

# Impact of centre volume, surgeon volume, surgeon experience and geographic location on reoperation after intramedullary nailing of tibial shaft fractures

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**Background:** Tibial shaft fractures are the most common long-bone injury, with a reported annual incidence of more than 75 000 in the United States. This study aimed to determine whether patients with tibial fractures managed with intramedullary nails experience a lower rate of reoperation if treated at higher-volume hospitals, or by higher-volume or more experienced surgeons.

**Methods:** The Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures (SPRINT) was a multicentre randomized clinical trial comparing reamed and nonreamed intramedullary nailing on rates of reoperation to promote fracture union, treat infection or preserve the limb in patients with open and closed fractures of the tibial shaft. Using data from SPRINT, we quantified centre and surgeon volumes into quintiles. We performed analyses adjusted for type of fracture (open v. closed), type of injury (isolated v. multitrauma), gender and age for the primary outcome of reoperation using multivariable logistic regression.

**Results:** There were no significant differences in the odds of reoperation between high- and low-volume centres ( $p = 0.9$ ). Overall, surgeon volume significantly affected the odds of reoperation ( $p = 0.03$ ). The odds of reoperation among patients treated by moderate-volume surgeons were 50% less than those among patients treated by very-low-volume surgeons (odds ratio [OR] 0.50, 95% confidence interval [CI] 0.28–0.88), and the odds of reoperation among patients treated by high-volume surgeons were 47% less than those among patients treated by very-low-volume surgeons (OR 0.53, 95% CI 0.30–0.93).

**Conclusion:** There appears to be no significant additional patient benefit in treatment by a higher-volume centre for intramedullary fixation of tibial shaft fractures. Additional research on the effects of surgical and clinical site volume in tibial shaft fracture management is needed to confirm this finding. The odds of reoperation were higher in patients treated by very-low-volume surgeons; this finding may be used to optimize the results of tibial shaft fracture management. **Clinical trial registration:** ClinicalTrials.gov, NCT00038129

**Contexte :** La fracture de la diaphyse tibiale est la plus commune des fractures des os longs, avec une incidence annuelle déclarée de plus 75 000 cas aux États-Unis. Cette étude visait à déterminer si les patients traités par enclouage intramédullaire pour une fracture du tibia sont moins souvent réopérés quand l'intervention est effectuée dans des établissements qui traitent de plus forts volumes de cas ou par des chirurgiens opérant un plus fort volume de cas ou plus expérimentés.

**Méthodes :** L'étude SPRINT (Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures) est un essai clinique multicentrique randomisé qui a comparé l'effet de l'enclouage alésé c. non alésé sur le taux des réinterventions visant à promouvoir la consolidation osseuse de la fracture, à traiter une infection ou à préserver le membre chez des patients victimes de fractures fermées ou ouvertes de la diaphyse tibiale. À partir des données de l'étude SPRINT, nous avons classé les établissements et les chirurgiens en quintiles selon les volumes de cas traités. Nous avons effectué des analyses ajustées en fonction du type de fracture (ouverte c. fermée), du type de blessure (isolée c. polytraumatisme), du sexe et de l'âge, pour établir le taux de réintervention (paramètre principal), en utilisant la régression logistique multivariée.

**Résultats :** On n'a noté aucune différence significative quant au risque de réintervention entre les centres qui traitaient des volumes élevés c. bas ( $p = 0,9$ ). Dans l'ensemble le volume d'opérations des chirurgiens a significativement influé sur le risque de réintervention ( $p = 0,03$ ). Le risque de réintervention chez les patients traités par des chirurgiens dont le volume d'interventions était moyen était de 50 % de moins que chez les patients traités par des chirurgiens dont le volume était très bas (risque relatif [RR] 0,50, intervalle de confiance [IC] à 95 % 0,28–0,88) et le risque de réintervention chez les patients traités par des chirurgiens dont le volume était très élevé était de 47 % de moins que chez les patients traités par des chirurgiens dont le volume était très bas (RR 0,53, IC à 95 % 0,30–0,93).

