Epidemiology of syndesmotic fixations in a pediatric center
A 12-year retrospective review

Stéphanie Lamer, MD\textsuperscript{a,b}, Jonah Hébert-Davies, MD\textsuperscript{b,c}, Stéphane Leduc, MD\textsuperscript{b,c}, Marie-Lyne Nault, MD, PhD\textsuperscript{b,c,*}

Abstract
Syndesmosis injuries need to be accurately diagnosed and managed to avoid chronic pain, early arthritis, and instability. To this end, the present study aimed to analyze the epidemiology of syndesmotic injuries in a pediatric ankle fracture cohort and identify patient and surgery-related characteristics.

A retrospective review of all the ankle fractures during a 12-year period at a single pediatric referral center was conducted. Inclusion criteria were: a fractured ankle that underwent a surgical fixation, at least 1 radiograph available for review before fixation, available information regarding surgery, including operative report and fluoroscopic images, and younger than 18 years at the time of surgery. Demographic information, trauma, radiographs, surgical details, clinical examination, follow up, outcomes, and physes status (skeletally immature, transitional, or mature) were recorded. Finally, patients were divided in 2 groups: with or without syndesmotic fixation. Statistical analysis included descriptive statistics, Mann–Whitney test for nonparametric data to compare continuous parameters, and $\chi^2$ test for categorical parameters.

A total of 128 patients were included with a mean age of 14.1 years. There were 80 boys and 48 girls. There were 51 skeletally immature patients, 23 with transitional fractures, and 54 that were skeletally mature. The main finding of this study is that only 11 patients from the mature group underwent syndesmotic fixation. There were no cases of syndesmotic fixation in the skeletally immature and transitional groups.

This is the first retrospective study to focus specifically on syndesmotic injuries in a pediatric population who underwent ankle fracture fixation. Only 11 skeletally mature patients underwent syndesmotic fixation out of 128 patients in this cohort. This result raises the question of whether there are accurate diagnostic tools to evaluate syndesmosis in children.

Abbreviations: MRI = magnetic resonance imaging, ORIF = open reduction and internal fixation.

Keywords: ankle, high ankle sprain, pediatric, syndesmosis

1. Introduction
Pediatric ankle injuries differ from those in the adult population in many ways. One important difference is the greater tensile strength in immature ligaments that often leads to a higher proportion of fractures, rather than sprains, in young patients.\textsuperscript{1–5} Furthermore, the increasing participation of skeletally immature athletes in high-level sports creates injury patterns not commonly found in adults.\textsuperscript{6} Although injury types, diagnostic methods, and treatment have been accurately described for syndesmotic injuries in the adult population,\textsuperscript{7} the same cannot be said for the pediatric population. Indeed, little is known about pediatric syndesmotic injuries and poorer outcomes have often been described in the young athletic population following syndesmosis strain.\textsuperscript{8} In both adults and adolescents, this injury can cause chronic ankle pain and post-traumatic arthritis when not properly treated.\textsuperscript{9,10}

The distal tibiofibular relationship is very difficult to qualify in children because of the ongoing ossification process. Although imperfect, magnetic resonance imaging (MRI) remains the best diagnostic tool available.\textsuperscript{10} However, according to Bozic et al, adult radiographic criteria used to assess syndesmosis integrity cannot be applied to the pediatric population.\textsuperscript{11} This raises the question of whether the lack of evidence for syndemistic injuries in skeletally immature children is the result of inadequate diagnostic methods, or whether this type of injury truly is almost nonexistent at this age.

