Clinical paper

Focused cardiac ultrasound after return of spontaneous circulation in cardiac-arrest patients

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Abstract

Background: Guidelines emphasize the clinician to consider the use of ultrasound to determine the cause of cardiac arrest. In this study we aimed to investigate how focused cardiac ultrasound (FOCUS) shortly after return of spontaneously circulation (ROSC) was associated with the use of further diagnostic measures and if the detection of pulmonary embolism, cardiac tamponade and acute myocardial infarction could be improved.

Methods: A retrospective, single-center, observational study at a tertiary hospital to evaluate FOCUS performed by cardiologists within 60 min after ROSC. Included were adult cardiac-arrest patients with ROSC, without restrictions in care. Excluded were patients with ECGs demonstrating ST elevation, patients with an obvious non-cardiac cause of cardiac arrest and patients where FOCUS was not performed.

Results: Between January 2012 and December 2017, FOCUS was performed in 237 (182 OHCA and 55 IHCA) patients. FOCUS findings influenced management and led to further immediate diagnostic measures in 52 (21.9%) patients. Left-ventricular regional wall motion abnormalities influenced the decision to perform emergency coronary angiography in 17 (7.2%) patients, of which nine were treated with PCI. Right-ventricular dilatation and/or pressure overload influenced a decision to perform computerized tomography of the thorax in 21 (8.9%) patients, of which 11 were diagnosed with pulmonary embolism. Cardiac tamponade was found in three patients (1.2%).

Conclusion: The retrospective data on this cardiac-arrest population supports that ALS-conformed post-resuscitation care could include FOCUS as an adjunctive diagnostic measure shortly after ROSC.

Keywords: Cardiac arrest, Focused cardiac ultrasound

Introduction

European Resuscitation Council and American Heart Association guidelines for adult advanced life support emphasize that ultrasound may be used in assisting with diagnosis and treatment of potentially treatable causes of cardiac arrest (CA)[1,2] such as pulmonary embolism, acute myocardial infarction and cardiac tamponade.

In resuscitated CA patients it may be challenging to establish the cause of arrest. In the emergency room, immediately after return of spontaneous circulation (ROSC), there are various tools to determine the cause of CA, such as an electrocardiogram (ECG) and medical history. Patients with ST elevation on the ECG have a high likelihood of a coronary cause of CA.[3] A medical history, with chest pain or dyspnea preceding CA, can often be difficult to obtain in the emergency room.[4] Ultrasound performed at an early stage is an established tool in emergency medicine and may be used to establish a diagnosis or as a guide to therapy in various conditions.[5] Focused cardiac ultrasound (FOCUS) is a simplified goal-directed application of echocardiography used to ascertain essential information needed in critical scenarios.[6]

Several trials have been carried out to investigate the potential role of ultrasound during cardiopulmonary resuscitation (CPR) to identify reversible causes of pulseless electric activity[7–10] such as massive

pulmonary embolism and cardiac tamponade, and to assist in the decision to withdraw resuscitation measures. However, ultrasound during CPR has been associated with an increased duration of pulse checks and CPR interruptions.[11,12]

The use of FOCUS shortly after ROSC in an attempt to determine the etiology of cardiac arrest has not been studied in detail. Post-ROSC FOCUS has the potential to facilitate decision-making regarding further diagnostic measures such as immediate coronary angiography or computerized tomography of the thorax (CT-thorax). In patients without ST elevation on the ECG, FOCUS may have the potential to detect left-ventricular regional wall motion abnormalities (RWMA), suggesting acute myocardial infarction as the cause of CA.

In this study we aimed to investigate how FOCUS shortly after ROSC was associated with the use of further diagnostic measures and if the detection of pulmonary embolism, cardiac tamponade and acute myocardial infarction could be improved.

Methods

Study design and ethics

This retrospective single-center observational study was conducted at Södersjukhuset, Stockholm, Sweden. The study was approved by the regional ethics committee in Stockholm (Identifier: 2016/1332-31).

