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EVALUATION OF COMPLICATIONS ASSOCIATED WITH CARDIOPULMONARY RESUSCITATION IN EMERGENCY DEPARTMENT

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Introduction: Resuscitation methods are commonly used to restore return of spontaneous circulation (ROSC) in patients with arrest. However, during these resuscitation practices, complications are inevitable.

Aim: The aim of this study was to compare complications due to cardiopulmonary resuscitation (CPR) performed in an adult emergency department (ED) as well as the diagnostic tools used to evaluate these complications.

Methods: This prospective study was conducted in the ED of Ankara Training and Research Hospital between 01.06.2012 and 30.05.2013. Participants consisted of all patients over the age of 18 with non-traumatic cardiac arrest who were brought to the hospital by ambulance, relatives, friends, or acquaintances. Those who arrested and received CPR during ED follow-up were also included.

Results: A total of 136 patients, comprised of 59 women (43.4%) and 77 men (56.6%), who presented with cardiopulmonary arrest were included in the study. Return of spontaneous circulation was observed in 62 patients (45.6%), while 74 patients (54.4%) were declared exitus following CPR. Rib fractures were detected in 36.7%, of patients, sternum fractures in 33.8%, pneumothorax in 2.9%, and liver injury in 0.7% of the patients. Although only 30.9% of rib fractures were diagnosed by chest X-ray, chest X-ray was found to be superior to ultrasonography (US) in the detection of rib fractures ($p < 0.005$). The diagnosis of rib fractures was achieved with combined chest X-ray and US in 19.8%.

Conclusion: The most common complications of CPR were found to be rib and sternal fractures. The results further suggest that evaluation of CPR-related complications using chest X-ray and US in combination can efficiency higher diagnostic accuracy.

Keywords: *Cardiopulmonary Resuscitation, Complications, Rib Fracture, Sternum Fracture.*

Резюме

ОЦЕНКА ОСЛОЖНЕНИЙ, СВЯЗАННЫХ С СЕРДЕЧНО-ЛЕГОЧНОЙ РЕАНИМАЦИЕЙ В ОТДЕЛЕНИИ НЕОТЛОЖНОЙ МЕДИЦИНЫ

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Введение: методы реанимации обычно используются для восстановления спонтанного кровообращения у пациентов с остановкой сердечной деятельности. Однако, во время этих реанимационных мероприятий, неизбежны осложнения.

Цель: оценка осложнений, вызванных сердечно-легочной реанимацией (СЛР) в отделении неотложной помощи для взрослых, а также диагностических инструментов, используемых для оценки этих осложнений.

Методы: проспективное исследование проводилось в отделении неотложной медицины Учебно-исследовательского госпиталя г.Анкары в период с 01.06.2012 по 30.05.2013. Участники исследования - пациенты старше 18 лет с нетравматической остановкой сердца, которые были доставлены в больницу на машине скорой

помощи, родственниками, друзьями или знакомыми. Также в исследование включены пациенты, у которых возникла остановка сердца во время лечения в отделении.

Результаты: В исследование были включены 136 пациентов, в том числе 59 женщин (43,4%) и 77 мужчин (56,6%), у которых была остановка сердца. Восстановление спонтанного кровообращения наблюдалось у 62 пациентов (45,6%), в то время как у 74 пациентов (54,4%) был признан умершим. Переломы ребер были обнаружены у 36,7% пациентов, переломы грудины у 33,8%, пневмоторакс у 2,9% и повреждение печени у 0,7% пациентов. Несмотря на то, что только 30,9% переломов ребер были диагностированы с помощью рентгенографии грудной клетки, установлено, что рентгенография грудной клетки превосходит по эффективности ультразвуковое исследование ($p < 0,005$). Диагноз переломов ребер был достигнут при комбинированной рентгенографии грудной клетки и УЗИ в 19,8%.

