## Diagnostic Errors in Orthopedic Surgery: Evaluation of Resident Documentation of Neurovascular Examinations for Orthopedic Trauma Patients


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# Diagnostic Errors in Orthopedic Surgery: Evaluation of Resident Documentation of Neurovascular Examinations for Orthopedic Trauma Patients

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## Abstract

The need for accuracy in neurovascular examinations of the extremities of trauma patients is well recognized. The goals of this study were to (*a*) evaluate the completeness of orthopedic house staff documentation of the neurovascular status of adult patients with extremity trauma, (*b*) identify the frequency of individual element documentation, and (*c*) determine if completeness was related to experience. The trauma center's database was reviewed for patients with extremity injuries (June 2006 through January 2008). For 114 patients, the authors assessed the neurovascular examination documentation for completeness (sensory, motor function, and vascular elements) and "perfection" (complete bilateral elements), identified the frequency of individual element documentation, and determined the relationship of completeness to experience (Pearson correlation coefficients; significance, $P \leq .05$). There was no complete (all elements) or perfect (complete bilateral) documentation. The element most often documented completely was the sensory examination. Increased examiner experience was significantly associated with decreased sensory and vascular documentation.

## Keywords

trauma, examination, neurovascular, safety, injury

Diagnostic errors are a major cause of morbidity, mortality, and liability claims, and these errors have received increasing attention.[1] Diagnostic errors can occur in a variety of ways: They may result from the failure to perform the appropriate history, physical, or tests; consider a diagnosis; interpret test results correctly; or recognize test results that require intervention.[2] Trauma patients represent a population of patients who are vulnerable to diagnostic errors because they may have injuries involving multiple organ systems that require the attention of many consulting services. The complexity of such patients and their injuries often can be a challenge to clinicians.

For patients with extremity trauma, the potential for misdiagnosis, especially with respect to neurovascular injury, is high and cannot be ignored.[3-8] Clinicians must maintain a high index of suspicion for neurovascular injury, the clinical manifestations of which can vary.[6,7,9,10] Because a missed or delayed diagnosis of neurovascular deficit can lead to substantial morbidity,[3,5,6,10-16] an accurate and thorough neurovascular examination is essential.

It is an accepted standard of care that any patient with extremity trauma undergo thorough neurovascular examinations at initial presentation and during hospitalization. The initial examination helps clinicians

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establish baseline status and guide treatment, and subsequent examinations assist in monitoring for neurovascular improvement or deterioration. For such patients who undergo surgery, documentation of a detailed preoperative (baseline) neurovascular examination also helps differentiate admission from iatrogenic deficits.[13,16,17]

In the authors' level I statewide trauma center, neurovascular extremity examinations often are performed by orthopedic house staff (ie, interns, residents). However, because by definition they are less experienced than more senior clinicians, they may not document such examinations as completely. Because there was no formal education process for the residents in terms of standardizing the documentation of neurovascular examinations, the authors were interested in how thoroughly residents documented those examinations.

To the authors' knowledge, there are no studies in the literature addressing the completeness of neurovascular examination documentation by orthopedic residents. Therefore, they sought to determine the baseline at their facility in terms of documentation of the examinations—information that could be used to reduce diagnostic errors and to serve as a basis for a prospective study of any identified educational needs or necessary interventions. The goals of the study were to (*a*) evaluate the completeness of house staff documentation of the neurovascular status of adult patients with extremity trauma (overall and by anatomical region), (*b*) identify the frequency of individual element documentation, and (*c*) determine if completeness was related to training year.

## Methods

After receiving institutional review board approval, the authors retrospectively reviewed the patient database and selected the first 150 consecutive adult patients with extremity injuries who were evaluated in the emergency room and subsequently admitted to the facility from June 2006 through January 2008. All medical charts consisted of handwritten admission and daily progress notes. The medical charts were reviewed, and 36 patients were excluded because of unavailable/incomplete charts (20) or bilateral injuries, altered mental status (ie, alcohol intoxication, illicit drug use, associated head trauma), or intubation (rendering the patients unable to cooperate with examinations; n = 16), which left 114 patients in the study population. There were 54 female and 60 male patients; the average age at time of injury was 49.6 years (range = 14.8-90.3 years). The injuries occurred in the upper extremity in 39 patients (13 above the elbow and 26 at or below the elbow) and in the lower extremity in 79 patients (39 above the knee and 40 at or below the knee). Of the 114 patients, 4 had upper- and lower-extremity injuries, but the contralateral extremities were uninjured.

