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ORIGINAL RESEARCH

Prevalence and Patterns of Resuscitation-Associated Injury Detected by Head-to-Pelvis Computed Tomography After Successful Out-of-Hospital Cardiac Arrest Resuscitation

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BACKGROUND: Patients resuscitated from out-of-hospital circulatory arrest (OHCA) frequently have cardiopulmonary resuscitation injuries identifiable by computed tomography, although the prevalence, types of injury, and effects on clinical outcomes are poorly characterized.

METHODS AND RESULTS: We assessed the prevalence of resuscitation-associated injuries in a prospective, observational study of a head-to-pelvis sudden-death computed tomography scan within 6 hours of successful OHCA resuscitation. Primary outcomes included total injuries and time-critical injuries (such as organ laceration). Exploratory outcomes were injury associations with mechanical cardiopulmonary resuscitation and survival to discharge. Among 104 patients with OHCA (age 56±15 years, 30% women), 58% had bystander cardiopulmonary resuscitation, and total cardiopulmonary resuscitation time was 15±11 minutes. The prevalence of resuscitation-associated injury was high (81%), including 15 patients (14%) with time-critical findings. Patients with resuscitation injury were older (58±15 versus 46±13 years; $P<0.001$), but had otherwise similar baseline characteristics and survival compared with those without. Mechanical chest compression systems (27%) had more frequent sternal fractures (36% versus 12%; $P=0.009$), including displaced fractures (18% versus 1%; $P=0.005$), but no difference in survival (46% versus 41%; $P=0.66$).

CONCLUSIONS: In patients resuscitated from OHCA, head-to-pelvis sudden-death computed tomography identified resuscitation injuries in most patients, with nearly 1 in 7 with time-critical complications, and one-half with extensive rib-cage injuries. These data suggest that sudden-death computed tomography may have additional diagnostic utility and treatment implications beyond evaluating causes of OHCA. These important findings need to also be taken in context of the certain fatal outcome without resuscitation efforts.

REGISTRATION: URL: https://www.clinicaltrials.gov; Unique identifier: NCT03111043.

Key Words: cardiopulmonary resuscitation ■ computed tomography ■ out-of-hospital cardiac arrest ■ out-of-hospital circulatory arrest ■ resuscitation complications ■ rib fracture ■ sudden-death CT

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CLINICAL PERSPECTIVE

What Is New?

- Head-to-pelvis sudden-death computed tomography in patients successfully resuscitated after out-of-hospital circulatory arrest was performed early (<6 hours) after hospital arrival and demonstrated a high prevalence of injuries associated with resuscitation, including rib-cage fractures in most patients, as well as time-critical or life-threatening complications (eg, organ laceration, internal hemorrhage).

What Are the Clinical Implications?

- These data suggest that sudden-death computed tomography may have an incremental benefit in the early post–out-of-hospital circulatory arrest period by assisting in the prompt identification of resuscitation injury to inform postarrest patient care.
- The downstream effect of this diagnostic intervention on clinical outcomes merits further study.

Nonstandard Abbreviations and Acronyms

OHCA   out-of-hospital circulatory arrest
SDCT   sudden-death computed tomography