**Conclusion :** Il ne semble y avoir aucun bienfait additionnel significatif au fait d'être opéré dans un centre où le volume d'interventions pour enclouage intramédullaire des fractures de la diaphyse tibiale est élevé. Il faudra approfondir la recherche sur les effets du volume chirurgical et de l'expérience clinique des établissements pour confirmer cette observation. Le risque de réintervention a été plus élevé chez les patients traités par des chirurgiens dont le volume d'interventions était très bas; cette observation pourrait être utilisée pour optimiser l'issue du traitement des fractures de la diaphyse tibiale. Enregistrement de l'essai clinique : ClinicalTrials.gov, NCT00038129.

**T**ibial shaft fractures are the most common long-bone injury, with a reported annual incidence of more than 75 000 in the United States.<sup>1</sup> Treatment aims to achieve union of the bone with good alignment while minimizing complications, such as infection and nonunion, which often necessitate secondary operations or reoperations to promote bone healing. Certification data for orthopedic surgeons show that intramedullary nailing of the tibial shaft is a procedure routinely performed in the practice of general orthopedic surgeons and orthopedic trauma surgeons.<sup>2</sup>

Data from a number of medical and surgical disciplines suggest that surgical volume significantly affects mortality and complications.<sup>3–5</sup> The inference is that higher volume leads to more experience, which translates to better patient outcomes. This relation also exists in the field of orthopedic surgery.<sup>6–9</sup> However, in orthopedic surgery, much of the research has focused on patients having primary hip or knee arthroplasty.<sup>10,11</sup> Findings from a systematic review examining the association between surgeon volume and primary knee arthroplasty outcomes suggested that, overall, there was a trend toward better outcomes for patients of high-volume surgeons.<sup>10</sup> Another study investigating the association between surgeon and hospital volumes and patient outcomes after hip fracture surgery provided evidence that surgeon volume, but not hospital volume, was associated with decreased mortality.<sup>11</sup> However, findings from that study suggested that both surgeon and hospital volume may be associated with nonfatal morbidity and length of stay. To our knowledge, no previous study has described the relation between surgeon and hospital volume and outcome in patients with tibial fractures.

The Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures (SPRINT) was a multinational multicentre randomized clinical trial comparing reamed and nonreamed intramedullary nailing on rates of reoperation to promote fracture union, treat infection or preserve the limb in patients with open and closed fractures of the tibial shaft.<sup>12,13</sup> Using data from

SPRINT, we aimed to determine the effect of centre volume, surgeon volume, surgeon experience and geographic location on reoperation following intramedullary nailing of fractures of the tibia.

## METHODS

### *Design and setting*

This secondary analysis aimed to determine the effect of centre volume, surgeon volume, surgeon experience (resident v. fellow v. attending surgeon) and geographic location (US v. Canada v. the Netherlands) on reoperation to promote healing, treat infection or preserve the limb in patients with open and closed fractures of the tibial shaft enrolled in SPRINT (ClinicalTrials.gov, NCT00038129). The trial received approval from the McMaster Research Ethics Board (REB# 99–077) and from the research ethics boards of all participating clinical sites. A total of 1226 adults with a closed or open tibial shaft fracture amenable to management with an intramedullary nail were enrolled from Canada, the US and the Netherlands. The methodology and trial results have been described elsewhere.<sup>12,13</sup>

### *Outcome measures*

The primary outcome was reoperation to achieve fracture union, measured 12 months postoperatively.<sup>13</sup> Secondary procedures considered as primary events included bone grafting, implant exchange and dynamization in patients with a fracture gap less than 1 cm, fasciotomy and drainage of hematomas.

### *Independent variables*

We categorized centre volume into 5 quintiles of the total number of SPRINT patients enrolled: very low, low,

**Table 1. Frequency of surgical procedures performed by surgeons, residents and fellows by centre volume**

Person performing the surgery	Centre volume; no. (%) of procedures					Total n = 1210
	Very low n = 242	Low n = 266	Moderate n = 190	High n = 237	Very high n = 275	
Attending surgeon	136 (56.2)	98 (36.8)	20 (10.5)	59 (24.9)	93 (33.8)	406 (33.6)
Resident	98 (40.5)	153 (57.5)	145 (76.3)	154 (65.0)	176 (64.0)	726 (60.0)
Fellow	8 (3.3)	15 (5.6)	25 (13.2)	24 (10.1)	6 (2.2)	78 (6.4)

moderate, high and very high. We stratified patients into groups by centre volume by calculating the annual enrolment of patients into SPRINT per centre. This figure was based on the total number of patients who were randomly assigned into the study. We then divided this number by the total length of time the centre was recruiting patients to obtain an enrolment rate. Centres that enrolled fewer than 10 patients were excluded because of higher variability in the care of these patients and potential impact on patient outcome. Twenty-six centres were included and 3 were excluded.