**Table 1.** Elements and Number of Neurovascular Documentations in the Affected Upper Extremity

| Elements by Component | Number of Documentations | | |
|---|---|---|---|
| | Above Elbow (n = 88) | Elbow or Below (n = 135) | Total (n = 223) |
| Sensory | | | |
| Axillary | 22 | N/A | 22 |
| Musculocutaneous | 4 | 3 | 7 |
| Radial | 75 | 97 | 172 |
| Median | 75 | 97 | 172 |
| Ulnar | 74 | 95 | 169 |
| Motor | | | |
| Axillary | 3 | N/A | 3 |
| Musculocutaneous | 4 | N/A | 4 |
| Radial | 79 | 93 | 172 |
| Median | 80 | 100 | 180 |
| Ulnar | 54 | 61 | 115 |
| Vascular | | | |
| Color | 13 | 32 | 45 |
| Temperature | 11 | 32 | 43 |
| Swelling | 10 | 18 | 28 |
| Swelling severity | 3 | 9 | 12 |
| Capillary refill | 41 | 66 | 107 |
| Pulse (≥1 tested) | 33 | 20 | 53 |
| Brachial | 0 | 0 | 0 |
| Radial | 33 | 20 | 53 |
| Ulnar | 2 | 4 | 6 |

Abbreviation: N/A, not applicable.

The authors reviewed and counted independently every neurovascular examination record documented by orthopedic house staff on the injured and contralateral extremity during each patient's hospitalization. Only notes with a recognizable signature were included in the analysis. If any part of the examination was illegible, it was considered not to have been performed. Documentation by nursing staff, midlevel providers, or attendings was excluded. Of the 879 injured extremity examinations, 223 were of the upper and 656 were of the lower extremity. Of the 118 contralateral examinations, 23 were of the upper and 95 were of the lower extremity. A complete documentation was defined as the documentation of all elements within all 3 components (sensory, motor, and vascular) of a neurovascular assessment (Tables 1 and 2). A perfect documentation was defined as the documentation of complete bilateral examinations.

### *Sensory Examination*

The criteria for complete documentation of an upper-extremity sensory examination were recordings of intact or diminished sensation for the axillary (for above-elbow injuries only), musculocutaneous, radial, median, and ulnar nerves. The criteria for complete documentation of

**Table 2.** Elements and Number of Neurovascular Documentations in the Affected Lower Extremity

| Elements Documented | Number of Documentations | | |
|---|---|---|---|
| | Above Knee (n = 320) | Knee or Below (n = 336) | Total (N = 656) |
| Sensory | | | |
| Femoral/Saphenous | 89 | N/A | 89 |
| Sural | 90 | 34 | 124 |
| Posterior tibial | 191 | 215 | 406 |
| Superficial peroneal | 217 | 256 | 473 |
| Deep peroneal | 219 | 269 | 488 |
| Motor | | | |
| Femoral | 40 | N/A | 40 |
| Sciatic | 24 | N/A | 24 |
| Tibial | 268 | 296 | 564 |
| Superficial peroneal | 0 | 0 | 0 |
| Deep peroneal | 274 | 299 | 573 |
| Vascular | | | |
| Color | 60 | 84 | 144 |
| Temperature | 45 | 110 | 155 |
| Swelling | 19 | 49 | 68 |
| Swelling severity | 5 | 14 | 19 |
| Capillary refill | 65 | 169 | 234 |
| Pulse (≥1 tested) | 140 | 71 | 211 |
| Popliteal | 2 | 0 | 2 |
| Dorsalis pedis | 135 | 71 | 206 |
| Posterior tibial | 66 | 30 | 96 |

Abbreviation: N/A, not applicable.

a lower-extremity sensory examination were recordings of intact or diminished sensation in the femoral/saphenous (for above-knee injuries only), sural, posterior tibial, and superficial and deep peroneal nerve distributions.

### *Motor Function Examination*

The criteria for complete documentation of an upper-extremity motor examination were recordings of strength testing of the muscles innervated by all peripheral nerves distal to the injury: the axillary (for above-elbow injuries only), musculocutaneous (for above-elbow injuries only), radial, median, and ulnar nerves. The criteria for complete documentation of a lower-extremity motor examination were recordings of strength testing of the muscles innervated by the femoral (above-knee injuries only), sciatic (for above-knee injuries only), posterior tibial, and superficial and deep peroneal nerves.

