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Favourable outcome in survivors of CPR-related chest wall injuries

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ABSTRACT

Background: There is a lack of studies focusing on long-term chest function after chest wall injury due to cardiopulmonary resuscitation (CPR). The purpose of this cross-sectional study was to investigate long-term pain, lung function, physical function, and fracture healing after manual or mechanical CPR and in patients with and without flail chest.

Methods: Patients experiencing out-of-hospital cardiac arrest between 2013 and 2020 and transported to Sahlgrenska University Hospital were identified. Survivors who had undergone a computed tomography (CT) showing chest wall injury were contacted. Thirty-five patients answered a questionnaire regarding pain, physical function, and quality of life and 25 also attended a clinical examination to measure the respiratory and physical functions 3.9 (SD 1.7, min 2-max 8) years after the CPR. In addition, 22 patients underwent an additional CT scan to evaluate fracture healing.

Results: The initial CT showed bilateral rib fractures in all but one patient and sternum fracture in 69 %. At the time of the follow-up none of the patients had persistent pain, however, two patients were experiencing local discomfort in the chest wall. Lung function and thoracic expansion were significantly lower compared to reference values (FVC 14 %, FEV1 18 %, PEF 10 % and thoracic expansion 63 %) ($p < 0.05$). Three of the patients had remaining unhealed injuries. Patients who had received mechanical CPR in additional to manual CPR had a lower peak expiratory flow (80 vs 98 % of predicted values) (p=0.030) =0.030) and those having flail chest had less range of motion in the thoracic spine (84 vs 127 % of predicted) (p = 0.019) otherwise the results were similar between the groups.

Conclusion: None of the survivors had long-term pain after CPR-related chest wall injuries. Despite decreased lower lung function and thoracic expansion, most patients had no limitations in physical mobility. Only minor differences were seen after manual vs. mechanical CPR or with and without flail chest.

Background

Cardiac arrest is a common medical emergency and cardiopulmonary resuscitation for out-of-hospital cardiac arrest was performed in 5855 cases in Sweden in 2021 [1]. During manual and/or mechanical cardiopulmonary resuscitation (CPR) a blunt force is applied to the thorax which may damage the chest wall, resulting in fractured ribs and sternum, as well as causing intrathoracic and intraabdominal injuries [2-5]. Earlier autopsy studies have reported rib fractures in 64 % of the cases after manual and 78 % after mechanical CPR, and sternal fractures in 54% vs. 58 % [4,6].

In a recently published study from our research group, 245 patients who had undergone a CT scan within two weeks after CPR were included [5]. The most common injuries were chondral and rib fractures (95 %) followed by sternal fractures (57 %) and flail segments were seen in 14 % of the patients. The overall 30-day mortality rate was 68% vs 47 % in those with and without chest wall injury respectively. The number of patients with flail chest was in accordance with earlier reports [7].

Multiple rib fractures cause pain when breathing or during movements of the chest wall, leading to increased risk of respiratory