Study population

Adult patients resuscitated from CA and admitted alive to the medical Intensive Care Unit (ICU) between January 2012 and December 2017 were included. All patients identified as having successful resuscitation following OHCA or IHCA and without any restrictions in care and without any signs of trauma were included. Patients with ST elevation on the ECG, patients admitted from other hospitals, patients without FOCUS examination and patients with obvious non-cardiac or respiratory causes of CA were excluded (Fig. 1).

Settings

The medical ICU at Södersjukhuset, Stockholm has a senior consultant echocardiography-certified cardiologist attending 24 h a day. The Cardiology Department also provides coronary intervention 24/7. The medical ICU at the hospital provides care for approximately 100 CA patients per year.

The FOCUS examination was performed by the attending echocardiography-certified cardiologist in charge of the medical ICU. Echocardiography certification in Sweden requires six
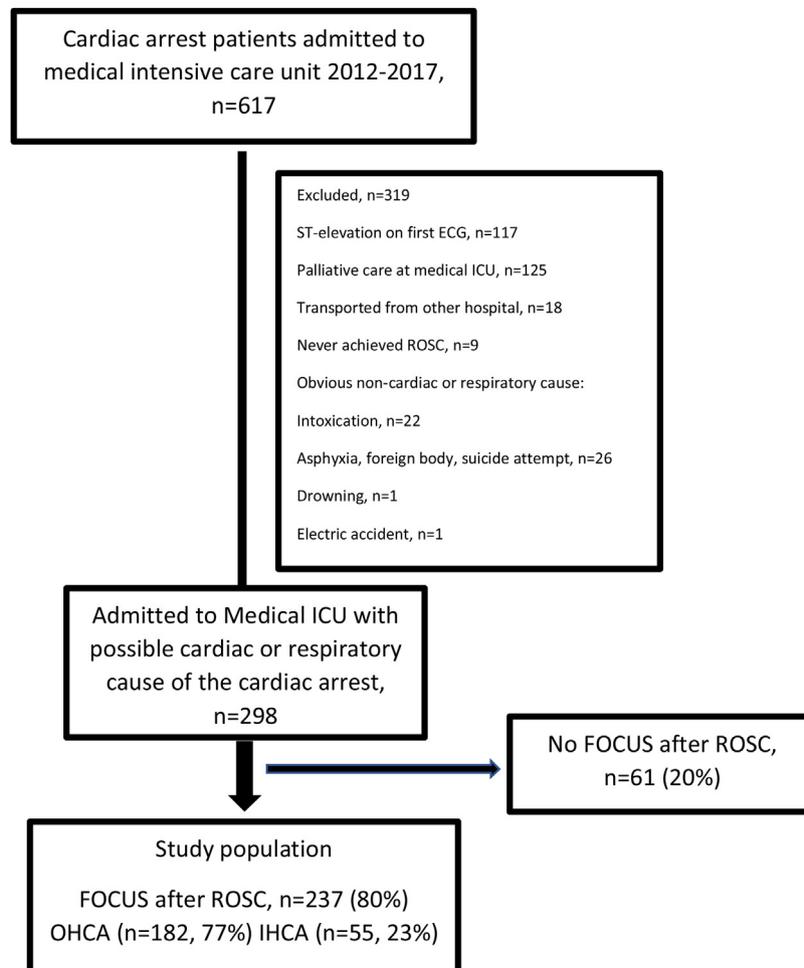

Fig. 1 – Study flow chart.

months of training at the Physiology Department and in general, after 1–2 years of clinical echocardiography experience, investigations and interpretation of findings can be done independently after achieving certification. The Swedish requirements for independent interpretation correspond to the European Association of Cardiovascular Imaging.

Images were interpreted in real-time during acquisition by the attending cardiologists. There were no stored images available for retrospective evaluation. The FOCUS examinations in this study were in accordance with ALS-guideline-conformed resuscitation ultrasound, with the purpose of detecting gross pathologies and not describing details of cardiac function.