### *Vascular Examination*

The criteria for complete documentation of a vascular examination were recordings of digit color, injury site temperature, presence or absence of swelling, swelling severity, capillary refill (normal or abnormal), and at least 1 pulse. The recording of ankle-brachial index testing was not considered necessary for the documentation to be considered complete.

### *Comparison of Examination by Year of Training*

Individuals performing the examination were characterized by their residency year (year of training; ie, 1, 2, 3, 4, or 5).

### *Statistical Analysis*

The primary outcome variable was a perfect documentation of a complete neurovascular examination, defined as reporting all sensory, motor, and vascular components of the extremity with a comparison to the other extremity. Secondary outcome variables included the documentation of a complete neurovascular examination without comparison to the other extremity and the level of experience of the examiner. Additionally, basic descriptive statistics were performed to determine the frequency of completeness of individual element evaluations. Pearson correlation coefficients were calculated to test the association between years of residency training and completeness of assessment. Significance was set at $P \leq .05$.

## Results

### *Overall*

For the affected extremity, no documentation (879 examinations) was complete (ie, no documentation recorded all elements of the sensory, motor, and vascular components; Table 3). Documentation of the sensory examination was more frequently complete (10.7%, 94/879) than the motor (6.3%, 55/879) or vascular (0.1%, 1/879) examination and was more frequently complete for the lower (12.9%, 87/656) than the upper (3.1%, 7/223) extremity. Documentation of the motor examination was more complete for the upper (24.7%, 55/223) than the lower (0.0%, 0/656) extremity. Documentation of the vascular examination was more complete for the upper (0.4%, 1/223) than the lower (0.0%, 0/656) extremity.

For the contralateral extremity, no documentation (118 examinations) was complete (ie, no documentation recorded all elements of the sensory, motor, and vascular components; Table 4). For examinations that tested both the affected and unaffected extremities, documentation of the sensory examination was more frequently complete (21.2%, 25/118) than the motor (5.9%, 7/118) or vascular (0.0%, 0/118) examination and was more frequently complete for the lower (22.1%, 21/95) than for the upper (17.4%, 4/23) extremity. Documentation of the motor examination was

**Table 3.** Sensory, Motor, and Vascular Examination Elements Documented by Anatomical Site in Affected Extremity

| Number of Elements Documented | Number of Documentations in Upper Extremity | | | Number of Documentations in Lower Extremity | | | Total Number of Documentations (N = 879) |
|---|---|---|---|---|---|---|---|
| | Above Elbow (n = 88) | Elbow and Below (n = 135) | Total (N = 223) | Above Knee (n = 320) | Knee and Below (n = 336) | Total (N = 656) | |
| Sensory examination | | | | | | | |
| 0 | 11 | 37 | 48 | 101 | 64 | 165 | 213 |
| 1 | 2 | 0 | 2 | 1 | 14 | 15 | 17 |
| 2 | 2 | 5 | 7 | 5 | 36 | 41 | 48 |
| 3 | 52 | 90 | 142 | 122 | 200 | 322 | 464 |
| 4 | 17 | 3 | 20 | 26 | 22 | 48 | 68 |
| 5 | 4 | N/A | 4 | 65 | N/A | 65 | 69 |
| Motor examination | | | | | | | |
| 0 | 7 | 33 | 40 | 45 | 36 | 81 | 121 |
| 1 | 1 | 3 | 4 | 4 | 5 | 9 | 13 |
| 2 | 28 | 46 | 74 | 235 | 295 | 530 | 604 |
| 3 | 47 | 53 | 100 | 12 | 0 | 12 | 112 |
| 4 | 3 | N/A | 3 | 24 | N/A | 24 | 27 |
| 5 | 2 | N/A | 2 | 0 | N/A | 0 | 2 |
| Vascular examination | | | | | | | |
| 0 | 15 | 32 | 47 | 87 | 63 | 150 | 197 |
| 1 | 45 | 55 | 100 | 158 | 131 | 289 | 389 |
| 2 | 23 | 26 | 49 | 53 | 78 | 131 | 180 |
| 3 | 2 | 19 | 21 | 19 | 49 | 68 | 89 |
| 4 | 2 | 2 | 4 | 2 | 12 | 14 | 18 |
| 5 | 0 | 1 | 1 | 1 | 3 | 4 | 5 |
| 6 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| All examinations | | | | | | | |
| 0 | 5 | 10 | 15 | 23 | 7 | 30 | 45 |
| 1 | 1 | 7 | 8 | 13 | 13 | 26 | 34 |
| 2 | 0 | 9 | 9 | 18 | 11 | 29 | 38 |
| 3 | 1 | 8 | 9 | 23 | 21 | 44 | 53 |
| 4 | 2 | 3 | 5 | 17 | 31 | 48 | 53 |
| 5 | 7 | 10 | 17 | 37 | 49 | 86 | 103 |
| 6 | 17 | 37 | 54 | 84 | 98 | 182 | 236 |
| 7 | 31 | 27 | 58 | 41 | 53 | 94 | 152 |
| 8 | 12 | 16 | 28 | 24 | 41 | 65 | 93 |
| 9 | 5 | 7 | 12 | 16 | 8 | 24 | 36 |
| 10 | 4 | 1 | 5 | 17 | 4 | 21 | 26 |
| 11 | 2 | 0 | 2 | 6 | 0 | 6 | 8 |
| 12 | 1 | 0 | 1 | 1 | 0 | 1 | 2 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | N/A | 0 | 0 | N/A | 0 | 0 |
| 15 | 0 | N/A | 0 | 0 | N/A | 0 | 0 |
| 16 | 0 | N/A | 0 | 0 | N/A | 0 | 0 |