To achieve a better understanding of this question, a retrospective study was undertaken to describe the epidemiology of syndesmotic fixations in a pediatric population and identify patient and surgery related characteristics. The rationale for this study was to set the stage for future research on pediatric syndesmosis injury.
2. Materials and methods
A retrospective review of all the ankle fractures occurring during a 12-year period at a single pediatric referral center was conducted. A database search of medical records of all pediatric patients who underwent surgical fixation of an ankle fracture from 2002 to 2013 at our level 1 referral pediatric center was undertaken. This retrospective study was approved by the local Director of Medical and Academic Affairs and Research Ethic Board of CHU Sainte-Justine. The 7 following keywords were used to ensure no patients were unintentionally excluded: ankle ORIF (open reduction and internal fixation), syndesmosis ORIF, malleolar ORIF, triplane, Tillaux, ankle fracture, and pilon fracture. The following inclusion criteria were selected to have the necessary patient information: a fractured ankle that underwent surgical fixation, at least 1 radiograph available for review before fixation, available information regarding surgery including operative report and fluoroscopic images, being younger than 18 years at time of surgery. Demographic data, trauma, radiographs, surgical details, clinical examination, follow-up, and outcomes were retrieved from patient charts.

Final diagnosis and ankle fracture classification based on physis status (immature, transitional, or mature skeleton) were determined on preoperative radiographs by a fellowship trained pediatric orthopaedic surgeon to reduce the chance of misclassification. Patients were then separated into 2 groups, depending on whether or not they had undergone syndesmotic fixation.

Demographic data recorded were sex, age at the time of fixation, month of the surgery, time between trauma and surgery, operative time, relevant patient history, surgeon, injury mechanism, length of follow-up, and time between surgery and removal of plate and screws when applicable. Additionally, preoperative evaluation, intraoperative tests to evaluate syndesmotic stability, all relevant imaging and final post-operative follow-up data were reviewed. Complications were noted, including residual pain and swelling, wound healing, deformity, neurovascular impairment, and decreased range of motion. Postoperative range of motion was recorded and was compared to normal values, according to sex and age, based on the guidelines published by Grimston et al. [12].

Statistical analysis included descriptive statistics, Mann–Whitney test for nonparametric data to compare continuous parameters, and $\chi^2$ test for categorical parameters. Statistical analysis was performed with SPSS 20.0 (IBM Armonk, NY).

3. Results
A total of 132 fractures were identified from the retrospective database. Four did not match the cohort’s inclusion criteria (no preoperative radiographs available), leaving 128 fractures for analysis. The average age at the time of surgery for the entire cohort was 14.5 years for boys and 13.4 years for girls. There were 51 skeletally immature patients, 23 with transitional fractures, and 54 that were skeletally mature.

3.1. Epidemiology of syndesmotic fixation
Eleven patients from the mature group had undergone a syndesmotic fixation. There were no cases of syndesmotic fixation in the skeletally immature and transitional groups. Results comparing patients with and without syndesmotic fixation are shown in Table 1 and Table 2. There were no missing data for the variables included in Table 1 and Table 2.

3.2. Patient and surgery characteristics associated to syndesmotic fixation
There was no statistical difference between the mechanism of injury for syndesmotic injuries compared to other mature ankle fractures. Among the 43 fractures in the mature group without syndesmotic fixation, 8 occurred in a motor vehicle accident, 12 occurred during daily living activities, and 23 occurred while playing sports. In the syndesmosis group, 3 injuries occurred in a motor vehicle accident, 3 occurred during daily living activities, and 5 occurred while playing sports. No statistical significance was found using $\chi^2$ test ($P = .688$).

Total surgical time was the only statistically significantly different data between the 2 groups, those involving syndesmotic fixation taking significantly longer than those without syndesmotic fixation (2 hour 8 minutes vs 1 hour 34 minutes, $P = .007$). There was no significant difference in follow-up length and in the delay between fixation and removal of plate and screws between patients with syndesmotic fixation and all the others, regardless of their physal status. However, as all syndesmotic fixations were in the mature group, fractures with closed physis were