Data collection

Study data were reviewed retrospectively from the patients' electronic medical records. To identify the patients the local register of CA patients was used.

The clinical report form (CRF) used for data collection

Free-text data, such as examination interpretation, were categorized into predefined categories. Diagnostic and therapeutic decisions related to the examination were extracted from the medical records (for examples, see Table 6, Supplementary data).

Variables collected were demographic data, ECG findings, first blood gas and symptoms preceding the cardiac arrest. FOCUS data collected were left-ventricular function (normal, moderately impaired, severely impaired), left-ventricular regional wall motion abnormalities (RWMAs), right-ventricular dilatation, right-ventricular pressure overload and presence of pericardial effusion. Cardiac tamponade was defined as findings of pericardial effusion together with right-ventricular compression suggesting cardiac tamponade. Information on management was documented, together with the patient's final diagnosis established by clinical judgment or autopsy.

Measurements

FOCUS was performed within 60 min after ROSC. Interpretation of whether or not the FOCUS findings influenced further management was adjudicated from the patient's records by two cardiologists at different time points. Thus, it had to be clearly stated in the medical record that FOCUS findings influenced the decision to perform further diagnostics. The relationships between left-ventricular RWMAs, coronary angiography and subsequent percutaneous coronary intervention (PCI) were also interpreted by a cardiologist. When normal FOCUS findings influenced further management, it implied that the clinician distinctly refrained from using coronary angiography or CT-thorax as a result of the normal FOCUS findings clearly expressed in the medical record. Normal FOCUS findings did not exclude other diagnostic tools such as CT of the brain.

Statistical analysis

Categorical variables are presented as total numbers of patients and proportions (%). Continuous variables are presented as medians and interquartile ranges (IQRs). Due to the descriptive design of this study no statistical tests were performed. All calculations were performed using SPSS version 22.0.

Results

During the study period 617 adult subjects were admitted after resuscitated cardiac arrest. After excluding patients with restrictions in care or a DNR decision taken in the ER, patients not achieving ROSC, patients with obvious non-cardiac or respiratory causes of CA, patients admitted from other hospital, and an ECG with ST elevation a total of 298 cases were identified. Documented FOCUS was found in 237 (80%) cases and included in the analysis. (Comparison between FOCUS and no FOCUS, see Table 5, Supplementary data) The majority of patients (n = 182, 77%) were resuscitated after OHCA and a minority (n = 55, 23%) were included after IHCA (See Fig. 1).

Most patients were male (67%) and had witnessed cardiac arrest (82%). The median time to ROSC was 17 min (IQR 10–26). Chest pain before CA was documented in 23 (9.7%) patients. ST depression (25.7%) was the most common ECG finding. An initial rhythm of ventricular fibrillation (VF) was more common in OHCA (32.4%) compared with IHCA (7.3%). Baseline characteristics are listed in Table 1.

Use and documentation of focused cardiac ultrasound

FOCUS was performed and documented in 237 (80%) patients (84% of the OHCA vs. 68% of the IHCA cases). The left ventricle was described in 206 (87.0%) patients and left ventricular ejection fraction (LVEF) was described 167 (70.5%). The right ventricle was described in 161 (67.9%) patients and right ventricular function was described 100 (62%) of these cases.

Focused cardiac ultrasound findings

Preserved LVEF ($>$55%) was described in 65/167 (38.9%) patients. LVEF $<$30% was found in 44/167 (26.3%) patients. Left ventricular regional wall motion abnormalities were described in 89 (37.6%) patients. Right ventricular dilatation was described in 40/161 (24.8%). Right ventricular pressure overload with "D-shaped" septum was described in 22/161 (14%) patients. Increased pericardial effusion was described in 11 patients. In total, pathological findings were found in 158/237 (66.7%) patients (See Table 2).

