Does Delay to Theater Lead to Increased Infection Rates in Hand Trauma? A Retrospective Cohort Study

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Background: In an ideal health system, traumatic wounds would be surgically managed within 24 hours; however, resource constraints result in patients with open wounds commonly waiting much longer for surgery. Does this result in increased morbidity? This study compares infection rates over time for patients who received operative management of traumatic hand injuries.

Methods: A retrospective analysis was undertaken of patients admitted between July 2014 and June 2015 who presented within 24 hours of sustaining a hand injury and subsequently underwent operative repair. Patient and injury data were collected from arrival time at emergency departments across 3 Victorian metropolitan hospitals within the same network. Admission and outpatient follow-up of these patients was reviewed for signs of infection and treatment with antibiotics.

Results: Six hundred thirty-eight patients met inclusion criteria, 8 of the 429 patients treated within 24 hours of presentation developed an infection (1.86%) compared with 11 of the 209 patients treated after 24 hours of presentation (5.26%). Using Fisher’s exact analysis, a statistically significant association was identified ($P = 0.024$). An odds ratio of 2.924 was calculated, with a number needed to harm of 26. When time was analyzed as a continuous variable using logistic regression, there was no statistical significance.

Conclusion: This study shows some evidence that a timing may be important to reduce the rates of infection and raises the possibility that there may be a double peak for infection risk at the 6-hour and 24-hour marks. This gives a basis of potential further study.

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BACKGROUND
Injuries involving the hand require prompt attention and meticulous management. If this is not achieved, the consequences of a poor outcome exist, potentially affecting the patients’ quality of life and income earning capacity. Throughout the literature, there has been much debate surrounding the concept of a “golden period,” that is, the time within which lacerations should be surgically managed. Historically, this critical time period was proposed to be within 6 hours of injury with significant infection rates observed as a consequence of delay in treatment; however, implementation of sterile technique and meticulous surgical wound irrigation is acknowledged as having considerably reduced infection rates observed as a consequence of delay in treatment; however, implementation of sterile technique and meticulous surgical wound irrigation is acknowledged as having considerably reduced infection rates and changed the way in which wounds are managed (Murphy et al., 2016). Many studies now conclude that the concept of a “golden period” does not exist; however, none of these studies attempt to investigate patients treated beyond 24 hours from incurring a hand injury (Hollander et al., 2001; Juon et al., 2014; McLain et al., 1991; Srour et al., 2015; van den Baar et al., 2010; Zehtabchi et al., 2012).
The lack of modern and reliable data on the timing of hand surgery and subsequent outcomes raises questions as to the effects of delayed surgical treatment. With increased pressure on operating theater priorities, are patients being denied the best possible outcomes by ignoring the important time period of intervention in the management of their wounds? This study aims to test this hypothesis to determine if the rate of infection increases over time for patients that present with open hand injuries and undergo surgical management.

METHODS

This study is a retrospective cohort analysis of patients that presented within 24 hours of sustaining an open hand injury between July 2014 and June 2015. Information was collected from arrival to the emergency departments of 3 different metropolitan hospitals within 1 healthcare network. All patients were referred to and underwent surgery at a single hospital. Admission and outpatient follow-up was reviewed through the use of electronic and scanned medical record systems. The diagnosis of infection was made clinically, whereby medical records were reviewed for documentation of patients that displayed all 4 signs of erythaema, tenderness, swelling and pus exudate in their postoperative follow-up. Authors reviewing patient records were blinded to the interval between injury and surgery. Patient histories were examined and data recorded for immunocompromising factors and for comorbidities conferring an increased susceptibility to infection. These included immunosuppressing medications, chemotherapy, lymphoma, diabetes (both type 1 and 2) and intravenous drug use.

In accordance with Australian therapeutic guidelines (Therapeutic Guidelines Limited eTG, 2014), antibiotics used included cefazolin (or clindamycin in the case of allergy) and piperacillin/tazobactam in the case of animal or human bites. Postoperative discharge oral antibiotic medication included a course of cephalaxin, clindamycin, or combination amoxicillin with clavulanic acid. Despite recent studies demonstrating evidence that routine postoperative antibiotics do not reduce infection rates (Murphy et al., 2016), patients who were discharged without a course of oral antibiotics (n = 4) were excluded to reduce the variables in this study. All wounds were determined to be class III/contaminated wounds based on the U.S. Centre of Diseases Control Surgical Site Infection classification system (Mangram et al., 1999). Class IV wounds were excluded as patients with these wounds all presented beyond 24 hours of sustaining injury and class I and II wounds being only applicable to postoperative wounds, which were excluded from this study.

