Evaluation of Rib Fractures on a Single-in-plane Image Reformation of the Rib Cage in CT Examinations

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Rationale and Objectives: This study aimed to evaluate the diagnostic performance of using a reformatted single-in-plane image reformation of the rib cage for the detection of rib fractures in computed tomography (CT) examinations, employing different levels of radiological experience.

Materials and Methods: We retrospectively evaluated 10 consecutive patients with and 10 patients without rib fractures, whose CT scans were reformatted to a single-in-plane image reformation of the rib cage. Eight readers (two radiologists, two residents in radiology, and four interns) independently evaluated the images for the presence of rib fractures using a reformatted single-in-plane image and a multi-planar image reformation. The time limit was 30 seconds for each read. A consensus of two radiologist readings was considered as the reference standard. Diagnostic performance (sensitivity, specificity, positive predictive value [PPV], and negative predictive value [NPV]) was assessed and evaluated per rib and per location (anterior, lateral, posterior). To determine the time limit, we prospectively analyzed the average time it took radiologists to assess the rib cage, in a bone window setting, in 50 routine CT examinations. McNemar test was used to compare the diagnostic performances.

Results: Single image reformation was successful in all 20 patients. The sensitivity, specificity, PPV, and NPV for the detection of rib fractures using the conventional multi-planar read were 77.5%, 99.2%, 89.9%, and 98.0% for radiologists; 46.3%, 99.7%, 92.5%, and 95.3% for residents; and 29.4%, 99.4%, 82.5%, and 93.9% for interns, respectively. Sensitivity, PPV, and NPV increased across all three groups of experience, using the reformatted single-in-plane image of the rib cage (radiologists: 85.0%, 98.6%, and 98.7%; residents: 80.0%, 92.8%, and 98.2%; interns: 66.9%, 89.9%, and 97.1%), whereas specificity did not change significantly (99.9%, 99.4%, and 99.3%). The diagnostic performance of the interns and residents was significantly better when evaluating the single-in-plane image reformations ($P < .01$). The diagnostic performance of the radiologists was better when evaluating the single-in-plane image reformations; however, there was no significant difference (statistical power: 0.32).

Conclusions: The diagnostic performance for the detection of rib fractures, using CT images that have been reformatted to a single-in-plane image, improves for readers from different educational levels when the evaluation time is restricted to 30 seconds or less.

Key Words: Computed tomography; rib fracture; post processing; in-plane; educational level; diagnostic performance.

INTRODUCTION

Rib fractures occur in 40%–50% of severely injured patients or after blunt chest trauma (1,2). Depending on the number and the location of rib fractures, patients may develop respiratory failure (3), experience abdominal solid organ injury (4), and demonstrate a mortality rate of up to 6% (3). Therefore, it is important to accurately and quickly detect the location and type of fracture and the number of fractured ribs because this information can be an indication of the direction and severity of trauma and can indicate potential associated complications (eg respiratory failure) (5). More than 50% of rib fractures are missed on radiographs (6). In addition, 43% of initial computed tomography (CT) scan reports have incorrectly identified the number and location of rib fractures (3). The semicircular shape and angulation of ribs makes it difficult to identify rib fractures using standard transverse images. Coronal images do not improve the detection rates significantly (7). An aggravating circumstance is the fact that ribs often break as a buckle or incomplete fracture (8,9). Buckle fractures are the most frequently missed type of fracture, and the anterior arc is the location with the most missed fractures (7). But what are the reasons for these inadequate detection rates of rib fractures in CT? Undoubtedly, identifying these often subtle findings is time-consuming, and no dedicated standardized rib cage reformation, similar to sagittal spinal reformations in a bone window setting, is routinely used for the detection of rib fractures.

Therefore, the aim of this study is to evaluate the diagnostic performance for the detection of rib fractures in a CT

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examination using readings from both conventional multiplanar images and a reformatted single-in-plane image of the rib cage. We evaluated readers with different levels of radiological experience. The evaluation time was restricted to 30 seconds or less.

MATERIALS AND METHODS

This retrospective study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of University Hospital Erlangen, Germany. The written informed consent requirement was waived by the Ethics Committee.

