Any health care facilities are unequipped to treat complex hand and upper extremity injuries, and patients are therefore transferred to tertiary care centers. Although the reasons for interhospital transfer may vary, these patients often require a higher level of care from better-resourced facilities and physicians with greater specialization.

Organizational guidelines and federal regulations have been established to guide providers in their decision to transfer a patient and to which facilities they should be referred. Among these were the trauma center criteria set forth by the American College of Surgeons in its *Resources for Optimal Care of the Injured Patient* in 1976. In it, the American College of Surgeons established a process for categorizing hospitals as Level I, II, or III based on their capacity to treat varying degrees of trauma. This designation has proven effective, with patients treated at verified trauma centers.
having a 25 percent lower risk of mortality compared to patients treated at nontrauma centers. In addition, the American Society for Surgery of the Hand has developed the Hand Trauma Network, which is designed to identify specialized facilities for the microsurgical treatment of hand trauma.

The Emergency Medical Treatment and Labor Act, enacted by Congress in 1986, aimed to provide emergency care to all patients irrespective of their ability to pay. Simply put, the Emergency Medical Treatment and Labor Act states that a hospital cannot deny a patient emergency care. However, through a revision of the Emergency Medical Treatment and Labor Act in 2003, hospitals are no longer required to have specialist coverage at all times. Instead, a hospital may transfer a patient to a tertiary care center where specialist care is available. Coupled with the decrease in overall U.S. trauma centers and hand surgeons who participate in trauma and microsurgery call, American College of Surgeons Level I trauma centers have experienced an overall increase in interhospital transfers since 2003.

Although some transfers continue to occur as a result of undesirable insurance or arrival times, the decision to transfer or not transfer a patient relies largely on the presumptive diagnosis made by the referring provider. An inaccurate diagnosis that leads to inappropriate transfer or lack of transfer can lead to suboptimal outcomes. For example, digital injuries falsely deemed unsalvageable could avoid amputation if transferred to specialized microsurgery centers, and many patients with nonemergent injuries are transferred unnecessarily, increasing overall health care costs and resource use.

This study aims to describe the characteristics of patients transferred to a Level I trauma center for hand and upper extremity injuries and to evaluate the accuracy of the provided diagnosis at the time of referral. Secondly, we aim to describe the characteristics of the referring hospital and to investigate which factors are associated with an inaccurate diagnosis.

PATIENTS AND METHODS

Following institutional review board approval, all adult patients consecutively transferred from outside facilities to the hand service of our American College of Surgeons Level I trauma center by means of direct communication with a hand surgery fellow on-call were included. Patients were not included if they (1) presented primarily to our emergency department or (2) were admitted by other inpatient services, such as internal medicine or the general surgery trauma service, and then referred to our service. Patient- and injury-related information, as indicated by the referring provider, was recorded by the receiving hand surgery fellow. This included data on the referring hospital and specialty requesting transfer, patient demographic information, the presumptive diagnosis(es) at the time of transfer, and which hand or digits were involved.

The trauma certification designation of each referring facility was determined from the American College of Surgeons website (http://www.facs.org/trauma/verified.html). The distances between our facility and the referring facilities were determined using the U.S. Postal Service zip codes. Point-to-point straight-line distances were calculated by measuring values (in miles) from the center of the transferring facility zip code to our facility.

The final diagnosis of each patient was recorded following clinical evaluation by a hand surgeon at our receiving tertiary care institution. These diagnoses were then compared to the presumptive diagnosis given by the referring provider at the time of transfer. Information on treatment parameters, such as the type of intervention performed, was also collected.

Data were analyzed with STATA Version 13.0 (StataCorp, College Station, Texas). Categorical variables were described using frequencies and percentages. Continuous variables were described using means and standard deviations if normally distributed or medians and interquartile ranges if nonnormally distributed. Associations between categorical variables, such as American College of Surgeons trauma center designation of the referring facility and inaccurately diagnosing an injury, were analyzed using chi-square or Fisher’s exact test. Statistical significance was set at \( p < 0.05 \).

