Resuscitation 84 (2013) 357–360

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Comparison of computed tomography and autopsy in detection of injuries after unsuccessful cardiopulmonary resuscitation☆

David Smekal[a,*,1], Tomas Hansen[b,1], Håkan Sandler[c,d], Sten Rubertsson[a]

[a] Department of Surgical Sciences – Anaesthesiology & Intensive Care, Uppsala University, S-751 85 Uppsala, Sweden
[b] Department of Radiology, Uppsala University, S-751 85 Uppsala, Sweden
[c] Department of Surgical Sciences – Forensic medicine, Uppsala University, S-751 85 Uppsala, Sweden
[d] Natl. Board of Forensic Med. S-75140 Uppsala, Sweden

ARTICLE INFO

Article history:
Received 16 March 2012
Received in revised form 14 June 2012
Accepted 24 June 2012

Keywords:
Cardiac arrest
Injury
Cardiopulmonary resuscitation (CPR)
Autopsy
Computed tomography (CT)
Rib fractures

ABSTRACT

Aim: Computed tomography (CT) has been suggested as an aid or even a replacement for autopsy. The aim of this trial was to study the conformity of the two methods in finding injuries in non-surviving patients after unsuccessful cardiopulmonary resuscitation.

Methods: In this prospective study, 31 patients were submitted to a CT prior to autopsy after unsuccessful resuscitation attempts. Pathological findings were noted by both the radiologist and the pathologists in a specified protocol. The pathologists and radiologist were blinded from each other's results.

Results: CT and autopsy revealed rib fractures in 22 and 24 patients respectively (kappa = 0.83). In 8 patients, CT revealed more rib fractures than autopsy; and in 12 patients, autopsy revealed more rib fractures than CT. In 7 patients, neither method showed any rib fractures. The mean difference between the two methods in detecting rib fractures was 0.16 (S.D.: ±3.174, limits of agreement: −6.19 to 6.51). The kappa value for sternal fractures was 0.49. A total of 260 pathological findings were noted by CT and 244 by autopsy. The average patient showed a median of 9 injuries (every fracture counted as one injury), independent of the method used in detecting the injuries.

Conclusions: There was a strong concordance between the two methods in finding rib fractures but not sternal fractures and these results support the concept of CT as a valuable complement to autopsy in detecting rib fractures after unsuccessful cardiopulmonary resuscitation but not as a replacement. Other injuries did not show the same concordance.

1. Introduction

In the field of clinical and forensic medicine, autopsy has long been the gold standard in examining the dead. However, new technologies in radiology have gained growing interest because of the possibilities they offer to aid or even replace the autopsy.[1–9] One such technology is computed tomography (CT), which can now be performed with sub millimetre slices yielding isotropic voxels that can be used for reconstructions in multiple directions.

Development is ongoing of new devices for performing mechanical chest compressions in cardiopulmonary resuscitation (CPR).[10,11] To ensure patient safety, it is important to reveal potential injuries from these devices and compare the incidence of injuries with that of today's standard, namely manual chest compressions. This comparison is associated with some difficulties; for example, there is uncertainty in the incidence of injuries after CPR with manual chest compressions. Trials presenting incidences of thoracic fractures have varying results, with numbers ranging almost from 0 to 100%.[12,13] The frequency of autopsies has also declined over the years, and so the difficulty of conducting reliable studies has increased.[14–17] In this context, there has been increased interest in the possibility of conducting a fast and non-invasive investigation. The aim of this study was to evaluate the level of agreement between two methods, CT and autopsy, in detecting injuries after unsuccessful CPR. We hypothesised that there would be a strong correlation in the ability of the two methods in finding rib and sternal fractures.

2. Methods

The study was reviewed and approved by the local human ethics committee in Uppsala, Sweden. The committee waived the need for informed consent. From 15 January 2008 to 15 February 2011, 131 patients with unsuccessful CPR after non-traumatic out-of-hospital

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at http://dx.doi.org/10.1016/j.resuscitation.2009.12.019.

* Corresponding author. Tel.: +46 18 6110000; fax: +46 18 559357.
E-mail address: dsmekal@gmail.com (D. Smekal).
[1] Shared first authorship.

0300-9572/$ – see front matter
http://dx.doi.org/10.1016/j.resuscitation.2012.06.023

Table 1
Demographic data of patients.

	$n = 31$
Age (years)[a]	62.3 ± 20.3
Sex (male)[b]	19 (61.3)
Number of days from death to CT[a]	3.9 ± 2.6
Number of days from CT to autopsy[a]	2.1 ± 1.8
Minutes of CPR[a] (1/31)[c]	33.3 ± 16.6

[a] Mean ± S.D.
[b] Numbers of patients (%).
[c] Patients with missing data.

cardiac arrest were included in an ongoing randomised trial. It involved chest compressions being given by the LUCAS™ device or manual chest compressions. The decision for autopsy was made by the admitting physician. Swedish law regulates the possibility of autopsy, and briefly, the relatives' view determines whether there will be an autopsy unless a forensic autopsy is required. An autopsy was performed in 43 cases, and in 31 of these cases the patients were submitted to a CT before the autopsy, thus making them eligible for the present study. Baseline characteristics of the population are presented in Table 1.