Out-of-hospital circulatory arrest (OHCA) occurs in ≈140 per 100 000 adults in the United States annually and is associated with poor outcomes.[1] High-quality cardiopulmonary resuscitation (CPR) is critical to survival in OHCA.[2] Injuries from chest compressions, defibrillation, intubation, vascular cannulation, and other interventions performed during cardiovascular life support are described.[3] However, the prevalence and types of skeletal and visceral injuries attributable to CPR, as well as their effect on clinical outcome, remain poorly characterized. We have previously reported the findings of a prospective observational study examining the utility of early head-to-pelvis sudden-death computed tomography (SDCT) in patients resuscitated after OHCA to identify the cause of circulatory arrest.[4] SDCT can also evaluate for resuscitation injuries, such as organ laceration, rib fracture, and vascular disruption. Rapid detection of such injuries may allow for early targeted intervention and improvement in outcomes. The aim of the present analysis is to describe the prevalence, severity, and effects on outcomes for injuries associated with resuscitation efforts as detected by SDCT imaging in patients hospitalized after OHCA.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request. The full methods of the study have been previously described (National Clinical Trial number 03111043).[4,5] Briefly, CT-FIRST (CT Feasibility In Resuscitated Patients for Sudden Death Triage) was a prospective, observational study of patients resuscitated after an OHCA event but without obvious cause for the OHCA event (termed *idiopathic OHCA*). The study was designed to evaluate the incremental diagnostic capability and safety of early (<6 hours from hospital arrival) head-to-pelvis SDCT in addition to standard care. Patients who survived an idiopathic OHCA between December 2015 and February 2018 and presented at 1 of 2 academic medical centers were eligible for enrollment if clinically stable to undergo computed tomography (CT) scanning within 6 hours of hospital arrival. Exclusion criteria included ST-segment–elevation myocardial infarction; known unrevascularized coronary artery disease or stent diameter <2.5 mm; estimated glomerular filtration rate <30 mL/min per 1.73 m^2 and serum creatinine >1.7 mg/dL, unless the ordering physician deemed SDCT clinically necessary; implantable defibrillator; known iodinated contrast allergy; and known hospice status or terminal disease (prognosis <3 months). Patients could be enrolled in 1 of 2 ways: (1) prospectively, in which informed consent could be obtained from the patient or legally authorized representative before SDCT followed by SDCT as part of the research protocol; or (2) retrospectively, in which patients who underwent clinically directed SDCT could have eligibility screening and the informed consent process performed post hoc. All patients subsequently underwent clinically directed SDCT, and thus no patients were prospectively prior to SDCT. Patients for whom the study had been ordered clinically and subsequently died with no identifiable legally authorized representative were also enrolled if they satisfied the inclusion criteria. Institutional Review Board/Human Subject Division approval was obtained for consenting and all study procedures. The study adhered to all Health Insurance Portability and Accountability Act requirements. The study was partially supported by a research grant from the Medic One Foundation (Seattle, WA).

The SDCT scan was performed on either a dual-source CT (FORCE, Siemens Medical Solutions, Forchheim, Germany) or a wide single-detector CT (REVOLUTION, GE Healthcare, Waukesha, WI), and consisted of (1) a noncontrast head CT from the vertex to below the mandible, (2) an ECG-gated CT scan of the thorax, and (3) a non–ECG-gated venous-phase CT scan extending from the diaphragm to just below the pelvis.

SDCT Evaluation

As previously described, all SDCT data, except for coronary imaging data, were read by an attending radiologist and were released to treating providers in real time.[4,5] These data included resuscitation injuries. For the purpose of this research analysis, the SDCT studies were independently reviewed by 2 board-certified radiologists (M.L.G. and R.M.E.) with 34 combined years of experience in tomographic imaging who were blinded to the patients' clinical data, including radiology reports. In addition, the chest CT images were independently reviewed by a third radiologist (B.S.) with 15 years of experience in chest CT to describe rib-cage fractures including location (rib number and angle) and morphology (Data S1).[6]

The radiology reports were subsequently independently evaluated by 2 cardiologists who had access to the patients' clinical data (A.K. and K.R.H.B.) to assess the likelihood the findings were potentially associated to resuscitation (rather than preceding or unrelated to resuscitative efforts) and graded to "time-critical" if the findings warranted urgent evaluation by specialty services, urgent additional imaging, or urgent treatments.[4] All discrepancies were resolved by consensus. Clinical outcomes studied were death from CPR injury detected by SDCT and survival to hospital discharge.

Statistical Analysis

All data were compiled into a Research Electronic Data Capture[7,8] database and summarized as number (percentage [95% CI]) or mean±SD. Continuous data were visually inspected for conformation with the normal distribution and were compared using a 2-tailed Student t test; categorical variables were compared using Fisher's exact test. Exploratory analyses were performed to evaluate resuscitation injuries for an association with survival to discharge and mechanical CPR. All analyses were performed using JMP Pro 15.0.0 (SAS, Cary, NC). A P value of <0.05 was considered statistically significant.