Abbreviation: N/A, not applicable.

more complete for the upper (30.4%, 7/23) than for the lower (0.0%, 0/95) extremity. Documentation of the vascular examination was equally incomplete for the upper and lower extremities.

There was no perfect documentation (ie, there was no complete documentation of the injured extremity examination paired with a complete documentation of the contralateral extremity examination). Of the 879

**Table 4.** Sensory, Motor, and Vascular Examination Elements Documented by Anatomical Site in the Contralateral Extremity

| | Number of Documentations in Upper Extremity | | | Number of Documentations in Lower Extremity | | | |
|---|---|---|---|---|---|---|---|
| Number of Elements Documented | Above Elbow (n = 7) | Elbow and Below (n = 16) | Total (N = 23) | Above Knee (n = 55) | Knee and Below (n = 40) | Total (N = 95) | Total Number of Documentations (N = 118) |
| Sensory examination | | | | | | | |
| 0 | 0 | 0 | 0 | 5 | 2 | 7 | 7 |
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| 3 | 0 | 12 | 12 | 25 | 29 | 54 | 66 |
| 4 | 3 | 3 | 6 | 0 | 4 | 4 | 10 |
| 5 | 1 | N/A | 1 | 17 | N/A | 17 | 18 |
| Motor examination | | | | | | | |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 4 | 5 | 23 | 9 | 32 | 37 |
| 3 | 3 | 5 | 8 | 6 | 0 | 6 | 14 |
| 4 | 1 | N/A | 1 | 7 | N/A | 7 | 8 |
| 5 | 2 | N/A | 2 | 0 | N/A | 0 | 2 |
| Vascular examination | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| All examinations | | | | | | | |
| 0 | 0 | 0 | 0 | 3 | 2 | 5 | 5 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 2 | 7 | 4 | 11 | 13 |
| 3 | 1 | 6 | 7 | 14 | 25 | 39 | 46 |
| 4 | 0 | 1 | 1 | 1 | 3 | 4 | 5 |
| 5 | 1 | 2 | 3 | 15 | 5 | 20 | 23 |
| 6 | 0 | 5 | 5 | 1 | 1 | 2 | 7 |
| 7 | 2 | 1 | 3 | 6 | 0 | 6 | 9 |
| 8 | 1 | 0 | 1 | 3 | 0 | 3 | 4 |
| 9 | 0 | 0 | 0 | 5 | 0 | 5 | 5 |
| 10 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | N/A | 0 | 0 | N/A | 0 | 0 |
| 15 | 0 | N/A | 0 | 0 | N/A | 0 | 0 |
| 16 | 0 | N/A | 0 | 0 | N/A | 0 | 0 |

Abbreviation: N/A, not applicable.

examinations, bilateral documentation was found for 104 sensory examinations, 63 motor examinations, and no vascular examination. Documentation for bilateral examinations of sensory and motor functions was found for only 49 of the 879 examinations (13 upper-extremity and 36 lower-extremity examinations).

