# Detection of Missed Fractures of Hand and Forearm in Whole-Body CT in a Blinded Reassessment

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**Research Article**

**Keywords:** polytrauma, fracture, hand, missed, delayed, late, diagnosis, whole-body CT, fatigue

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# Detection of missed fractures of hand and forearm in whole-body CT in a blinded reassessment

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**Abstract**

**Background**: We examined the visibility of fractures of hand and forearm in whole-body CT and its influence on delayed diagnosis. This study is based on a prior study on delayed diagnosis of fractures of hand and forearm in patients with suspected polytrauma.

**Methods**: Two blinded radiologists examined CT-scans of patients with fractures of hand or forearm that were diagnosed later than 24 hrs after admission and control cases with unremarkable imaging of those areas. They were provided with clinical information that was documented in the admission report and were asked to examine forearm and hands. After unblinding, the visibility of fractures was determined. We examined if time of admission or slice thickness was a factor for late or missed diagnoses.

**Results**: We included 72 known fractures in 36 cases. Of those 65 were visible. Sixteen visible fractures were diagnosed late during hospital stay. Eight more fractures were detected on revision by the radiologists. Both radiologists missed known fractures and found new fractures that were not reported by the other. Missed and late diagnoses of fractures occurred more often around 5 pm and 1 am. Slice thickness was not significantly different between fractures and cases with fractures found within 24 hrs and those found later.

**Conclusions**: The number of late diagnosis or completely missed fractures of the hand and forearm may be reduced by a repeated survey of WBCT with focus on the extremities in patients with suspected polytrauma who are not conscious.

**Level of Evidence** III

**Keywords**: polytrauma, fracture, hand, missed, delayed, late, diagnosis, whole-body CT, fatigue

## Background

Injuries of the hand may be missed in 3.5 to 25 % of patients with polytrauma [1, 2]. While there is no definition of 'missed', delayed', or 'late', we decided to use the term 'late diagnosis' for injuries that were detected 24 h after admission but during hospitalisation as they were eventually found [3-6]. Fractures of the upper extremity may be associated with reduced quality of life [7-9]. A timely treatment has been shown to be beneficial for a return to work [10]. We found that fractures of hand are more often detected in patients in cases with full inclusion of the hand in the whole-body CT (WBCT). This was more often achieved by placing the hands on the abdomen [6]. The ISS did not have an influence on the number of late diagnoses in our sample [6]. The question remained if the fractures are visible for the human eye on retrospection which may also depend on the slice thickness of the WBCT. Other causes for missed or late diagnoses can be fatigue which has been associated with worse diagnostic performance of radiologists [11]. This study is a follow up of a retrospective analysis of patient data on the sensitivity of WBCT for the detection of fractures of hand and/or forearm in intubated patients with suspected polytrauma [6].

## Aim

We wanted to assess how many fractures of hand and forearm, that were diagnosed late, were visible in the WBCT on retrospection. Additionally, the influence of the time of day of the WBCT and slice thickness on the occurrence of late diagnoses was analysed.

## Methods

The study is based on cases that were identified in the previous publication [6]. The sample consisted of patients who were admitted for suspected polytrauma, sedated and ventilated and received a WBCT. Sedated, intubated patients were chosen to avoid the influence of patient related factors like level of consciousness, self-awareness, and pain sensation.

Two radiologists from two different hospitals that did not provide data for the first study were tasked to examine WBCTs for bony injuries of hand or forearm. They were presented 44 cases with the clinical data provided on the CT request form. The cases were in random order and consisted of 12 cases with a late (> 24 h after admission) diagnosis of a fracture of the hand and/or forearm, 25 cases with a diagnosis within 24 h, and 7 control cases who had no injury. The control cases were chosen among cases who received additional imaging of the hand and wrist that showed no bony pathology. Fractures reported in the discharge letter are named ‘reported fractures. Further data after discharge were not available.

Radiologist 1 was a 4th year resident, radiologist 2 had more than 20 years of working experience. They were permitted to use all sequences of the WBCT and do additional reconstruction if needed. After blinded reassessment, all reported, and previously unreported fractures were tested for inclusion and visibility in the CT by three of the authors. Discrepancies were solved by majority vote.

Eight fractures were found that have not been reported during hospitalisation. Those missed fractures were added to the number of fractures with diagnosis later than 24 h.

As they probably would not have needed a surgical treatment and likely full healing, we decided to not contact the patients. The patient should not be confronted with memories of the traumatic event.

Time of imaging and slice thickness of the axial layers analysed. For the time diagrams, fractures and cases were categorised into diagnosis ‘< 24 h’, ‘> 24 h’, and ‘missed’. Cases with at least one missed fracture were labelled ‘missed’, then cases with at least one late diagnosis were labelled ‘> 24h’. The other were ‘< 24 h’.

Statistical tests of categorial variables with at least 5 expected cases for each field were performed with Chi-square, and Fisher’s exact for tables that did not meet the requirement. Differences between continuous variables were tested using the unpaired t-test. A p-value of ≤ 0.05 was defined as significant.

The local institutional ethics committee of the University of Greifswald (Ethikkommission an der Universitätsmedizin Greifswald, Greifswald, Germany) approved the study (BB 054/16a) and stated that there are no ethical or legal concerns regarding this study. The decision was based on the Helsinki declaration. The need for consent for the retrospective use of patient data was waived by the institutional ethics committee of the University of Greifswald.

Informed consent was obtained from the radiologists that participated in the study.

