Which Factors Affect Ankle Joint Swelling in Ankle Fracture Patients? - Radiological Measurement Method

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Abstract

Background: Ankle joint swelling (AJS) in fracture patients is important for predicting soft tissue complications and deciding urgent surgery. Most surgeons still predict the progression of AJS based on their extensive experience. This study was conducted to identify factors that may affect the progression of AJS.

Methods: The clinical data and radiographic images of 120 patients who have undergone surgical treatment for ankle fracture were obtained. The immediate radiographs after surgery were representative of the swelling of the ankle joint, and the radiographs 2 weeks after device removal were representative of the normal ankle joint. We defined AJS as the sum of the ankle joint skin contour diameters in the anteroposterior and lateral views. We performed multivariate regression analysis to compare the correlation between variables and AJS.

Results: A total of 90 patients were included and followed up for an average of 18.1 months (range, 14–20). Three significant factors (preoperative serum glucose level, injury mechanism, and duration of surgery) were identified to affect AJS.

Conclusion: Elevated preoperative serum glucose level, high-energy injury, and extended duration of surgery were more likely to aggravate AJS. These findings will help surgeons to predict the prognosis of patients with AJS and to provide proper management for patients with an ankle fracture.

Level of Evidence: Retrospective cohort study, III

Background

Ankle fracture is one of the most common fractures, and a large number of patients require surgical treatment. Most cases of ankle fracture are followed by pain and swelling, which can induce blister formation. Swelling at the injured site is a normal healing process; however, overwhelming edema can have adverse effects. The progression of swelling in fracture patients is important for predicting soft tissue complications and deciding urgent surgery.

Initial inflammation occurs when a bone is broken. Immediately following injury, the damaged area becomes red, warm, and painful, and it begins to swell. The swelling process, also known as edema, is the result of acute inflammation, a response triggered by damage to living tissues. Following inflammation, the process to remove damaged tissues begins. As the blood vessels are dilated, redness and swelling progress. As a result, vascular permeability increases, and fluid, proteins, and white blood cells migrate to the damaged area. Swelling lasts for several days and is reduced following the removal of apoptotic cells by phagocytosis.

However, swelling, part of the healing response, can adversely affect the prognosis of fracture patients. Severe swelling induces blister formation, which can lead to infection and scarring. These soft tissue complications occur frequently in ankle fracture because the medial and lateral malleoli are located directly
under the skin.\(^1\) A previous study of tibial plateau fracture suggested within 4 hours and 5–8 days after trauma as the optimal surgical timing. When there is no obvious swelling or subsided limb swelling, significantly lower wound complication rates were observed.\(^2\) Furthermore, although it is rare in the ankles, compartment syndrome can develop with severe swelling, similar to the lower legs and forearms. Clinical awareness, early fasciotomy, and fracture fixation could prevent the potentially disastrous sequelae of compartment syndrome.\(^3\) To prevent adverse side effects, urgent surgery is recommended in most cases of ankle fracture. Previous studies have reported higher rates of infection and longer hospital stays with delayed surgery compared with early surgery\(^4\)–\(^6\).

Most surgeons still predict the progression of ankle joint swelling (AJS) based on their extensive experience; however, factors that could specifically affect swelling have not been identified. To predict the progression of soft tissue injury, the factors affecting swelling should be clarified. The purpose of this study was to identify factors that may affect the progression of AJS. This study hypothesized that elevated preoperative serum glucose level and high-energy injury are related to the progression of AJS.

**Methods**

**Study population**

Our institutional review board approved this retrospective study (IRB No. 2019-04-003). From January 2016 to January 2018, the clinical data and radiographic images of 120 patients who have undergone operative treatment for ankle fracture were obtained retrospectively. The inclusion criteria were as follows: 1) ankle fracture, 2) aged 20–80 years, and 2) surgery within 24 hours after injury. The exclusion criteria were as follows: 1) combined lower leg and foot injury, 2) short follow-up period of less than 1 year, 3) pathologic fracture, 4) external fixator application, and 5) open fracture (Fig. 1).