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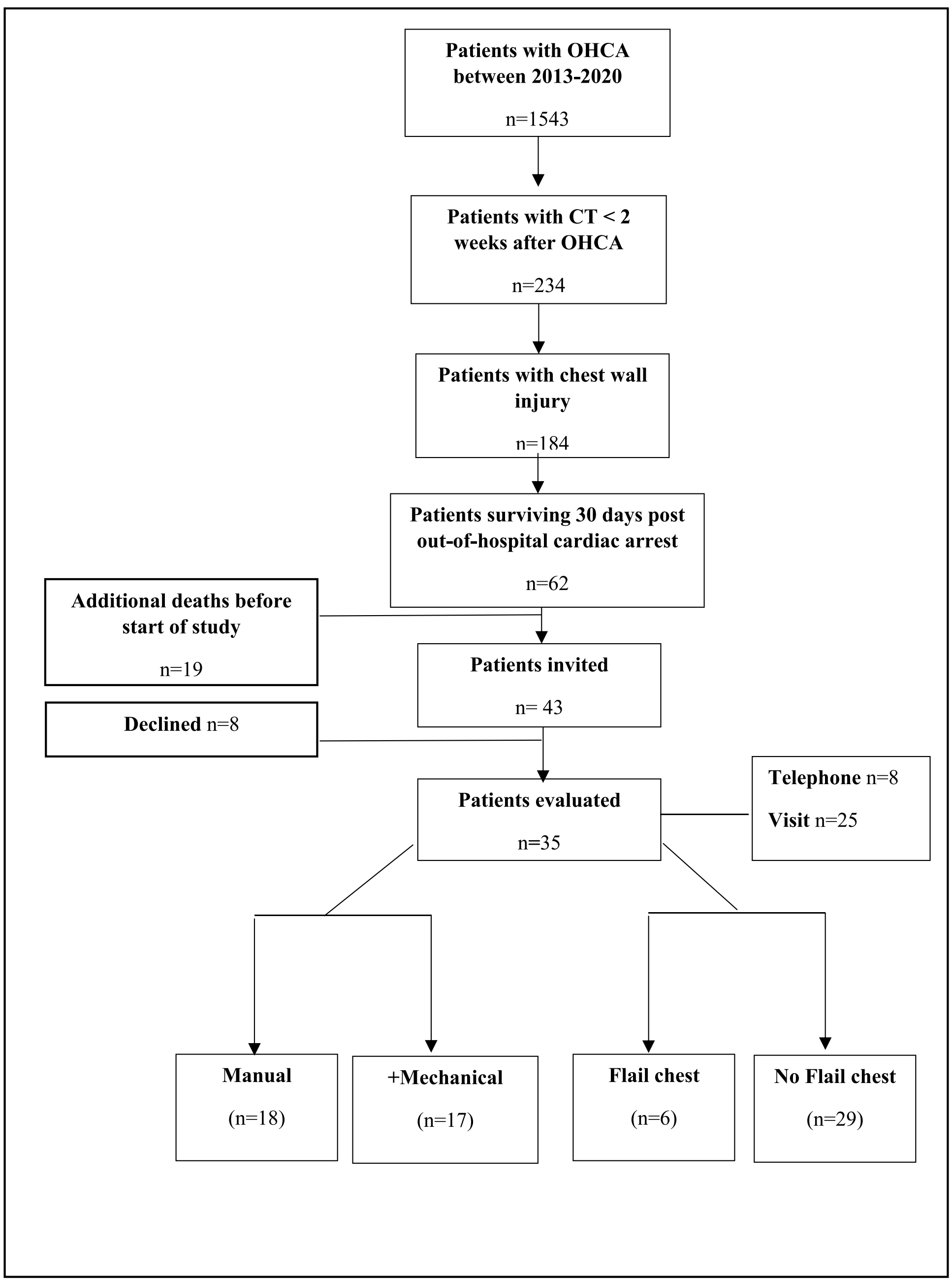
insufficiency and need of mechanical ventilation [8-10]. Chest wall injuries including sternal fractures cause pain and impaired lung function that may last more than six weeks from the trauma [11,12]. Flail chest may also cause persistent pain, chest wall deformity, and breathlessness during physical effort in the long term [13]. Previous non-CPR-related thoracic trauma research has found several consequences of trauma with rib-fractures such as pain, impaired lung function and physical function six months after chest trauma [14] but there is a lack of studies investigating long-term (here defined as ≥ two years after the injury) chest function after chest wall injury due to CPR.

The purpose of this cross-sectional study was to investigate long-term outcome in patients with chest wall injury after successful CPR regarding pain, lung function, physical function, fracture healing and quality of life (QoL). The secondary aim was to evaluate differences between manual or manual and mechanical CPR and in patients with and without flail chest.

Material and methods

Study design

This is a cross-sectional study on the long-term outcome of chest wall injury in patients surviving out-of-hospital cardiac arrest after successful CPR. The study was approved by the Swedish Ethical Review Authority (Dnr 2020-07008) and the Swedish CPR Registry (RS 2021-01425). Patients experiencing out-of-hospital cardiac arrest between 2013 and 2020 and who were admitted to Sahlgrenska University Hospital were identified in the Swedish CPR Registry. Survivors fulfilling the inclusion criteria were identified and contacted via mail and telephone. Inclusion criteria were age ≥ 18 years at the time of the cardiac arrest, receiving



OHCA, Out-of-Hospital Cardiac Arrest; CT, computed tomography; CPR, Cardiopulmonary Resuscitation

Fig. 1. Flowchart of patient inclusion.

manual CPR and/or mechanical CPR with LUCAS®, and chest wall injury identified on computed tomography (CT) performed < two weeks from the time of CPR. Exclusion criteria were traumatic cardiac arrest, surgical management of chest wall injuries, previous rib fractures, muscle disease or thoracic deformity. The patients gave their informed consent to participate after receiving written and oral information. The primary outcome was pain.

