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REVIEW

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Frequent and rare complications of resuscitation attempts

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Abstract *Introduction:* Resuscitation attempts require invasive iatrogenic manipulations on the patient. On the one hand, these measures are essential for survival, but on the other hand can damage the patient and thus contain a significant violation risk of both medical and forensic relevance for the patient and the physician. We differentiate between frequent and rare resuscitation-related injuries. Factors of influence are duration and intensity of the resuscitation attempts, sex and age of the patient as well as an anticoagulant medication. *Materials and methods:* Review of current literature and report on autopsy cases from our institute (approximately 1,000 autopsies per year). *Results:* Frequent findings are lesions of tracheal structures and bony chest fractures. Rare injuries are lesions of pleura, pericardium, myocardium and other internal organs as well as vessels, intubation-related damages of neural and cartilaginous structures in the larynx and perforations of abdominal organs such as liver, stomach and spleen. *Conclusion:* We differentiate between frequent and rare complications. The risk of iatrogenic CPR-related trauma is even present with adequate execution of CPR measures and should not question the employment of proven medical techniques.

Keywords Resuscitation-related injuries · Frequencies · Medical relevance · Forensic relevance

Introduction

Resuscitation measures such as external cardiac massage [cardiopulmonary resuscitation, (CPR)], external defibrillation, endotracheal intubation and cannulation of peripheral and central vessels for the application of drugs have been performed for a long time in patients with cardiopulmonary arrest and uncertain death signs until either a sufficient spontaneous circulation is achieved or the definitive death of the patient is stated [16]. These necessary, potentially life-saving emergency measures contain a significant violation risk of both medical and forensic relevance for the patient and the physician.

In the following, we report on cases from literature as well as on autopsy cases from our institute (approximately 1,000 autopsies per year are performed here) in which resuscitation-related trauma caused by iatrogenic manipulations became obvious during autopsy.

Frequent complications

Neck

Besides the chest wall, airways are often affected by iatrogenic resuscitation trauma—reclination of the head for manual artificial respiration as well as endotracheal

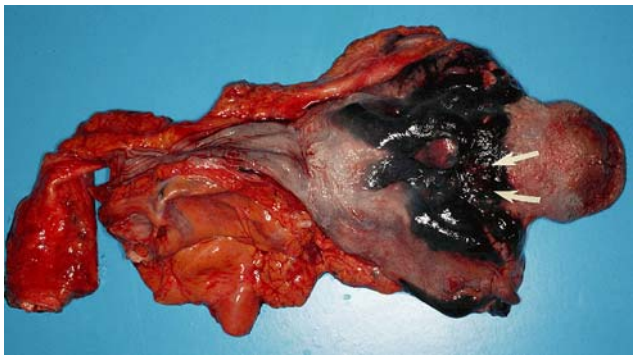

Fig. 1 Substantial hematoma in the neck musculature and soft parts (*arrows*), caused by repeated intubation attempts and hyperextension of the head. Resuscitation of a patient undergoing phenprocoumon therapy

intubation can be considered as external blunt injuries. Frequent consequences of resuscitation attempts (9.2%) are retropharyngeal bleedings. Apart from tooth damage, (tracheal) mucosa lesions caused by multiple intubation attempts are frequently observed resuscitation-related injuries (18%) [10, 19]. In an autopsy case from our institute, a massive hematoma in larynx and pharynx was caused by unsuccessful, repeated intubation efforts and hyperextension of the head when artificially respirating a patient who was anticoagulated with Phenprocoumon. The inner neck hematoma after futile resuscitation caused petechial bleedings in the conjunctivas and a vena cava superior syndrome, which at first appeared to be death by strangling (Fig. 1). During autopsy, cause of death was found to be an acute myocardial infarction.

