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Variation in radial head fracture treatment recommendations in terrible triad injuries is not influenced by viewing two-dimensional computed tomography

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Background: We analyzed association between viewing two-dimensional computed tomography (2D CT) images in addition to radiographs with radial head treatment recommendations after accounting for patient and surgeon factors in a survey-based experiment.
Methods: One hundred and fifty-four surgeons reviewed 15 patient scenarios with terrible triad fracture dislocations of the elbow. Surgeons were randomized to view either radiographs only or radiographs and 2D CT images. The scenarios randomized patient age, hand dominance, and occupation. For each scenario, surgeons were asked if they would recommend fixation or arthroplasty of the radial head. Multi-level logistic regression analysis identified variables associated with radial head treatment recommendations.
Results: Reviewing 2D CT images in addition to radiographs had no statistical association with treatment recommendations. A higher likelihood of recommending prosthetic arthroplasty was associated with older patient age, patient occupation not requiring manual labor, surgeon practice location in the United States, practicing for five years or less, and the subspecialties "trauma" and "shoulder and elbow."
Conclusions: The results of this study suggest that in terrible triad injuries, the imaging appearance of radial head fractures has no measurable influence on treatment recommendations. Personal surgeon factors and patient demographic characteristics may have a larger role in surgical decision making.
Level of evidence: Level III, therapeutic case-control study.

Keywords: Elbow prosthesis; Radius fracture; Computed tomography; Clinical practice variation

INTRODUCTION

Restoration radiocapitellar contact by repairing or replacing the radial head helps maintain elbow alignment after a terrible triad fracture dislocation [1-3]. The downsides of attempted fixations include the potential for elbow subluxation related to loosening of tenuous fixation with loss of alignment or from residual deformity; restriction of forearm rotation due to deformity, articular irregularities, or prominent implants; and the potential for nonunion [2,4-7]. A prosthesis restores stability without these concerns, but raises potential issues related to metal articulation with the capitellum, particularly if it is too large, osteolysis from particulate debris for articulating prostheses, and loosening of a press-fit prosthesis with erosion of the radial neck as was observed with one recalled implant [8,9].

Among factors influencing radial head fixation versus replace-

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ment, some surgeons may use the number and size of radial head fracture fragments [10,11]. Given that radial head fracture characteristics are more reliably and accurately depicted on computed tomography (CT) scans, if fracture characteristics are used to decide between fixation or prosthesis for fracture of the radial head, providing surgeons CT scans should reduce variation. CT scan can better delineate the size and location of radial head fracture fragments as well as other fractures.

We created a survey-based experiment to study the relative association of imaging as well as other patient and surgeon factors with treatment recommendations for a displaced fracture of the radial head for terrible triad injuries of the elbow. We tested the primary null hypothesis that there are no factors associated with recommending a radial head arthroplasty versus open reduction and internal fixation (ORIF) surgery for patients with a terrible triad injury including patient factors and viewing radiographs alone compared with viewing radiographs and CT scans. We also tested a secondary null hypothesis that there are no surgeon factors associated with recommending radial head arthroplasty.

METHODS

Institutional Reviewed Board of Albany Medical Center approval (No. 5604) was obtained for this survey-based experiment. Informed patient consent was waived.

Study Design and Setting

We identified all consecutive patients who underwent operative treatment for a terrible triad elbow injury (i.e., elbow dislocation, radial head or neck fracture, and a coronoid fracture) at our level 1 trauma center between January 2012 and December 2019 using Current Procedural Terminology codes 24665 and 24666 in a billing database. Patients were included if they had a terrible triad injury and both a radiograph and CT imaging of the injured elbow. Among 27 patients identified with terrible triad injuries, 16 (59%) had both a radiograph and a CT scan available to view and encompassed a spectrum of injury. One patient was excluded because of a previous elbow injury with significant heterotopic ossification present at the time of injury, leaving 15 patients available for analysis.

