



RESEARCH ARTICLE

Reduced-dose computed tomography to detect dorsal screw protrusion after distal radius volar plating [version 1; referees: 1 approved]

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Abstract

Background: Tenosynovitis and tendon rupture caused by screw penetration of the dorsal cortex are common complications after fixed-angle volar plating of a distal radius fracture. Detecting screw prominence with plain radiography is difficult due to the topography of the distal radius dorsal cortex. Computed tomography (CT) offers more detailed imaging of the bone topography, but is associated with radiation exposure. The present cadaveric study compared reduced-dose and standard-dose CT protocols in the detection of dorsal screw protrusion after fixed-angle volar plating of distal radius fracture. If found equivalent, a reduced-dose protocol could decrease the total radiation exposure to patients.

Methods: Standard size distal radius volar locking plates were placed using a standard Henry approach in 3 matched pairs of cadaver wrists. A total of 3 distal locking screws were placed at 3 different lengths for a total of 3 rounds of CT scans per wrist pair. Each wrist pair was imaged by CT using standard-dose and reduced-dose protocols. Dorsal screw penetration was measured in each imaging protocol by 3 radiologists at two time periods to calculate inter- and intra-observer variability. Variability was calculated using the concordance correlation coefficient (CCC), intra-class correlation coefficient (ICC), and Pearson correlation coefficient (PCC). Bland-Altman plots were used and assessed 95% limits of agreement.

Results: Intra- and inter-observer variabilities, either with the reduced-dose or standard-dose protocol, were >0.85. Pairwise CCC, ICC, and PCC were >0.91. In the comparison of reduced dose versus standard dose between radiologists, correlations were always >0.95.

Conclusions: Comparison of a reduced-dose CT protocol and a standard-dose CT protocol for the detection of dorsal penetrating screws after fixed-angle volar plating showed >0.95 correlation in this cadaveric model. A reduced-dose CT protocol is equivalent to a standard dose CT protocol for orthopedic imaging and should reduce radiation exposure.

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report

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Comments (0)

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Introduction

Distal radius fractures are the most prevalent bony injury in the upper extremity, accounting for 17.5% of all fractures encountered by orthopedic trauma surgeons¹. Fixed-angle volar plating is the surgical method most frequently used for the internal fixation of these fractures. However, tenosynovitis due to extensor tendon irritation and tendon rupture are common complications of volar plate fixation when the posteriorly directed screws protrude through the dorsal cortex. Among 114 patients followed up for at least 1 year, prominent dorsal screw tips accounted for over half of the complications associated with volar plate fixation of unstable distal radius fractures².

Although most surgeons routinely use intraoperative radiography to assess the adequacy of volar plate and screw placement, accurately determining the presence of dorsal cortex screw protrusion by plain radiography is extremely difficult because of the triangular shape of the distal radius. In the assessment of dorsal screw protrusion in cadaveric distal radii by true lateral radiographs, the sensitivity varied between 56–75% among hand surgeons depending on their years of experience³. In another cadaveric study, Maschke *et al.* assessed the sensitivity of oblique pronation and supination imaging views and found that although these angled images were more sensitive than the true lateral view, 2–3 mm of dorsal screw protrusion could still go undetected⁴.

Computed tomography (CT) is frequently used to evaluate the extent of volar-plate dorsal screw protrusion in distal radius fractures in symptomatic patients, and has proven to be more sensitive than plain radiography in this application⁵. However, concerns exist because CT requires a significant increase in radiation exposure and all of its associated risks⁶.

Recently, several studies have suggested that CT at reduced doses has merit in the accurate assessment of a variety of non-orthopedic and orthopedic medical conditions^{7–11}. However, the efficacy of reduced-dose CT for the accurate imaging of dorsal screw protrusion in the distal radius has not been determined, and gauging it was the objective of this study. Our hypothesis was that the accuracy of distal radius dorsal screw protrusion detection would not differ between reduced-dose and standard-dose CT protocols.