123 **Results**

124 Seventy-two fractures of hand or forearm were reported in the discharge letter of 36
125 cases. Forty-nine were found within 24 h after admission by WBCT or additional
126 diagnostic imaging. On reassessment of all reported fractures, 65 were visible resulting
127 in 25 % (16 of 65) of diagnoses that could have been detected additionally on
128 admission in the initial WBCT (Table 1).

129

130

131 Table 1 Reported fractures and their visibility in WBCT

| | Patient chart | | Study review | |
|---|---|---|---|---|
| Fracture location | reported | reported within 24 h | area shown | fracture visible |
| Ulna | 20 | 16 | 19 | 19 |
| Radius | 16 | 14 | 15 | 15 |
| Carpus | 7 | 5 | 7 | 7 |
| MC | 18 | 15 | 17 | 17 |
| Phalanx | 11 | 6 | 10 | 7 |
| Total | 72 | 56 | 68 | 65 |

132 *The number of fractures that were known at discharge are shown with the number of fractures*
133 *that were found within 24 h. On review of all imaging data we determined how many fractures*
134 *were included in the CT scan area and how many could be recognised.*

135

136

137 Twenty-four requests forms had clinical data on suspected injuries. A suspected injury
138 of forearm and hands was documented in 13 cases. Eight of those had no injury in the
139 suspected area, of which three were control cases. Five cases had a corresponding
140 injury. Fourteen cases reported the mechanism of injury only, of which four only
141 mentioned 'traffic injury'. Five request forms gave information that the patient is
142 sedated and intubated only, and one had no entry.

143

144 Blinded reassessment

145 Both blinded radiologists missed reported fractures and suspected 15 more fractures
146 (Table 2).

147

148 Table 2 Missed and reported fractures on blinded and unblinded reassessment.

| | Radiologist 1 | | | Radiologist 2 | | | unblinded |
|---|---|---|---|---|---|---|---|
| Fracture location | missed | new | confirmed | missed | new | confirmed | total visible |
| Ulna | 7 | 0 | 0 | 3 | 3 | 3 | 22 |
| Radius | 4 | 0 | 0 | 3 | 1 | 0 | 15 |
| Carpus | 7 | 1 | 1 | 3 | 4 | 3 | 11 |
| MC | 2 | 1 | 1 | 3 | 4 | 1 | 18 |
| Phalanx | 6 | 1 | 0 | 10 | 0 | 0 | 7 |
| Total | 26 | 3 | 2 | 22 | 12 | 7 | 73 |

149 *The 'missed' column shows the number of visible fractures from table 1 that were not*
150 *found by each radiologist. 'New' are previously not reported fractures of which*

*'confirmed' could be confirmed in the WBCT upon review. The 'total visible' column adds the number of visible reported (65) and confirmed new fractures (8). One metacarpal fracture was described by both radiologists. All other 'new' were only mentioned by one of both radiologists which includes the remaining eight 'confirmed'.*

We could confirm eight fractures on unblinded reassessment. One was found by both. Added to the 65 visible fractures that were reported in the discharge documentation, in total 73 fractures were visible in 33 cases and 11 % (8/73) were missed. The remaining 11 cases were 7 controls and 4 cases with fractures not visible in WBCT.

Radiologist 1 missed all reported carpal and phalangeal fractures but found a previously unknown carpal injury (pisiform fracture: Figure 1 and Additional file 1).

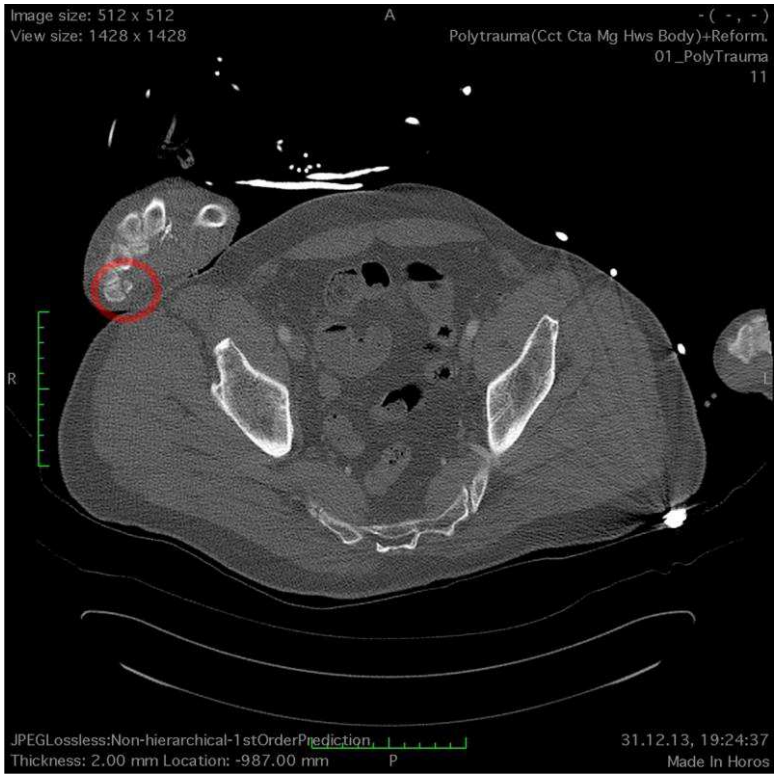


Figure 1

*Fracture of the pisiform bone that was found on blinded reassessment. The adjacent slices are shown in the additional video file (additional file 1).*

Additional file 1.avi

Additional File 1

*Picture sequence combined to a video of an excerpt of the axial WBCT images. On the right patient wrist, a fracture of the pisiform bone can be seen that was found on blinded reassessment. The location of the fracture is marked in Figure 1.*

Eighteen known fractures were missed by both radiologists, 26 by Radiologist 1 only, and 4 by Radiologist 2 only. Of note is the use of the localiser by Radiologist 2 to look for an injury, as one ulnar fracture was only included there (Fig. 2).