RESULTS

A total of 307 patients presented after OHCA to the 2 centers during the enrollment period; 111 underwent

Table 1. Baseline Clinical and Out-of-Hospital Circulatory Arrest Characteristics

Characteristic*	Patients (n=104)	CPR injury Yes (n=84)	No (n=20)	P value
Age, y	56±15	58±15	46±13	<0.001
Female sex	31/104 (30)	25/83 (30)	6/21 (29)	1.000
Body mass index, kg/m^2	25±8	24±8	27±8	0.219
Available medical history	95	77	18	…
Hypertension	38/95 (40)	32/77 (42)	6/18 (33)	0.753
Dyslipidemia	15/95 (16)	12/77 (16)	3/18 (17)	1.000
Heart failure	12/95 (13)	10/77 (13)	2/18 (11)	1.000
Diabetes	19/95 (20)	17/77 (22)	2/18 (11)	0.513
Chronic kidney disease	12/95 (13)	10/77 (13)	2/18 (11)	1.000
History of coronary artery disease	11/95 (12)	9/77 (12)	2/18 (11)	1.000
Prior cardiac arrest	2/95 (2)	2/77 (3)	0/18 (0)	1.000
Prior PCI	5/95 (5)	4/77 (5)	1/18 (6)	1.000
Prior valvular disease	5/95 (5)	4/77 (5)	1/18 (6)	1.000
Prior stroke	6/95 (6)	3/77 (4)	3/18 (17)	0.080
Initial rhythm				0.778
Pulseless electrical activity	40/104 (38)	33/84 (40)	7/20 (35)	
VT/VF	30/104 (29)	25/84 (30)	5/20 (25)	
Asystole/unknown	34/104 (33)	26/84 (31)	8/20 (40)	
Witnessed arrest	59/99 (59)	46/79 (58)	13/20 (65)	0.621
Bystander CPR	57/99 (58)	46/79 (58)	11/20 (55)	0.805
Mechanical CPR	28/104 (27)	25/84 (30)	3/20 (15)	0.263
Mean CPR time, min	15±11	16.1±11.0	12.3±8.5	0.138

Data are shown as number, number/total number (percentage), or mean±SD. CPR indicates cardiopulmonary resuscitation; LV, left ventricle; PCI, percutaneous coronary intervention; VF, ventricular fibrillation; and VT, ventricular tachycardia.

*Of 104 (91%) patients, 95 had complete past medical history obtained during the hospitalization, resulting in discrepant numbers of total patients and denominators for the patient characteristics.
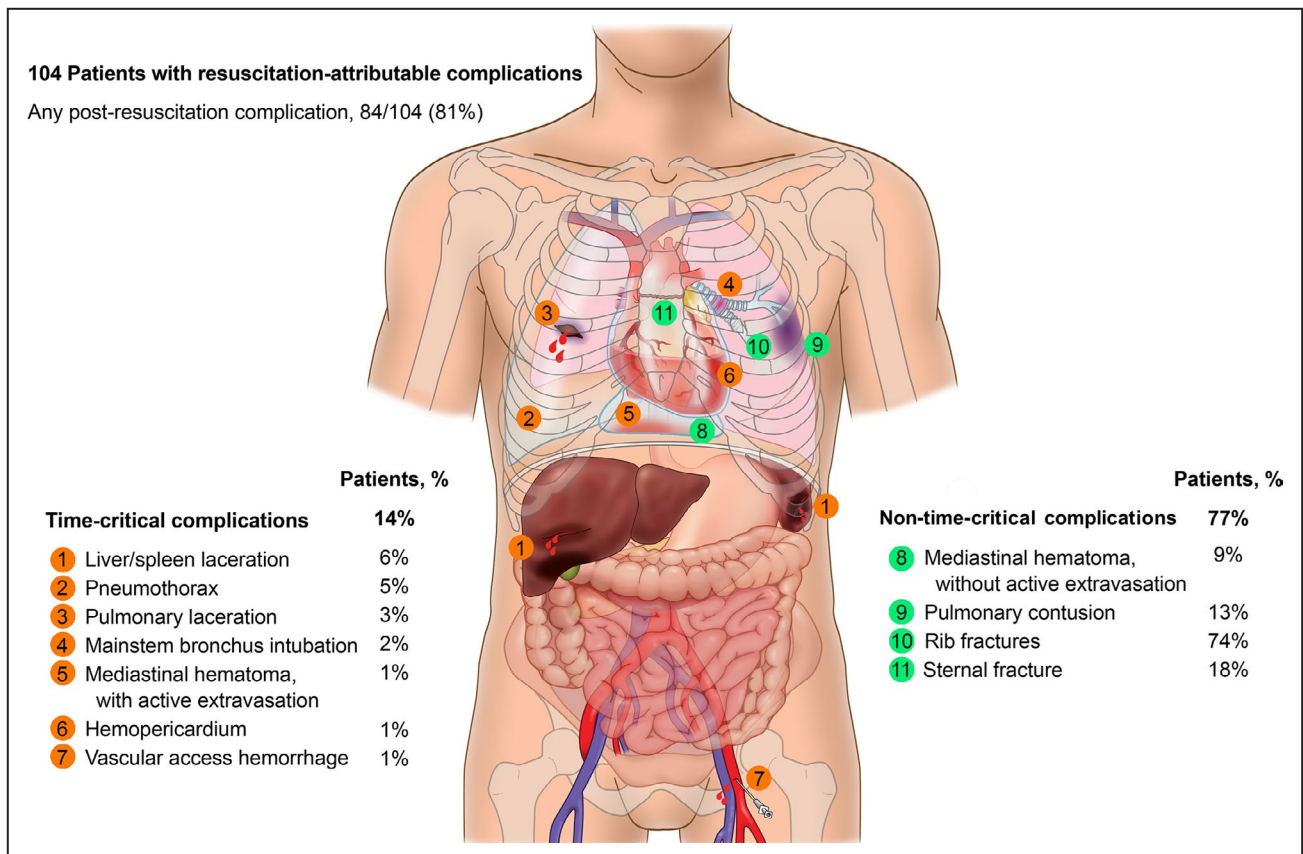
104 Patients with resuscitation-attributable complications