FOCUS influence on management

FOCUS pathology was judged to influence management in terms of leading to further diagnostic measures in 52/237 (21.9%) of the patients. Left ventricular FOCUS findings, with regional wall motion abnormalities influenced the decision to perform emergency coronary angiography in 17/237 (7.2%) patients. Among patients with left ventricular regional wall motion abnormalities that led to coronary angiography, PCI was performed in nine cases.

Right ventricular dilatation and/or right ventricular pressure overload influenced the decision to perform CT-thorax in 21/237 (8.9%) patients. Pulmonary embolism was diagnosed in 11 of these patients. Right ventricular findings after FOCUS influenced the decision to treat with a thrombolytic agent in 15 patients. All these patients were treated with a thrombolytic agent prior to CT-thorax.

Table 1 – Baseline characteristics of patients divided into out-of-hospital cardiac arrests (OHCAs) and in-hospital cardiac arrests (IHCAs).

	Total, n = 237	OHCA, n = 182	IHCA, n = 55
Demographic and cardiac-arrest factors			
Age, years, median (IQR)	68 (59–75)	67 (57–74)	74 (64–82)
Female (%)	77(32.5%)	53 (29.1%)	24 (43.6%)
First rhythm VF (%)	63 (26.6%)	59 (32.4%)	4 (7.3%)
Bystander CPR (%)	121 (51.1%)	112 (61.5%)	NA
Witnessed cardiac arrest (%)	194 (81.9%)	147 (80.8%)	47 (85.5%)
Estimated time to ROSC, median, minutes (IQR)	17 (10–26)	20 (10–30)	10 (5–15)
Comorbidities			
Ischemic heart disease (%)	56 (23.6%)	39 (21.4%)	17 (30.9%)
Hypertension (%)	115 (48.5%)	85 (46.7%)	30 (54.5%)
Heart failure (%)	52 (21.9%)	40 (22.0%)	12 (21.8%)
Diabetes mellitus (%)	55 (23.2%)	40 (22.0%)	15 (27.3%)
Renal failure (%)	17 (7.2%)	13 (7.1%)	4 (7.3%)
Chronic obstructive pulmonary disease (%)	42 (17.7%)	23 (12.6%)	19 (34.5%)
Previous pulmonary embolism (%)	9 (3.8%)	6 (3.3%)	3 (5.5%)
Previous deep vein thrombosis (%)	8 (3.4%)	8 (4.4%)	0 (0.0%)
Cancer diagnosis (%)	24 (10.1%)	19 (10.4%)	5 (9.1%)
ECG after ROSC			
Normal ECG (%)	51 (21.5%)	41 (22.5%)	10 (18.2%)
Left bundle branch block (LBBB) (%)	26 (11.0%)	18 (9.9%)	8 (14.5%)
Right bundle branch block (RBBB) (%)	34 (14.4%)	41 (22.5%)	7 (12.7%)
ST-depression (%)	61 (25.7%)	51 (28.0%)	10 (18.2%)
T-wave inversion (%)	7 (2.9%)	4 (2.2%)	3 (5.5)
Q-wave (%)	5 (2.1%)	5 (2.7%)	0 (0.0%)
Other ECG findings (%)	41 (17.3%)	32 (17.6%)	9 (16.4%)
ECG missing (%)	12 (5.1%)	2 (1.1%)	10 (18.2%)
ECG rhythm			
Sinus rhythm (%)	166 (70.0%)	133 (73.1%)	33 (60.0%)
Atrial fibrillation (%)	41 (17.3%)	31 (17.0%)	10 (18.2%)
Total AV-block (%)	4 (1.7%)	4 (2.2%)	0 (0.0%)
Other (%)	14 (5.9%)	10 (5.5%)	4 (7.3%)
ECG rhythm missing (%)	12 (5.1%)	4 (2.2%)	8 (14.5%)
First blood gas after ROSC			
pH, median (IQR)	7.12 (6.95–7.27)	7.13 (6.95–7.27)	7.12 (6.91–7.29)
Lactate, mmol/L, median, (IQR)	9.3 (6.4–13.1)	9.3 (6.9–13.4)	9.0 (3.8–11.8)
pO$_2$, kPa, median, (IQR)	15.9 (10.6–31.7)	19.3 (11.8–37.4)	10.9 (8.4–14.8)
Blood pressure, systolic, mmHg, median (IQR)	110 (85–139)	110 (83–138)	115 (90–140)
Symptoms before cardiac arrest			
Chest pain before cardiac arrest (%)	23 (9.7%)	16 (8.8%)	7 (12.7%)
Dyspnea before cardiac arrest (%)	72 (30.4%)	45 (24.7%)	27 (49.1%)
Discharged alive from ICU (%)	112 (47.3%)	85 (46.7%)	27 (49.1%)