The 15 clinical scenarios were distributed using SurveyMonkey, and all members of the Science of Variation Group (SOVG) were invited to participate. SOVG is an international web-based collaboration of orthopedic, trauma, and plastic surgeons predominately in the United States and Europe. SOVG aims to define variation in treatment without financial incentive. All members of SOVG received an email with a link to participate in the online survey. Approximately 200 members respond to at least one survey annually, and about 125 members respond monthly. Respondents typically participate in surveys in the region of their expertise; thus, a meaningful response rate cannot be measured. Those that responded to the survey were randomized into one of two groups (simple randomization, 1:1): one group of surgeons who received 15 radiographs of elbow fractures, and the other group who received the radiograph and a corresponding CT scan. All participants received the same radiographs of each elbow injury. Those randomized to additionally view CT scans were provided with videos consisting of separate sagittal, axial, and coronal series. Prior studies evaluating this method of viewing medical imaging have shown no difference in observer satisfaction rate compared with standard Digital Imaging and Communications in Medicine viewing [12]. Nine patients (60%) were aged between 24 and 47 years (average 40 years). Five patients (33%) were classified as manual laborers. Eleven of the 15 fractures had three or more fragments in our estimation. All participants received the same personal and demographic characteristics of the patients, including age, hand dominance, occupation, and mechanism of injury. For each scenario, surgeons were asked if they would recommend either ORIF and or radial head arthroplasty. A survey sample can be viewed in Supplementary Fig. 1.

Characteristics of Surgeons Completing the Survey

A total of 154 surgeons completed the survey (Table 1). SOVG

Table 1. Surgeon demographics

Variable	Computed tomography scan	
	Yes (n=67)	No (n=87)
Surgeon	44 (67)	56 (87)
Male sex	93 (62)	92 (80)
Continent		
United States	45 (30)	45 (39)
Europe	36 (24)	34 (30)
Other	19 (13)	21 (18)
Year in practice		
0–5	31 (21)	25 (22)
6–10	21 (14)	17 (15)
11–20	30 (20)	26 (23)
≥21	18 (12)	31 (27)
Subspecialty		
Hand and wrist	39 (26)	28 (24)
Trauma	34 (23)	39 (34)
Shoulder and elbow	12 (8)	16 (14)
General or other	15 (10)	17 (15)
Supervising trainees	82 (55)	87 (76)

Values are presented as percent (number).

experiments rely on diversity of responses within the sample, not on participation rates. Sixty-seven (44%) surgeons evaluated both the radiographs and CT imaging, while 87 (56%) surgeons evaluated radiographs alone. Most surgeons practice in the United States (45%) or Europe (35%). Most observers were subspecialized in trauma (37%), hand and wrist (32%), or shoulder and elbow (12%).

Statistical Analyses

We performed multi-level logistic regression to seek patient factors associated with a recommendation for radial head arthroplasty, accounting for nesting (intercorrelation) within surgeons. Additionally, a single-level multivariable logistic regression analysis was performed to identify surgeon factors associated with recommending radial head arthroplasty, sex, continent, years in practice, subspecialty, and supervising trainees in the operating room (yes or no). To estimate the effect size, we calculated the delta-Akaike Information Criterion (AIC), and for each variable, the AIC of the full model was compared to the model without the target variable. Because lower AIC values indicate lower prediction error, higher delta-AICs indicate greater improvement in model fit. Odds ratios (ORs) 95% confidence intervals (CIs), standard errors, delta-AIC values, and P-values are reported.

An a priori sample size calculation indicated that 1,250 ratings would provide 80% power to detect statistical significance with an $\alpha = 0.05$ if one standard deviation above the mean in an explanatory variable would increase the chance of radial head arthroplasty by 20% with a base rate of 40%. Because responses were intercorrelated, we increased our sample size by 50%, resulting in a required sample size of 125 surgeons.

RESULTS

Accounting for potential confounders in multi-level logistic regression analysis, there was no difference in the recommendation rates for radial head arthroplasty between surgeons who viewed both CT scans and radiographs compared with surgeons who viewed radiographs alone (OR, 1.1; 95% CI, 0.7–1.7; P = 0.80) (Table 2). A higher likelihood of a recommendation for radial head arthroplasty was associated with older patient age (65 vs. 40; OR, 3.9; 95% CI, 3.0–5.1; P < 0.001) and occupation not requiring manual labor (OR, 0.4; 95% CI, 0.3–0.5; P < 0.001).