Any post-resuscitation complication, 84/104 (81%)

Time-critical complications	Patients, % 14%
1 Liver/spleen laceration	6%
2 Pneumothorax	5%
3 Pulmonary laceration	3%
4 Mainstem bronchus intubation	2%
5 Mediastinal hematoma, with active extravasation	1%
6 Hemopericardium	1%
7 Vascular access hemorrhage	1%

Non-time-critical complications	Patients, % 77%
8 Mediastinal hematoma, without active extravasation	9%
9 Pulmonary contusion	13%
10 Rib fractures	74%
11 Sternal fracture	18%

Figure 1. Resuscitation-associated injuries including time-critical injuries.

head-to-pelvis SDCT; 7 patients were subsequently excluded as a result of incorrect SDCT protocol (n=4) or refusing enrollment after awakening (n=3), resulting in a study cohort of 104 patients.

Baseline characteristics of the study population are shown in Table 1. Mean age was 56±15 years, and 30% were women. The majority (43%) of events occurred at home, and most (58%) patients received bystander CPR. The most common initial OHCA rhythm was pulseless electrical activity (38%). Mean CPR duration was 15±11 minutes; a mechanical chest compression system was used in 27% of cases. Compared with patients without injury, patients with injury associated with CPR were older (58±15 versus 46±13 years; $P<0.001$) but otherwise exhibited similar characteristics (Table 1).

The overall prevalence of injury attributable to resuscitation was 81% (95% CI, 72%–87%; 84/104 patients; Figure 1); 37 patients (36% [95% CI, 27%–45%]) had >1 injury. A total of 15 patients (14% [95% CI, 9%–22%]) had 19 total time-critical findings, including liver/spleen laceration, pneumothorax or pulmonary laceration, or hemorrhage in another site (Figure 2; Table 2). A total of 32 downstream evaluations or treatments occurred in 13/15 (87%; 13% of the overall study population)

patients as a result of SDCT identifying time-critical injuries, including repeat or additional imaging in 11 patients, surgical consultations for 9 patients, blood transfusions in 5 patients (per our institutional protocol, 2 "massive" transfusions and 3 standard transfusions), chest/abdominal drains placed in 5 patients, and endotracheal tube repositioning in 2 patients.

The anatomical distribution of rib fractures (N=519; 5.0±4.6 fractures per patient) is shown in Figure 3. The majority (80% [95% CI, 76%–83%]) of fractures were anterolateral, and more than half (58% [95% CI, 54%–62%]) were on the third, fourth, or fifth ribs.