Categorical variables presented as n (%); continuous variables presented as median (IQR).

Pulmonary embolism was confirmed with CT-thorax or at autopsy in 11/15 (73%) of these patients.

Normal FOCUS findings influenced further management in 28/237 (11.8%) patients where the clinician distinctly refrained from coronary angiography or CT-thorax according to the text clearly expressed in the medical record (See Table 3).

Etiology of the cardiac arrest

In this population of CA patients, without ST elevation on the ECG, the most frequent cause of arrest was of cardiac origin (49%). Acute coronary syndrome accounted for 47% of these cases. Pulmonary embolism as

the final etiology of the arrest was found in 12 (5.1%) patients. In these patients 10/12 (83%) had dilatation of the right ventricle in combination with pressure overload of the right ventricle (Table 4).

Discussion

The main finding of this observational study was that focused cardiac ultrasound immediately post-ROSC is frequently used in an emergency setting. This retrospective data supports the use of FOCUS as an adjunctive diagnostic measure in ALS-conformed post-resuscitation care.

Table 2 – FOCUS parameters of all patients divided into out-of-hospital cardiac arrests (OHCAs) and in-hospital cardiac arrests (IHCAs).

FOCUS performed after ROSC	Total n = 237	OHCA n = 182	IHCA n = 55
Pericardial effusion (%)	11 (4.6%)	6 (3.3%)	5 (9.1%)
Cardiac tamponade (%)	3 (1.3%)	1 (0.5%)	2 (3.6%)
Any pathological findings (%)	158 (66.7%)	130 (71.4%)	28 (50.1%)
Left ventricle			
Left ventricle described (%)	206 (87.0%)	160 (87.9%)	46 (83.6%)
Regional wall motion abnormalities described (%)	89 (37.6%)	73 (40.1%)	16 (29.1%)
Left ventricular ejection fraction described (%)	167 (70.5%)	130 (71.4%)	37 (67.3%)
LVEF > 55% (%)	65/167 (38.9%)	51/130 (39.2%)	14/37 (37.8%)
LVEF 45–55% (%)	18/167 (10.8%)	16/130 (12.3%)	2/37 (5.4%)
LVEF 30–45% (%)	40/167 (23.9%)	35/130 (26.9%)	5/37 (13.5%)
LVEF < 30% (%)	44/167 (26.3%)	28/130 (21.5%)	16/37 (43.2%)
Right ventricle			
Right ventricle described (%)	161 (67.9%)	133 (73.1%)	28 (51.0%)
Tricuspid annular plane systolic excursion (TAPSE) described (%)	25/161 (15.5%)	20/133 (15.0%)	5/28 (17.9%)
Dilated right ventricle (%)	40/161 (24.8%)	33/133 (24.8%)	7/28 (25.0%)
Right ventricle pressure overload (%)	22/161 (13.7%)	16/133 (12.0%)	6/28 (21.4%)
Dilated and pressure overload; right ventricle (%)	19/161 (11.8%)	16/133 (12.0%)	3/28 (10.7%)

Categorical variables presented as n (%) Abbreviations: LVEF, Left ventricular ejection fraction.

The ERC's Advanced Life Support algorithm suggests that potentially treatable conditions in cases of cardiac arrest should be investigated.[1] Post-ROSC FOCUS addresses the potential diagnoses of tamponade, pulmonary embolism or coronary occlusion as the cause of CA.