Surgeon characteristics including surgeon practice location in the United States, being in practice for five years or fewer, and the subspecialties "trauma" and "shoulder and elbow" were associated with higher recommendation rates for radial head arthroplasty (Table 3).

Table 2. Multi-level logistic regression analysis of patient and imaging factors associated with recommending radial head arthroplasty, accounting for nesting (intercorrelation) within surgeons

Variable	Odds ratio (95% CI)	SE	P-value	ΔAIC[a)]
Computed tomography scan				
Absent	Reference			
Present	1.1 (0.7–1.7)	0.24	0.8	–1.9
Age				
40 yr	Reference			
65 yr	3.9 (3.0–5.1)	0.52	< 0.001*	113.0
Sex				
Female	Reference			
Male	1.2 (0.9–1.5)	0.15	0.17	–0.1
Manual laborer				
No	Reference			
Yes	0.4 (0.3–0.5)	0.06	< 0.001*	40.0
Dominant arm fracture				
No	Reference			
Yes	1.2 (1.0–1.5)	0.13	0.07	1.3

CI: confidence interval, SE: standard error, Δ AIC: delta-Akaike information criterion.
[a)]The AIC was calculated for a model with all variables and compared to the AIC of the model without that target variable. Higher delta-AIC value indicate that the target variable improves model fit.
*Indicates statistical significance, P < 0.05.

Table 3. Multivariable logistic regression analysis of surgeon factors associated with recommending radial head arthroplasty

Variable	Odds ratio (95% CI)	SE	P-value	ΔAIC[a)]
Sex				
Female	Reference			
Male	0.83 (0.60–1.20)	0.14	0.28	–0.8
Continent				
United States	Reference			
Europe	0.27 (0.22–0.34)	0.03	< 0.001*	148.0
Other	0.48 (0.37–0.61)	0.06	< 0.001*	
Year in practice				
0–5	Reference			
6–10	0.63 (0.48–0.83)	0.09	0.001*	12.0
11–20	0.91 (0.71–1.20)	0.12	0.47	
≥ 21	0.67 (0.52–0.85)	0.08	0.001*	
Subspecialty				
Hand and wrist	Reference			
Trauma	1.40 (1.10–1.70)	0.16	0.008*	7.2
Shoulder and elbow	1.30 (1.00–1.80)	0.19	0.04*	
General or other	0.88 (0.66–1.20)	0.13	0.40	
Supervising trainees				
No	Reference			
Yes	1.1 (0.83–1.4)	0.14	0.60	–1.7

CI: confidence interval, SE: standard error, Δ AIC: delta-Akaike information criterion.
[a)]The AIC was calculated for a model with all variables and compared to the AIC of the model without that target variable. Higher delta-AIC value indicate that the target variable improves model fit.
*Indicates statistical significance, P < 0.05.

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DISCUSSION

Terrible triad injuries involve displaced fractures of the radial head that are treated with ORIF or prosthetic replacement [1,3,5]. Given that the number and size of radial head fracture fragments is often described as influencing this decision, it is possible that CT, which better depicts these fracture characteristics, might be associated with less variation in treatment recommendations. We performed a survey-based experiment among an international group of orthopedic surgeons and found that CT scans are not associated with surgeon recommendations of radial head fixation or arthroplasty, but age and activity level were. There was also variation in treatment recommendations by surgeon practice location, years of experience, and subspecialty.