Figure 2

*Fracture of the ulnar diaphysis that was only visible on the localiser as the arms were not included in the WBCT. Contrast and brightness were adjusted to better show the bones of the forearm.*

This fracture was labelled visible in WBCT. Three new fractures of the ulna were of the styloid process in association with a distal radius fracture and might be considered not relevant by some doctors. The remaining four carpal fractures would be treated by a splint, the metacarpal fracture could be fixated by K-wire or splinted depending on possible malrotation as there was no angulation.

188 Possible factors for missed/late diagnoses

189 On reassessment, all reported fractures were considered visible by both radiologists
190 when confronted with the diagnosis. Reasons for missed fracture on reassessment
191 included visibility in only one orientation, artifacts, and no reason. Two suspected
192 fractures (scaphoid and metacarpal) on reassessment could not be confirmed or
193 rejected and would have been followed up by additional imaging. They were not
194 counted as fractures for this study.

195 Analysis of the time of day showed a tendency for missed or late diagnoses of
196 potentially visible fractures for WBCT that were performed around 5 pm and 1 am (Fig.
197 3).

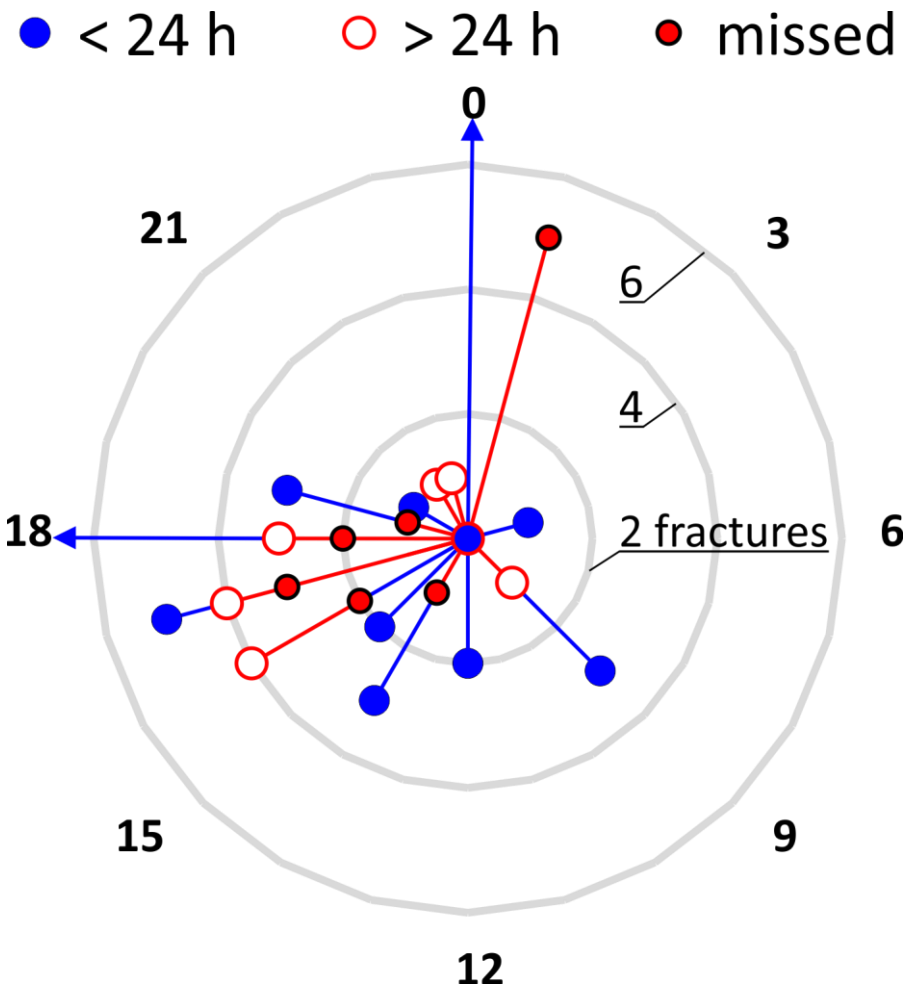
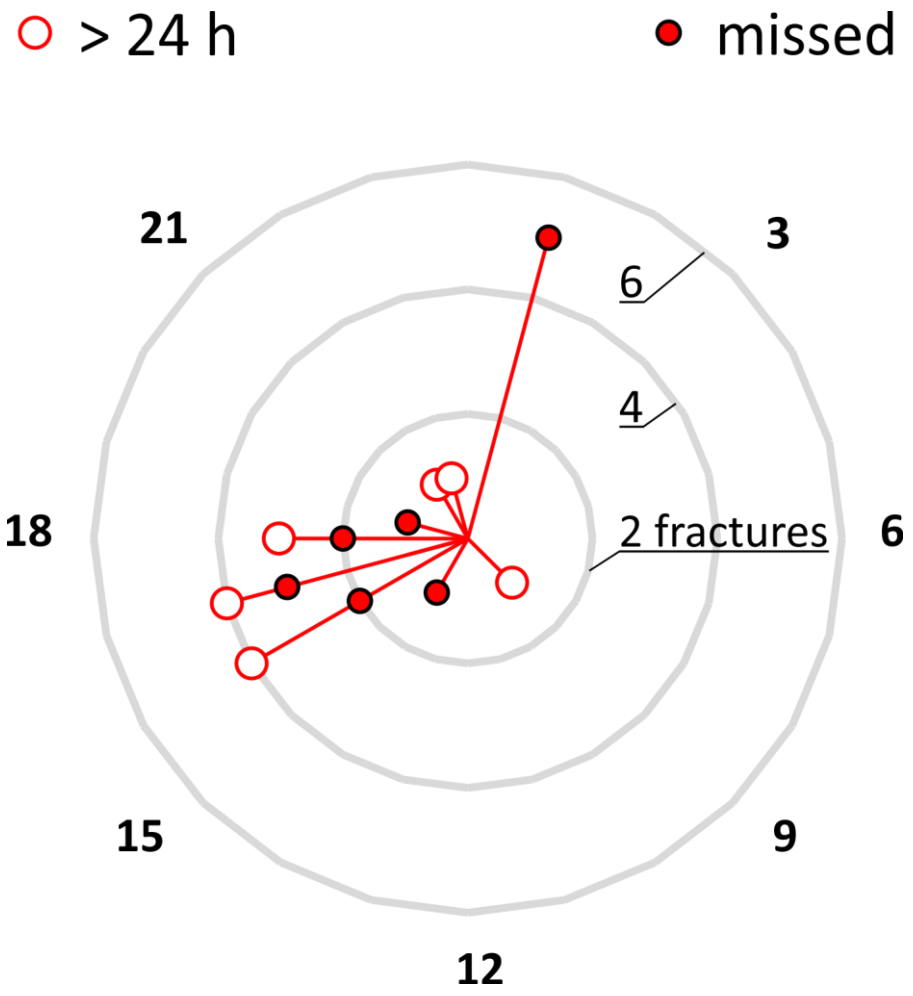