In the present study, FOCUS with left ventricular regional wall motion abnormalities influenced the decision to perform immediate coronary angiography in 17 (7.2%) patients without ST elevation on the ECG, of which nine had a culprit lesion. It has been suggested that regional wall motion abnormalities observed in ultrasound are not definitive for diagnosis of coronary artery disease as the cause of cardiac arrest[13] and left ventricular regional wall motion abnormalities are difficult to detect shortly after ROSC. The data from this study supports this observation. Despite the fact that cardiologists with long experience of detecting left ventricular regional wall motion abnormalities performed all the examinations, only about half of the patients had a culprit lesion. Thus, the accuracy may be somewhat improved compared with when only ECG findings are taken into account. At this early stage in the management of cardiac arrest, the rate of patients with known left ventricular regional wall motion abnormalities due to previous myocardial infarction is often unclear. This will most likely influence the accuracy of finding patients with acute coronary occlusion. Furthermore, a negative finding (FOCUS without RWMA) cannot rule out significant coronary artery disease.

Lee et al. evaluated the accuracy of echocardiography combined with ECG (including ST elevations) and biomarkers to predict AMI (confirmed by coronary angiography) in patients with OHCA.[14] They

Table 3 – Influence of FOCUS findings.

FOCUS performed after ROSC	Total n = 237	OHCA n = 182	IHCA n = 55
FOCUS pathology influenced management (%)	52 (21.9%)	37 (20.3%)	15 (27.3%)
Normal FOCUS findings influenced management (%)	28 (11.8%)	23 (12.6%)	5 (9.1%)
Left ventricle (LV)			
FOCUS findings influenced decision to perform emergency coronary angiography (%)	20 (8.4%)	16 (8.8%)	4 (7.3%)
LVEF influenced decision to perform emergency coronary angiography (%)	9 (3.8%)	7 (3.8%)	2 (3.6%)
LV RWMA influenced decision to perform emergency coronary angiography (%)	17 (7.2%)	13 (7.1%)	4 (7.3%)
Patients with RWMA and a culprit vessel in coronary angiography (%)	9/17 (53.0%)	8/13 (61.5%)	1/4 (25%)
Patients with RWMA and PCI (%)	9/17 (53.0%)	7/13 (53.8%)	2/4 (50%)
Right ventricle (RV)			
RV abnormalities[a] influenced decision to perform CT-thorax (%)	21 (8.9%)	13 (7.1%)	8 (14.5%)
RV findings influenced decision to treat with thrombolytic agent prior to CT-thorax (%)	15 (6.3%)	9 (4.9%)	6 (10.9%)
Correlation of FOCUS findings and pulmonary embolism in CT-thorax or at autopsy (%)	11/21 (52.4%)	8/13 (61.5%)	3/8 (37.5%)

Categorical variables presented as n (%). Abbreviations: LVEF, Left ventricular ejection fraction, PCI, Percutaneous coronary intervention, RWMA, Regional wall motion abnormality.

[a] Right ventricular dilatation and/or RV pressure overload.

Table 4 – Etiology of the cardiac arrest.

Final Etiology[a]	Total n = 237 n (%)	OHCA n = 182 n (%)	IHCA n = 55 n (%)
Cardiac cause	116 (48.9)	97 (53.3)	19 (34.5)
Acute coronary syndrome	54 (22.8)	47 (25.8)	7 (12.7)
Chronic ischemic heart disease	17 (7.2)	15 (8.2)	2 (3.6)
Cardiac arrythmia[b]	28 (11.8)	26 (14.3)	2 (3.6)
Cardiac,other[c]	17 (7.2)	9 (4.9)	8 (14.5)
Respiratory cause			
Pulmonary embolism	12 (5.1)	8 (4.4)	4 (7.3)
Hypoxia[d]	59 (24.9)	37 (20.3)	22 (40.0)
Infection[e]	9 (3.8)	5 (2.7)	4 (7.3)
Neurological[f]	14 (5.9)	13 (7.1)	1 (1.8)
Metabolic[g]	6 (2.5)	3 (1.6)	3 (5.5)
Others[h]	21 (8.9)	19 (10.4)	2 (3.6)
Final etiology judged at autopsy	50 (21.1)	42 (23.1)	8 (14.5)