Вывод: Установлено, что наиболее частыми осложнениями СЛР являются переломы ребер и грудины. Результаты также свидетельствуют о том, что оценка осложнений, связанных с СЛР, с использованием рентгенографии грудной клетки и УЗИ в сочетании может повысить точность диагностики.

Ключевые слова: сердечно-легочная реанимация, осложнения, перелом ребра, перелом грудины.

Түйіндеме

ШҰҒЫЛ МЕДИЦИНА БӨЛІМШЕСІНДЕ ЖҮРЕК-ӨКПЕ РЕАНИМАЦИЯСЫМЕН БАЙЛАНЫСТЫ АСҚЫНУЛАРДЫ БАҒАЛАУ

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Кіріспе: Реанимация әдістері әдетте жүрек қызметі тоқтаған емделушілерде өздігінен қан айналымын қалпына келтіру үшін қолданылады. Алайда, осы реанимациялық іс-шаралар кезінде асқынулар сөзсіз.

Мақсаты: Ересектерге арналған шұғыл көмек бөлімшесінде жүрек-өкпе реанимациясынан (ЖӨР) туындаған асқынуларды, сондай-ақ осы асқынуларды бағалау үшін қолданылатын диагностикалық құралдарды бағалау.

Әдістері: Бұл проспективалық зерттеу 2012 жылдың 1 маусымынан 2013 жылдың 30 мамырына дейін Анкара қаласының оқу-зерттеу госпиталінің шұғыл медицина бөлімінде жүргізілді. Зерттеуге қатысушылар-ауруханаға жедел жәрдем көлігімен, туыстарымен, достарымен немесе таныстарымен жеткізілген жүректің жарақаттық емес тоқтауы бар 18 жастан асқан пациенттер. Сондай-ақ, зерттеуге бөлімшеде емдеу кезінде жүрек тоқтауы пайда болған пациенттер енгізілген.

Нәтижелер: Зерттеуге 136 пациент енгізілді, оның ішінде 59 әйел (43,4%) және 77 ер адам (56,6%) жүрек тоқтаған. Спонтанды қан айналымының қалпына келуі 62 пациентте (45,6%) байқалды, ал 74 пациентте (54,4%) қайтыс болды деп танылды. Қабырғалардың сынуы пациенттердің 36,7% - да, төс сынуы 33,8% - да, пневмоторакс 2,9% - да және бауырдың зақымдануы 0,7% - да анықталды. Қабырғалар сынықтарының тек 30,9% - ы ғана кеуде қуысының рентгенографиясы арқылы анықталғанына қарамастан, кеуде қуысының рентгенографиясы ультрадыбыстық зерттеуден ($p < 0,005$) асып түседі. Қабырға сыну диагнозы кеуде қуысының аралас рентгенографиясында және УДЗ 19,8% - да қол жеткізілген.

Қорытынды: ЖӨР-ның ең жиі асқынуы қабырға мен төстің сынуы болып табылатыны анықталды. Нәтижелер сондай-ақ, кеуде рентгенографиясын және УДЗ ұштастыра отырып, ЖӨР-мен байланысты асқынуларды бағалау диагностиканың дәлдігін арттыра алады.

Түйін сөздер: жүрек-өкпе реанимациясы, асқынулар, қабырға сынуы, төстің сынуы.

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Introduction

Cardiopulmonary resuscitation (CPR) has taken a long journey to arrive at the set of best practices recommended today. Contemporary resuscitation techniques were first introduced in 1957 when an Austrian anesthesiologist, Dr. Peter Safar, described a novel method for opening patient airways using oral mouth breathing [1].

This method was soon combined with Kouwenhoven et al. [2] 1960 proposal for the use of external cardiac massage during cardiac arrest. Over two decades later, the American Heart Association (AHA) hosted the first International Liaison Committee on Resuscitation (ILCOR) conference in 1999, where resuscitation methods then in use were evaluated and a set of professional practices was agreed upon, thus creating the first-ever AHA guidelines. In February 2010 and again in 2015, ILCOR gathered to share the latest empirical data related to CPR, reach consensus regarding some of the more controversial issues associated with the practice, and further revise the AHA guidelines [3, 4].