| Table 1 | Descriptive parameters comparing the ankle fractures according to the presence of syndesmotic fixation. |
|---------|--------------------------------------------------------------------------------------------------|
| **Descriptive parameters** | **Ankle fractures without syndesmotic fixation** | **Ankle fractures with syndesmotic fixation** |
| N       | 117                                               | 11                                               |
| Sex     |                                                   |                                                  |
| M       | 73                                                | 7                                                |
| F       | 44                                                | 4                                                |
| Age, y  | 14.0                                              | 15.1                                             | .132                                           |
| Operative time, h | 1:34                                              | 2:08                                             | .007                                           |
| Follow-up length, mo | 12.1                                              | 16.6                                             | .271                                           |
| Plate and screws removal | 49                                                | 6                                                |                                                  |
| Time length between fixation and plate and screws removal, mo | 10.1                                              | 8.8                                              | .484                                           |

| Table 2 | Descriptive parameters comparing skeletally mature patients according to their syndesmotic status. |
|---------|--------------------------------------------------------------------------------------------------|
| **Descriptive parameters** | **Mature group without syndesmotic fixation** | **Mature group with syndesmotic fixation** |
| N       | 43                                                | 11                                               |
| Sex     |                                                   |                                                  |
| M       | 25                                                | 7                                                |
| F       | 18                                                | 4                                                |
| Age, y  | 15.1                                              | 15.1                                             | .614                                           |
| Operative time, h | 1:31                                              | 2:08                                             | .007                                           |
| Follow-up length, mo | 7.1                                               | 16.6                                             | .029                                           |
| Plate and screws removal | 13                                                | 6                                                |                                                  |
| Time length between fixation and plate and screws removal, mo | 8.9                                               | 8.8                                              | .467                                           |
divided in 2 subgroups, based on syndesmotic fixation (Table 2). Again, surgeries with syndesmotic fixations were significantly longer than those without (2 hour 8 minutes vs 1 hour 31 minutes, \( P=.007 \)). Furthermore, patients having undergone a syndesmotic fixation had a longer average follow-up (16.6 months vs 7.1 months, \( P=.029 \)). Among the syndesmotic fixation group, 6 had 2-screw fixation (3 with 3.5-mm screws and 3 with 4.5-mm screws), 4 had 1-screw fixation (3.5mm), and 1 underwent syndesmotic fixation with a single tight rope. Figure 1 shows an example of fibular plating with syndesmotic fixation. Time between fixation and plate and screws removal was comparable in both groups.

Discrete numerical data for range of motion were only available in 42% of patients. When compared to normal range of motion values described by Grimston et al,\(^{[12]}\) both postoperative dorsiflexion and plantarflexion were not significantly different for patients with syndesmotic fixations compared to those without. There were 32 cases of minor complications (17 persistent edemas and 15 hypertrophic/adherent scarring) of 128 patients. More severe complications included peroneal nerve hypoesthesia in 3 patients and postoperative coronal plane deformity in 11 patients. Details of all complications are presented in Table 3. Unfortunately, owing to the small size of the syndesmotic group (11 patients), it was not possible to compare complication rates between the 2 groups.

Owing to the retrospective nature of this study, there were some missing data in the patient charts and, therefore, they were not included in the statistical analysis. However, there were no missing data in the descriptive parameters displayed in Tables 1 and 2.

### 4. Discussion

Our objectives were to analyze the epidemiology of syndesmotic injuries in a pediatric ankle fracture cohort and identify patient and surgery-related characteristics. The main finding of our study was the absence of syndesmotic fixation in the skeletally immature population.

Diagnosis of syndesmotic injuries can be difficult in the adult population\(^{[13–15]}\) and even more so in the pediatric population because of the undergoing ossification process.\(^{[10]}\) This could explain, in part, why the 11 patients requiring syndesmotic fixation were all skeletally mature. Compared to other studies, the proportion of syndesmotic injuries in the skeletally mature patients in this cohort (20%) is similar to existing data on ankle fractures in adults.\(^{[7,16,17]}\) The absence of syndesmotic injury fixation in the 2 immature groups raises the following questions: either syndesmotic injuries are essentially nonexistent in skeletally immature patients or they cannot be diagnosed accurately with current techniques.