RESULTS

Sixty-three consecutive patients were transferred to our hand surgery service from outside facilities over a 1-year period from August of 2016 through July of 2017 (Table 1). These were predominantly (86 percent) men, with a mean age of 43 \( \pm \) 18 years. The majority of transfers (41 of 63 (65 percent)) were initiated either during the night (6 PM to 6 AM) or the weekend (Saturday to Sunday). Most patients were referred by emergency medicine physicians \( [n = 47 (76\%) ] \), followed by midlevel emergency department
providers (physician assistants or nurse practitioners) \[n = 12 (19\%\)] or hand surgeons \[n = 3 (5\%\)]. The median time interval between the initial referral of a patient and their arrival to our institution was 170 minutes (interquartile range, 100 to 240 minutes).

The median straight-line distance from the referring hospital to our center was 31 miles (interquartile range, 14 to 69 miles). Thirty-seven patients (59\%) were referred from facilities not designated as American College of Surgeons trauma centers, 16 (25\%) from American College of Surgeons Level III trauma centers, three (4.8\%) from American College of Surgeons Level II centers, and six patients (9.6\%) from another Level I trauma center. Of these six patients transferred from Level I trauma centers, three required microsurgical procedures, two others were referred for potential microsurgical procedures, and one was transferred because there was no hand surgeon on-call at the referring Level I trauma center.

Twenty-one transferred patients (33\%) had an inaccurate initial diagnosis relayed at the time of referral over the telephone (Fig. 1). Ten patients (16\%) were “underdiagnosed,” as defined by an injury that was missed or omitted by the referring provider or an injury that was described as less severe than the final diagnosis (e.g., flexor tenosynovitis instead of necrotizing fasciitis). These included seven of 16 of all tendon injuries (44\%), one closed fracture in the contralateral hand, one case of necrotizing fasciitis reported as flexor tenosynovitis, and one case of pyoderma gangrenosum–associated dysvascula-

TABLE 1. Patient- and Referral-Related Characteristics

| Factor                                      | All Patients | Accurately Diagnosed | Inaccurately Diagnosed | \(p\)   |
|---------------------------------------------|-------------|---------------------|------------------------|--------|
| No. of patients                             | 63          | 41                  | 22                     |        |
| Male                                        | 54 (86)     | 38 (95)             | 16 (73)                | 0.022* |
| Mean age ± SD, yr                           | 43 ± 18     | 41 ± 20             | 45 ± 14                | 0.45   |
| Dominant extremity injured                  | 31 (49)     | 17 (41)             | 14 (64)                | 0.15   |
| Bilateral injury                            | 2 (3.2)     | 1 (2)               | 1 (5)                  | 0.36   |
| Referring center characteristics            |             |                     |                        |        |
| ACS trauma designated                       | 25 (40)     | 15 (38)             | 10 (45)                | 0.40   |
| ACS trauma level                            |             |                     |                        |        |
| I                                           | 6 (9.5)     | 6 (15)              | 0 (0)                  | 0.64   |
| II                                          | 3 (4.8)     | 2 (4.9)             | 1 (4.5)                |        |
| III                                         | 16 (25)     | 7 (17)              | 9 (41)                 | 0.042* |
| Fellowship-trained hand surgeon             | 30 (48)     | 22 (55)             | 8 (38)                 | 0.11   |
| Referring specialty                         |             |                     |                        |        |
| EM physician                                | 47 (76)     | 31 (78)             | 16 (73)                |        |
| Midlevel provider                           | 12 (19)     | 7 (18)              | 5 (23)                 |        |
| Hand surgeon                                | 3 (4.8)     | 2 (5)               | 1 (5)                  |        |
| State of referring hospital                 |             |                     |                        |        |
| Massachusetts                               | 42 (69)     | 25 (62.5)           | 17 (81)                |        |
| New Hampshire                               | 12 (20)     | 9 (22.5)            | 3 (14)                 |        |
| Maine                                       | 2 (3.3)     | 2 (5)               | 0 (0)                  |        |
| Vermont                                     | 3 (5)       | 2 (5)               | 1 (5)                  |        |
| Other                                       | 2 (3.3)     | 2 (5)               | 0 (0)                  | 0.78   |
| Distance to our center, miles               |             |                     |                        |        |
| Median                                      | 31          | 32                  | 29                     | 0.39   |
| IQR                                         | 14–69       | 14–82.5             | 14–43                  |        |

ACS, American College of Surgeons; EM, emergency medicine; IQR, interquartile range.