Today, ILCOR-recommended resuscitation methods (e.g., external cardiac massage, external defibrillation, endotracheal intubation, peripheral or central vascular catheterisation) are commonly used across the globe to restore return of spontaneous circulation (ROSC) in patients with cardiac arrest [5]. However, unwanted and unexpected results (i.e., complications) can often occur with these practices.

The most frequently reported complications of CPR are skeletal system injuries, especially rib and sternal fractures. Sternal fractures have been reported in approximately one-fifth of adult patients who underwent traditional CPR, while as many as one-third reported sustaining rib fractures and other sternal injuries [6].

Such ruptures and perforations can occur when force applied during CPR is transferred from the non-stabilised thorax to the internal organs. Thus laceration, hemorrhage and contusion have been reported in the lung. Similarly, hemothorax, pneumothorax, and pneumomediastinum have also been reported in thorax. Abdominal upper quadrant organs, particularly the liver, spleen, and stomach, can also be damaged during resuscitation due to their anatomical location. Misplaced airway, dental and lip injuries, larynx and tracheal injury, may occur during intubation, furthermore misplaced intubation can lead to esophageal rupture. Haemoperitoneum may be encountered on account of laceration of small vessels. Major cardiovascular or vascular injury are less common complications [7].

Accordingly, the present study sought to compare complications associated with CPR in an adult emergency department (ED) as well as the diagnostic modalities used to identify such complications.

Materials and methods

This prospective study was conducted in a third-degree hospital ED after obtaining approval from the facility's Board of Education Planning and Coordination Ethics Committee (3878/465, 16/05/2012).

Patient selection.

All non-traumatic arrest cases in patients over the age of 18 brought to the ED by ambulance, relatives, friends, or

acquaintances between 01.06.2012 and 30.05.2013 were included in the study. Patients over the age of 18 who arrested and underwent CPR during ED follow-up were also included. Patients under 18 years of age; who presented with drowning-, hypothermia-, pregnancy-, or trauma-related arrests; and whose next of kin did not give consent or were not available to give consent for their loved one's participation in the study were excluded.

Study protocol and data collection

All patients presenting with cardiac arrest brought to the ED by ambulance, relatives, friends, or acquaintances as well as patients who arrested during ED follow-up, were promptly taken to the resuscitation room and all up-to-date and essential CPR applications were initiated without delay.

During the study, information about the patients and their cardiac events was gathered from ambulance crew members and the patients' relatives by an independent observer who did not participate in the CPR process and one of the author of this study.

Each step of the resuscitation process was also recorded using the relevant study form by the same observer. For the purposes of this study, ROSC will be defined as restoration of sustained spontaneous pulse and maintenance of this rhythm for one hour following cardiac arrest, while exitus will be defined as failure to achieve ROSC despite the provision of all essential interventions.

All patients were examined and evaluated via chest X-ray and bedside ultrasonography (US) to assess for complications associated with ROSC. Prior to transfer from the ED, rib and sternal fractures, haemothorax, pneumothorax, pulmonary contusion, and upper airway injury were diagnosed using a portable X-ray device at the patient's bedside with the patient in an anteroposterior (AP) position. Bedside US was performed using 7L4A model linear, abdominal, and cardiac transducers from a Mindray DC-3 US device.

After termination of CPR (exitus or ROSC), liver and spleen injury, haemothorax, pneumothorax, and rib and sternal fractures were investigated using extended focused assessment with sonography for trauma (e-FAST). Radiography and US evaluation was performed by authors of the study.

Statistical analysis

The SPSS 18.0 package program was used for all statistical analysis. Descriptive statistics (percentage, mean, median), a Chi-square test for percentage comparisons, and a Fisher's exact test were implemented. Results with a type-I error rate of less than 0.05 were interpreted as statistically significant.