Diagnosis of syndesmotic injury in adults is made either on preoperative imagining or intraoperatively with stress testing. Several radiological criteria and stress tests have been defined for the adult population, although their reliability has been disputed.\(^{[11,13,18–24]}\) However, according to Bozic et al, these

| Complications                        | No syndesmotic fixation | Syndesmotic fixation | Total |
|--------------------------------------|-------------------------|----------------------|-------|
| Total                                | 117                     | 11                   | 128   |
| Postoperative edema status           |                         |                      |       |
| Normal evolution                     |                         |                      |       |
| Presence of edema at the last follow-up | 101                     | 5                    | 106   |
| Missing information                  | 13                      | 4                    | 17    |
| Missing information                  | 3                       | 2                    | 5     |
| Postoperative wound status           |                         |                      |       |
| Normal evolution                     | 102                     | 9                    | 111   |
| Hypertrophic or adherent             | 14                      | 1                    | 15    |
| Missing information                  | 1                       | 1                    | 2     |
| Postoperative deformation status     |                         |                      |       |
| Normal evolution                     | 107                     | 9                    | 116   |
| Valgus deformation                   | 5                       | 0                    | 5     |
| Varus deformation                    | 3                       | 0                    | 3     |
| Pseudarthrosis                       | 1                       | 0                    | 1     |
| Arthritis/chondrolysis               | 1                       | 0                    | 1     |
| Talus deformation                    | 0                       | 1                    | 1     |
| Missing information                  | 0                       | 1                    | 1     |
| Postoperative neurovascular status   |                         |                      |       |
| Normal evolution                     | 114                     | 10                   | 124   |
| Deep fibular nerve hypoesthesia      | 1                       | 0                    | 1     |
| Superficial fibular                  | 2                       | 0                    | 2     |
| Nerve hypoesthesia                   | 0                       | 1                    | 1     |
radiologic criteria are not reliable in the pediatric population because of the progressive appearance of the incisura fibularis.\[11]\n
Furthermore, in the current cohort, only 21 syndromoses underwent intraoperative stress testing. Although some patients could have been tested without it being recorded in the operative report, syndrometic testing is definitely not routine during most pediatric ankle fracture fixations where the study was conducted.

Ideally, patients should undergo systematic intraoperative syndromesis evaluation to help establish radiological criteria (tibiofibular clear space, tibiofibular overlap, and medial clear space) for both stable and unstable joints. However, even in adults, intraoperative radiological criteria to assess syndromesis stability have been reported to be unreliable.\[23]\n
Theoretically, a combination of radiological assessment and direct visualization would allow adequate evaluation of syndromesis integrity, but this can be challenging depending on the type of fracture and the fixation technique.\[25]\n
Recently, Kramer et al.\[26]\nconducted a study evaluating isolated syndromesis injuries and their risk factors in the pediatric population. Their results showed that 43 of 220 patients had syndrometic injuries with open physes, but only 9 required syndrometic fixation.\[26]\n
They concluded that an open physe might be a protective factor against syndrometic ligamentous injury without associated ankle fracture. They also concluded that syndrometic fixations were most often associated with closed physes and combined ankle fractures.\[26]\n
In the present study, syndrometic fixation was only found in the skeletally mature children and severe syndrometic injuries were only reported in the mature group, with minor injuries (thus not requiring fixation) in the skeletally immature children. Because Kramer et al. used standard adult radiological criteria to diagnose syndrometic injuries, they could have overestimated the prevalence of these injuries in immature patients.\[11,26]\n
Furthermore, if x-rays were inconclusive, they used physical examination (positive squeeze test, tenderness over the syndesmosis, pain with external rotation of the foot) to help confirm diagnosis.\[26]\n
Although this may be common practice, it has not been shown to accurately diagnose a syndromesis injury and can be another reason why Kramer et al. may have overestimated the rate of syndrometic injuries in skeletally immature patients.\[19,27–29]\n
Accurate diagnosis and treatment are important as syndrometic injuries are associated with poorer outcomes. Indeed, Gerber et al. found that syndrometic strains are a strong predictor of chronic ankle disability. Boytim et al.\[20]\ncompared lateral ankle sprains and syndrometic sprains in a professional football team and also reported a prolonged recovery time and the need for more treatment when the syndromesis was affected. In the present study, when comparing the skeletally mature patients, the follow-up time was also significantly longer for those with syndrometic fixation. The fact that syndrometic injuries are more complex and high-energy might explain why they require a longer recovery time.