The STrengthening the Reporting of OBservational studies in Epidemiology checklist (STROBE) was used to report this data.

Study population

Of the 1543 patients admitted after successful CPR for out-of-hospital cardiac arrest in the period 2013–2020, 234 underwent CT, which showed chest wall injury in 184 patients. Sixty-two patients survived 30 days. At the time of follow-up, 43 patients were alive and invited to participate in the study. Eight patients declined and the remaining 35 were included 3.9 (SD 1.7, min 2-max 8) years after the CPR of which 25 attended the clinical follow-up. The patients were divided into groups based on the mechanism of injury (manual vs manual and mechanical CPR) and injury pattern (with and without flail chest) (Fig. 1).

Data collection

Data were collected from the Swedish CPR Registry, medical records, radiological reports and images, and interviews with the subjects.

CPR-related injuries

Chest wall injuries were re-examined on the CT scans taken within two weeks after CPR. The indications for performing CT were mainly to identify conditions causing the cardiac arrest; pulmonary embolism, aortic pathology, pneumonia or aspiration. The re-examination was made by one consultant specialist in thoracic radiology and the presence of rib fractures and sternal fractures was recorded. The number of rib fractures was documented. Radiological flail chest was defined as ≥3 consecutive ribs fractured in ≥2 locations [15] and/or rib fractures in conjunction with sternal fractures [16]. Patients participating in a clinical follow-up also underwent a CT of the thorax to identify non-healed injuries. Injuries in the lung parenchyma, mediastinum and upper abdomen were also documented.

Pain

Pain was examined by questions regarding remaining chest wall pain, local discomfort, and breathlessness (yes/no). Patients were also asked about medication for chest wall pain. Pain was examined concerning: persistency, intensity, type (continuous/intermittent) what aggravated/eased it and whether it disturbed sleep. Pain drawings of the body were used, to describe the pain character and location of the pain.

Lung function and respiratory muscle strength

Forced Vital Capacity (FVC), Forced Expiratory Volume 1 s (FEV_1) and Peak Expiratory Flow (PEF) were tested by using an EasyOne® Ultrasonic Spirometer (nnd Medical Technologies Inc., MA, US), and Maximal inspiratory and expiratory muscle pressure (MIP / MEP) were measured by using MicroRPM™ (Care Fusion, Sollentuna, Sweden). The tests were performed in the sitting position according to guidelines and the values were compared to age- and gender-related reference values [17-19].

Breathing movements, thoracic expansion, and range of motion in the thorax and shoulder

Breathing movements were tested by the Respiratory Movement Measuring Instrument, RMMI® (ReMo Inc. Keldnaholt, Reykjavik, Iceland) [20]. It consists of three pairs of lasers placed at three levels: at the third rib, at the xiphoid process and at the level of the umbilicus. Measurements were performed during breathing at rest and maximal breathing [20].

Thoracic expansion was measured using a tape measure at the level of the fourth rib, and at the xiphoid process [21]. The circumferences at maximal inhalation and exhalation were measured and the difference was recorded.

The range of motion in the thorax was examined by thoracic flexion, extension, and lateral flexion [22] and the range of motion in the shoulder by the Boström Index [23].

Physical activity and physical function

Physical activity was estimated by the Grimby activity scale, where the patients graded their activities from 1 (almost nothing) to 6 (more strenuous exercise >3 hrs/week) [24]. Physical function was assessed by using the Disability Rating Index (DRI) [25]. The ability to perform 12 activities was rated on visual analogue scales and the results were interpreted as degrees of impact of condition: No disability, some disability, mild to moderate and very serious disability according to Sahlén et al. [25].

Quality of life

Health-related quality of life was estimated by the EQ-5D-5 L index score, based on Swedish reference data, and a Visual Analogue Scale (VAS) [26].

Statistical analysis

As there was no previous data for this patient group, no power calculation was performed and all patients in the study-cohort were therefore included. Data was analysed using the statistical programme IBM Statistics SPSS version 28 (IBM® SPSS® 2022). Continuous variables were reported as mean with standard deviation (SD) and comparative analysis was done using Mann Whitney *U test*. Comparisons between measured values and reference values were carried out by using Wilcoxon's signed-rank test. Categorical variables were reported as n and % and compared using the Pearson chi-square test and the Fisher's Exact test. Differences between groups in QoL (index score and VAS) and DRI were analysed by a Mann-Whitney U test. $P < 0.05$ was considered statistically significant.