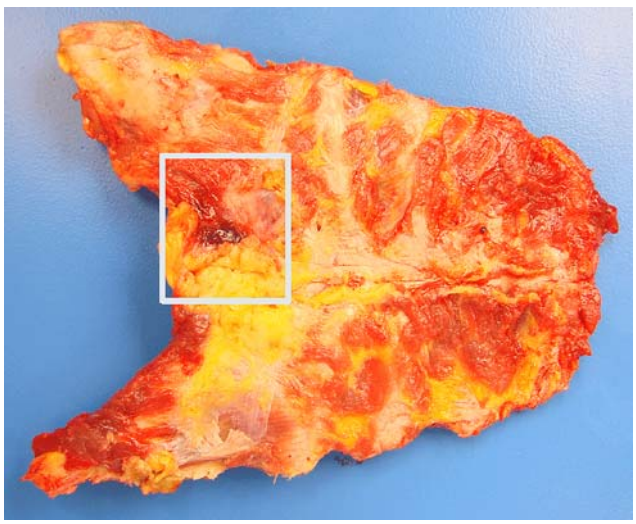

Fig. 2 Sternal fracture (*square*) after external CPR

Fig. 3 Rib fracture (*square*) after external CPR

Chest

In connection with resuscitation measures, the most frequent bony injuries which can be observed are rib and sternal fractures caused by external CPR with 13–97% of cases, depending on literature (Figs. 2, 3) [5, 9]. Rib fractures are more often situated on the left side (second–seventh rib) than on the right side (second–sixth rib) of the chest wall in the medial clavicle line and are widespread in older patients, as for chest compression increased energy expenditure is necessary because of increased chest wall rigidity [5]. In addition, with higher age the risk of underlying osteopenia is increased, especially in females [37]. These injuries must be distinguished forensically from other causes of chest wall trauma, for example attack or accident [33]. Remarkable in this context is the fact that conventional X-ray examinations have limitations when it comes to diagnosing bony thorax injuries; these injuries are often only confirmed by autopsy [18].

Resuscitation-related injuries of the thorax wall are rarely observed in children; on the one hand, the infantile chest is of higher elasticity than in older people, on the other hand resuscitation measures are altogether rarer during infancy. If infantile bony injuries are present, they must be differentiated from trauma caused by repetitive child abuse and/or battering [25]. It appears complicating that in rare cases, well-known abuse-related injuries like retinal bleedings or rib fractures may be provoked by resuscitation attempts in infants [3, 24]. As well as in adults, increasing duration of resuscitation measures raises the probability to provoke serious injuries of the bony chest in children [28].

After external cardiac defibrillation, energy passing through the chest wall may cause temporary skin erythemas in case that the defibrillation electrodes have direct contact with the skin, not being separated from the skin surface by a protecting but current-conducting gel layer (80% of cases); this erythema usually heals after

successful resuscitation [1] without forensic relevance. Bony chest injuries can be connected with further superficial skin lesions caused by external CPR in the sternal area. Dermabrasiones are very often found after resuscitation measures and are usually without forensic relevance, but may hint to underlying bone lesions of the chest wall. We observed sternal dermabrasio combined with solid iatrogenic serial rib fractures as well as sternal fractures in the case of a fatal aortic dissection with following pericardial tamponade; with pericardial tamponade, the rescue team was unable to generate sufficient blood circulation. Thus, external CPR was performed with increased energy expenditure, which caused, apart from skin lesions, pronounced bony chest injuries.

Abridged

Frequent findings after unsuccessful CPR in the upper airways are above all lesions of tracheal structures caused by protracted intubation attempts. In the thoracal region, rib and sternal fractures are often caused by external CPR, while perforations of abdominal organs can be due to gastric air insufflations after tracheal false intubation.

Rare and very rare complications

Neck

Rare injuries within the neck area after resuscitation attempts are lesions of the recurrent nerves, the sinus piriformis, the vocal cords and the arytenoids' cartilages, which result from mechanical manipulations connected with endotracheal intubation [5]. Lacerations of the intima of the carotids have been observed as a result of mechanical tractive forces during hyperextension of the head [29]. Life-saving emergency measures like tracheotomy or coniotomy may cause further complications [2]. Depending on the size of the incision, mucous membrane lesions and expanded bleedings with aspiration and transfer of blood to the respiratory system have been described. Since performance of tracheotomy and coniotomy—due to the described complications—has decreased in today's preclinical routine, the smaller portion of the autopsy-confirmed resuscitation-related injuries of the cervical region is accompanied by stricter indication position.