Syndrometic injury is not well understood in children (under-diagnosed, no tests specific to immature skeleton) and specific diagnostic methods and criteria are needed to accurately assess syndrometic instability in the pediatric population and prevent long-term complications. A diagnostic test should be developed and validated to classify syndrometic injuries. Then, it will be possible to undertake a prospective study to assess the mid- and long-term quality of life after this type of injury in a pediatric population. These promising research avenues are currently being pursued.

There are several limitations to this study, mostly deriving from its retrospective nature. There were missing data and data collection was not standardized which could create some interpretation bias. Furthermore, the data were collected 5 years ago but the conclusions that can be drawn from them remain. Finally, the follow-up was shorter than is normally deemed optimal, and the syndrometic group was too small to perform a well-powered analysis. However, the present study also has several strengths including the long time-period covered and the relatively large number of patients included. It is also one of the few studies specifically focused on the issue of syndrometic fixation in a pediatric population treated for ankle fractures.

5. Conclusions

Surgical fixation of syndrometic injuries associated with ankle fractures is rare in the pediatric population. All patients who had a syndrometic fixation in this study were skeletally mature, which raises the question of whether the diagnostic tools to detect syndrometic injuries in skeletally immature patients are accurate. This study is a first step which could help launch new prospective research to address these shortcomings, potentially improve diagnostic accuracy and, eventually, patient outcomes.

Author contributions

Conceptualization: Jonah Hébert-Davies, Stéphane Leduc, Marie-Lyne Nault.

Data curation: Stéphanie Lamer.

Formal analysis: Marie-Lyne Nault.

Funding acquisition: Marie-Lyne Nault.

Investigation: Jonah Hébert-Davies, Stéphane Leduc, Marie-Lyne Nault.

Project administration: Marie-Lyne Nault.

Supervision: Marie-Lyne Nault.

Writing – original draft: Stéphanie Lamer, Marie-Lyne Nault.

Writing – review & editing: Jonah Hébert-Davies, Stéphane Leduc.

References

[1] Lee MC, Parrino A. Ankle fractures in children. Curr Orthop Pract 2013;24:617–24.

[2] Kay RM, Matthis GA. Pediatric ankle fractures: evaluation and treatment. J Am Acad Orthop Surg 2001;9:268–78.

[3] Wuerz TH, Gurd DP. Pediatric physical ankle fracture. J Am Acad Orthop Surg 2013;21:234–44.

[4] Marsh JS, Daigneault JP. Ankle fractures in children. J Bone Joint Surg Am 2012;94:1234–44.

[5] Blackburn EW, Aronsson DD, Rubright JH, et al. Ankle fractures in children. J Bone Joint Surg Am 2012;94:1234–44.

[6] Frank JB, Jarit GJ, Bravman JT, et al. Lower extremity injuries in the skeletally immature athlete. J Am Acad Orthop Surg 2007;15:356–66.

[7] Van Heest TJ, Lafferty PM. Injuries to the ankle syndromesis. J Bone Joint Surg Am 2014;96-A:603–13.

[8] Gerber JP, Williams GN, Scoville CR, et al. Persistent disability associated with ankle sprains: a prospective examination of an athletic population. Foot Ankle Int 1998;19:633–60.

[9] Cummings RJ, Hahn GA. The incursural fracture. Foot Ankle Int 2004;25:132–5.

[10] Hermans JJ, Wentink N, Beumer A, et al. Correlation between radiological assessment of acute ankle fractures and syndrometic injury on MRI. Skeletal Radiol 2012;41:787–801.