Results

Thirty-five patients were included in the study and 25 participated in the clinical examinations (Fig. 1). The mean time from cardiac arrest to follow-up was 3.9 (SD 1.7) (min 2-max 8) years. Demographic data are presented in Table 1. Of the 35 patients who participated, 29 were men and the mean age at the time of cardiac arrest was 62 (SD 13) years, ranging between 32 and 83 years. The mean Body Mass Index was 26.6 (SD 4.2) kg/m^2. Six patients had previously diagnosed lung disease: asthma ($n = 4$) and Chronic Obstructive Pulmonary Disease (COPD) ($n = 2$). Three were current smokers and 11 were previous smokers. The reason for CA was in most cases cardiac disease ($n = 20$) (Table 1). Median time from CA to CPR was 0 (0–15) min and median time to return of spontaneous circulation (ROSC) 13 (1–40) minutes. Eighteen patients had received only manual CPR and 17 patients a combination of manual and mechanical CPR. There were no significant differences in demographic data between patients having manual CPR or also mechanical CPR. Most patients, 26/35 received defibrillation. The group who had flail chest ($n = 6$) was significantly older (15.3 years, $p < 0.003$) but there were no other significant differences in demographics between the groups.

During the re-evaluations of the CT scans performed < two weeks from the CPR, rib fractures were seen in 34 of the patients with a mean of 8.5 (±3.6) fractured ribs (Table 2). In total 33 patients had bilateral rib fractures and 24 had sternal fractures. One patient had an isolated sternal fracture. Flail chest was seen in six patients and tended to be

Table 1
Demographic data according to the mechanism of injury of the study population. Mean (SD) or n (%).

		All ($n = 35$)	Manual ($n = 18$)	+Mechanical ($n = 17$)	p-value	No flail chest ($n = 29$)	Flail chest ($n = 6$)	p-value
Male gender, n (%)		29 (83)	15 (83)	14 (82)	>0.999	23 (79)	6 (100)	0.561
Age, years		61.6 (13.1)	59.6 (12.2)	63.8 (14.0)	0.245	59.0 (12.9)	74.3 (2.7)	0.003
BMI, kg/m^2, n		26.6 (4.2)	26.2 (3.7)	27.0 (4.9)	0.866	26.7 (4.7)	26.2 (2.2)	0.393
Lung disease, n (%)		7 (20)	3 (17)	4 (24)	0.691	5 (17)	2 (33)	0.576
Smok-ing, n	Yes	3	2	1	0.801	3	0	0.890
	No	21	11	10		17	4	
	Former	11	5	6		9	2	
Reason for CA	Cardiac disease	20 (57.1)	9(50.0)	11(64.7)	> 0.05	16(55.2)	4(66.7)	> 0.05
	Overdose	1 (2.9)	1(5.6)	0(0)		1(3.4)	0(0)	
	Asphyxia	1 (2.9)	0(0)	1(5.9)		1(3.4)	0(0)	
	Other	6(17.1)	5(27.8)	1(5.9)		6(20.7)	0(0)	
	Unknown	7(20.0)	3(16.7)	4(23.5)		5(17.2)	2(33.3)	
Time to CPR (min)		0 (0–15)	0 (0–5)	0.5 (0–15)	0.336	0 (0–15)	0.5 (0–3)	0.903
Unknown, n		4	1	3		4	0	
Time to ROSC, min		13 (1–40)	13 (1–40)	14.5 (4–24)	>0.999	13 (1–40)	15 (5–25)	>0.999
Unknown, n		10	3	7		10	0	
Defibrillation, n (%)		26 (74)	12 (67)	14 (82)	0.443	21 (72)	5 (83)	>0.999

CPR, Cardiopulmonary Resuscitation; SD, Standard Deviation; BMI; Body Mass Index.

Table 2
CPR-related injuries in the study population.

	Al ($n = 35$)	Manua ($n = 18$)	+Mechanica ($n = 17$)	p-value
Rib fracture, n (%)	34 (97)	18 (100)	16 (94)	0.486
Number of fractured ribs, n	8.5 ± 3.6	8.1 ± 3.2	9.1 ± 3.9	0.413
Bilateral rib fractures, n (%)	33 (94)	17 (94)	16 (94)	>0.999
Sternal fracture, n (%)	24 (69)	11 (61)	13 (77)	0.471
Flail chest, n (%)	6 (17)	2 (11)	4 (24)	0.402
Lung contusion, n (%)	30 (86)	13 (72)	17 (57)	**0.045**
Pneumothorax, n (%)	2 (6)	1 (6)	1 (6)	>0.999
Haemothorax, n (%)	10 (29)	4 (22)	6 (35)	0.471
Thoracic vascular injury*, n (%)	2 (6)	0 (0)	2 (12)	
Cardiac injury, n (%)	4 (11)	2 (11)	2 (12)	>0.999
Thoracic spine fracture, n (%)	3 (9)	2 (11)	1 (6)	>0.999
Scapular fracture, n (%)	1 (3)	1 (6)	0 (0)	
Liver injury, n (%)	1 (3)	0 (0)	1 (6)	
Stomach injury**, n (%)	1 (3)	1 (6)	0 (0)	