We also defined surgeon volume by quintiles of the total number of SPRINT patients enrolled: very low, low, moderate, high and very high. We stratified patients into groups by surgeon volume by calculating the annual enrolment of patients into SPRINT per surgeon. This figure was based on the total number of eligible patients randomly assigned into the study. We then divided this number by the total length of time the centre was recruiting to obtain a surgeon enrolment rate. Surgeon volume included not only study operations performed by surgeons, but also those performed by fellows and residents.

We established the location of the surgery (US, Canada, the Netherlands) and the surgeon performing the operation (resident, fellow, attending) from the case reports submitted by the treating institution.

### Statistical analysis

We analyzed the data using SAS version 9.2 (SAS Institute). We performed analyses adjusted for type of fracture (open v. closed), type of injury (isolated v. multitrauma), gender and age for the primary outcome of reoperation using multivariable logistic regression. The results were reported as odds ratios (ORs) and 95% confidence intervals (CIs). Statistical significance was defined as  $p < 0.05$ .

## RESULTS

### Centre volume, surgeon volume and surgeon experience

Centre volume ranged from 4.85 to 47.43 patients enrolled per year, with a 20th percentile of 12.94 patients enrolled per year, a 40th percentile of 16.63 patients enrolled per year, a 60th percentile of 18.80 patients enrolled per year

and an 80th percentile of 29.91 patients enrolled per year. Surgeon volume ranged from 0.2 to 16.64 patients enrolled per year, with a 20th percentile of 1.68 patients enrolled per year, a 40th percentile of 2.93 patients enrolled per year, a 60th percentile of 3.96 patients enrolled per year and an 80th percentile of 7.77 patients enrolled per year.

The majority of patients were treated by residents across all centre volumes, except in very-low-volume centres, where they were treated primarily by attending surgeons (Table 1).

### Reoperation

There were no significant differences in the odds of reoperation between high- and low-volume centres. Overall, surgeon volume significantly affected the odds of reoperation ( $p = 0.03$ ). The odds of reoperation among patients treated by moderate-volume surgeons were 50% less than those among patients treated by very-low-volume surgeons (OR 0.50, 95% CI 0.28–0.88), and the odds of reoperation in patients treated by high-volume surgeons were 47% less than those among patients treated by very-low-volume surgeons (OR 0.53, 95% CI 0.30–0.93) (Table 2). There were

**Table 2. Effect of centre volume, surgeon volume, surgeon experience and geographic location on reoperation\***

Variable	OR (95% CI)
Centre volume	
Very high v. very low	1.19 (0.55–2.55)
High v. very low	0.87 (0.44–1.71)
Moderate v. very low	0.92 (0.43–1.97)
Low v. very low	1.06 (0.56–2.01)
Surgeon volume	
Very high v. very low	1.17 (0.64–2.17)
High v. very low	0.53 (0.30–0.93)
Moderate v. very low	0.50 (0.28–0.88)
Low v. very low	0.80 (0.48–1.33)
Person performing the surgery	
Resident v. attending surgeon	0.88 (0.63–1.24)
Fellow v. attending surgeon	0.94 (0.48–1.83)
Location	
Canada v. United States	0.77 (0.52–1.14)
Netherlands v. United States	1.67 (0.65–4.31)

CI = confidence interval; OR = odds ratio.  
\*Adjusted for type of fracture (open v. closed), type of injury (isolated v. multitrauma), gender and age.

no significant differences between very-high and very-low-volume surgeons in the odds of having a reoperation. There were no significant differences between residents and attending surgeons or between fellows and attending surgeons in the odds of having a reoperation. There were no statistically significant differences in rates of reoperation between being treated in Canada compared with the US or between being treated in the Netherlands compared with the US.

