and intrusion into the cranial vault has been reported in head injured patients with base of skull fracture.<sup>16,17</sup> Oesophageal intubation may result in perforation of the oesophagus.<sup>18</sup>

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From retrospective<sup>19</sup> and prospective studies<sup>20</sup> there is no convincing evidence that facial or conjunctival petechiae result from cardiopulmonary resuscitation.

Retinal haemorrhages in children may result from inflicted head injury; however, there has also been discussion as to whether they may occur as a complication of resuscitation.<sup>21,22</sup> Goetting and Sowa suggest that chest compression from any source increases intrathoracic pressure, which can directly increase retinal venous pressure resulting in haemorrhages.<sup>23</sup> Thus, they warn that forensic pathologists should be wary of attributing retinal haemorrhages to inflicted injury if this is the only significant finding when cardiopulmonary resuscitation has been performed<sup>23</sup>; however, careful investigation of the circumstances of death is required if retinal haemorrhages are found.<sup>24</sup> A study of 22 children who had received cardiopulmonary resuscitation revealed retinal haemorrhages in six; five had other factors (trauma or raised intracranial pressure) present, leaving only one with mild haemorrhages at the posterior pole that appeared attributable to resuscitation.<sup>22</sup> A reported case in which retinal haemorrhages were documented to be absent before cardiopulmonary resuscitation, but were present within the retina, as well as in a subhyaloid location, from the posterior pole to the mid-periphery following resuscitation for 60 min adds to the suggestion that retinal haemorrhage may result from resuscitation.<sup>25</sup>

Mild basal subarachnoid haemorrhage produced by resuscitation has been observed by one of the authors (NEIL) and has also been reported.<sup>26</sup>

Deep haemorrhage may be seen in the neck from the insertion of central venous lines. Mucosal injuries of the larynx can occur,<sup>10,13</sup> as well as contusions from the base of the tongue to the oropharynx such that resuscitative intubation can cause artifactual injury that may simulate inflicted injuries caused by neck compression.<sup>27</sup> In the 1960's Sellick<sup>28</sup> described the use of cricoid pressure in resuscitation to prevent the reflux of gastric contents into the airways.<sup>29</sup> It is, however, difficult to judge the correct amount of force to apply, with experienced staff exerting a variable amount of pressure ranging from 10.8 to 120.6 N and fracture of the cricoid cartilage has been reported as a result.<sup>30</sup> Fractures of the larynx (hyoid bone and thyroid cartilage) appear to be a rare complication of resuscitation and intubation, but have been reported.<sup>13,31</sup> Haemorrhages<sup>9</sup> and haematomas within the larynx and pharynx may be observed following intubation.<sup>13,32</sup> Ulceration or laceration can occur.<sup>33</sup> Oedema of pharyngeal structures may result from use of a laryngeal mask.<sup>12</sup> Haemorrhage can be an immediate complication of emergency tracheostomy.<sup>34,35</sup>

## 1.2. Chest

Parchmented abrasions/bruising of the central chest may mark areas where external compression has been applied.<sup>10,36,37</sup> Abrasion, electrical burns or parchmending from defibrillation may also be present<sup>13,38,39</sup>; in addition, burns can occur from external pacing.<sup>40</sup> Also on the chest there may be incisions from drain insertion or puncture marks from the use of cannulae to decompress pneumothoraces<sup>37,41</sup> or from emergency pericardiocentesis.<sup>42</sup>