Results

A total of 162 patients initially participated in the study; of these, 26 were excluded due to missing data or failure to meet the inclusion criteria. A total of 136 patients were thus included in data analysis. Participants were between the ages of 19 and 99 (Mn = 65.7), with 59 identifying as female (43.4%) and 77 as male (56.6%). All demographic data for participants are given in Table 1.

Table 1. Demographic data of study participants.

Gender	n (%)
Female	59 (43.4%)
Male	77 (56.6%)
Median (IQR% 25-75)	67 (54, 25-67)
Comorbidities	n (%)
Hypertension	47 (34.6%)
Diabetes mellitus	30 (22.1%)
Coronary artery disease	25 (18.4%)
Chronic obstructive pulmonary disease	14 (10.3%)
Admission to emergency department (ED)	n (%)
Ambulance	108 (79.4%)
Ambulation	28 (20.6%)
In-hospital arrest	31 (22.8%)
Procedures applied in the ED	n (%)
Monitorisation	136 (100%)
Oxygen support	136 (100%)
Cardiopulmonary resuscitation (CPR)	131 (96.3%)
Intravenous adrenaline administration	131 (96.3%)
Peripheral venous catheterisation	134 (98.5%)
Finger-stick glucose monitoring	136 (100%)
Endotracheal intubation	124 (91.1%)
Electrocardiography	106 (77.9%)
Defibrillation	54 (39.7%)
Intravenous drug administration	45 (33.1%)
Capnometric monitoring	38 (27.9%)
Central venous catheterisation	30 (22.1%)
CPR duration in ED	n (%)
< 15 min	46 (33.8%)
16-20 min	15 (11.0%)
21-30 min	26 (19.1%)
31-40 min	18 (13.2%)
> 40 min	31 (22.8%)
Return of spontaneous circulation (ROSC)	n (%)
Yes	62 (45.6%)
No	74 (54.4%)
Presence of complication(s)	n (%)
Yes	71 (52.2%)
No	65 (47.8%)

As shown in Table 2, a number of complications related to CPR were identified.

As shown in Table 3, at least one complication related to CPR was found in 52.2% of the overall sample. Further, the complication rate was found to increase with patient age and CPR duration in excess of 21 minutes, with the rate of complications increasing in relation to the number of minutes.

Table 2. Distribution of complications related to cardiopulmonary resuscitation.

Complication	n (%)
Chest wall haematoma	1 (0.7%)
Liver injury	1 (0.7%)
Pneumotorax	4 (2.9%)
Gastric aspiration	5 (3.7%)
Rib fracture	50 (36.7%)
Sternum fracture	46 (33.8%)

As shown in Table 4, complications were initially evaluated via physical examination, followed by the use of diagnostic tools (chest X-ray and US).

As seen in Table 5, rib fractures were detected in 50 patients (36.7%). The diagnosis of rib fractures was achieved with chest X-ray only in 11% of patients, US only in 5.8%, and combined chest X-ray and US in 19.8%. Chest X-ray was found to be superior to US in the diagnosis of rib fractures ($p < 0.005$).

Complications were detected in 47 patients (66.2%) in the exitus group (74 patients), and 24 patients (33.8%) in the ROSC group. Thus the rate of complications was significantly higher in the exitus group than in the ROCS group ($p = 0.04$, $\chi^2 = 8.318$).

Table 3.

Complication rates by age and cardiopulmonary resuscitation duration.

Age	Presence of complication(s)				Total		χ^2	p
	Yes		No		N	%		
	N	%	N	%	N	%		
≤ 44	7	41.2	10	58.8	17	100		
45-64	17	45.9	20	54.1	37	100		
65-74	20	52.6	18	47.4	38	100	2.892	0.409
> 74	27	61.4	17	38.6	44	100		
Duration	Yes		No		Total		χ^2	p
	N	%	N	%	N	%		
<15 min	20	43.5	26	56.5	46	100		
16-20 min	5	33.3	10	66.7	15	100		
21-30 min	14	53.8	12	46.2	26	100	7.144	0.128
31-40 min	11	61.1	7	38.9	18	100		
> 40 min	21	67.7	10	32.3	31	100		
Total	71	52.2	65	47.8	136	100		

Table 4.