**Surgical timing and procedure**

Operative treatment was performed within 24 hours for all patients. The surgical procedures differed according to the fracture pattern; however, open reduction and internal fixation were performed using an anatomical locking plate and screws as the basic method. The device was removed around 1 year postoperatively.

**Radiographic evaluation and AJS measurement**

All radiographic images including the ankle anteroposterior view, lateral view, and the mortise view (non-weight bearing) were taken at arrival in the emergency room, the immediate postoperative period, the postoperative device removal, and the postoperative 2 weeks of device removal. Radiographic calibration was performed using a 10 cm ruler marker. There is still no established method of AJS measurement using radiographic images. Therefore, we defined AJS as the sum of the ankle joint skin contour diameters in anteroposterior and lateral views. We defined the immediate postoperative radiographic image of the ankle joint as indicating a swollen status and the postoperative 2 weeks of device removal image as indicating a normal status. At the time of the emergency room visit, swelling did not reach a peak, and considering that
intraoperative factors may affect swelling, the radiograph of the ankle joint immediately after surgery was regarded as indicating a swollen status. The results are unlikely to be affected by the implanted plate as the same thickness plate was used in all patients. The contralateral radiograph showing a ‘normal status’ ankle joint could not be obtained; thus, the postoperative 2 weeks of device removal radiograph (closest to the normal status) was used. In the anteroposterior view, we drew a line between the medial and lateral malleolus skin contour parallel to the tibia plafond. In the lateral view, we drew an extended line between the point of the anterior and posterior tibial plafond (Fig. 2). Considering the individual BMI, the value obtained by dividing the difference between the two values by the postoperative 2 weeks value after device removal (defined as the normal value) was used as the %AJS. The measurement was performed by two orthopedic surgeons. Interobserver and intraobserver reliabilities were assessed by calculating the interclass correlation coefficient.

Clinical factors potentially associated with the worsening of AJS

We determined the effects of several variables on AJS, which included sex, age, BMI (kg/m²), hypertension, diabetes mellitus, preoperative serum glucose level (mg/dL), injury mechanism, timing of surgery after injury, duration of surgery, presence of pilon fracture, presence of Maisonneuve fracture, Danis-Weber classification, and fracture-dislocation injury. The injury mechanism was divided into three categories: simple fall (low-energy injury), sports injury (medium-energy injury), and traffic accident injury (high-energy injury). A comparison was performed between high- and low-energy injuries and medium- and low-energy injuries.

Statistical analysis

The Shapiro-Wilk test was used to confirm the distribution of continuous variables. Descriptive data are presented as the mean and 95% confidence interval for continuous variables, and categorical variables are expressed as the absolute value and percentage. Univariate and multivariate regression analyses were conducted to determine the association of the variables with AJS. The backward elimination method was used to select variables. For categorical variables, the values were converted to dummy variables. The data were analyzed using SPSS version 23.0 statistical software package (IBM Corp., Armonk, NY) to identify the factors related to AJS. p values < 0.05 were defined as significant.

Results

A total of 90 patients were followed up for an average of 18.1 months (range, 14–20). The sex and injury site ratios were similar. The interobserver and intraobserver reliabilities were satisfactory (mean interclass correlation coefficient of 0.95 and 0.83, respectively). Two of the four patients diagnosed with diabetes had a preoperative glucose level (mg/dL) of 200 or more. Other patients had a level within a normal range. Patients who simply fell and had Danis-Weber type B fracture were the largest group of patients. Surgery required an average of 4.98 hours (95% CI, 4.28–5.70) after the emergency room visit, and the average surgery duration was 96.33 minutes (95% CI, 86.73–107.33) (Table 1).
Table 1
Patient demographic features