Two types of documentation were used in this study: the initial assessment in the emergency room and subsequent

floor assessments. Documentation of initial examinations was significantly more complete in terms of sensory, vascular, and motor recordings than documentation for examinations performed after admission to the floor.

### *By Anatomical Region*

Documentation for the sensory, motor, and vascular examinations is summarized by region in Table 3. Of the 223 examinations performed in the upper extremity, there was complete documentation for 7 sensory, 55 motor, and 1 vascular assessments. For the sensory assessment, documentation of 48 examinations recorded no sensory element. The sensory nerve examination most often documented was that of the ulnar nerve (169 examinations); the least documented was the musculocutaneous nerve (7 examinations). For the motor assessment, documentation of 40 examinations recorded no motor element. The motor nerve examination most documented was that of the median nerve (180 examinations); the least tested was the axillary nerve (3 examinations). For the vascular assessment, documentation of 47 examinations recorded no vascular element. The vascular element examination most often documented was that of capillary refill (107 examinations), and the least often documented was swelling severity (12 examinations).

Of the 656 examinations performed in the lower extremity, documentation was complete for 87 sensory assessments, but no documentation was complete for motor or vascular assessments. For the sensory assessment, documentation of 165 examinations recorded no sensory element. The sensory nerve examination most often documented was that of the deep peroneal nerve (488 examinations); the least documented was the femoral/saphenous nerve (89 examinations). For the motor assessment, documentation of 81 examinations recorded no motor element. The motor nerve examination most documented was that of the deep peroneal nerve (573 examinations); the least tested was the sciatic nerve (24 examinations). For the vascular assessment, documentation of 150 examinations recorded no vascular element. The vascular element examination most often recorded was capillary refill (234 examinations), and the least often tested was swelling severity (19 examinations).

### *Relationship of Year of Training to Completeness*

Staff experience (postgraduate year) showed a significant and negative correlation with completeness of the sensory and vascular examination documentation: more years of residency training was associated with a decrease in completeness (Pearson correlation coefficient, –.096, $P = .005$, and –.181, $P < .001$, respectively). There was no relationship between examiner experience and completeness of the motor assessment documentation (–.048, $P = .158$; Table 5).

When stratifying by examination location, there were significant and negative correlations between staff experience and completeness of the documentation for the sensory examination above the elbow (Pearson correlation coefficient –.218, $P = .042$) and above the knee (Pearson correlation coefficient –.121, $P = .031$). There also were significant and negative correlations between staff experience and completeness of the documentation for the vascular examination above the knee (Pearson correlation coefficient –.285, $P < .001$) and below the knee (Pearson correlation coefficient –.129, $P = .018$).

## Discussion

Although there is little disagreement about the importance of a thorough neurovascular examination for every trauma patient, there is no consensus as to what is considered an "optimal," "adequate," or "perfect" examination. To our knowledge, there are no studies that show which examination elements are critical for the prevention of complications or that an appropriate examination is necessary to prevent complications. Because of this, we found that the degree of completeness of neurovascular examinations varied widely. There was no complete documentation (defined as recordings of all the sensory, motor, and vascular elements in the involved extremity), and there was no perfect documentation (defined as complete recordings of sensory, motor, and vascular examinations bilaterally). Although there are no national standards regarding the necessity of comparing 1 extremity with another, we have anecdotally found that doing so helps in the detection of subtle differences in sensation, motor strength, and perfusion. In addition, it is known that neurovascular examinations in many patient populations are often incompletely documented,[18] but it should be emphasized that the lack of complete documentation does not necessarily indicate a lack of complete examination.

There may have been several reasons for the lack of complete documentation in our study. First, residents continually face the challenge of upholding comprehensive clinical and surgical responsibilities within the constraints of duty-hour restrictions. Time spent performing a thorough clinical examination of the patient may come at the expense of documenting only certain aspects of that examination. To our knowledge, there are no studies that evaluate discrepancies between the examination performed and the documentation of that examination. Second, we considered some shorthand notations, such as "NVI" (neurovascularly intact), "NV stable" (neurovascularly stable), or "NV