Methods

Three matched pairs of fresh-frozen cadaver wrists (United Tissue Network; Norman, OK, USA) were grossly screened before and during dissection to exclude the presence of prior pathology, trauma, and/or deformity. The cadaver work was performed in accordance with UTMB policies and regulation regarding procuring and handling cadavers (UTMB Notification of Use 04272015). In each wrist, a modified Henry approach was performed to access the volar surface of the distal radius, where a standard 3-hole distal radius volar locking plate (Biomet, Warsaw, IN, USA) was applied just proximal to the watershed area and centered on the radial shaft. Proximally, a volar plate diaphyseal screw was placed in routine fashion to secure this standard longitudinal position, which remained constant

throughout the study. The distal locking holes were drilled using the locking drill guide and measured with a depth gauge. The closest length of screw (15mm) that would be short of this measurement and not penetrate the dorsal cortex was used. A total of 3 short locking screws were placed: radial, middle, and ulnar. Thereafter, the wrist was pronated to permit a surgical exposure incision at the dorsal distal radius, allowing direct visualization of each screw hole. After the absence of screw protrusions was documented, the incision was closed with Vicryl® suture (Ethicon; Bridgewater, NJ, USA).

Each wrist pair was imaged 3 times using a CT scanner (SOMATOM® Definition Flash; Siemens Healthcare, Erlangen, Germany) and following a reduced-dose protocol and a standard-dose protocol. The first evaluation followed the placement of the non-penetrating screws and the suturing of the incision. After our musculoskeletal radiologist confirmed the quality of the images, the short distal screws were exchanged for screws 2.0 mm or longer to breach the dorsal cortex. The sutured dorsal incision was opened and the extent of distal screw dorsal penetration was measured with a ruler and recorded (Figure 1). The skin was re-approximated and the specimens were subsequently imaged again using the standard-dose and reduced-dose protocols. Thereafter, these longer screws were exchanged for screws 2.0 mm longer, and all specimens were subjected to a third evaluation by CT.

The standard-dose protocol utilized a fixed-tube current of 120 mA and a voltage of 120 kV. For the reduced-dose protocol, Siemens's **Combined Applications to Reduce Exposure (X-CARE) software** was employed. This dose-reduction software automatically modulates the tube current according to the specimen's anatomy and position during the CT scan. The adjusted mA values for the reduced-dose protocol ranged from 69–115 mA (Table 1); the overall average was 98 mA with a

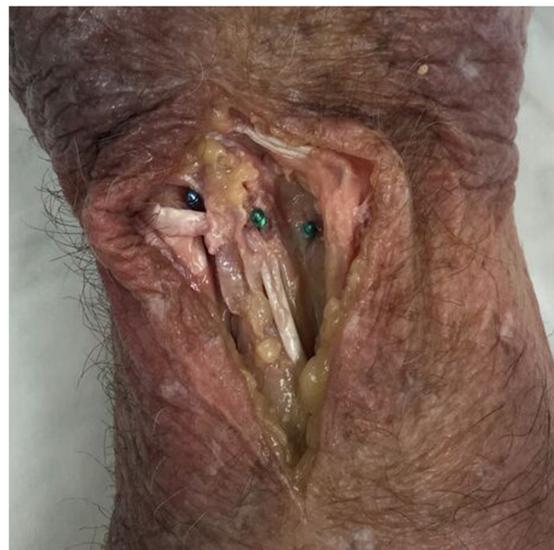


Figure 1. Dorsal incision used to confirm screw penetration.

standard deviation of 13. As in the standard-dose protocol, the voltage was a constant 120 kV.

Following CT imaging, the extent of dorsal screw penetration was measured in all 3 screw groups by 3 radiologists (senior radiologist [GMG], senior radiology resident, and junior radiology resident) at 2 time points to permit the assessment of inter- and intra-observer variabilities. The radiologists measured the maximal cortical extrusion of each screw from the level of the cortical breach to the screw tip (Figure 2) by utilizing the ruler caliper of the OsiriX DICOM imaging software v.6.5.2 (Apple Computers, Cupertino, CA, USA).

Initial data analysis consisted of verifying the radiologists' assessment repeatability. The first and second assessments for each observer were compared for all data using the concordance correlation coefficient (CCC), intra-class correlation coefficient (ICC), and Pearson correlation coefficient, as well as Bland-Altman plots. After repeatability was established, the average of each paired set of measurements was determined, and that value was used for all subsequent analyses. Similar analyses were done to examine the inter-observer agreement of the reduced-dose CT reads. Finally, the previous analyses were repeated to compare the reduced-dose and standard-dose protocol readings of each radiologist. All statistical analyses were

performed using R statistical software package (version 3.5.1; The R Foundation for Statistical Computing; Vienna, Austria).