Chest

Cases of rhabdomyolysis and myoglobinuric renal failure after external defibrillation and cardioversion have been reported but seem to be quite rare events [22]. If fractured ribs cause a pericardial tamponade, injuries of myocardium, pericardium, pleura, diaphragm or pneumo- and/or hematothoraces, success of resuscitation measures is affected negatively [32]. Bode and Joachim [4] describe cases of aortic ruptures from CPR, particularly located in the Pars descendens, and give the incidence of 1%. According to literature findings, these complications are rare and arise more frequently if external CPR is performed with active compression–decompression devices like the Cardio Pump® [26]. Aspiration of stomach contents may be evoked if external CPR is performed with substantial energy expenditure [17].

Abdomen

Naturally, visceral structures are less affected from resuscitation-related trauma than thoracic structures as mechanical resuscitation attempts focus primarily on heart and chest—however, upper belly organs such as liver, stomach and spleen might be injured due to the topographic conditions [12, 20, 23]. Injuries of visceral structures are mainly based on fractured ribs and/or the sternal bone—with external CPR exerted forces being transferred through the unstable thorax to the visceral organs, which may lead to ruptures and perforations. Due to the anatomical situation, the left liver lobe is mainly affected; Meron and colleagues report in an autopsy series on liver lesions in 0.6% of all cases, while spleen or gastric affections were even rarer. An inadequately performed CPR is regarded as a main factor for resuscitation-related visceral injuries [20, 35]. Krischer et al. [15] reported on injuries of the liver in 2.1% of cases (Figs. 4, 5). Spleen or gastric ruptures are still rarer. In case of stomach lesions, the incidence is indicated with 1% [6]; however, not only

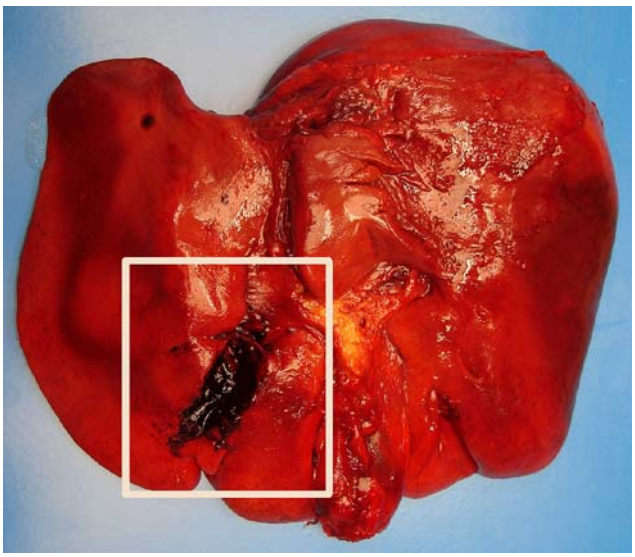

Fig. 4 Hepatic rupture (*square*) after CPR

Fig. 5 Subcapsular hematoma of the liver (*square*) after CPR

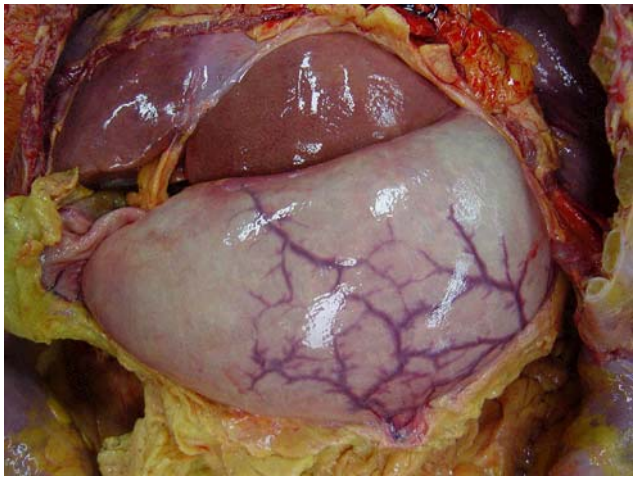

Fig. 6 Air-filled stomach after false intubation

mechanical conditions, but also artificial respiration with high-pressure ratios are made responsible here.