Patient Population

The radiology information system (RIS) was used to search for thoraco-abdomino-pelvic CT examinations of 10 consecutive patients with at least one reported rib fracture. Ten consecutive patients without rib fractures were used as controls.

Imaging Technique

CT examinations were performed with a 64-detector row system (SOMATOM Sensation, Siemens AG, Erlangen, Germany) with the following parameters: craniocaudal thoraco-abdomino-pelvic CT data acquisition, 120 kV, Care Dose (Siemens); pitch, 0.9; collimation, 0.6 mm; section thickness, 0.75 mm; hard recon kernel. Images were acquired at the portal venous contrast agent phases (intravenous application of weight-adapted, warmed Imeron 400 [Bracco Imaging, Konstanz, Germany]) followed by a saline flush with a flow rate of 3 mL/s through an 18- or 20-gauge catheter in an antecubital vein.

Single-in-plane Image Reformation

Analysis of image data was performed using dedicated, commercially available software enabling in-plane rib reading in CT data (syngo.via, version: VB10A; workflow: Bone Reading, Siemens Healthcare GmbH). After automated segmentation, a spider-like image was generated with the vertebral column as the body and the 24 ribs as perpendicular extremities (Fig 1). The vertebrae and the ribs of each side are labeled with numbers from 1 to 12. The labels are constantly displayed next to the ribs. The single image featuring in-plane reformation of the rib cage was obtained for each of the 20 patients from the thin-slice data. These reformations were performed automatically in a postprocessing step and visualized by the software. We evaluated the reformatted images visually for the presence of artifacts (eg from mis-segmentation) leading to a non-diagnostic quality of the reformation. In our study group, no reformation had to be excluded because of poor image quality. All 20 single-in-plane images were archived in the hospital's picture archiving and communication system (PACS) for evaluation.

Reading Time

To assess the average reading time, a resident from the radiological department documented the time it took for nine different radiologists to read the rib cage data in a bone window setting. The time it took the radiologists to scroll through and evaluate the rib cage in the bone window in 50 random routine CT scans in a trauma setting was recorded.

Reference Standard

A consensus read of two radiologists using interactive three-dimensional (3D) multi-planar thin-slice reformations of all 20 patients was considered the reference standard. All ribs were

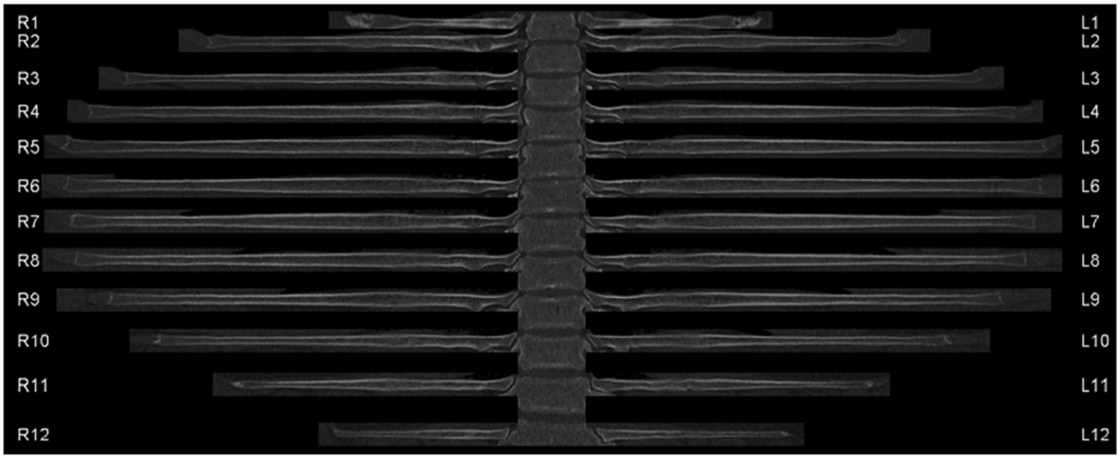

Figure 1. Example of a single-in-plane image reformation of the rib cage. These were reconstructed from the thin-slice data with dedicated software and archived for each patient in the hospital's picture archiving and communication system (PACS). Note how the ribs on each side are automatically numbered from 1 to 12, and how the 11th left rib features a subtle bicortical fracture.