In exploratory analyses, 44 (42%) patients survived to discharge, and there was no significant difference in survival between those with or without overall resuscitation-associated injury (39% versus 55%; $P=0.22$). Patients who did not survive had more rib fractures (5.7±4.7 versus 4.0±4.4; $P=0.03$; Table S1) and sternal fractures (25% versus 9%; $P=0.04$) than survivors. No patient died as a direct consequence of time-critical injuries. Those who underwent mechanical CPR (n=28, 27%) had similar rates of overall (89% versus 78%; $P=0.26$) and time-critical (21% versus 12%; $P=0.22$) resuscitation-associated injuries compared with patients who only received manual CPR (Table S2). Mechanical CPR was
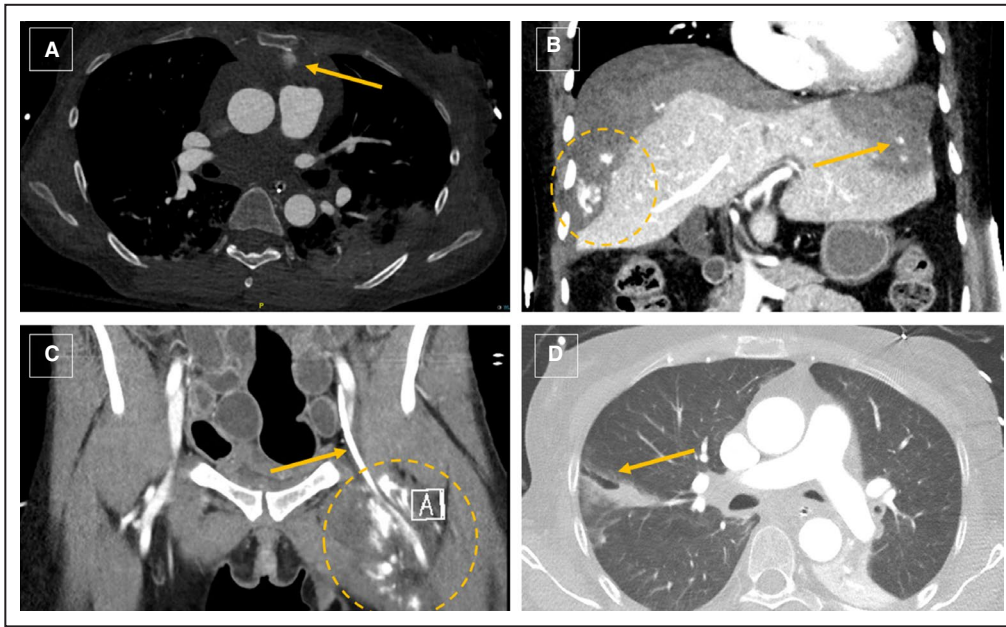
Figure 2.   Illustrative radiographic examples of cardiopulmonary resuscitation complications.
(**A** and **C**) Anterior mediastinal hematoma (arrow, **A**) and left thigh medial compartment hematoma (circle) associated with a femoral artery catheter (arrow, **C**), both exhibiting active extravasation in a patient with disseminated intravascular coagulation treated with massive transfusion. (**B**) Extensive subcapsular liver hematoma with multiple foci of active extravasation (circle, arrow) and several lacerations treated conservatively because of a poor prognosis with multiple transfusions and eventual autotamponade of bleeding. (**D**) Right lower lobe pulmonary laceration (arrow) associated with bilateral rib and sternal fractures in a patient with hereditary pheochromocytoma/paraganglioma syndrome who underwent prolonged resuscitation.

associated with more frequent sternal fractures (36% versus 12%; P=0.009), including displaced fractures (18% versus 1%; P=0.005), compared with nonmechanical CPR, but this did not adversely impact survival to discharge (46% versus 41%; P=0.66).

DISCUSSION

Our study demonstrated that resuscitation-associated injuries after an OHCA event are common and are identified by SDCT scanning in ≈80% (95% CI, 72%–87%) of survivors of OHCA. Although the most prevalent complication was rib fracture, radiographic flail chest or sternum occurred in a significant proportion (40% [95% CI, 31%–50%]) of patients, and time-critical resuscitation injuries occurred in 14% (95% CI, 9%–22%) of patients, including organ laceration and significant bleeding requiring massive transfusion. These data support the use of a head-to-pelvis SDCT protocol to provide important diagnostic information in patients successfully resuscitated from OHCA.