Nine patients (14\%) were “overdiagnosed” at the time of referral, as defined by a referring provider erroneously overestimating the presence of disease or trauma. These included five of 11 patients (45\%) transferred for a dysvascular digit, one of six patients transferred for infection, one patient reported to have an extensor tendon injury, one laceration at the wrist thought to have caused median nerve injury, and one digital tip amputation that was transferred as a middle phalanx–level amputation. Two patients (3.2\%) had a reported diagnosis that was incorrect but of similar severity to their actual diagnosis. These were two patients with hand abscesses reported as flexor tenosynovitis.

Six referrals (9.5\%) described the incorrect digit or omitted an injured digit in their report. These were not mutually exclusive with other inaccurately diagnosed injuries. Cases of an omitted digit included (1) an unmentioned index finger nerve and flexor tendon injury in the setting of a concurrent thumb amputation, (2) index finger tendon injury, and (3) dysvascular digit.
Cases of an incorrect digit included (1) report of a ring finger extensor injury that did not have any injury, (2) report of a table saw injury to a ring finger that was not involved, and (3) a separate injury to the thumb instead of the mentioned index finger.

Bivariate analyses suggested that inaccurate diagnosis was not associated with the referring provider type \((p = 0.78)\) or the time of transfer \((p = 0.351)\). However, an inaccurate diagnosis was associated with patient sex, such that 15 of 54 men (28 percent) were misdiagnosed and six of nine women (67 percent) were misdiagnosed \((p = 0.022)\). Inaccurate diagnosis was also associated with the trauma level of the referring hospital \((p = 0.042)\), such that the inaccurate diagnosis proportions were as follows: zero of six patients (0 percent) from Level I centers, one of three patients (33 percent) from Level II centers, and nine of 16 patients (56 percent) from Level III centers (Table 1). Bivariate analyses to investigate which diagnoses provided at referral were more likely to be associated with inaccurate diagnosis suggested that a presumptive diagnosis of dysvascularity was significantly associated with inaccurate diagnosis \((p = 0.041)\) (Table 2).

Forty-eight patients (75 percent) underwent surgical intervention (Fig. 2). Of these, 43 (90 percent) underwent operative treatment during their initial hospital stay and five (10 percent) underwent elective surgery at a later date. Seventeen patients (27 percent) underwent microsurgical procedures. Fifteen patients (25 percent) transferred did not undergo surgical intervention. Thirteen of these 15 (87 percent) were transferred from non–American College of Surgeons trauma centers or American College of Surgeons Level III centers. Ten of 15 patients (75 percent) who did not undergo surgery had a bedside procedure performed as definitive treatment. These bedside procedures included an irrigation and debridement in five patients, revision amputation in two patients, extensor digitorum communis tendon repair in one patient, closed reduction of a fracture in one patient, and laceration repair in one patient.

Of the nine patients overdiagnosed, four patients (44 percent) required surgical treatment. Compared to other patients, overdiagnosed patients were significantly less likely to undergo surgical treatment (75 percent versus 44 percent; \(p = 0.016\)) or any intervention (including bedside procedures) (96 percent versus 67 percent; \(p = 0.002\)). Of the 10 patients underdiagnosed, nine (90 percent) underwent surgery during this stay compared with other patients, of whom 34 of 53 (64 percent) underwent same-stay surgery \((p = 0.107)\).