Figure 3

*Number of fractures for time of the day of the WBCT. The circles show if the fracture was found within or after 24 hrs after submission or during this study (missed). The number of fractures found at 18 and 0 within 24 hrs were 14 and 9. The same diagram ist shown without fractures found within 24 hrs in additional file 2.*




Additional File 2

*Number of fractures for time of the day of the WBCT. The circles show if the fracture was found after 24 hrs after submission or during this study (missed). The same diagram ist shown with fractures found within 24 hrs in figure 3.*

Cases with at least one missed or late diagnosis of a fracture of hand or forearm showed a similar distribution (Fig. 4).

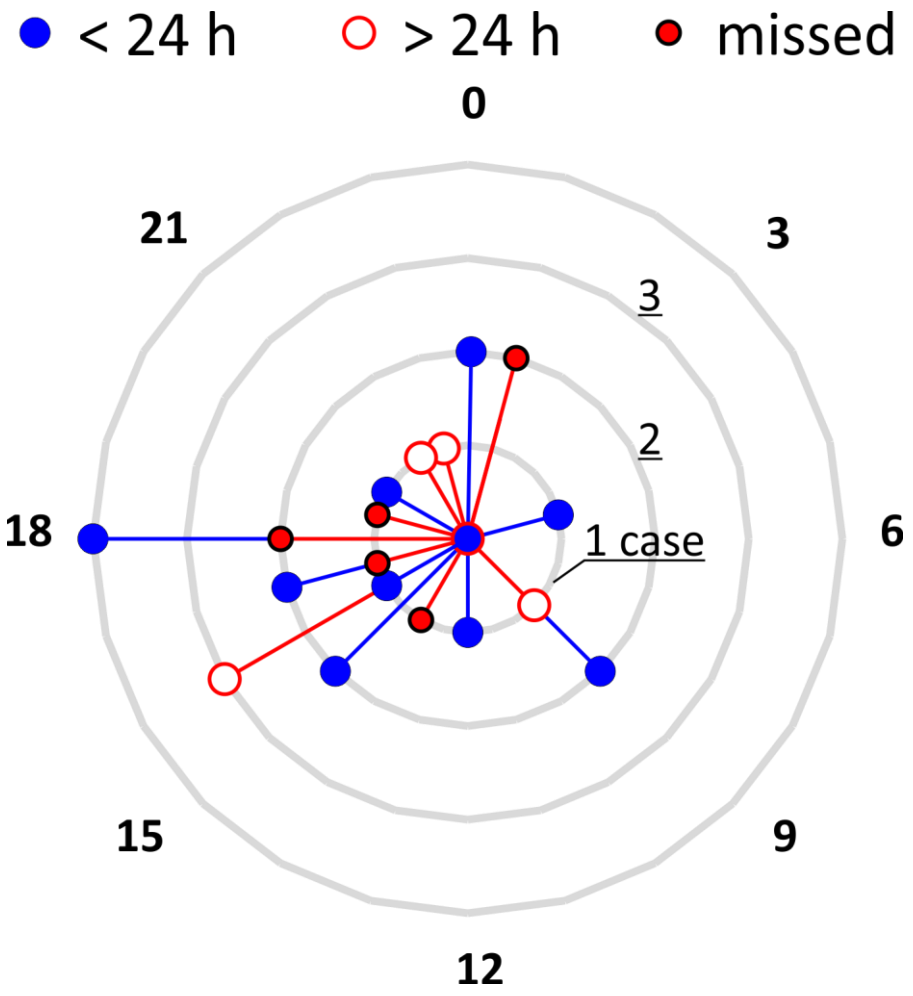
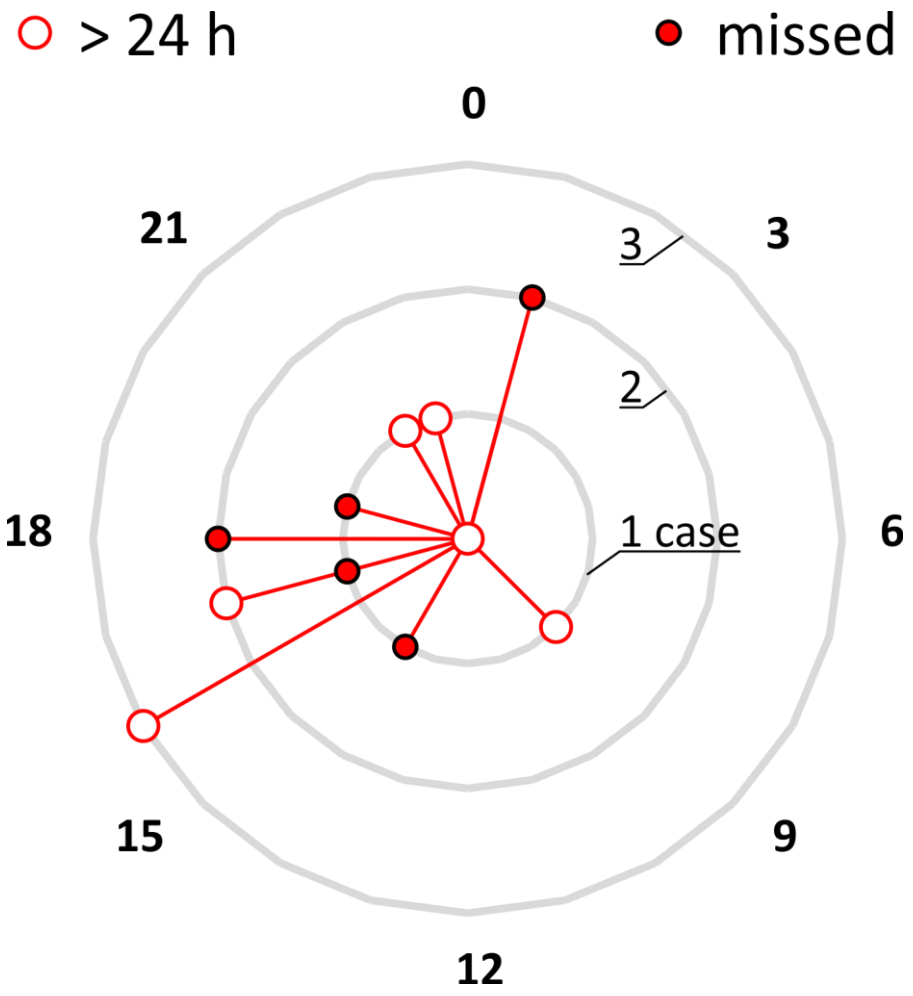