CPR, Cardiopulmonary Resuscitation.
* The right Internal mammary artery and intramural hematoma in the thoracic aorta.
** Injury to and bleeding from the stomach wall.

more common in the group experiencing manual and mechanical CPR than in the patients experiencing only manual CPR, although this difference was not significant (24 vs. 11 %, $p = 0.402$). Apart from lung contusions being more common in the manual CPR patients (72 vs. 57 %, $p = 0.045$), there was no significant difference in the incidence of thoracic and abdominal injuries according to the mechanism of injury in the studied patients.

Pain

No patient experienced any remaining chest wall pain or used pain medication. Two patients (6 %) with manual ($n = 1$) and +mechanical ($n = 1$) CPR and without flail chest experienced local discomfort on the chest. One described a local firmness anteriorly on the left fourth rib, while the other described diffused lateral discomfort while lying on the left side.

Four patients reported breathlessness at rest, two due to lung disease (COPD and asthma), one had remaining symptoms after a Covid-19 infection and one due to a swollen thyroid gland.

Spirometry and respiratory muscle strength

The results of lung function tests are shown in Table 2. FVC, FEV_1 and PEF (in% of predicted values) were significantly lower than individual reference values by 14, 18 and 10 % respectively ($p < 0.05$). Respiratory muscle strength was within normal values in most of the patients, but eight patients had a MIP and four a MEP below 80 % of the predicted. No significant clinical differences were seen between the groups except that those who also had mechanical CPR had a significant lower PEF ($p < 0.019$).

Breathing movements, thoracic expansion, range of motion in the thorax and shoulder

Fig. 2 and Table 3 show the results of breathing movement, thoracic expansion, and range of motion in the thorax. The predicted thoracic excursion measuring the lower part of thorax was significantly decreased (63.4 %; $p < 0.001$) compared to age- and gender-related reference values but the range of motion in the thorax was normal compared to reference values (92 – 102 %; $p > 0.05$). There were no significant differences between the groups except that the patients who had flail chest after the CPR had significantly lower range of motion in thoracic extension ($p = 0.030$).

The mean range of motion in the shoulder was normal compared to reference values. There were no significant differences between those with or without flail chest and between manual or +mechanical CPR (data not shown).

Physical activity and physical function

Physical activity was in median rated as “moderate” but ranged from “mostly sitting” to “hard physical exercise”. The patients in the flail chest group had a significantly lower level of physical activity, ($p = 0.035$), however, they were also older.

The patients’ level of disability was categorised as no disability ($n = 23$), some disability ($n = 9$) and mild to moderate disability ($n = 3$). No significant differences were found between the groups.

Quality of life

Quality of life according to EQ-5D-5 L is shown in Table 4. About 60 % of the patients had pain/discomfort due to orthopaedic ailments and malignancy. Anxiety/depression was experienced by 34 % of the patients. The median of EQ-5D VAS value was 80 (40– 100). There were no significant differences between the groups.