Thoracic and abdominal injury are relatively common after CPR and cardiovascular life support. Injuries can range from relatively benign, such as nondisplaced rib fractures, to life-threatening, including hemorrhage from organ injury. Autopsy series identified thoracic and abdominal complications at a high frequency, including rib and sternal fractures in up to 89% and 47%, respectively. Laceration or rupture of either the liver or spleen occurred in up to 21% and 10%, respectively.[3,9,10] Current guidelines for postresuscitative care suggest only ECG, chest radiograph, and echocardiography as routine diagnostic modalities in the early resuscitation period,[2,11,12] but these cannot evaluate for all resuscitation injuries. Chest radiography alone substantially underestimates thoracic injuries and only identified 50% of total rib or sternal fractures at autopsy in patients with OHCA.[9] CT scanning, on the other hand, has the capabilities to simultaneously evaluate bony structures, thoracic and abdominal organs and soft tissue, and intravascular line and endotracheal tube placement. Kashiwagi et al. evaluated 223 patients after OHCA with whole-body CT (65% postmortem; 35% within 72 hours after the return of spontaneous circulation) and found a similarly high prevalence of rib fractures (70%), sternal fractures (8.1%), and pneumothorax (7.6%)[13]; our findings are more clinically relevant given that all scans in our study were performed in alive patients within 6 hours (mean, 1.9±1.0 hours) of arrival. Seung et al. published a retrospective CT study of 148 patients and showed a high overall prevalence of complications (rib fractures in 75%, "serious complications"

Table 2. Resuscitation-Associated Injuries (n=104 Patients)

Type of resuscitation-associated injury	Patients
Any postresuscitation injury	84/104 (81 [72–87])
Time critical*	15/104 (14 [9–22])
Liver/spleen laceration	6 (6 [3–12])
Pneumothorax	5 (5 [2–11])
Mediastinal hemorrhage, active extravasation	1 (1 [0–5])
Hemopericardium	1 (1 [0–5])
Pulmonary laceration	3 (3 [1–8])
Vascular access hemorrhage	1 (1 [0–5])
Mainstem bronchus intubation	2 (2 [1–7])
Not time critical*	80/104 (77 [68–84])
Mediastinal hematoma without active extravasation	9 (9 [5–16])
Pulmonary contusion	14 (13 [8–21])
Rib fractures	77 (74 [65–82])
Displaced	16 (15 [10–24])
Meets surgical stabilization screening criteria	45 (43 [34–53])
Displaced rib fractures, ≥3	3 (3 [1–8])
Flail chest	1 (1 [0–5])
Flail sternal segment	42 (40 [31–50])
Number of rib fractures per patient	5.0±4.6
Sternal fracture	19 (18 [12–27])
Displaced	6 (6 [3–12])

*Data are shown as number (percentage [95% CI]), number/total number (percentage [95% CI]), or mean±SD of patients with each injury type; some patients had >1 injury.

in 7.4%) as well as a higher prevalence of complications in survivors of OHCA compared with in-hospital cardiac arrest.[14] However, only a chest CT was required for inclusion, which would not reveal resuscitation complications in the nonvisualized portions of the abdomen and the pelvis, several of which were identified with our head-to-pelvis CT protocol.

Our study supports the high prevalence of resuscitation-associated injury in a prospective cohort of survivors of OHCA, adds granularity, and confirms the feasibility and utility of an early (<6 hours) SDCT protocol to identify resuscitation complications. In particular, the extent of rib-cage injuries was striking, with an estimated 40% meeting institutional criteria for consideration of surgical stabilization. This included a 3-fold increase in sternal fractures in the 27% of patients who received mechanical chest compressions, consistent with prior studies showing sternal fractures,[15] and other thoracic injuries such as myocardial rupture.[16] Thoracic injuries after resuscitation have been associated with prolonged mechanical ventilation, tracheostomy, pneumonia, acute respiratory distress syndrome, and increased mortality among others.[17] Interestingly, severe injuries that could be missed by plain radiography and echocardiography (such as life-threatening hemorrhage or organ laceration) were frequent in our study, and SDCT significantly affected downstream clinical evaluations and treatments in at least 13% of cases. These data suggest that SDCT may have additional diagnostic utility and treatment implications beyond evaluating causes of OHCA, a hypothesis that merits further study in a larger, randomized trial.[4] Fortunately, despite their high frequency, only a small minority of patients required invasive procedures to treat resuscitation-associated injury, and no patients died as a direct consequence thereof.