[a] Final etiology judged clinically or at autopsy.
[b] *Cardiac arrythmia* includes AV-block III, LQTS, Primary arrythmia.
[c] *Cardiac other* includes Chronic heart failure, Hypertrophic CM Myocarditis, Cardiac tamponade.
[d] *Hypoxia* includes COPD, Pneumonia.
[e] *Infection* includes Sepsis, Hypovolemia.
[f] *Neurological* includes Cerebral bleeding, Cerebral infarction and Epileptic seizures.
[g] *Metabolic* includes Hypokalemia, Hyperkalemia, Metabolic acidosis and Anaphylaxis.
[h] Others includes unknown cause. Categorical variables presented as n (%).

showed that regional wall motion abnormalities in echocardiography were more likely in patients with AMI as a cause of OHCA than in those with other causes of OHCA (64% vs. 18%, $p < 0.001$), but RWMAs were seen in patients without angiographic evidence of coronary artery disease as well. The timing of echocardiography in this study was defined as the first interpretable data post-ROSC.

Right ventricular echocardiographic abnormalities are common after resuscitation from cardiac arrest. Acute right ventricle dilatation occurs after a few minutes of arrest as blood is translocated from the systemic circulation to the right side of the heart along its pressure gradient.

Previous studies have described that there is significant right ventricular dysfunction and dilatation present in the post-arrest patient,[15,16] and this may lead physicians to assume that a pulmonary embolism is the cause of the arrest, leading to potentially fatal administration of thrombolytics. One previous study has shown an increased risk of intracranial bleeding associated with the use of fibrinolytics during resuscitation in non-traumatic cardiac-arrest patients.[17] Again, we see that right ventricular dilatation *per se* is not well correlated to pulmonary embolism and should not alone be a reason for fibrinolytic therapy. In our population most of the patients with diagnosed pulmonary embolism had both dilatation of the right ventricle in combination with pressure overload. This finding should be taken into consideration if fibrinolytics are started before definitive diagnosis of pulmonary embolism.

In the present study, the frequency of pericardial effusion was low (n = 11, 4.6%), which is in line with previous studies where pericardial effusion has been a very rare finding in non-traumatic cardiac-arrest patients.[18–20] The use of ultrasound is widely accepted in the diagnosis of cardiac tamponade. Cardiac tamponade is identified by visualizing pericardial effusion and right-ventricular collapse in either the parasternal views or the subcostal view. In our study (excluding trauma patients) cardiac tamponade was infrequent (n = 3, 1.3%).

In summary, there is a need for a structured approach to improve the accuracy of FOCUS after cardiac arrest to establish a gold standard of post-resuscitation cardiac ultrasound interpretation.

There are several limitations in this study. First, there is the lack of a gold standard in comparison with ultrasound findings in the post-resuscitation setting. In addition, the study was conducted at a hospital without any definite algorithm or cut-off limits for the interpretation of FOCUS after ROSC; thus, inter-variability among users is possible. Second, due to technical issues it was not possible to store the images and therefore it was not possible to independently review them. Third, this is a retrospective study with data from the patient's medical records without the possibility to compare with recordings. Fourth, although this study demonstrates that FOCUS can be used in the emergency room and ICU settings to diagnose potentially causes of cardiac arrest, we cannot know how the findings were weighted compared with other clinical information such as medical history, laboratory and ECG findings. Fifth, there may have been cases were FOCUS was performed but not documented in the medical record.

Conclusion

The retrospective data in this cardiac-arrest population supports that ALS-conformed post-resuscitation care could include FOCUS as an adjunctive diagnostic measure shortly after ROSC.

Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.06.282.