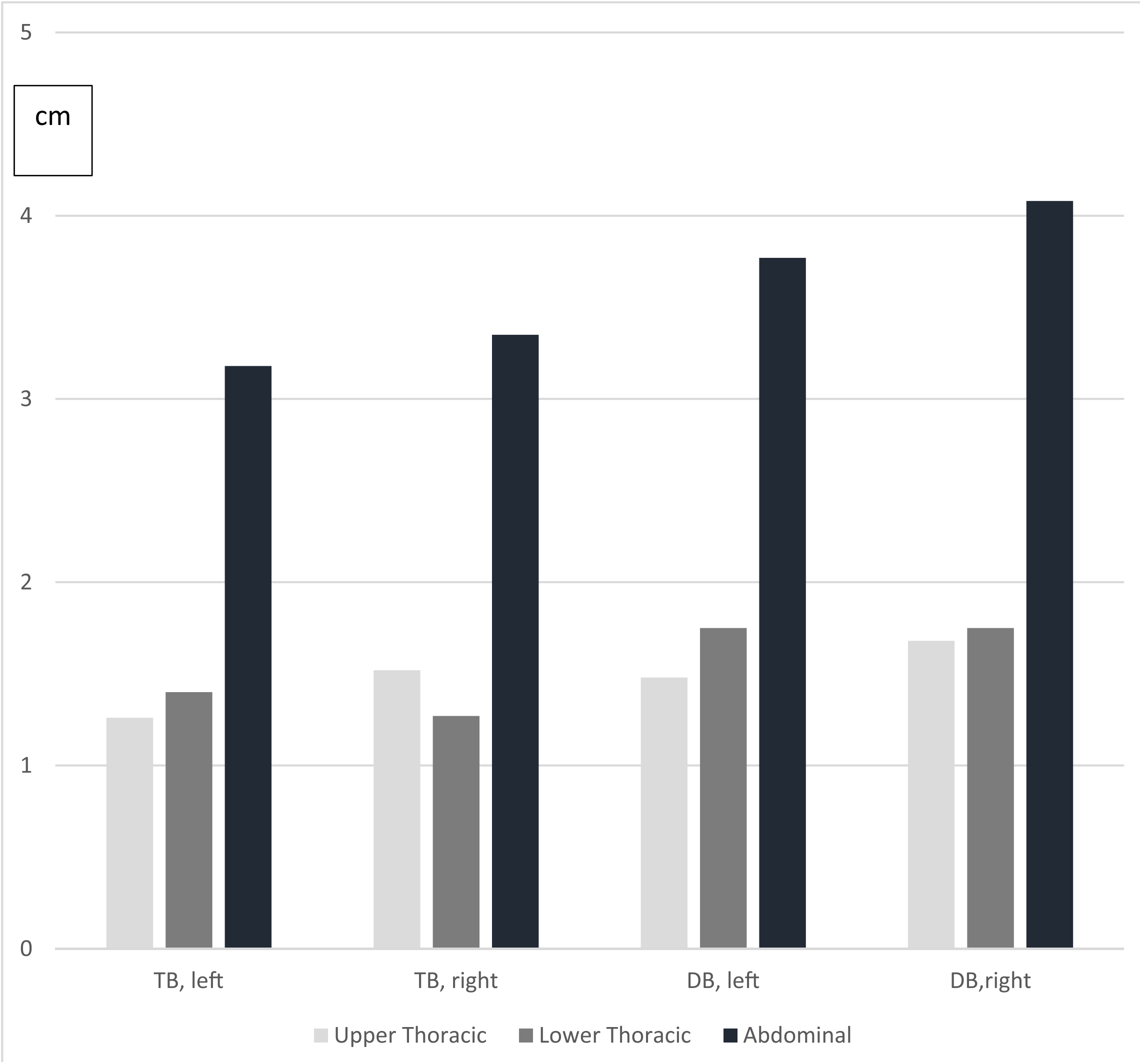


Fig. 2. Respiratory movements measured by RMMI. TB: Tidal Breathing, DB: Deep Breathing.

Table 3
Spirometry, respiratory muscle strength, breathing movements, thoracic excursion, and range of motion in the thorax after manual or mechanical CPR and in patients with or without flail chest. The results are presented in % of predicted values or cm (mean ± SD).