The current study is limited by total number of patients as well as selection bias of the prospective cohort studied as all patients underwent a clinically ordered SDCT at 1 of 2 academic medical centers. We did not collect data on survivors of OHCA presenting at the participating centers during the study period who were eligible for the study but did not undergo SDCT (n=196), and thus we cannot assess for systematic differences between this group and the present study cohort. Thus, data from this cohort may not be generalizable to all survivors of OHCA. There also is no standard for identification and of injuries potentially associated with resuscitation in survivors of OHCA such that SDCT acts as its own standard. SDCT readings were blinded to clinical data and performed by 2 board certified radiologists to reduce observer bias. We also cannot definitively assess the effect of SDCT imaging on clinical outcomes as all scan data were available clinically and there was no comparator group. Whether clinical outcomes would have been altered with or without SDCT remains unclear. Outcomes may be confounded by the small sample size and patient characteristics (eg, frailty) such that further prospective study is needed to define the role of early SDCT in assisting with clinical care. Finally, while not being dismissive of injuries potentially related to resuscitation from OHCA, one must bear in mind that the alternative to efforts that might result in such complications from urgently needed treatment is certain death.

In conclusion, in patients who survived an OHCA event as a result of resuscitation protocols, resuscitation-associated injuries are common and are identifiable by a head-to-pelvis SDCT. Resuscitation injury has a range of diagnoses and severities, but in our study nearly 1 in 7 had time-critical diagnoses by SDCT that required further evaluation or intervention, and up to half had extensive rib-cage injuries that might have impacted clinical care. Thus, although resuscitation injuries were not associated with survival to discharge in our study, SDCT scanning can identify
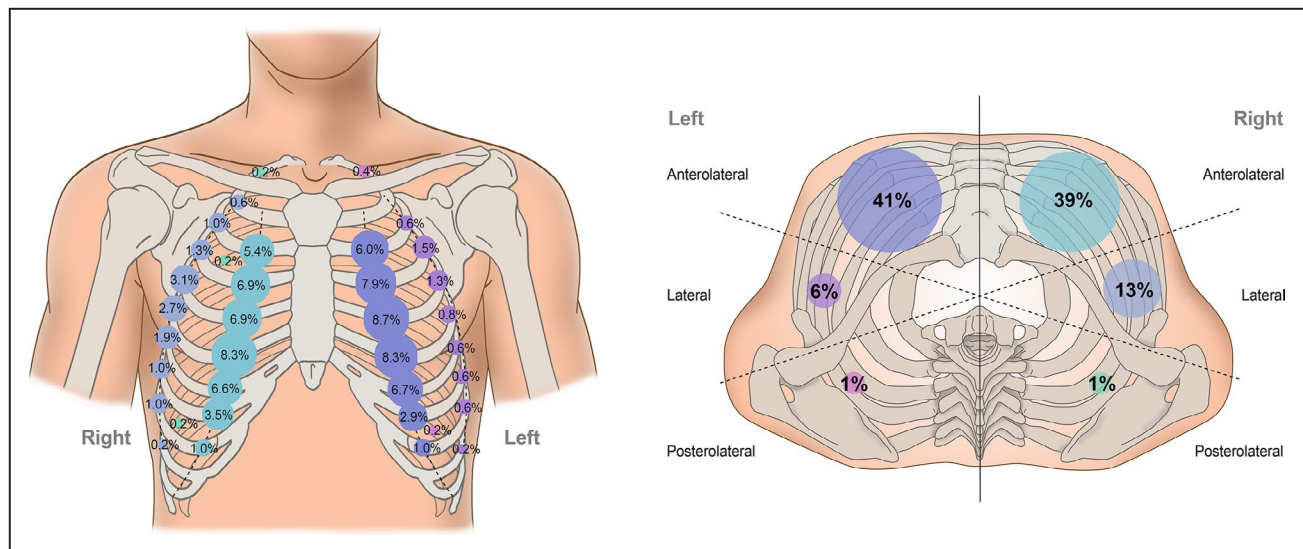
Figure 3. Anatomical distribution of rib fractures.
Distribution of rib fractures by transverse sector (anterolateral, 0–72 °; lateral 73–108 °; posterolateral, 109–180 °) shown by rib number (**left**) and for the overall sector (**right**). Numbers are shown as percentage of total rib fractures (N=519); circle size is proportionate to frequency in respective anatomic location.

clinically important and actionable complications of resuscitation as well as causes for OHCA. Importantly, these findings need to be taken in the context of the certain fatal outcome were resuscitation to not be performed after OHCA.

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SUPPLEMENTAL MATERIAL

Data S1.