Figure 4

*Number of cases with fractures for time of the day of the WBCT. The circles show if the fracture was found within or after 24 hrs after submission or during this study (missed). If at least one fracture was missed or found after 24 hrs, the label was set to missed or > 24 h. The same diagram ist shown without cases of which all fractures were found within 24 hrs in additional file 3.*




Additional File 3

*Number of cases with fractures for time of the day of the WBCT. The circles show if the fracture was found after 24 hrs after submission or during this study (missed). If at least one fracture was missed or found after 24 hrs, the label was set to missed or > 24 h. The same diagram ist shown with cases of which all fractures were found within 24 hrs in figure 4.*

The same figures showing only the number of missed and late fractures and cases are shown in Additional files 2 and 3.

230 Slice thickness ranged between 0.9 and 5 mm with an average of 1.7 (CI 1.5-2.0, SD
231 1.1) for all 73 visible fractures.

232 Fractures that were diagnosed late or missed showed no difference in WBCT slice
233 thickness to those found within 24 h (late/missed: n=12, 1.7 mm, CI 1.1-1.2, SD 1.3 vs
234 other n=52, 1.7 mm, CI 1.5-2.0, SD 1.0, p=0.743, t-test). The same was true looking at
235 cases with late or missed fractures (late/missed: n=12, 1.3 mm, CI 0.8-1.7, SD 0.7 vs
236 other: n=21, 1.8 mm, CI 1.4-2.3, SD 1.0, p=0.092, t-test).

237

238 **Discussion**

239 Fractures of forearm and hand in patients with multiple trauma can occur in 36 % of
240 cases [12]. In our original study population, we determined a prevalence of 12.1 % for
241 late diagnosis of fractures of forearm and hand [6]. In this subsample, we found 8
242 visible fractures in addition to 65 reported that were all visible in WBCT on
243 reassessment. Missed fractures that were found during reassessment accounted for
244 11 % of visible fractures in the WBCT. Even not counting three fractures of the ulnar
245 styloid that were associated with a radius fracture, the remaining five fractures would
246 add more than 7 % that might not get proper treatment.

247 The treatment consequences of reported delayed diagnoses have been shown in our
248 previous study [6]. In this study, one missed fracture might have needed a surgical
249 treatment.

Previous studies reported a range of missed injuries up to 39 %, corresponding to 65 % of analysed patients who had a missed injury [3, 13, 14]. But they were eventually found during the treatment of the patient and not completely missed.