		All ($n = 25$)	Manual CPR ($n = 13$)	Mechanical CPR ($n = 12$)	p-value	No flail chest ($n = 20$)	Flail chest ($n = 5$)	p-value
Spirometry	FVC, %	86.1 (16.5)**	88.2 (16.3)	81.9 (19.3)	0.470	81.8 (22.9)	87.2 (15.0)	0.737
	FEV_1, %	82.4 (20.7)**	82.8 (24.7)	82.8 (16.5)	0.852	82.2 (20.2)	84.2 (20.8)	0.447
	PEF, %	89.5 (24.2)*	98.3 (26.4)	80.0 (18.2)	0.030	96.2 (32.0)	87.8 (22.6)	0.668
Respiratory muscle strength	MIP , %	94.3 (21.9)	90.7 (20.1)	98.2 (24.0)	0.406	98.1 (15.8)	93.3 (23.4)	0.575
	MEP, %	109.3 (20.3)*	113.2 (20.8)	105.1 (19.7)	0.168	109.4 (2.6)	109.3 (22.7)	0.303
Thoracic expansion	Upper level, cm	5.9 (0.6)	5.9 (0.6)	5.9 (0.6)	0.979	6.1 (0.1)	5.9 (0.7)	0.767
	Lower level, %	63.4 (26.0)	64.9 (25.5)	61.9 (27.6)	0.538	59.4 (25.4)	64.5 (26.7)	0.408
Range of motion	Thoracic flexion, %	102.0 (42.6)	106.5 (41.7)	97.1 (44.8)	0.611	100.0 (50.6)	102.5 (41.8)	0.818
	Thoracic extension, %	92.6 (46.0)	99.9 (51.4)	84.6 (40.2)	0.611	127.0 (13.4)	84.0 (47.5)	0.019
	Lateral flexion towards right, %	94.1 (28.1)	95.9 (33.8)	92.2 (21.6)	0.347	100.0 (12.5)	92.7 (30.9)	0.974
	Lateral flexion towards left, %	95.7 (21.3)	103.5 (87.2)	87.2 (20.0)	0.035	91.4 (13.5)	96.7 (23.0)	0.447

[*] $p < 0.05$, significant difference compared to reference value.
[**] $p < 0.001$, significant difference compared to reference value.

Table 4
Number of patients rating at least minor symptoms in the subscales of EQ-5D (n) and the median value (min-max) of index values and the VAS.

	All ($n = 35$)	Manual CPR ($n = 18$)	+Mechanical CPR ($n = 17$)	*p*-value	No flail chest ($n = 29$)	Flail chest ($n = 6$)	*p*-value
Mobility, n	8	4	4	0.562	8	0	0.342
Self-care, n	2	0	2	0.229	1	1	0.318
Usual activities, n	6	2	4	0.527	4	2	0.159
Pain/discomfort, n	21	12	9	0.752	18	3	0.862
Anxiety/depression, n	12	5	7	0.380	10	2	0.830
Index values	0.943 (0.703–0.976)	0.940 (0.703–0.9755)	0.943 (0.817–0.976)	0.987	0.943 (0.703–0.976)	0.934 (0.823–0.976)	0.724
EQ-5D VAS	80 (40–100)	80 (40–95)	75.5 (40–100)	0.568	80 (40–100)	77.5 (50–95)	0.758

Fracture healing

Of the 35 patients included in the study, 22 underwent a CT of the thorax in conjunction with the follow-up. Two of the patients had remaining unhealed chondral injuries and one patient had an unhealed rib-fracture but none of these patients reported any pain or discomfort of the unhealed fractures.

Discussion

Chest wall trauma after CPR have been reported in several studies both immediately after CPR in autopsy studies and in retrospective cohort studies [4-6,27]. However, there is a lack of studies focusing on long-term chest function after CPR. This cross-sectional study suggested no persistent pain, or reduced lung function in the long-term perspective. When comparing sub-groups, PEF was significantly superior in the group with manual CPR (after ≥two years) compared to patients receiving also mechanical CPR. Except for being significantly older and being less active after having flail chest, no significant differences were found in pain, lung function, or physical function between the groups with and without flail chest.

The lack of previous studies concerning chest function after CPR makes it difficult to compare the results of this study. We found that no patients had remaining chest wall pain, however during the examination many described having pain for a period directly after the CPR. Previous studies concerning pain after trauma to the chest wall, reported reduced pain during the first year after the injury [14,28,29]. Pain after orthopaedic trauma reduces over time and this study can confirm that this is the case also after CPR-related trauma.

In the current study all but one patient had rib fractures (97 %) directly after the CPR. Most injuries were bilateral (94 %), and the average number of fractured ribs was 8.5. At the time of the follow-up, three patients had remaining pathology, with unhealed chondral injuries or unhealed rib fracture. Despite this, none of the patients had remaining pain at the time of the follow-up. Two patients experienced local discomfort anteriorly and laterally over the left chest wall, but this was not related to unhealed injuries. It may be difficult to detect injuries on CT in patients after resuscitation as rib fractures can be missed in initial chest CT. Nevertheless, a study has found that CT and autopsy are able to equally discriminate between such patients with or without rib fractures [30]. However, the longer time since the trauma the easier is it to detect fractures and other injuries.