**Table 5.** Association of Year of Training With Completeness of Documentation, Overall and by Examination Type[a]

| Parameter | Overall | Upper-Extremity Examination | | Lower-Extremity Examination | |
|---|---|---|---|---|---|
| | | Above Elbow | At or Below Elbow | Above Knee | At or Below Knee |
| Sensory score[b] | **–0.096 (.005)** | **–0.218 (.042)** | .018 (.838) | **–0.121 (.031)** | –0.088 (.106) |
| PGY1 | 2.82 (1.24) | 3.26 (0.58) | 2.25 (1.24) | 3.18 (1.52) | 2.58 (1.03) |
| PGY 2 | 2.91 (1.34) | 2.40 (1.96) | 2.47 (1.30) | 3.93 (1.14) | 2.84 (0.97) |
| PGY 3 | 1.81 (1.75) | 3.60 (0.89) | 2.00 (1.44) | 1.38 (2.06) | 1.89 (1.56) |
| PGY 4 | 2.12 (1.75) | 2.54 (1.41) | 1.39 (1.59) | 2.35 (2.07) | 1.95 (1.38) |
| PGY 5 | 2.64 (1.17) | 2.56 (1.38) | 2.69 (0.99) | 2.64 (1.43) | 2.65 (0.78) |
| Vascular score[b] | **–0.181 (<.001)** | –0.086 (.425) | –0.114 (.188) | **–0.285 (<.001)** | **–0.129 (.018)** |
| PGY 1 | 1.52 (0.96) | 1.32 (1.05) | 1.47 (0.98) | 1.45 (0.93) | 1.66 (0.93) |
| PGY 2 | 1.53 (1.11) | 1.40 (1.17) | 1.27 (1.22) | 1.36 (1.08) | 1.77 (1.06) |
| PGY 3 | 1.41 (1.11) | 1.60 (1.14) | 1.32 (1.03) | 1.17 (0.88) | 1.66 (1.27) |
| PGY 4 | 1.12 (0.98) | 1.13 (0.95) | 1.54 (1.14) | 0.98 (0.87) | 1.17 (1.05) |
| PGY 5 | 1.07 (1.02) | 1.17 (0.79) | 2.00 (0.77) | 0.73 (0.69) | 1.49 (1.23) |
| Motor score[b] | –0.048 (.158) | .159 (.139) | –0.120 (.166) | –0.087 (.120) | .016 (.782) |
| PGY 1 | 2.03 (0.64) | 2.42 (0.56) | 2.19 (0.97) | 1.97 (0.49) | 1.84 (0.51) |
| PGY 2 | 2.07 (1.01) | 2.00 (1.63) | 2.07 (1.33) | 2.64 (0.74) | 1.84 (0.52) |
| PGY 3 | 1.66 (1.13) | 3.00 (0.00) | 1.80 (1.32) | 1.67 (1.24) | 1.47 (0.89) |
| PGY 4 | 1.86 (1.03) | 2.42 (1.10) | 1.36 (1.47) | 1.95 (1.13) | 1.75 (0.65) |
| PGY 5 | 1.95 (0.71) | 2.89 (0.96) | 2.00 (0.77) | 1.74 (0.67) | 1.92 (0.37) |

Abbreviation: PGY, postgraduate year.
[a]Unless otherwise indicated, numbers are presented as mean (standard deviation) of completeness scores for each year of residency.
[b]Numbers are presented as Pearson correlation coefficient (*P* value). Boldface values indicate statistical significance ($P < .05$).

unchanged" (neurovascularly unchanged), as equivalent to not documenting an examination. These forms of shorthand documentation imply that a neurovascular examination was performed but do not provide any details as to how thorough the examination was. Even if the house staff perform a comprehensive examination and determine that the status is stable, a lack of detailed documentation could potentially lead to questions regarding the true thoroughness of the examination should a change in neurovascular status occur. In addition, because a patient may not be seen by the same provider from day to day, shorthand notations become less reliable because they do not account for the differences in the examination performed by the various providers. Third, all documentation in our study was handwritten into the medical record, and therefore, there were no stamps or inserts to prompt the residents to document particular parts of the examination. Other studies have suggested that medical documentation via handwritten, free-form notes is often inconsistent and may lack important patient data.[19-21] Fourth, house staff may have used or relied on documentation by other providers, such as nurse practitioners or physician assistants, although residents in our orthopedic department are expected to avoid such reliance on other reports. Finally, senior residents may have documented less of the examination because they assumed that it had been documented by another provider or because they had a different concept of what constituted sufficient documentation based on their perhaps more focused examinations.