REFERENCES

1. Soar J, Nolan JP, Bottiger BW, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult advanced life support. Resuscitation 2015;95:100–47.
2. Link MS, Berkow LC, Kudenchuk PJ, et al. Part 7: adult advanced cardiovascular life support: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2015132: S444-64.
3. Geri G, Dumas F, Bougouin W, et al. Immediate percutaneous coronary intervention is associated with improved short- and long-term survival after out-of-hospital cardiac arrest. Circulation Cardiovasc interventions 20158:.
4. Marijon E, Uy-Evanado A, Dumas F, et al. Warning symptoms are associated with survival from sudden cardiac arrest. Ann Intern Med 2016;164:23–9.
5. Moore CL, Copel JA. Point-of-care ultrasonography. N Engl J Med 2011;364:749–57.
6. Via G, Hussain A, Wells M, et al. International evidence-based recommendations for focused cardiac ultrasound. J Am Soc Echocardiogr 2014;27:683 e1-.e33.
7. Chardoli M, Heidari F, Rabiee H, Sharif-Alhoseini M, Shokoohi H, Rahimi-Movaghar V. Echocardiography integrated ACLS protocol versus conventional cardiopulmonary resuscitation in patients with pulseless electrical activity cardiac arrest. Chin J Traumatol 2012;15:284–7.
8. Breitkreutz R, Price S, Steiger HV, et al. Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: a prospective trial. Resuscitation 2010;81:1527–33.
9. Comess KA, DeRook FA, Russell ML, Tognazzi-Evans TA, Beach KW. The incidence of pulmonary embolism in unexplained sudden cardiac arrest with pulseless electrical activity. Am J Med 2000;109:351–6.
10. Tayal VS, Kline JA. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. Resuscitation 2003;59:315–8.
11. Huis In' t Veld MA, Allison MG, Bostick DS, et al. Ultrasound use during cardiopulmonary resuscitation is associated with delays in chest compressions. Resuscitation 2017;119:95–8.
12. Clattenburg EJ, Wroe P, Brown S, et al. Point-of-care ultrasound use in patients with cardiac arrest is associated prolonged cardiopulmonary resuscitation pauses: a prospective cohort study. Resuscitation 2018;122:65–8.
13. Long B, Alerhand S, Maliel K, Koyfman A. Echocardiography in cardiac arrest: an emergency medicine review. Am J Emerg Med 2018;36:488–93.
14. Lee SE, Uhm JS, Kim JY, Pak HN, Lee MH, Joung B. Combined ECG, echocardiographic, and biomarker criteria for diagnosing acute myocardial infarction in out-of-hospital cardiac arrest patients. Yonsei Med J 2015;56:887–94.
15. Wardi G, Blanchard D, Dittrich T, Kaushal K, Sell R. Right ventricle dysfunction and echocardiographic parameters in the first 24h following resuscitation in the post-cardiac arrest patient: A retrospective cohort study. Resuscitation 2016;103:71–4.
16. Ramjee V, Grossestreuer AV, Yao Y, et al. Right ventricular dysfunction after resuscitation predicts poor outcomes in cardiac arrest patients independent of left ventricular function. Resuscitation 2015;96:186–91.
17. Bottiger BW, Arntz HR, Chamberlain DA, et al. Thrombolysis during resuscitation for out-of-hospital cardiac arrest. N Engl J Med 2008;359:2651–62.
18. Milne J, Atkinson P, Lewis D, et al. Sonography in Hypotension and Cardiac Arrest (SHoC): rates of abnormal findings in undifferentiated hypotension and during cardiac arrest as a basis for consensus on a hierarchical point of care ultrasound protocol. Cureus 2016;8:e564.
19. Gaspari R, Weekes A, Adhikari S, et al. Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest. Resuscitation 2016;109:33–9.
20. Lien WC, Hsu SH, Chong KM, et al. US-CAB protocol for ultrasonographic evaluation during cardiopulmonary resuscitation: validation and potential impact. Resuscitation 2018;127:125–31.