Previous studies have reported a normal FVC one year after chest wall trauma [14] in contrary to the results of respiratory function in our study-cohort which were significantly decreased compared to reference values. A possible explanation of the discrepancy in results is the different origin of the injury to the chest wall- CPR vs. trauma. Bilateral injuries were more common after CPR causing a significantly decreased thoracic excursion which have affected the lung expansion and thereby lung function. Even though there were no differences between the groups concerning lung function between the two types of CPR the results were decreased compared to reference values. This must be further addressed.

Most of the patients in this follow-up were reported to be physically and mentally recovered and managed to achieve their daily activities. This corroborates previous results that most survivors are self-sufficient in daily activities one year after CPR [31]. However, the difficulties concerning self-care and usual activity in our study seem to be less in comparison to a previous study six months after CPR [32]. Information about course of physical and psychological recovery is important to give survivors with several symptoms in the acute phase after the CPR to improve realistic expectations of the outcome.

In the initial evaluations of the CT images of the thorax, rib fractures, sternal fractures and pulmonary contusion were seldom reported by the responsible radiologist as the indication for the CT was to investigate reasons for the cardiac arrest rather than to diagnose injuries. When the images were re-assessed, several injuries were found, as shown in Table 2. Almost all patients had bilateral rib fractures and 69 % had sternal fractures. Most of to these were healed at the time of the follow-up and the unhealed injuries caused no pain or discomfort. There were no differences CPR technique. This contrasts with previous studies which have presented more rib fractures, sternal fractures, and anterior chest lesions such as bruises and abrasions after mechanical CPR with LUCAS [6]. However, more prospective studies are needed with larger study populations to draw a definitive conclusion on whether different kinds of CPR or flail chest cause long-term concerns in patients who have suffered a cardiac arrest.

There are no current guidelines concerning surgical management of CPR-related chest wall injuries and it is unclear if this patient group benefits from surgery in the same way that traumatic chest wall injury patients do, with a decreased incidence of pneumonia, need for mechanical ventilation and intensive care [33-36]. In one retrospective multicentre study no benefit was found concerning hospital outcome and mortality [27]. Prospective studies are needed to address the issue of patient selection and timing of surgery especially regarding patients with ischaemic heart disease in need of cardiac intervention and anti-coagulant therapy. Currently, patients are sometimes operated in order to wean them off the ventilator [36,37]. However, it is unclear what the long-term effects of surgery could be in this group, although improved long-term lung function is one possibility.

Limitations and strengths

The study has several limitations. This is a cross-sectional study that represents findings concerning pain, lung function, movement, and disability with no regard to the patients' function before the cardiac arrest, immediately after the CPR or their character and effect over time. The study is based on a small sample. This may affect the detection of significant differences in all variables and entails to extra caution when interpreting the results, even though the study population is based on a consecutive series of patients fulfilling the inclusion criteria. However, the size of the study sample is large enough to be able to perform analyses between the groups as a base for future trials. In addition, patients from only one hospital were included and 8 out of the 43 survivors declined participation with which may also impact the generalisability of the results.

Another limitation is that there was no previous data for this patient group, no power calculation could be performed. In addition, the suggested inclusion criteria with a two-week period for CT scan after the cardiac arrest was decided to enhance the probability that the confirmed chest wall injuries were CPR-related. This margin excluded 81 patients, which could be a selection bias. Some possible candidates might have been excluded such as those with CPR-related chest wall injures with a later CT scan or with no CT scan, since this radiological examination is not regularly performed on the survivors. An additional limitation is that many of those who declined participation were seriously ill. It is possible that patients with the most severe injuries were deceased and that group would have a higher prevalence of remaining symptoms which may present a selective sample and affect the correlation with reality. However, participating by mail or telephone may have reduced the quantity of measurements, but gave those patients the opportunity to share experiences and thoughts. The same examiner performed all measurements, which reduces the risk of detection bias. Despite the limitations, the study adds knowledge about long-term symptoms and experiences of this patient group, results which may be useful as a base for comparison for future research.

Conclusions and implications

Patients with CPR-related chest wall injury who survived cardiac arrest had no persistent pain and a normal range of motion in the thorax and shoulder > two years after the resuscitation. Despite decreased lung function (14–20 % of predicted), most patients reported no disability in physical activity. There were no major significant differences in lung function, physical function and QoL between the groups with and without flail chest.

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Registration

The study was registered in FoU in VGR (Research & development in Vastra Gotaland Region) No **276517**

Data statement

Data is available on reasonable request.

CRediT authorship contribution statement

Micheline Al Nouh: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Eva-Corina Caragounis:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Rauni Rossi Norrlund:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Monika Fagevik Olsén:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no competing interest.

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