Results

Intra-observer agreement

When all measurements were examined for either reduced dose or standard dose, the CCC, ICC, and Pearson correlation were all >0.96 (0.96–0.99) for raters 1 and 2. The correlations for rater 3 ranged from 0.86–0.96. The limits of agreement for the first 2 radiologists were 0.55–0.71. The limits were wider, 1.09–1.45, for the third radiologist.

Inter-observer agreement

The inter-observer agreement patterns were similar to those of repeatability. Three-way ICC ranged from 0.93–0.96. Pairwise ICC, CCC, and Pearson correlation were high, >0.91. Similar to reliability, the limits of agreement ranged from 0.72–1.27.

Reduced-dose protocol versus standard-dose protocol

In comparing the reduced-dose and standard-dose protocol readings within radiologists, correlations were very high, always >0.99. The limits of agreement ranged from 0.44–0.56 (Figure 3–Figure 5).

Dataset 1. Computed tomography (CT) reading results and anatomic measurement

<http://dx.doi.org/10.5256/f1000research.15056.d213893>

Table 1. Computed tomography mA values of each wrist pair according to reduced dose evaluation.

Wrist pair	First scan average (range)	Second scan average (range)	Third Scan average (range)
1	110 (106 – 114)	80 (69 – 113)	96 (82 – 115)
2	102 (93 – 114)	102 (92 – 114)	111 (108 – 115)
3	109 (97 – 115)	83 (70 – 108)	93 (83 – 107)

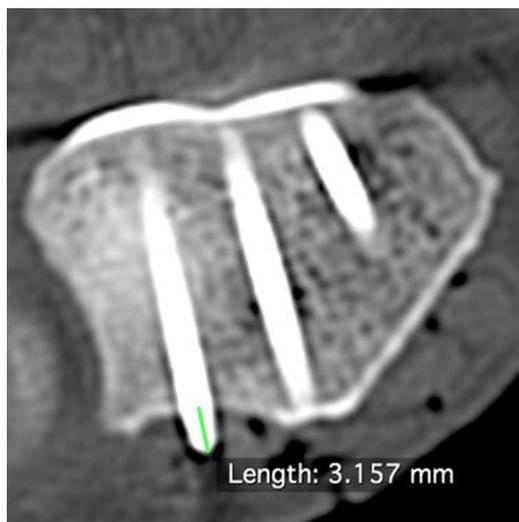


Figure 2. Screenshot depicting the measurement technique for screw protrusion.

Discussion

An accurate assessment of distal screw placement during volar-plate fracture fixation can be clinically challenging, both intra- and postoperatively, with or without conventional radiography^{3,4}. This study demonstrated that a reduced-dose CT protocol is equivalent to a standard-dose CT protocol, with correlations >0.99, in the detection of dorsal screw protrusion after fixed-angle volar plating of distal radius fracture. In intra- and inter-observer variability, the radiologists' assessments demonstrated good agreement throughout the study. Moreover, the reduced-dose CT protocol was able to maintain a current below the standard 120 mA, with an average in-scan value as low as 80 mA (Table 1)—a 33% reduction that could potentially significantly decrease a patient's overall radiation exposure. Any technique that can consistently decrease radiation exposure without compromising its diagnostic utility should be viewed favorably.

The clinical relevance of this study is considerable. As noted above, volar-plate fixation of distal radius fractures is a common surgical procedure and the topography of the dorsal cortex makes the plain radiography detection of screw prominence difficult. Prominent screws, if undetected, pose a great risk for postoperative morbidity that can include tendon irritation, tendon rupture, and/or the need for additional surgery. Although conventional CT detection of dorsally prominent screws certainly provides greater sensitivity, the elevated radiation exposure associated with the approach is a major concern. The dose-reduction software