Fractures of the ribs and sternum are the most commonly encountered internal resuscitation injuries<sup>13,36</sup>; however the range of their reported incidence<sup>43</sup> may relate to the method of their detection. Rib fractures become more likely with age and are encountered anterior to the mid-axillary line.<sup>37,44</sup> It is unclear whether prolonged and/or untrained resuscitation is associated with a greater number of rib fractures. Pneumothoraces, haemothoraces and/or subcutaneous emphysema may result.<sup>44</sup> Rib fractures may contribute to death by causing pneumothoraces or cardiac lacerations.<sup>13,45,46</sup> However, when a pneumothorax is found

consideration has to be given to it being the cause of the arrest.<sup>47</sup> Similarly, haemothorax has been observed due to a tear of the azygos vein resulting from external cardiac massage,<sup>48</sup> but spontaneous haemothorax can be a rare cause for cardiac arrest.<sup>49</sup> Distinguishing between primary (arrest causing) and secondary (caused by resuscitation) pathology can be difficult and reliance may have to be placed on the history in addition to the findings. The more recent squeezing, rather than compressive, type of resuscitation that is being employed in infants<sup>50,51</sup> may be associated with an increased number of rib fractures. Fractures of the spine are extremely rare.<sup>52,53</sup>

Epicardial petechial haemorrhages are not uncommon and are more likely to be seen on the posterior surface.<sup>11</sup> Epicardial contusions may also be present.<sup>54</sup> Myocardial haemorrhages attributed to the effects of compression of the heart may be present in the septum<sup>11</sup> and in the region of the bundle of His.<sup>54,55</sup> Haemorrhage may also be seen in the adventitia of the aorta.<sup>13</sup> 'Fractures' of the coronary arteries have been described as disruption of the intima, media or adventitia associated with evidence of haemorrhage; such lesions are reportedly more common in the left anterior coronary artery, at branch points and in areas of calcified atherosclerosis.<sup>54</sup> Histological examination of the myocardium may reveal the presence of contraction bands and areas of myocyte necrosis.<sup>37,56</sup> Although this could be a direct consequence of blunt trauma<sup>57</sup> from chest compressions, the finding is more likely to be attributable to the effects of adrenaline.<sup>58</sup>

Laceration of the heart and pericardial sac may result from fractures of the ribs.<sup>46</sup> Cardiac rupture during resuscitation is, nonetheless, very rare and is postulated to be due to a hydrostatic effect from increased pressure from attempted compression of an incompressible fluid (blood)<sup>59</sup>; it would be expected ruptures would be more likely to occur in regions with a thinner wall, such as the right ventricle or atria.<sup>60</sup> Thus, rupture of the right ventricle of the heart is believed to occur when there is increased pressure in the right side of the heart (for example due to outflow obstruction by pulmonary thromboembolus) or as a consequence of the application of an incorrect technique.<sup>60</sup> It is considered that rupture of infarcted regions of the left ventricle does not occur due to resuscitation, but that the rupture of the infarct with resulting haemopericardium precedes application of chest compressions.<sup>61</sup> However, rupture of areas of non-infarcted heart has been recorded<sup>46</sup> and cases with small volumes (less than 200 ml) of non-clotted blood in the pericardial sac in association with a ruptured myocardial infarction have been encountered at this centre that suggest the rupture was caused by the external cardiac massage. Haemopericardium can also result from a tear of the inferior vena cava within the pericardial sac.<sup>45</sup>

Laceration of the pleural surface of the lungs can result from fractures of the ribs.<sup>45</sup>

## 1.3. Abdomen and retroperitoneum

Haematomas may be encountered in the mesocolon, pancreas<sup>62</sup> and omentum.<sup>13</sup> Perinephric haematoma has been reported.<sup>62</sup> Haemoperitoneum may be encountered for which the only apparent cause may be laceration of small vessels.<sup>13</sup>

Incorrect placement of the hands over the xiphoid process of the sternum during cardiopulmonary resuscitation can increase the likelihood of visceral injuries.<sup>45</sup> Abnormalities of the spleen or liver may contribute to an increased risk of laceration.<sup>62</sup> Ossification of a thoracotomy scar has caused a resuscitation laceration of the liver.<sup>63</sup>

Mouth to mouth resuscitation or the use of a bag and mask may create gastric distension and promote gastric rupture<sup>64,65</sup> that must be differentiated from gastromalacia.<sup>66,67</sup> Gastric rupture from

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