Evaluation of complications via chest X-ray and ultrasonography.

Evaluation method	Complication	N	%
Physical examination	Chest wall haematoma	1	0.7
	Gastric aspiration	5	3.7
Chest X-ray only	Rib fracture	42	30.9
	Pneumotorax	4	2.9
Ultrasonography (US) only	Sternum fracture	46	33.8
	Rib fracture	35	25.7
	Pneumotorax	4	2.9
	Liver injury	1	0.7
Chest X-ray and US	Rib fracture	27	19.8
	Pneumotorax	4	2.9

Table 5.

Comparison of chest X-ray and ultrasonography in rib fracture diagnosis.

		Ultrasonography				Total		χ^2	p
		Yes		No					
		n	%	n	%	N	%	47.251	< 0.005
Chest X-Ray	Yes	27	64.3	15	37.5	42	30.9		
	No	8	8.5	86	91.5	94	69.1		
Total		35	25.7	101	74.3	136	100		

Discussion

The present study investigated complications associated with CPR performed on patients with cardiac arrest as well as the imaging modalities used to diagnose them. Rib and sternal fractures were found to be the most common complications related to resuscitation procedures. Comparison of the accuracy of diagnosis using US and chest X-ray individually or in combination will enable clinicians to diagnose such complications with greater accuracy.

CPR has been a standard clinical practice for the achievement of ROSC in patients with cardiac and/or respiratory arrest for more than 50 years. However, since Kouwenhoven et al. [2] first reported on the use of external chest compression with 14 cardiac arrest survivors in 1960, many advancements have been made. According to the 2010 AHA guidelines [8], early identification of sudden cardiac arrest, early activation of the emergency response system, early initiation of high-quality CPR, early defibrillation (when needed), and early access to emergency medical care are the most important steps in reestablishing spontaneous circulation. Published in 2015, the most recent guidelines have further sought to enhance the quality of CPR performed on patients during in-hospital arrests, highlighting the importance of developing a highly coordinated interdisciplinary team consisting of physicians, nurses, respiratory therapists, and other relevant healthcare professionals [9].

However, despite its many benefits, CPR performed with the aim of ROSC can cause significant complications, even when applied by qualified professionals using the appropriate techniques. Indeed, the literature calculates the incidence of resuscitation-related complications to be anywhere between 21% and 65% [10]. Bone fractures, soft tissue damage, cardiac contusion and laceration, liver and spleen laceration, haemothorax, and lung laceration can all develop due to external chest compression. Errors in intubation and/or ventilation application can lead to additional complications, such as lip injury, laryngeal and tracheal injury, gastric dilatation, gastric rupture, pneumothorax, haemothorax, and interstitial emphysema [5, 7, 10].

Although rib and sternum fractures are the most commonly reported complication of CPR performed on adult patients, there are contradictory findings regarding their precise incidence [11].

Black et al. [12], *Hashimoto et al.* [10], and *Baubin et al.* [13] reported the incidence of rib and sternum fractures as 29% and 14%, 52% and 39%, and 55% and 30%, respectively. The present study detected rib fractures in 36.7% of patients, sternum fractures in 33.8%, and co-occurring rib and sternum fractures in 20.6%. The rates for rib and sternum fractures were thus significantly lower than those reported by Hashimoto et al. [10] and Baubin et al. [13], yet somewhat higher than those reported by *Black et al.* [12].