While both radiologists performed poorly in the reassessment of the WBCT as they missed more than 20 of 65 known fractures, but both found previously undetected fractures. The high number of missed fractures could be explained by the incomplete clinical data in the request forms. In both hospitals, the trauma surgeon would talk to the radiologist directly and discuss clinical signs that could hint to an injury. Depending on the patient's condition, the one responsible for requesting the WBCT might not want to delay the procedure by writing a detailed essay. As little clinical data was available for the reassessment, both radiologists who reassessed the cases had few clues on possible injury areas, and they had to scan all areas with the same attention. In our sample, late and missed diagnoses cannot be attributed to a lower image quality regarding slice thickness.

Tertiary trauma survey can detect 56 % of early missed injuries within 24 h[14]. The rate might be increased by addition of a radiological repeated survey along with the clinical examination.

In a systematic analysis of emergency radiographs for the extremities, the most common reason for a missed fracture was subtlety of the fracture [15]. The proposed solution was adequate training. Regarding our sample, the same might be true beginning with paying attention to hand and forearm when vital injuries have been excluded.

While not enough to be certain, we most missed fractures in our sample appeared late afternoon and shortly after midnight. In the participating centres that provided the cases, around 5 pm the first shift would end and the second would already have worked for several hours. Atypical working times may have a negative effect on psychomotor performance, lead to a higher risk of accidents and mood disturbances [16]. In addition, time of day was shown to matter for alerting attention in contrast to orienting and executive attention, the first being likely more important for assessment of radiographs [17]. Radiology reports were more often edited at end of shifts at 5 pm and with increasing working hours [18]. Fatigue and experience of radiologists has an influence on diagnostic efficiency and efficacy [19, 20]. Shift workers who worked into the night were shown to show a peak in the Karolinska Sleepiness Scale as the night advanced [21]. As we analysed a defined area and the radiologists missed fractures on reassessment without discernible pattern, a satisfaction of search effect cannot be excluded but is not likely in our study [22].

**Conclusions**

The number of late diagnosis or completely missed fractures of the hand and forearm may be reduced by a repeated survey of WBCT with focus on the extremities.

**List of abbreviations**

WBCT: whole-body CT

## Declarations

### Ethics approval and consent to participate

The local institutional ethics committee of the University of Greifswald (Ethikkommission an der Universitätsmedizin Greifswald, Greifswald, Germany) approved the study (BB 054/16a) and stated that there are no ethical or legal concerns regarding this study. The decision was based on the Helsinki declaration. The need for consent for the retrospective use of patient data was waived by the institutional ethics committee of the University of Greifswald.

Informed consent was obtained from the radiologists that participated in the study.

### Consent for publication

Not applicable for patients

Consent was obtained from the radiologists that participated in the study.

### Availability of data and materials

The dataset used and analysed during the current study is available on Mendeley Data: Münn, Friederike; Kim, Simon (2021), “Polytrauma: missed fractures hand/forearm”, Mendeley Data, V1, doi: 10.17632/f9vm3c4d7v.1

## Competing interests

The authors declare that they have no conflict of interest.

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No funding was received

## Author Contribution

SK Project development, Data management, Data analysis and interpretation, Manuscript writing

LG Data analysis and management, Manuscript editing

FM Project development, Data collection and analysis, Manuscript writing

DK Data collection, Manuscript editing

MM Data analysis and interpretation, Manuscript editing

AE Project development, Manuscript editing

ST Data analysis, Manuscript editing

ML Data management and interpretation, Manuscript editing

329

330 All authors have read and approved the manuscript.

331

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334

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385 Figure legend

386

387 Figure 1

388 Fracture of the pisiform bone that was found on blinded reassessment. The adjacent slices are
389 shown in the additional video file (additional file 1).

390

391 Figure 2

392 Fracture of the ulnar diaphysis that was only visible on the localiser as the arms were not
393 included in the WBCT. Contrast and brightness were adjusted to better show the bones of the
394 forearm.

395

396 Figure 3

397 Number of fractures for time of the day of the WBCT. The circles show if the fracture was
398 found within or after 24 hrs after submission or during this study (missed). The number of
399 fractures found at 18 and 0 within 24 hrs were 14 and 9. The same diagram ist shown without
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401