[11] Bonc RJ, Jaramillo D, DiCanzio J, et al. Radiographic appearance of the normal distal tibiotibial syndromesis in children. J Pediatr Orthop 1999;19:14–21.
[12] Grimston SK, Nigg BM, Hanley DA, et al. Differences in ankle joint complex range of motion as a function of age. Foot Ankle Int 1993;14:215–22.
[13] Molinari A, Stolley M, Amendola A. High ankle sprains (syndesmotic) in athletes: diagnostic challenges and review of the literature. Iowa Orthop J 2009;29:130–8.
[14] McCollum GA, van den Bekerom MPJ, Kerkhoffs GMMJ, et al. Syndesmosis and deltoid ligament injuries in the athlete. Knee Surg Sports Traumatol Arthrosc 2013;21:1328–37.
[15] Williams GN, Jones MH, Amendola A. Syndesmotic ankle sprains in athletes. Am J Sports Med 2007;35:1197–207.
[16] Waterman RR, Belmont PJ, Cameron KL, et al. Risk factors for syndesmotic and medial ankle sprain: role of sex, sport, and level of competition. Am J Sports Med 2011;39:992–8.
[17] Hunt KJ, Goeb Y, Behn AW, et al. Ankle Joint Contact Loads and Displacement with Progressive Syndesmotic Injury. Foot Ankle Int 2015;36:1095–103.
[18] Lynch SA. Assessment of the injured ankle in the athlete. J Athl Train 2002;37:406–12.
[19] Nault ML, Hébert-Davies J, Laflamme GY, et al. CT scan assessment of the syndesmosis: a new reproducible method. J Orthop Trauma 2013;27:638–41.
[20] Oae K, Takao M, Naito K, et al. Injury of the tibiofibular syndesmosis: value of MR imaging for diagnosis. Radiology 2003;227:155–63.
[21] Jiang KN, Schulz BM, Tsui YL, et al. Comparison of radiographic stress tests for syndesmotic instability of supination-external rotation ankle fractures: a cadaveric study. J Orthop Trauma 2014;28:e123–7.
[22] Stoffel K. Comparison of two intraoperative assessment methods for injuries to the ankle syndesmosis: a cadaveric study. J Bone Joint Surg Am 2009;91:2646–52.
[23] Matuszewski PE, Dombroski D, Lawrence JTR, et al. Prospective intraoperative syndesmotic evaluation during ankle fracture fixation: stress external rotation versus lateral fibular stress. J Orthop Trauma 2015;29:e157–60.
[24] Pakarinen H, Flinkkilä T, Ohtonen P, et al. Intraoperative assessment of the stability of the distal tibiofibular joint in supination-external rotation injuries of the ankle. Sensitivity, specificity, and reliability of two clinical tests. J Bone Joint Surg Am 2011;93:2057–61.
[25] Gosselin-Papadopoulos N, Hébert-Davies J, Laflamme GY, et al. Direct visualization of the syndesmosis for evaluation of syndesmotic disruption: A cadaveric study. OTA Int 2018;2:e006.
[26] Kramer DE, Cleary MX, Miller PE, et al. Syndesmosis injuries in the pediatric and adolescent athlete: an analysis of risk factors related to operative intervention. J Child Orthop 2017;11:57–63.
[27] Ebraheim N, Lu J, Yang H. Radiographic and CT evaluation of tibiofibular syndesmotic diastasis: a cadaver study. Foot Ankle Int 1997;18:693–8.
[28] Mukhopadhyay S, Metcalfe A, Guha AR, et al. Malreduction of syndesmosis—are we considering the anatomical variation? Injury 2011;42:1073–6.
[29] Nicholson J, Gardner M, Peterson M, et al. Radiographic measurements do not predict syndesmotic injury in ankle fractures: an MRI study. Clin Orthop Relat Res 2005;216–21.
[30] Boytim MJ, Fischer DA, Neumann L. Syndesmotic ankle sprains. Am J Sports Med 1991;19:294–8.