This study has several limitations. First, the radiographs viewed by the surgeon were taken at the initial time of injury, and many were rotated or angulated. However, given the absence of an association between CT imaging and treatment recommendations, it is unlikely that the quality of radiographs affected surgeon recommendations, and imperfect imaging reflects daily practice. Second, the clinical scenarios and descriptions are an oversimplification of patient-physician interactions and did not account for patient preferences and values, all of which are factors that can and should influence treatment recommendations. We acknowledge that real-world scenarios are often more complex and future studies may perform a more detailed analysis of the different surgical procedures for radial head fractures. Third, the majority of SOVG members practice in an academic setting (85% supervise trainees) where they may more frequently encounter this type of injury. However, SOVG experiments depend on diversity within the sample more than sample representativeness, and the associations should be given more weight than the absolute rates. Furthermore, the CT scans were distributed as videos and may not reflect the manner in which some surgeons view CT images. Prior studies have demonstrated a higher survey response rate when viewing MEPG4 videos compared with DICOM videos, with no statistical difference in observer satisfaction [12]. Three-dimensional reconstructions or the fractures were not available to view, which some surgeons may prefer, although prior evidence suggests that three-dimensional reconstructions do not affect treatment recommendations for radial head fractures [13]. In this series, 11 of 27 patients had only radiographs available to view in our database and were not used in the survey. A selection bias may have been present in our patient cohort because only patients with both CT scans and radiographs were included in this study. Reasons for obtaining CT were not reported, but it is possible that this cohort represents more complex fracture patterns. Despite these limitations, this study reveals important factors associated with variation in treatment recommendations. A follow up study to this experiment could assess the influence of CT scan by evaluating an individual surgeon's decision to change treatment after first viewing radiographs alone, followed by CT.

The observation that viewing a CT scan had no measurable influence on surgeon recommendation for either radial head replacement or ORIF suggests that the imaging appearance of the fracture is a relatively minor consideration compared with patient personal factors such as age and activity level. It is generally thought that radial head fractures involving three or more fragments are more likely to have problems with early loosening of fixation and later nonunion or restriction of forearm rotation [2,4-7]. It is possible that the radiographs were adequate to determine the number and size of the fragments for the fractures in this series, and that CT scan did not add additional meaningful information.

In the cohort of surgeons surveyed, younger patients were more likely to be recommended for ORIF. This may reflect surgeon concern about prosthesis longevity in younger patients: This is less of a concern for radial head arthroplasty, where the prosthesis can serve as a "spacer" to stabilize the elbow while the ligaments heal and may not be important long-term. In other words, it functions more like a silicone spacer in metacarpophalangeal arthroplasty than a typical total joint arthroplasty such as those used for hip and knee arthritis. Some surgeons prefer to use intentionally loose-fitting, smooth neck, spacer prostheses [14,15]. The higher reoperation rate noted in patients treated with radial head replacement seems related to concerns about radiographic features that may or may not benefit from intervention [16]. Radiographic changes including radiolucency and radiographic loosening are common, but these radiographic findings do not correlate well with symptoms, and several studies have demonstrated acceptable mid- and long-term patient outcomes for radiographic variations [17-20]. If there is a problem with the prosthesis, such as infection or a prosthesis that is too large, it can be removed, and, as long as there is no interosseous ligament injury, the elbow will be fine as demonstrated in long-term studies [21-23].

The observation that surgeons from the United States are more likely to recommend radial head replacement is consistent with a prior similar study that found surgeons in the United States are up to 10 times more likely to recommend radial head replacement over fixation compared with European surgeons [24]. This

study is a follow-up to that study, which specifically investigated whether surgeons would be more likely to recommend arthroplasty for terrible triad injuries of the elbow, which can be particularly prone to redislocation, particularly if they had the additional detail of CT images. Differences in culture, training, and principles regarding injury management may contribute more to treatment recommendation variation, rather than alternative interpretations of evidence.

CONCLUSIONS

Restoration of radiocapitellar contact is an important aspect of treatment algorithms that have led to improved results in the treatment of terrible triad injuries of the elbow [3,11]. Our survey-based experiment among a large, international group of orthopedic surgeons suggests that the choice between repair or replacement for restoration of radiocapitellar contact hinges on personal surgeon factors rather than important patient or injury factors. Future research may address the notable variation in treatment recommendations for terrible triad elbow injuries by aiding the development of consensus treatment strategies based on agreed principles and current best evidence.

NOTES

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Conflict of interest

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Data availability

Contact the corresponding author for data availability.

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Supplementary materials

Supplementary materials can be found via https://doi.org/10.5397/cise.2022.01368.

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