Our exclusion criteria also included closed hand injuries because the postoperative infection rate is not directly attributable to delay to surgery, patients that underwent replantation surgeries as these patients usually proceeded directly to theater on arrival and often underwent multiple surgeries, patients who sustained burns due to an inherent increased risk of infection and external referrals from regional/rural hospitals because of the time delays often encountered and the paucity of preoperative wound care information able to be retrospectively reviewed.

Surgical treatment varied depending on the degree and location of injury, the presence of fractures, and the involvement of soft tissues. Mechanisms of injury are recorded in Table 1 and operative management in Table 2 with wound dressings at the surgeons’ discretion. The patients included in this study were triaged based on order of presentation and children under the age of 16 were operated on as a priority to avoid long fasting periods. On review of patient histories, no other priority was given that influenced operative timing for any of the patients. Time delay to surgical management was due to operative theater availability for all cases.

Continuous variables are reported as medians and proportions as percentages with 95% confidence intervals (CIs). Group comparisons were performed using Fisher’s exact test for categorical data and exact logistic regression for continuous variables. Significance level was set at 0.05 with an odds ratio and number needed to harm extrapolated from the data sets.

RESULTS

Over a 12-month period, 723 patients met inclusion criteria with 85 lost to follow-up with a remaining cohort of 638 patients, aged between 3 months and 95 years. The

| Injury Sustained | No Infection <24 Hours | Infection <24 Hours | No Infection >24 Hours | Infection >24 Hours |
|------------------|------------------------|---------------------|------------------------|---------------------|
| Laceration       | 290                    | 3                   | 120                    | 7                   |
| Crush injury     | 124                    | 3                   | 42                     | 2                   |
| Animal/human bite| 15                     | 1                   | 10                     | 0                   |
| Penetrating      | 27                     | 1                   | 12                     | 1                   |
| Puncture         | 32                     | 0                   | 11                     | 1                   |
| Degloving        | 3                      | 0                   | 3                      | 0                   |
| Total            | 421                    | 8                   | 198                    | 11                  |

Table 1 demonstrates that for all mechanism of injury, a higher number of patients developed a postoperative infection when treated over 24 hours compared with those that treated within 24 hours.

| Surgical Procedure | Number Repaired <24 Hours | Number Repaired >24 Hours | Total |
|--------------------|---------------------------|---------------------------|-------|
| Washout + simple repair | 215                        | 90                        | 305   |
| Washout + tendon repair | 62                         | 34                        | 96    |
| Washout + graft (SSG/FTSG) | 40                         | 27                        | 67    |
| Washout + tendon + NVB repair | 22                       | 15                        | 37    |
| Complex repair | 62                         | 34                        | 96    |
| Washout + NVB repair | 31                         | 6                         | 37    |

Table 2 demonstrates that the type of surgical procedure required did not determine operative priority with a fairly equal proportions treated within 24 hours among the groups.

FTSG, full-thickness skin graft; NVB, neurovascular bundle; SSG, split skin graft.
postoperative infection rate for the patients treated within 24 hours was 1.8% (8 of 429 patients) as compared with 5.3% (11 of 209) in those treated over 24 hours after presentation. Using chi-square analysis, results demonstrated that patients managed over 24 hours after presentation have a statistically significant increased rate of infection with a \( P \) value of 0.024, an odds ratio of 2.9 (95% CI, 1.2–7.1) and a NNH of 29. Using a logistic regression model, the time to operating theater was not a significant predictor for infection (\( z = 1.208, P = 0.304 \)).

The median age of the patients was 34 years, and 79% were male (n = 502). The median age of patients who sustained a postoperative infection was 30 years. The shortest time to surgery was 1.7 hours, and the longest time to surgery was 95 hours with an average time to surgery of 21 hours. All patients sustained open hand injuries.

Of the 19 patients who developed an infection post-operatively, 2 had a significant risk factor for increased likelihood of developing an infection, that being type 2 diabetes mellitus with one from each group. Table 1 demonstrates the mechanisms of injury in the 19 patients who developed a postoperative infection. Their histories were reviewed, and no other contributing factors such as cardiovascular incident, comorbidities, or other life-threatening events were identified to have contributed to a delay to operative management or poor wound healing. Of these patients, 14 of these patients were treated successfully with oral antibiotics in the outpatient setting, 2 required readmission for intravenous antibiotics, and 3 patients required surgical debridement.

Analysis of 401 patients who sustained hand injuries requiring a washout with simple debridement, primary repair, and/or tendon repair, excluding any patient who had a neurovascular bundle repair, any form of graft, k-wire insertion, or plating/metalwork to repair a fracture demonstrated that 2 of the 277 patients treated within 24 hours developed an infection (0.7%) compared with 6 of the 118 patients treated over 24 hours after presentation (5.1%). This demonstrated an increased risk of infection with a \( P \) value of 0.012 and an odds ratio of 7.0 (95% CI, 1.2–7.1) and a NNH of 29. Using a logistic regression model, the time to operating theater was not a significant predictor for infection (\( z = 1.208, P = 0.304 \)).