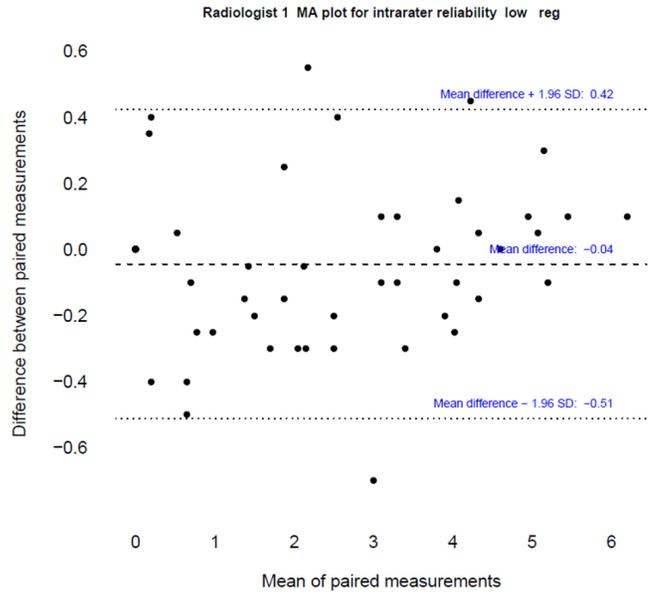
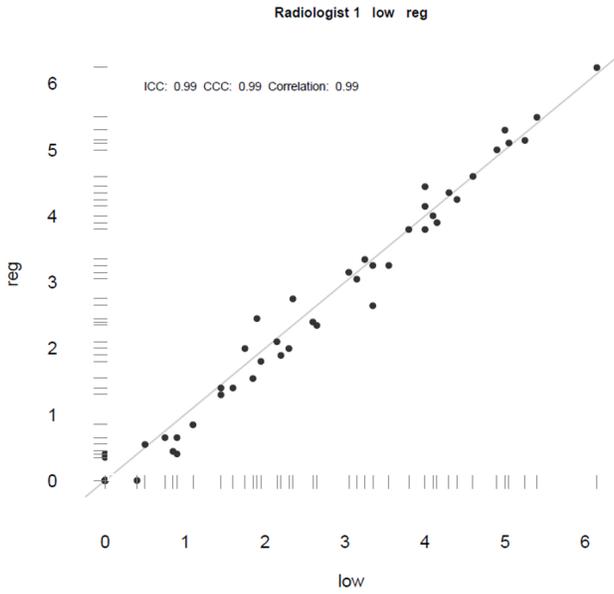


Figure 3. Intra-observer reliability of radiologist 1.

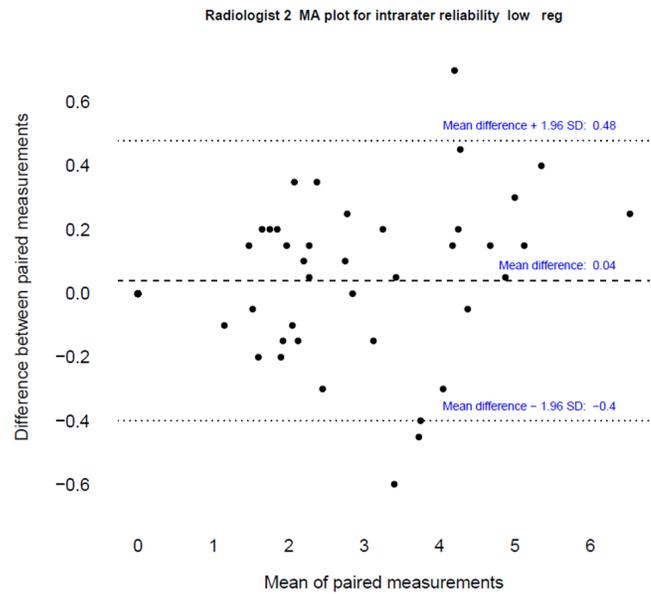
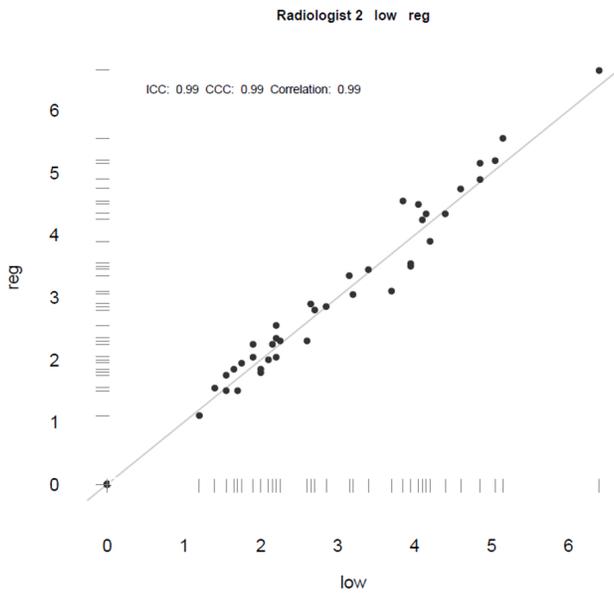


Figure 4. Intra-observer reliability of radiologist 2.

employed in this study is used for patients, so it is applicable to clinical practice.