Incorrect intubation of the trachea—the endotracheal tube is placed in the esophagus—may lead to gastric overstretching due to continuous air insufflation into the stomach (Fig. 6), in the worst case followed by gastric rupture, hemato- and pneumoperitoneum (Fig. 7) if undiscovered [6, 7, 14, 21, 30]. Gastric rupture during CPR is a relatively rare event. Fewer than 30 cases have been reported in the English-language literature during the past two decades [34]. With ongoing CPR, the risk of provoking a gastric perforation or rupture increases as the stomach then will be compressed at the same time from the inside by air and from the outside by external CPR. Altogether, false intubations are easier to detect than visceral perforations by fractured bones with following bleeding into the abdominal cavity, since false intubations quickly present clinical indications such as cyanosis and curvature of the abdomen. These situations are easy to

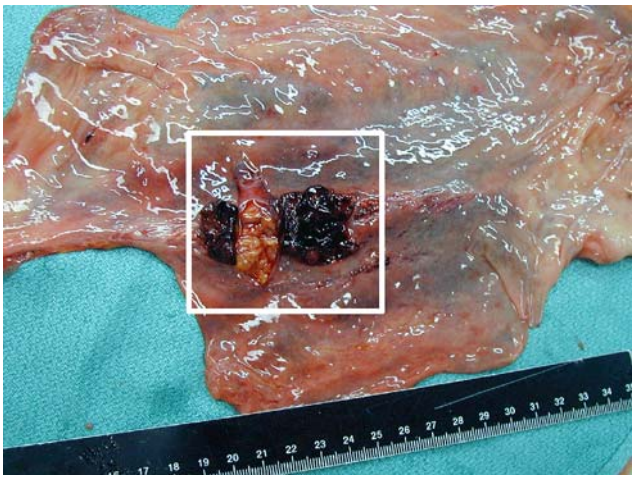

Fig. 7 Gastric rupture (*square*) after false intubation

recognize and immediately remediable by replacing the ventilation tube into the trachea. We suppose that false intubation may occur frequently, but is corrected during resuscitation measures. Thus, evidence of false intubation in forensic routine is seldom found.

Visceral traumas after resuscitation attempts are rare, but serious and under ongoing resuscitation, they cannot be treated, contrary to inadvertent intubations of the trachea. Free fluid in the abdominal cavity, particularly with two-stage bleeding, may appear with latency intervals. Becoming symptomatic with hemodynamic instability, abdominal bleedings require immediate surgery if resuscitation measures are successful. Altogether, clinical proceedings are complicated by visceral bleedings [40]. Discovering abdominal bleedings due to resuscitation measures is difficult as circulation depressions are usual findings in patients under resuscitation [20]. Furthermore, emergency physicians may perform a thrombolytic treatment since acute myocardial infarction is an assumed frequent cause of cardiac arrest. Thrombolytic treatment increases the risk of bleeding complications to up to 10%—especially if patients are already anticoagulated. It seems that the duration of resuscitation measures has no influence on the occurrence of visceral bleedings [13]. Figure 8 shows a human bony skeleton annotated with percentages of injury frequencies.

Further injuries

A further rare, but dangerous complication is iatrogenically provoked air embolism after cannulation of the external jugular vein. This vessel is frequently cannulated in resuscitation attempts, as it is located at the exterior of the neck and thus easily accessible for the physician who usually works at the head of the patient. With sufficient external CPR, (physiologic) negative pressure can be