**DISCUSSION**

The transfer of patients to American College of Surgeons Level I trauma centers for upper extremity injury relies primarily on the presumptive diagnosis made by the referring provider. This study describes the characteristics of patients transferred from other hospitals to our Level I trauma center and investigates the accuracy of the presumptive diagnosis at the time of referral. We found that (1) 33 percent of transferred patients had an inaccurate diagnosis at the time of referral, with cases of dysvascularity, tendon injury, and infection constituting the highest proportion of inaccurate diagnoses; and (2) diagnostic
inaccuracy was related to eventual treatment, with patients who were overdiagnosed being less likely to require surgery or other intervention.

This study must be interpreted in light of its limitations. These data represent 63 patients referred to one Level I trauma center and therefore this study is limited by its relatively small sample size and generalizability. Second, the interactions with referring providers were not standardized to ask in an itemized manner whether each injury type was presumed to be present or nonpresent; instead, questions were tailored to the chief complaint. For example, if a patient was transferred for a single-digit amputation, the hand fellow would likely ask about the injury mechanism, involvement of other digits, presence of nerve/vascular injury, dysvascularity, or other concomitant injuries, but would be unlikely to specifically ask whether there is infection or dorsal combined injury, for example. This was done to mimic a “real-life scenario” and to limit the burden for referring providers, especially in the setting of emergent care. Another consideration is that we only compared the presumptive referral diagnosis to our clinical diagnosis, and did not use an operative explorative diagnosis as the gold standard (as not all patients underwent surgical intervention). However, a comparison between clinical diagnoses was more relevant to this study because it is the initial clinical diagnosis that is used in deciding to transfer a patient or manage an injury surgically.

The cause of disparate diagnoses at the time of referral may be multifactorial. Some injuries may be more difficult to accurately diagnose; we found that presumptive diagnoses of infection and dysvascularity were often overdiagnosed, whereas tendon injuries were often underdiagnosed. Three of the four cases of inaccurately

| Table 2. Diagnoses at Referral and Proportion of Patients Inaccurately Diagnosed |
|---------------------------------|----------------|----------------|----------------|----------------|
| All Patients (%) | Accurately Diagnosed (%) | Inaccurately Diagnosed (%) | p  |
|--------------------|-----------------|-----------------|--------|
| No. of patients 63  | 41              | 22              |       |
| Injury             |                 |                 |       |
| Open fracture 23 (37) | 14 (34)         | 9 (41)          | 0.46   |
| Closed fracture 2 (3.2) | 1 (2)           | 1 (5)           | 0.61   |
| Digital amputation 16 (25) | 12 (29)         | 4 (18)          | 0.41   |
| Partial digital amputation 9 (14) | 6 (15)         | 3 (14)          | 1.00   |
| Fingertip injury 10 (16) | 8 (20)          | 2 (9)           | 0.33   |
| Dysvascularity 12 (19) | 5 (12)          | 7 (32)          | 0.041* |
| Infection 6 (9.5) | 2 (5)          | 4 (18)          | 0.069  |
| Nerve injury 6 (9.5) | 3 (7)           | 3 (14)          | 0.36   |
| Foreign body 6 (9.5) | 4 (10)          | 2 (9)           | 1.00   |
| Mangled extremity 5 (7.9) | 4 (10)         | 1 (5)           | 0.099  |
| Dislocation 4 (6.4) | 3 (7)           | 1 (5)           | 0.14   |
| Flexor tendon injury 3 (4.8) | 2 (5)          | 1 (5)           | 1.00   |
| Extensor tendon injury 2 (3.2) | 1 (2)         | 1 (5)           | 0.61   |
| Volar combined injury 2 (3.2) | 1 (2)          | 1 (5)           | 0.61   |

*Statistically significant (p < 0.05).