Given these differences between chi-square and logistic regression models, an exact logistic regression model with 45,000 Monte Carlo iterations and time grouped into 1 hour intervals that gave a significant result, with an estimated co-efficient of 0.01194 (95% CI, 1.2–7.1) and a \( P \) value of 0.01564 (Monte Carlo n = 45,000), which was statistically significant.

**DISCUSSION**

This study reignites the debate of the existence of a “Golden Period.” Where the period within which open hand wounds should be managed was previously open ended (Angly et al., 2012; McLain et al., 1991; Zehtabchi et al., 2012), this study highlights that there may be a critical time within which hand trauma wounds should be surgically managed. Delayed treatment of open hand injuries may occur for reasons such as difficulty accessing centers with a hand surgery unit, bed allocation constraints, limitations of operating room availability, and other comorbidities or injuries that require stabilization prior surgery (Angly et al., 2012; Juon et al., 2014). Review of the literature since the introduction of antibiotic therapy suggests that the existence of a critical time period for repair is not proven; however, these conclusions are drawn from patients treated within a 24-hour period (Hollander et al., 2001; Zehtabchi et al., 2012). No study as yet has reliably determined a time limit for wound age beyond which the infection rate would increase significantly.

Despite thorough review of individual patient medical histories for factors which may contribute to the risk of infection, limitations such as incomplete medical records are a limitation of retrospective cohort analyses. There was no ability to randomize patients nor standardize preoperative and postoperative care; however, the unit policies for the management of hand trauma were followed for all patients. These included intravenous antibiotics before and on induction of surgery and a postoperative course of oral antibiotics, tetanus status was checked and updated if required, all wounds preoperatively were irrigated and redressed using sterile technique in the principle hospital where the operation was undertaken and all patients were followed up 7–14 days postoperatively in the principle hospital outpatient clinic. A small group of 12 patients were excluded as their care deviated from the standard unit management. Factors such as smoking status, completion of postoperative course of oral antibiotics, dressing type and redressing regime, level of wound irrigation, care rendered in the emergency department, or in other outside facilities could also be considered in future research. Larger cohort studies could further assess specific patient and treatment variables for incorporation into a multivariate analysis of patients sustaining a postoperative wound infection to further enhance these findings and analyze for contributing factors. Specific type of wound infection using microbial analysis, severity of infection, standardization of wound dressings, operative time duration, length of hospital stay, and hardware use could also be analyzed in future prospective studies.

A variety of hand wounds were considered in this research, including animal and human bites. Patients were triaged in order of presentation, with children under the age of 16 the only exception to this triaging rule. Patients with animal and human bite injuries were therefore not excluded from this analysis as they were not given operative theater time priority. Using 3 different hospital sites increased the population diversity of captured patients making the extrapolation of these results more applicable to the greater metropolitan area; however, further studies capturing patients from regional and rural settings would increase the strength of these results and the sample size.

Postoperative infections are a financial burden to the healthcare system with increased costs of readmission,
prolonged hospital stay, potential return to theater, use of hospital in the home/community nursing resources, and increased outpatient follow-up time. Additionally, there is a financial burden on public funding with postoperative infections delaying return to work and the long-term effects of increased scarring, chronic pain, and subsequent impaired joint mobility.

It is noted that the logistic regression model differed from the chi-square results and therefore we examined different cutoffs for bucketing the “Time to OT” predictor variable and found an additional significant cutoff at 6 hours, in addition to 24 hours as detailed earlier. This raised the question of whether the underlying distribution of the predictor variable, in addition to the relative rarity of the outcome variable, was causing the standard logistic regression to give a nonsignificant result (Fig. 1). Given this, we used an exact logistic regression model with 45,000 Monte Carlo iterations and time grouped into 1 hour intervals that gave a significant result. Future larger cohort studies could further assess this eliminating the need for exact logistic regression models.

CONCLUSIONS

There appears to be some evidence of a higher risk of postoperative infection in hand trauma patients surgically managed more than 24 hours after hospital presentation; however, when time is analyzed as a continuous variable, there is limited statistical significance. With increasing demands on the public healthcare system, patients are facing longer than 24 hour delays to surgery and to date there is a lack of research studying this time delay effect. This research appears to have implications for surgical hand wound management and recognizes time as an important factor perhaps overlooked in the management of open hand wounds. Further evaluation of this outcome should be considered with a larger cohort and standardization of perioperative management. This is the first study to raise the possibility of a double peak for infection risk giving basis for a larger prospective study which accounts for confounding variables to further assess the contention that a critical time period exists in the management of open hand wounds.

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