The bodies were scanned with a 64 slice CT scanner (Definition, Siemens Medical Solutions, Forchheim, Germany) prior to the autopsy. One scan including thorax and abdomen was obtained with a slice collimation of 64 mm × 0.6 mm. Additional scan parameters were 120 kV, 160 ref mAs, pitch 0.5, and rotation time 0.5 s. The raw data were reconstructed with a slice thickness of 3.0 mm with 2.5 mm increments between each slice in an axial, coronal, and sagittal plane using a standard soft tissue algorithm (b30f). Two additional axial reconstructions (1.0 mm slice thickness, 0.75 mm increments) were calculated from the raw data; one with a softer algorithm (b20f) for the purpose of additional virtual reconstructions and one with a sharper algorithm (b70sharp) for the detection of fractures. The CT examinations were performed on a scanner in clinical use but scheduled in the afternoon after the regular program. This time slot was available every Monday to Friday. The bodies were transported to the scanner from the autopsy department and back afterwards. The duration of the procedure including transportation was approximately 1 h.

2.1. CT readings

The CT examinations were analysed on a PACS station (Carestream Health) by a radiologist (TH) with 10 years of experience including 7 years of reading post mortem examinations. The series with thinner slices and sharper algorithm were primarily used for the evaluation of rib fractures, but all planes were evaluated. A fracture was defined as a discontinuity or dislocation of the bone, or a non-alignment of the normal curvature of a rib. Retrosternal bleeding was defined as an increased attenuation in the fat between the sternum and the mediastinal structures.

2.2. Autopsy

The pathological procedure started with an external examination to detect the presence of markings on the skin. After a midline incision, the subcutaneous and epithoracic/sternal tissue was checked for haemorrhages and structural stability. In case of mechanical instability, this area was freed from the overlying tissue and the exact position and character of the fissure/fracture at the frontal side was documented. Opening of the thoracic cage was performed in a conventional way, but with great care to avoid already detected findings. The cavity side of the thoracic cage was checked for visible fissures/fractures and misalignment of the ribs and sternum. The presence of pneumothorax and haemothorax,

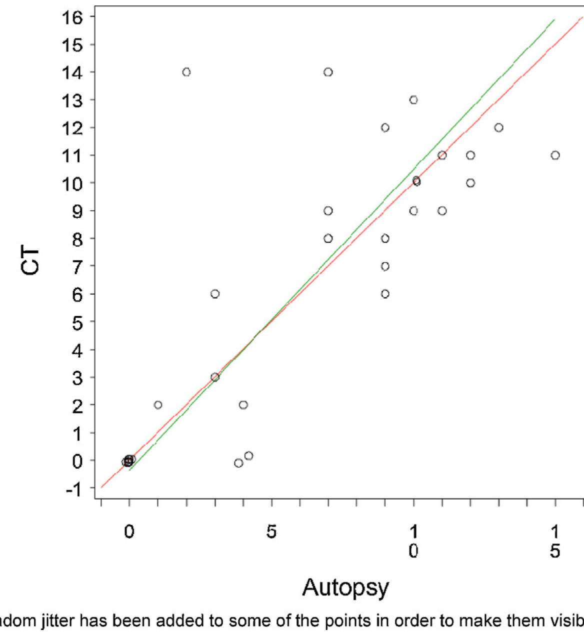

Fig. 1. Number of rib fractures detected by CT and autopsy. A random jitter has been added to some of the points in order to make them visible.

retrosternal and mediastinal haemorrhages, haemopericardium, and epicardial and myocardial damage was noted. The intrapericardial fluid was carefully examined to differentiate between pure transudate, slightly contaminated transudate, and blood. The great vessels were inspected for abnormal findings and the contribution of present sclerosis to eventual damage was evaluated. The abdominal cavity was inspected for lesions on the capsulae/parenchyma of the liver, spleen, and pancreas. The great vessels were inspected for findings, and the contribution of the present sclerosis to eventual damages was made. The macropathological session ended with a notation of a tentative cause of death.

The radiologist and the pathologists used the same standardised protocol for the presence of thoracic fractures and soft tissue and inner organ injuries in the thoracic cavity and abdomen. After the CT, an autopsy was performed. The pathologists and radiologist were blinded from each other's results.

2.3. Statistical analysis

The incidence of rib and sternal fractures based on CT and autopsy was compared using Cohen's kappa coefficient. The mean difference between the two methods in detecting rib fractures was calculated with standard deviation and limits of agreement.

3. Results

CT and the following autopsy revealed rib fractures in 22 and 24 patients respectively (kappa = 0.83 (95% C.I. 0.61–1.00)). In 12 cases, autopsy revealed more rib fractures than CT; and in 8 cases, CT revealed more rib fractures than autopsy. In 7 cases, neither method showed any rib fractures. The mean difference between the two methods in detecting rib fractures was 0.16 (S.D.: ±3.174, limits of agreement: −6.19 to 6.51, Fig. 1). The total number of rib fractures detected by CT was 197 and 192 by autopsy respectively. CT detected sternal fractures in 14 cases and autopsy detected 18 cases of sternal fractures (kappa = 0.4983 (95% C.I. 0.20–0.79)). Injuries other than rib and sternal fractures are presented in Table 2.

Examples of findings on CT examinations are presented in Fig. 2. Bilateral rib fractures with typical locations for CPR induced injury