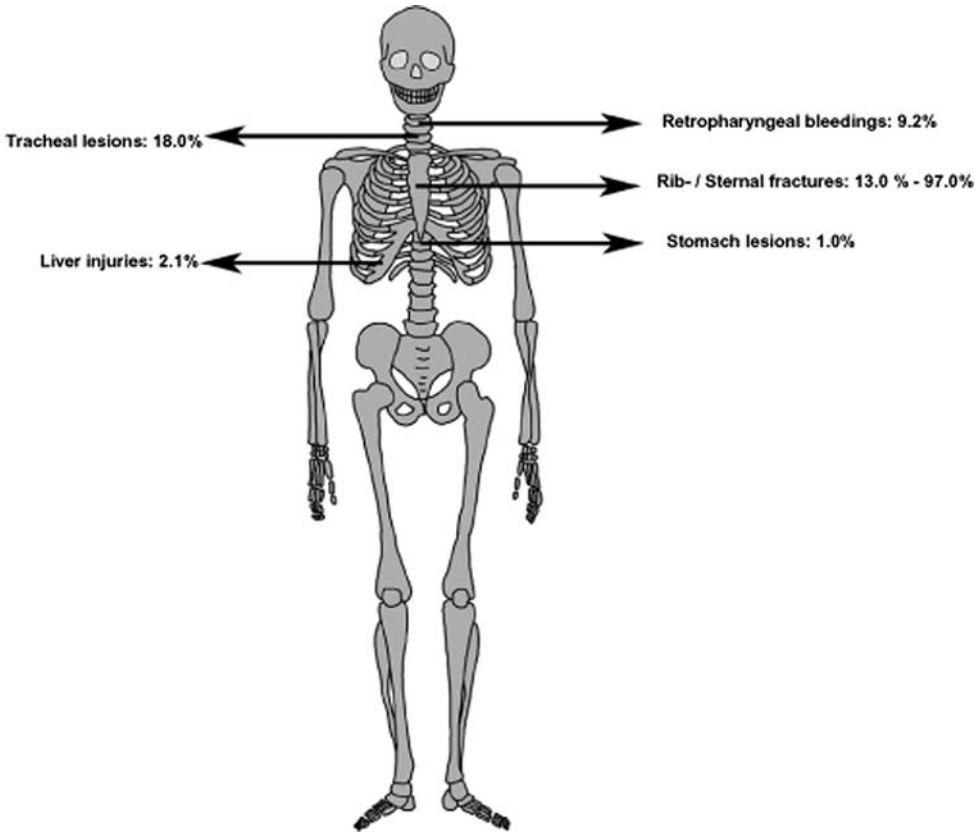

Fig. 8 Human bony skeleton, annotated with percentages of injury frequencies

produced in this vessel and ambient air may be sucked into the venous system of the head. Also, pulmonary barotrauma caused by intubation and artificial respiration may provoke cerebral air embolism [31, 39].

Abridged

Besides conio- or tracheotomy-induced complications, rare post-resuscitation neck injuries are intubation-related damages of neural and cartilaginous structures in the larynx. Rare chest injuries are lesions of pleura, pericardium, myocardium and other internal organs as well as vessels, caused by fractured ribs, while within the abdomen primarily liver, stomach and spleen are affected by inadequately performed CPR and incorrect pressure ratios.

Table 1 gives an overview on the different injury patterns and their frequency of occurrence according to the literature.

Table 1 Resuscitation-related injuries, percentage of occurrence with reference to the literature

Injury pattern	Percentage of occurrence	Reference no.
Resuscitation-related injuries	21.0–65.0	[8]
Frequent complications		
(Temporary) skin erythema	80.0	[1]
Rib fractures in adults	13.0–97.0	[5, 9]
Sternal fractures	1.0–43.0	[5, 9]
Tracheal lesions	18.0	[10]
Retropharyngeal bleedings	9.2	[19]
(Very) rare complications		
Liver injuries	0.6–2.1	[15, 20]
Rib fractures in children	0.0–2.0	[9]
Aortic ruptures	1.0	[4]
Stomach lesions (excl gastric rupture)	1.0	[6]
Gastric rupture	<1.0	[27]
Post-defibrillation rhabdomyolysis	<1.0	[22]
Spleen lesions	<1.0	[15]
Air embolism	<1.0	[31, 38]

Discussion

Medical aspects

Resuscitation attempts require invasive iatrogenic manipulations on the patient such as external CPR, external defibrillation, endotracheal intubation and cannulation of peripheral and central vessels for the application of drugs. These measures are essential for successful resuscitation, but may damage the patient's health. The total incidence of resuscitation-related injuries is indicated altogether with 21–65% [8].

The successful execution of CPR requires the knowledge of topographic and anatomical conditions, the applied techniques and their specific risks. Thus, among emergency medical professionals the question is raised whether the avoidance of serial rib fractures is to be settled higher than the acceptance of a smaller mechanical effect on the heart by performing CPR with smaller energy expenditure.