The question of adequate and complete documentation is particularly germane with the advent of electronic documentation. Although some studies have shown that use of a sticker in the chart requiring the resident to document elements of the examination for suspected compartment syndrome can result in better documentation,[22,23] the impulse also might be to record fewer rather than more findings.

Diagnostic errors represent an area of patient safety that has largely been overshadowed by the focus on medication errors and system-based errors, including heath care–associated infections and postsurgical complications.[1,2,24] Nevertheless, misdiagnosis accounts for up to 80 000 deaths annually.[25] The lack of a valid scientific method to measure diagnostic errors makes the true magnitude unknown. In the current study, regardless of the possible explanations for the lack of clinical documentation, the failure to document a complete examination could potentially lead to a diagnostic error and therefore may represent an area of preventable harm. However, it should be noted that not all misdiagnoses

result in harm and that the harm may not result in patient mortality, especially in a complex trauma patient.

To our knowledge, the exact impact of incomplete documentation of a neurological evaluation on orthopedic trauma patients has not been extensively reported in the literature, nor did our study address that question. We did not evaluate whether the documentation was less than what was really performed nor did we determine if the documentation had any impact on clinical care. In our study, there were no adverse events, so the adequacy of the examination and clinical result could not be determined. Although we identified a complete examination as one that included all elements of the neurovascular examination, it is likely that an adequate examination may vary depending on the patient and the injury. This study was not designed to define an adequate examination but rather to determine how often an extensive and complete examination was performed. It may be that a perfect or complete examination as we defined it is not needed each time for every patient.

However, it should be noted that 1 recent study examining postoperative neurovascular monitoring in pediatric orthopedic surgery patients discovered an association between inadequate documentation of abnormal neurovascular findings preoperatively and subsequent adverse events.[17] In addition, adverse events as a result of medical mismanagement occur in 4.1% of hospitalized orthopedic surgery patients,[26] and orthopedic surgery ranks fifth among medical specialties with regard to the total number of malpractice claims filed.[27] These claims are most commonly filed for extremity injuries—specifically, fractures of the femur, tibia, and fibula. Poor documentation has been cited as a contributing factor to the delayed diagnosis of compartment syndrome in 12.5% of claims.[28] Documentation of the neurovascular examination is often critical not only to patient care but also to the evaluation of malpractice claims.[23,27,28] A high percentage of claims is paid in cases where there are problems with inadequate medical documentation.[27] Additional study is needed to determine whether more or less documentation would be helpful in this clinical setting.

Our study results should be viewed with the following caveats. We selected only patients who were admitted to the hospital for fractures to the appendicular skeleton. We did not include patients with spinal injuries, cranial injuries, central nervous system lesions, or neurological injuries, for which documentation might be more thorough because of the perceived severity or nature of the condition. We also did not include patients admitted for elective spine or appendicular skeleton surgery. In this study, we did not evaluate the completeness or the competency of the neurovascular examinations themselves but rather the extent to which our orthopedic residents documented their neurovascular examinations for adult orthopedic trauma patients. This may misclassify actual performance.

Another consideration in our study is the effect of splint placement on the ability to perform a thorough neurovascular examination. The splint placement should not prevent the examiner from being able to test all major sensory and motor nerve branches in addition to vascular status. Areas of the splint can be opened to test sensation and vascular integrity in different areas that may be under the splint without affecting the integrity of the splint. Motor testing may be more difficult with splint placement, but most of the motor groups should be able to be tested without difficulty. Splint placement may affect motor testing only; although we did not control for this factor in our study, it is unlikely that it would change the outcome or implications.

Although one cannot conclude from our study that a more thorough documentation of the neurovascular status is needed, it does suggest that standardization of the documentation of the neurovascular examination may be useful.[17] Interventions that simplify and standardize documentation (eg, checklists) have been shown to reduce morbidity and mortality in surgical patients, critically ill trauma patients at risk for compartment syndrome, and emergency room patients.[10,29,30] Additional study is needed to establish what the standards should be for documentation of the neurovascular examination of orthopedic surgery patients who have sustained extremity trauma. Finally, our results would suggest that documentation of neurovascular examinations by residents might be improved with educational sessions, but that point was not specifically addressed. A prospective study with a larger number of patients would be warranted to fully define what constitutes optimum documentation for patient safety and legal purposes.

## Declaration of Conflicting Interests

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