| No. of patients | 90 |
|-----------------|----|
| Sex (male/female) | 49 (54.4%) / 41 (45.6%) |
| Follow-up (months) | 18.1 (14–20) |
| Age (years) | 44.62 (41.26–47.98) |
| Injury site (right/left) | 43 (47.8%) / 47 (52.2%) |
| BMI (kg/m$^2$) | 25.14 (24.32–25.94) |
| Hypertension | 13 (14.4%) |
| Diabetes mellitus | 4 (4.4%) |
| Preoperative serum glucose level (mg/dL) | 115.16 (110.10–121.23) |
| Injury mechanism (slip down/sports injury/traffic accident) | 45 (50%) / 28 (31.1%) / 17 (18.9%) |
| Timing of surgery after injury (hours) | 4.98 (4.28–5.70) |
| Duration of surgery (minutes) | 96.33 (86.73–107.33) |
| Denis-Weber classification (A/B/C/others*) | 7 (7.8%) / 63 (70%) / 17 (18.9%) / 3 (3.3%) |
| Fracture-dislocation injury | 12 (13.33%) |
| Pilon fracture | 3 (3.3%) |
| Bimalleolar fracture | 62 (68.9%) |
| Trimalleolar fracture | 25 (27.8%) |

Data are expressed as the mean and 95% confidence interval (CI).

BMI, body mass index

*Pilon fracture

Three significant factors were identified to affect AJS by multivariate regression analysis, which were preoperative serum glucose level, injury mechanism, and duration of surgery. The model was determined by 13 steps of backward elimination, and there was no multicollinearity variable ($R = 0.475, R^2 = 0.225$). For the preoperative serum glucose level, an association was observed with a standardized beta coefficient of 0.187 ($p$ value = 0.078). In terms of the injury mechanism, an association was observed for patients who were in a traffic accident compared with patients who simply fell ($p$ value = 0.001, standardized beta coefficient = 0.344). Furthermore, the duration of surgery showed a significant association ($p$ value = 0.017, standardized beta coefficient = 0.021) (Table 2).
Table 2
Univariate and multivariate regression analysis of factors affecting ankle joint swelling

|                                | Univariate |                      |                      |                      | Multivariate |                      |                      |                      |                      | p value |
|--------------------------------|------------|-----------------------|----------------------|----------------------|--------------|-----------------------|----------------------|----------------------|----------------------|---------|
|                                | B          | SE                    | Standardized B       | p value              | B           | SE                    | Standardized B       | p value              |                      |         |
| Sex (male vs. female)          | -1.387     | 0.830                 | -0.176               | 0.098                |              |                       |                      |                      |                      |         |
| Age (years)                    | -0.003     | 0.027                 | -0.013               | 0.903                |              |                       |                      |                      |                      |         |
| BMI (kg/m\(^2\))              | -0.075     | 0.109                 | -0.073               | 0.494                |              |                       |                      |                      |                      |         |
| Hypertension                   | 0.397      | 1.193                 | 0.035                | 0.740                |              |                       |                      |                      |                      |         |
| Diabetes mellitus              | 0.749      | 2.035                 | 0.039                | 0.714                |              |                       |                      |                      |                      |         |
| Preoperative serum glucose level (mg/dL) | 0.028     | 0.016                 | 0.187                | 0.078                | 0.033       | 0.016                 | 0.220                | 0.043*               |                      |         |
| Injury mechanism (sports injury vs. slip down) | -0.904 | 0.901                 | -0.106               | 0.319                |              |                       |                      |                      |                      |         |
| Injury mechanism (traffic accident vs. slip down) | 3.455 | 1.007                 | 0.344                | 0.001*               | 3.281       | 0.975                 | 0.326                | 0.001*               |                      |         |
| Timing of surgery after injury (hours) | 0.010 | 0.122                 | 0.009                | 0.934                |              |                       |                      |                      |                      |         |
| Duration of surgery (minutes)  | 0.021      | 0.009                 | 0.251                | 0.017*               | 0.023       | 0.008                 | 0.278                | 0.005*               |                      |         |
| Pilon fracture                 | 3.601      | 2.306                 | 0.164                | 0.122                |              |                       |                      |                      |                      |         |
| Maisonneuve fracture           | -3.256     | 2.826                 | -0.122               | 0.252                |              |                       |                      |                      |                      |         |
| Denis-Weber classification (B vs. A) | -0.009 | 0.916                 | -0.001               | 0.992                |              |                       |                      |                      |                      |         |

B, beta coefficient; SE, standard error of the mean; BMI, body mass index

*p value < 0.05
### Table

|                          | Univariate |          |          | Multivariate |
|--------------------------|------------|----------|----------|--------------|
| Denis-Weber classification (C vs. A) | 0.001      | 1.072    | 0.000    | 0.999        |
| Fracture-dislocation injury | -0.854     | 1.231    | -0.074   | 0.490        |

B, beta coefficient; SE, standard error of the mean; BMI, body mass index

*p value < 0.05

### Discussion

In the present study, we identified three significant factors affecting the progression of AJS, which were preoperative serum glucose level, injury mechanism, and duration of surgery. These results supported our hypothesis that elevated preoperative serum glucose level and high-energy injury are related to the progression of AJS.