The guidelines to CPR of the European Resuscitation Council of 2005 recommend a compression depth of 4–5 cm with a compression frequency of 100/min to ensure an effective arterial blood flow. Moreover, the value of a sufficient thorax compression is emphasized in relation to breath donation, since 80% of cardiopulmonary arrests are based cardiacally and arterial oxygen content is still sufficiently high in the first minutes after cardiopulmonary arrest [11]. This can be interpreted in such a manner that—in particular with a rigid thorax—a sufficient effect of CPR is only enabled if rib or sternal fractures are taken in purchase. Altogether, complication rates are lower and outcome is higher if CPR measures are executed according to guidelines. This mainly applies if thorax compression—even in the first minutes after cardiac arrest—is not interrupted [36, 38].

We remark that rib and sternal fractures often occur after successful CPR (Lederer and colleagues [18] give a frequency of 94.7%), but rarely affect the patient's outcome after resuscitation negatively. On the other hand, sternal or rib fractures can cause pneumo- and/or hematothoraces and/or lung injuries, so that secondarily respiration disturbances in the post-resuscitation phase may occur frequently, containing the long-term risk of lethal complications such as the "Adult Respiratory Distress Syndrome" (ARDS) [4]. Thus, iatrogenically induced traumata are not only of high significance pre-clinically while performing CPR, but also injuries can become evident in the hospital after successful stabilization, e.g., splenic two-stage bleeding or covered organ perforations.

It is more important to further consider the means and circumstances and to seize measures which on the one hand minimize the risk of immediate complications and on the other hand save the patient from damage in the further process. The placement of a gastric tube may be performed, e.g., for pressure relief and aspiration prophylaxis; an iatrogenically induced complication can be the aspiration of stomach contents [17] or gastric rupture after artificial respiration with high pressure ratios, usually located in the small curvature [4, 27].

Forensic aspects

From our own practice, we do not know of any case in which solely an iatrogenic induced CPR injury would have entailed legal consequences. Scenarios—also in connection with CPR measures—which involve legal consequences for the physician after obviously wrong treatment of the patient, for example false intubations of the trachea, are conceivable, of course. However, it is negligent to miss necessary CPR measures to prevent oneself from prosecution. Forensic relevance also exists in omitting CPR attempts without safe death signs being present. From the medicolegal point of view, complications and accidental iatrogenic injuries will never be completely avoidable but their possibility has to be taken into consideration throughout further medical treatment. Beside physicians, medical assistance personnel such as nurses and paramedics are concerned. For forensic pathologists, forensic relevance lies in the secure, autopsy-confirmed differentiation between CPR-related and other injury causes.

Table 2 Possible post-resuscitation injury complications

Injury Pattern	Possible post-resuscitation injury complications
(Temporary) skin erythema	None
Defibrillation	Rhabdomyolysis
Rib-/sternal fractures	Hemato- and pneumothorax, traumatic lesions of heart, lungs and upper belly organs
Tracheal lesions	Pneumomediastinum, hypoxemia
Retropharyngeal bleedings	Vena cava superior syndrome
Liver and spleen injuries, aortic ruptures	Hemorrhagic shock, exsanguination
Stomach lesions	Pneumoperitoneum
Air embolism	Apoplectic insult

Consequences for hospitals and practice

Resuscitation-related injuries cannot be avoided and will appear inevitably with increasing duration of resuscitation attempts, particularly if some factors are added; factors of influence are duration and intensity of the resuscitation measures, sex and age of the patient as well as an anticoagulant medication. Furthermore, these injuries are often not conspicuous immediately, but manifest themselves rather by missing success of CPR measures. Thus, a diagnostic consideration of the physicians must be to look for iatrogenic injuries if the condition of a patient under CPR cannot be stabilized and no causes are recognizable which let the success of CPR measures appear improbable (e.g., traumatic genesis with hemorrhagic shock after blunt trauma [5]) and/or these factors can be treated causally.

Conclusions

In connection with CPR, we differentiate between frequent and rare complications. The spectrum of possible complications following resuscitation measures is given in Table 2. The risk of iatrogenic CPR-related trauma is

even present with adequate execution of CPR measures and should not question the employment of proven medical techniques.

Forensic scientists as well as clinical practitioners should know about the relevance and frequency of the occurrence of iatrogenically induced resuscitation injuries to avoid these traumas if possible and to be able to distinguish them from injuries of other origin.

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