![Fig. 2. Therapeutic management of the 63 patients who were transferred to our American College of Surgeons Level I trauma center from outside facilities for upper extremity injuries.](image)
diagnosed infection were other infections mistaken for flexor tenosynovitis. Flexor tenosynovitis is a clinical diagnosis. Although traditional physical examination maneuvers such as Kanavel signs may be sensitive, they are often not specific for flexor tenosynovitis. Dysvascularity, which was inaccurately diagnosed in five of 11 cases (45 percent), can be more objectively diagnosed because the presence of ischemia can be measured using pulse oximetry. We recommend that all surgeons who receive patient transfers for dysvascular digits should regularly inquire about the use of pulse oximetry. Tendon injuries were not diagnosed in 44 percent of patients within our study. This finding is consistent with prior literature that found hand surgeons are more likely to identify tendon injuries than emergency providers. However, among hand surgeons, the clinical diagnosis of flexor tendon injuries carries a relatively low diagnostic concordance (56 percent) with operative findings. Hand surgeons can miss nearly 30 percent of injuries during the clinical evaluation compared to objective findings at operative exploration. Among injuries missed clinically, tendon injuries are among the most common.

Other potential reasons for inaccurate diagnosis include the referring hospital’s capabilities and organizational workflow. In our study, we found that lower level trauma hospitals (American College of Surgeons Level III) were more likely to inaccurately diagnose an injury as compared to American College of Surgeons Level I or II centers. This finding probably relates to the familiarity of evaluating these injuries and experience in treating these patients. Among our transferred patients, 52 percent were transferred from hospitals without a fellowship-trained hand surgeon on-call.

However, even in cases when referring hospitals have a hand surgeon on-call, studies suggest that most patients with hand injuries are transferred without prior evaluation by a hand surgeon. Although the reason for this may vary from hospital to hospital, some studies with emergency medicine physicians report that orthopedic and plastic surgeons are among the most difficult on-call specialists to respond. It is important to recognize that, in the large majority of cases, referring providers are trying to assist patients as best as possible within existing constraints. If no additional resources are available at their institution, it is reasonable and ethically responsible to request assistance in the patient’s care. It is also important to emphasize that our institution’s hand surgery policy is to accept all patients for which urgent or emergent hand surgery evaluation is requested.

In our series, six patients (9.6 percent) were transferred directly from another Level I trauma center. Despite American College of Surgeons guidelines mandating that all American College of Surgeons Level I trauma centers provide hand surgery and microsurgery coverage, one patient was specifically transferred because there was no hand surgeon on-call. Prior studies have suggested that increased time to transfer can lead to deleterious outcomes. However, as prior studies have previously suggested, it is possible that some patients who are deemed in need of microsurgical treatment are preferably referred to centers perceived as high-volume microsurgery facilities.

An inaccurate diagnosis that leads to inappropriate transfer increases the costs of care and delays the time to treatment. In addition, the transfer of patients that do not necessarily need a higher level of care may divert resources from other patients in need. In light of our findings, it is essential to critically evaluate the referral process and the diagnostic accuracy of those patients who are referred. First, we recommend that all patients be seen by a hand surgeon on-call, if one is reasonably available, before the decision to transfer the patient. Another increasingly popular option for referring providers—who may not have access to a hand surgeon—is telemedicine. Other authors have endorsed the use of telemedicine and have shown that its use decreases unnecessary hand trauma transfers. Tripod et al. described the use of telemedicine and its ability to provide emergency department physicians with specialty hand consultations before transfer. In addition to providing the referring provider with a diagnostic consultation from a hand surgeon, telemedicine can help improve communication between the referring and accepting providers and eliminate the need to transfer low-acuity cases. The American Society of Plastic Surgeons has recognized telemedicine as an effective communication modality and has described both its benefits and its medicolegal concerns.

The transfer of patients to American College of Surgeons level trauma centers is often effective in decreasing mortality for more severe and complex injuries. However, transfers can be costly and can delay the time to treatment, and in some cases patients are transferred inappropriately. By investigating the interaction between a referring facility and an American College of Surgeons Level I trauma center, we have identified areas
of discordant diagnosis that can potentially be improved. Improvement of diagnostic accuracy before patient transfer may save health care costs and facilitate more expeditious, definitive care for patients with hand injuries and other abnormality. Our center will always accept patient transfers for hand surgery evaluation, as we believe that referring providers act in good faith in the vast majority of cases. However, we believe that improving diagnostic accuracy before referral is an achievable goal that will benefit patients and society as a whole.

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