402 Figure 4

403 Number of cases with fractures for time of the day of the WBCT. The circles show if the
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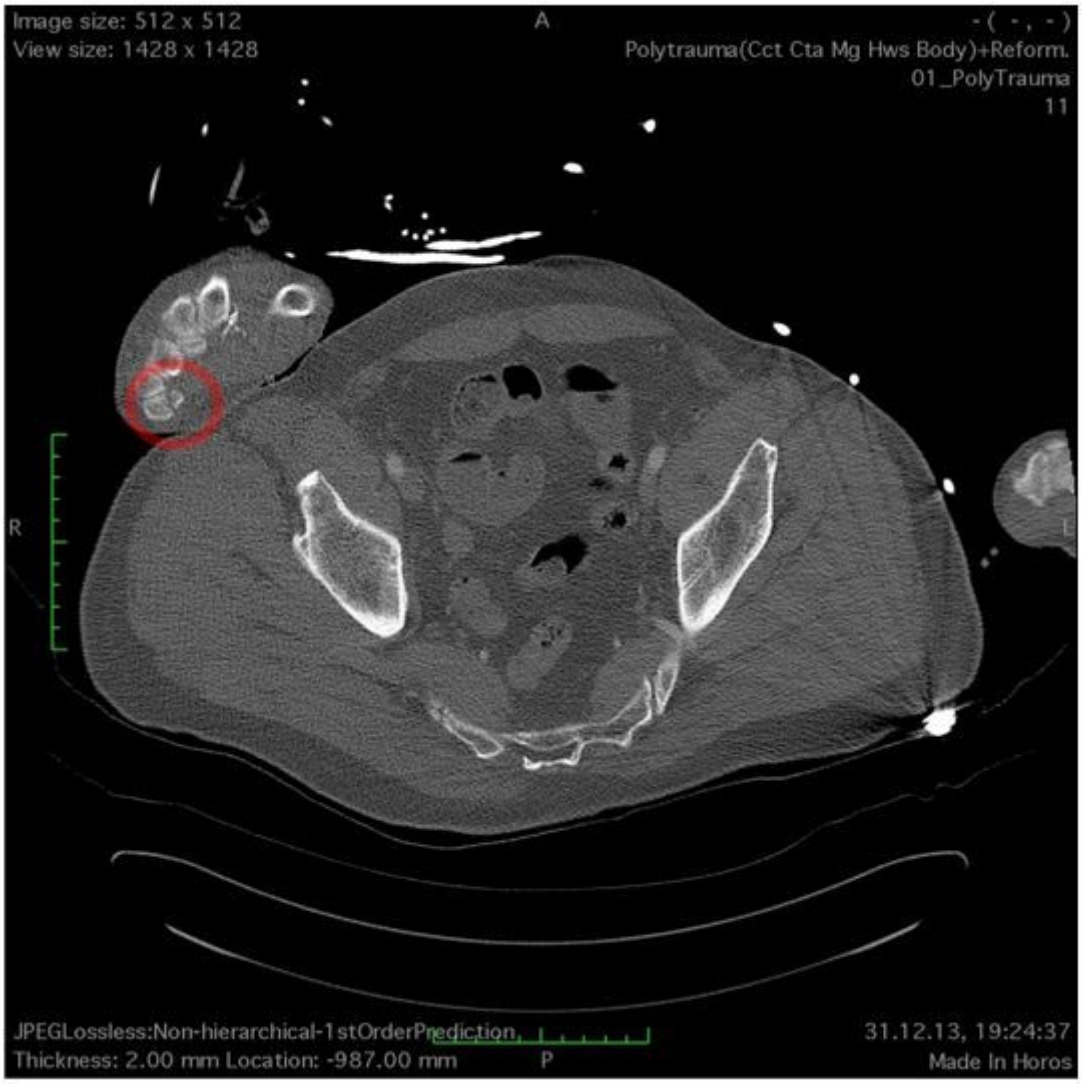
406 same diagram ist shown without cases with fractures found within 24 hrs in additional file 3.

407

# Figures

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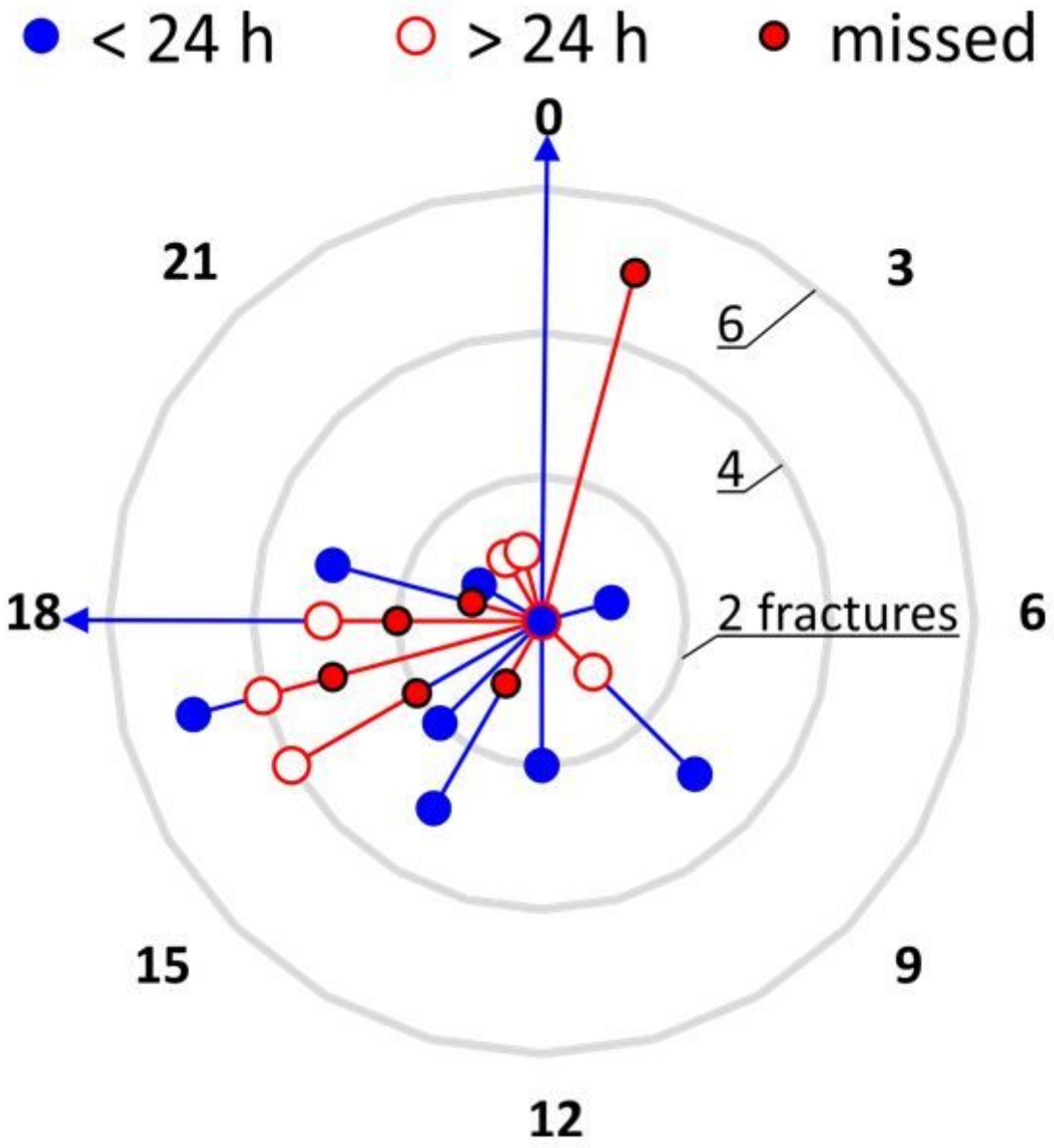