A previous study has reported that preoperative serum glucose levels could affect the formation of fracture blisters. Quavedo et al. found that the presence of postoperative blisters in ankle fracture was associated with prolonged surgical procedures and high serum glucose levels. Blister formation is proposed to result from the increased interstitial pressure of post-traumatic swelling. This decreases the cohesion between epidermal cells and facilitates fluid transport into the blister cavity. Diabetic patients are prone to nonenzymatic glycosylation and are exposed to glycation end products. These products lead to the disjunction and abnormal function of soft tissues. Four patients were diagnosed with diabetes in this study. However, two of the four diagnosed patients had normal preoperative serum glucose levels. It can be assumed that serum glucose levels before surgery are relevant rather than whether diabetes is diagnosed. In comparison with patients who simply fell, patients injured by traffic accidents showed a tendency of swelling. A previous study reported a significantly higher incidence of perioperative soft tissue complications after high-energy trauma and primary soft tissue injury. Varela et al. showed an association between high-energy injury and the formation of fracture blisters. The duration of surgery was also correlated with AJS in this study. Usually, surgeons try to shorten the surgical time to prevent infection, soft tissue damage, tourniquet syndrome, etc. Surgical time is often prolonged by the difficulty in reducing swelling. It is known that a series of processes for reducing fracture fragments can cause soft tissue damage, and the swelling is more severe.

Swelling is a normal body defense mechanism that responds to fractures. Due to swelling, substances and cells for fracture healing are sent to the fracture site, and unstable sites can be mechanically protected. However, if the healing process is excessive, it can have an adverse effect. Excessive fluid retention can cause blisters and infections at surgical sites. Moreover, persistent inflammation and swelling can cause muscle atrophy around the joints and a decrease in physical ability. To reduce the adverse effect caused by
severe swelling, immediate reduction, immobilization, elevation, and urgent surgery should be performed as soon as possible after trauma. Furthermore, close observation of the surgical wound is required.

There are several limitations in our study. First, it is unclear whether the radiological measurement results are representative of AJS. If techniques such as figure-of-eight and water volumetry methods were used, a more accurate result could be obtained. Second, we defined the postoperative 2 weeks of device removal radiograph of the ankle joint as indicating a normal status. However, even at that time, swelling can still be caused by an incision at the surgical site. If we can obtain a contralateral radiograph of the ankle at the point of injury, a more accurate comparison would have been possible. Finally, the study was conducted retrospectively. A study comparing more variables with randomized controlled trials should be conducted.

This is the first study of factors affecting swelling in fracture patients. In this study, only ankle fracture was assessed; however, the results could be applied to other fracture areas. In particular, the findings may be applicable to forearm and leg fractures, where compartment syndrome is common. For patients with swelling-related factors, we could prevent more severe swelling and determine whether urgent surgery is required.

Conclusion

In conclusion, preoperative serum glucose level, high-energy injury, and duration of surgery were more likely to affect the progression of AJS in fracture patients. These findings will help surgeons to predict the progression of AJS and to provide proper management for patients with an ankle fracture.

List Of Abbreviations

AJS; Ankle joint swelling, BMI; Body mass index

Declarations

Ethics approval and consent to participate

Our institutional review board approved this retrospective study (Institutional Review Board CHA Bundang Medical Center, CHA University, Approval No. 2019-04-003).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests

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None received.

**Authors’ contributions**

SL, CH was involved in acquiring the data, writing the manuscript and also researching the topic. KC performed the data acquisition, analysis of results, statistical testing, YC conceived the study and performed all of the surgery and prepared and edited the manuscript. All authors read and approved the final manuscript.

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