Supplemental Methods

Rib-cage injury definitions: Fractures were characterized as "segmental" when ≥ 2 fractures were identified on the same rib; and "displaced" when there was one full shaft-width displacement. For angle measurements, an anteroposterior line was drawn traversing from the midline sternum to the posterior rib line (a line tangential to the posterior margin of the ribcage). Angles were measured from the midpoint of the anteroposterior line to the fracture, such as to create three sectors on the sagittal plane: $0 - 72^o$ (anterolateral), $72 - 108^o$ (lateral), and $108 - 180^o$ (posterolateral). For segmental fractures, only the location of the anterior-most fracture was recorded as that would be more relevant for determination of possible early surgical intervention. Surgical consultation for consideration of early stabilization was suggested for fractures satisfying any of the following radiographic criteria: $3 \geq$ displaced, $3 \geq$ contiguous segmental ("radiographic flail chest"), or $3 \geq$ continuous bilateral anterior or costochondral ("radiographic flail sternal segment") rib fractures, or for displaced sternal fractures.

Table S1. Distribution of resuscitation-associated injuries according to survival to discharge.

Type of resuscitation-associated injury	Survival to discharge		
	Yes **(n=44)**	**No** **(n=60)**	**p**
Any post-resuscitation injury	33/44 (75%)	51/60 (85%)	0.218
Time-critical*	5/44 (11%)	10/60 (17%)	0.576
Liver/spleen laceration	3 (7%)	3 (5%)	0.696
Pneumothorax	3 (7%)	2 (3%)	0.648
Mediastinal hemorrhage, active extravasation	0 (0%)	1 (2%)	1.000
Hemopericardium	0 (0%)	1 (2%)	1.000
Pulmonary laceration	1 (2%)	2 (3%)	1.000
Vascular access hemorrhage	0 (0%)	1 (2%)	1.000
Mainstem bronchus intubation	0 (0%)	2 (3%)	0.507
Not time-critical*	32/44 (73%)	48/60 (80%)	0.481
Mediastinal hematoma w/o active extravasation	2 (5%)	7 (12%)	0.296
Pulmonary contusion	6 (14%)	8 (13%)	1.000
Rib fractures	30 (68%)	47 (78%)	0.265

Displaced	6 (14%)	10 (17%)	0.787
Meets surgical stabilization screening criteria	17 (39%)	28 (47%)	0.431
3 ≥ displaced rib fractures	0 (0%)	3 (5%)	0.261
Flail chest	0 (0%)	1 (2%)	1.000
Flail sternal segment	15 (34%)	27 (45%)	0.314
Mean number of rib fractures per patient	4.0 ± 4.4	5.7 ± 4.7	**0.034**
Sternal Fracture	4 (9%)	15 (25%)	**0.043**
Displaced	2 (5%)	4 (7%)	1.000

*Data are expressed as n and % of patients with each injury type; some patients had more than one injury.

Table S2. Distribution of resuscitation-associated injuries according to utilization of mechanical CPR.

Type of resuscitation-associated injury	Mechanical CPR		
	Yes (n=28)	No (n=76)	p
Any post-resuscitation injury	25/28 (89%)	59/76 (78%)	0.263
Time-critical*	6/28 (21%)	9/76 (12%)	0.224
Liver/spleen laceration	3 (11%)	3 (4%)	0.340
Pneumothorax	2 (7%)	3 (4%)	0.609
Mediastinal hemorrhage, active extravasation	0 (0%)	1 (1%)	1.000
Hemopericardium	1 (4%)	0 (0%)	0.269
Pulmonary laceration	1 (4%)	2 (3%)	1.000
Vascular access hemorrhage	0 (0%)	1 (1%)	1.000
Mainstem bronchus intubation	1 (4%)	1 (1%)	0.468
Not time-critical*	24/28 (86%)	56/76 (74%)	0.294
Mediastinal hematoma w/o active extravasation	5 (18%)	4 (5%)	0.057
Pulmonary contusion	6 (21%)	8 (11%)	0.195
Rib fractures	23 (82%)	54 (71%)	0.319

Displaced	6 (21%)	10 (13%)	0.360
Meets surgical stabilization screening criteria	12 (43%)	33 (43%)	1.000
3 ≥ displaced rib fractures	0 (0%)	3 (4%)	0.562
Flail chest	0 (0%)	1 (1%)	1.000
Flail sternal segment	9 (32%)	33 (43%)	0.370
Mean number of rib fractures per patient	5.4 ± 4.0	4.9 ± 4.8	0.595
Sternal Fracture	10 (36%)	9 (12%)	**0.009**
Displaced	5 (18%)	1 (1%)	**0.005**

*Data are expressed as n and % of patients with each injury type; some patients had more than one injury.