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Number of fractures for time of the day of the WBCT. The circles show if the fracture was found within or after 24 hrs after submission or during this study (missed). The number of fractures found at 18 and 0 within 24 hrs were 14 and 9. The same diagram ist shown without fractures found within 24 hrs in additional file 2.

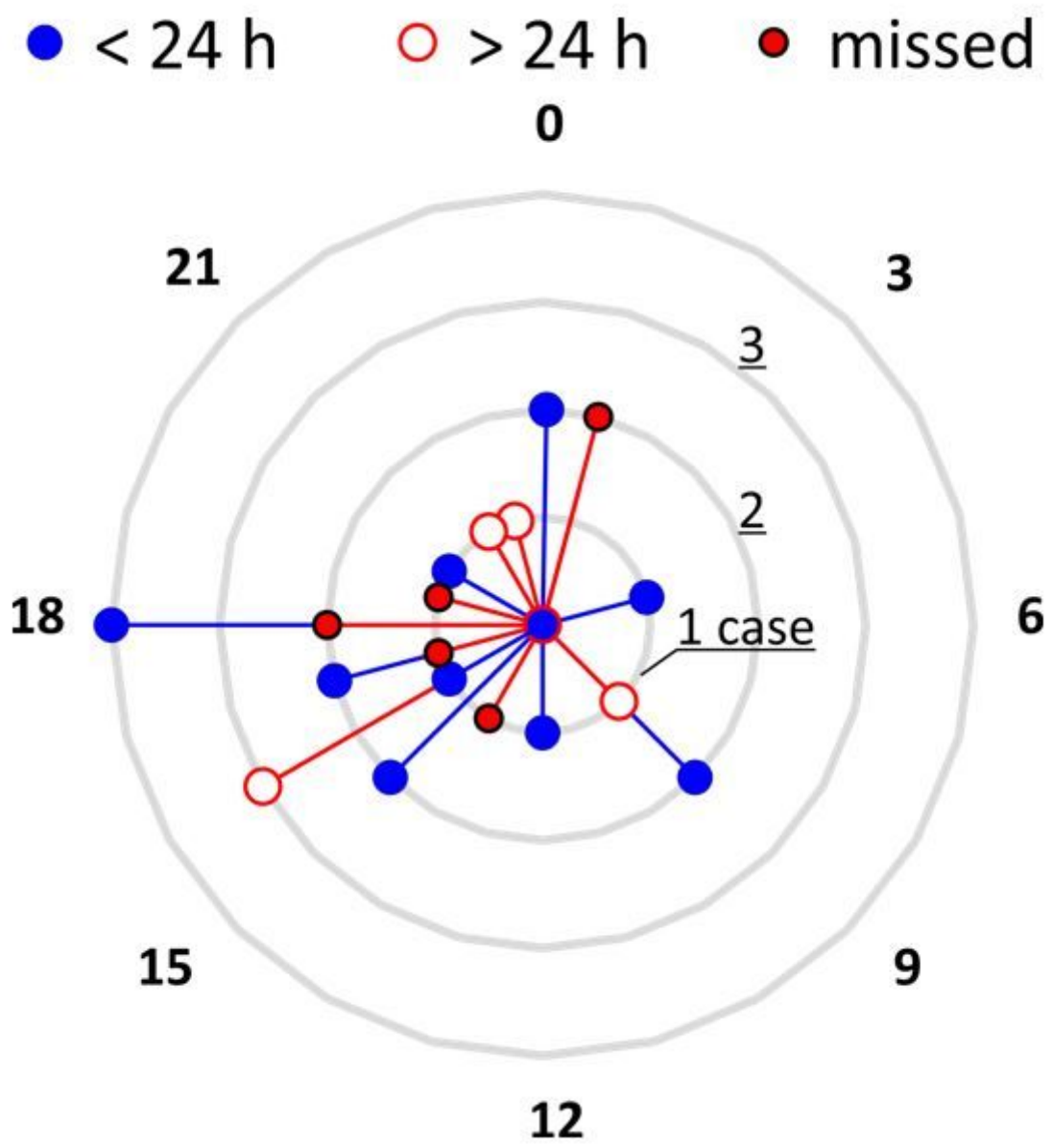


**Figure 4**

Number of cases with fractures for time of the day of the WBCT. The circles show if the fracture was found within or after 24 hrs after submission or during this study (missed). If at least one fracture was missed or found after 24 hrs, the label was set to missed or > 24 h. The same diagram ist shown without cases with fractures found within 24 hrs in additional file 3.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1.avi
- Additionalfile2.png

- Additionalfile3.png
- Additionalfilelegends.docx