It is known that rib fractures can sometimes lead to secondary damage, particularly in patients who have sustained multiple and unattached rib fractures. Complications due to rib and sternum fractures include cardiac and pulmonary injury, both of which can potentially lead to haemothorax, pneumothorax, and, in rare cases, cardiac rupture and liver injury [7, 14, 15]. In this study, pneumothorax was detected in 2.9% of cases, which is consistent with the literature. Liver injury associated with rib and sternum fracture was only found in one patient.

Research has also shown that patients with age-related degenerative skeletal changes are more likely to develop fractures from chest compressions during CPR [7, 16]. The present study did find that the risk of complications related to CPR increased with age, with rib and sternum fractures among patients 74 years old and older being particularly common. However, the correlation between complications and age did not reach statistical significance.

Another potential mediating factor affecting the rate of complications is the duration of CPR. Previous studies have found that as the duration of CPR increases, the focus or attention of the rescuer as well as the quality of chest compressions decreases and the rate of complications increases [7, 14, 17]. However, the present study did not find a statistically significant correlation between the duration of CPR and the rate of complications.

Interestingly, this study did find that the rate of complications was significantly higher among out-of-hospital arrest patients for whom CPR was initiated in an ambulance. Conversely, the rate of complications associated with CPR performed in-hospital was significantly lower. This may be because clinical settings represent a stable environment where members of the interdisciplinary healthcare team can be easily accessed.

These findings are particularly important given that the existing literature has predominantly assessed complications related to CPR via autopsy or chest X-ray alone, an approach that is not without its limitations. For example, Leeder et al. [11] found rib fractures in 39% of patients and sternum fractures in 26% using AP projection chest X-rays, but the rates jumped to 89% and 47%, respectively, when diagnosed via autopsy. In the present study, chest X-ray and US used separately calculated the rate of rib fractures at 11% and 5.8%, respectively, while the use of both modalities in combination recorded the rate at 19.8%, yielding an overall rate of 36.7%.

The rate of sternum fracture detected was 33.8%. However, it should be noted that while sternal fractures are generally only visible when radiographic imaging is performed from a lateral view, only US was used for sternal evaluation in the current study due to difficulties in safely positioning arrest patients. Further, all patients enrolled in the study were evaluated in the ED by emergency specialists alone; thus, autopsy evaluation was not conducted.

Limitations

Duration of the study was 12 months and the number of patients recruited for participation in the study was

limited to this period. Further, while the study sought to compare the accuracy of chest X-ray and bedside US in the diagnosis of CPR-related complications, the quality of diagnosis obtained via chest X-ray may have been limited by the radiographic techniques employed. The standard AP chest X-ray provides the best results for assessing the thorax when the patient is upright during deep inspiration [11], but the present study obtained posteroanterior chest X-rays with the patient in a supine position. Performing chest X-rays under these conditions might have made it more difficult to detect skeletal and respiratory pathologies, including non-displaced or displaced rib fractures, sternum fracture, pneumothorax, and haemothorax.

Conclusion

As the duration of resuscitation efforts increases, complications associated with CPR become inevitable. Such diverse factors as the location at which the patient arrested, age and sex of the patient, presence of comorbidities, onset and duration of resuscitation, and rescuer skill and experience all play a role in the development or prevention of complications. The most common complications related to CPR recorded in both the existing literature and the present work are rib and sternal fractures, while the incidence of life-threatening complications, such as internal organ injury, were found to be relatively low.

To avoid complications, CPR should be performed according to up-to-date scientific criteria and without interruption. To this end, Basic Life Support (BLS) training should be regularly delivered to healthcare professionals, emergency responders, and even members of the general public interested in acting as rescuers. Further, as the results of the current study indicate, chest X-ray and US should be used in combination to assess for complications related to CPR in patients following cardiac arrest and ROSC. This practice can improve not only professional follow-up of arrest patients, but can also guide the planning and provision of ongoing management interventions.

Conflicts of interest:

The authors have no conflicts of interest to declare

Contribution of the authors to the study:

The author declares that this material has not been announced earlier for publication in other publications.

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