The limitations of this study include the variability of cadaveric specimens and the variability of the reduced-dose radiation utilized. A cadaveric specimen may not fully reflect all of the issues associated with soft tissues *in vivo*. For example, the variations in bone, periosteum, and other soft tissues surrounding the dorsal cortex may affect the accuracy of the screw-tip assessment. Additionally, there were no fracture fragments or callus or

other soft tissue reactions typically associated with distal radius fractures. However, since both the reduced-dose and standard-dose protocols were applied in cadaveric specimens, we anticipate that their equivalence would be maintained *in vivo*. Studies with living patients are needed to confirm this study’s findings.

We recommend that if dorsal screw penetration is a concern, clinicians should consider a reduced-dose CT protocol to assess screw penetration of the dorsal cortex in patients with clinical presentations that warrant enhanced imaging.

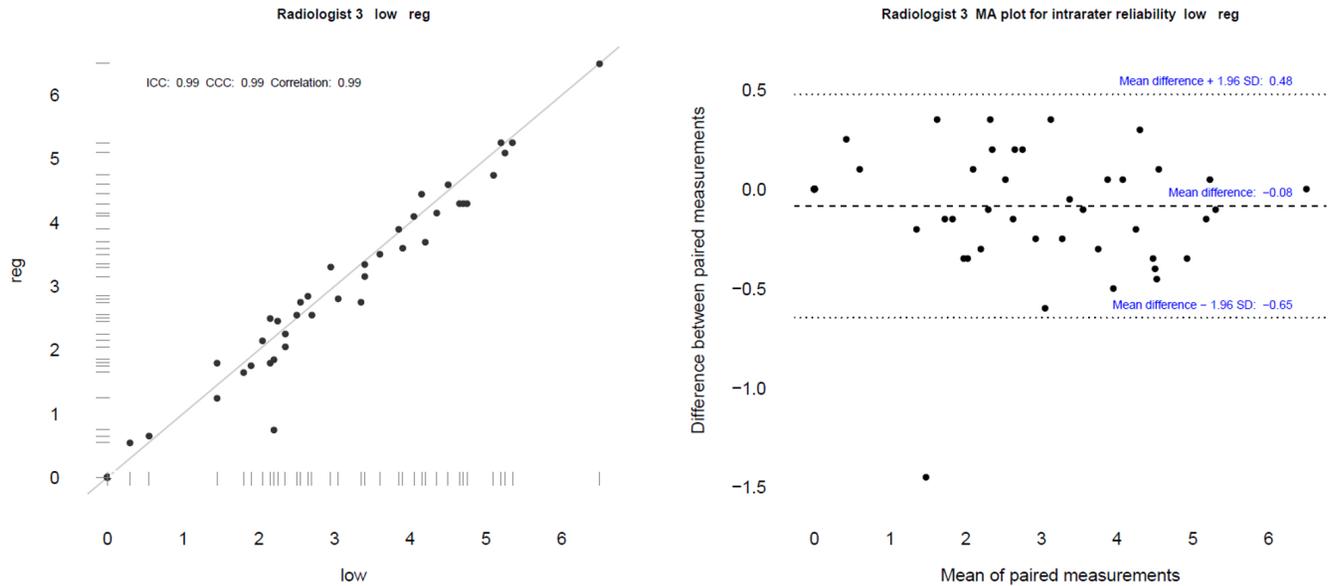


Figure 5. Intra-observer reliability of radiologist 3.

Data availability

Dataset 1: Computed tomography (CT) reading results and anatomic measurement [10.5256/f1000research.15056.d213893](https://doi.org/10.5256/f1000research.15056.d213893)¹²

Content and images used in this paper have previously been published by the authors as part of a poster for the Orthopaedic Research Society annual meeting, 2016 (poster available [here](#)).

Competing interests

No competing interests were disclosed.

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Referee Report 10 October 2018

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This is a well designed study to evaluate the accuracy of low dose CT scan in detecting screw penetration of the dorsal cortex of the distal radius when compared to high dose CT. Inter and intraobserver validation was used. The methodology, statistical analysis, and conclusions were sound.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

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