## DISCUSSION

In this secondary analysis designed to evaluate the effect of surgeon volume, institutional volume, surgeon experience and geographic location on the reoperation rate for intramedullary nailing of tibial fractures, surgeon volume was the only factor found to have a significant impact: the odds of reoperation were significantly lower among patients treated by moderate- and high-volume surgeons versus very-low-volume surgeons. We also discovered that being treated by a very-high-volume surgeon did not result in lower odds of reoperation as compared with being treated by a very-low-volume surgeon. This may be related to case-mix, as more severe cases, which are prone to reoperation, are more likely to be managed by very-high-volume surgeons.

To our knowledge, the only published studies assessing the relation between surgeon volume and reoperation in orthopedics are for hip fractures and knee and total hip arthroplasty procedures; these studies have reported varying findings.<sup>14,15</sup> One cohort study included 6716 patients who had undergone total hip arthroplasty carried out by surgeons who had done 35 or fewer total hip arthroplasty procedures in the previous year and were matched to patients whose surgeon had performed more than 35 procedures.<sup>14</sup> Patients who had their procedure done by a low-volume surgeon had significantly higher rates of revision surgery ( $p = 0.03$ ). Okike and colleagues<sup>15</sup> examined relations between surgeon volume and reoperation following hip fracture surgical procedures and found no associations between surgeon volume and reoperation ( $p > 0.05$ ). Although the findings of our study suggest a possible relation between higher surgeon volume and lower odds of reoperation in patients with tibial fractures managed with intramedullary nails, additional studies focusing on this patient group are necessary to confirm these results. Future studies should also consider examining whether there are specific volume thresholds which are associated with better outcomes and whether other factors influence the impact of surgical volumes.

Okike and colleagues<sup>15</sup> assessed whether hospital volume affected reoperation in patients with hip fracture and, like us, found no association between hospital volume and reoperation. In a Finnish study, Pamilo and colleagues<sup>16</sup> identified 54 505 total hip replacement procedures for primary osteoarthritis and classified them into 4 groups

according to the number of annual procedures over the entire study period: 1–199, 200–499, 500–899, or 900 or more; they also found that hospital volume had no significant impact on the odds of reoperation.

Numerous orthopedic studies have examined the relation between centre volume and fracture complications. Poeze and colleagues<sup>8</sup> performed a systematic review of the literature looking at the relation between outcomes and hospital fracture load in patients with displaced intra-articular calcaneal fractures. They found a significant inverse relation between deep infection rate and fracture volume. A similar relation was seen for the presence of symptomatic subtalar arthritis. However, operative treatment of an intra-articular calcaneal fracture is a type of procedure better suited for a fellowship-trained surgeon with a focus on foot and ankle surgery, whereas treatment of a tibial shaft fracture is widely performed by general orthopedic or orthopedic trauma surgeons.

We found that surgeon experience had no significant effect on the odds of reoperation. This finding differs from that of a study by Palm and colleagues<sup>17</sup> investigating the influence of the performing surgeon's experience on the rate of reoperation in patients with proximal femoral fractures. Those authors found that the 6-month reoperation rate was significantly higher when surgery was performed by an unsupervised junior registrar versus when performed by or supervised by a more experienced surgeon ( $p = 0.02$ ). Given that SPRINT did not have any unsupervised junior trainees performing operations and that most current guidelines require that faculty attending surgeons supervise surgical residents when performing procedures, cases were likely performed in a similar manner by surgeons and residents.

There may be other reasons why no differences were found for reoperation depending on who performed the surgery. Although a definitive learning curve threshold has not been defined for intramedullary nailing of tibial shaft fractures, it has been suggested that other, more complex orthopedic procedures have a learning curve of about 30–50 cases.<sup>18,19</sup> Given that tibial nailing is widely performed, the learning curve may be less than this, allowing trainee surgeons to overcome the learning curve for all but the most complex of fractures. In addition, the tools for resident education had improved over the decade before the start of this randomized trial, and this may have had an impact.

## Limitations

Grouping of centres into quintiles of patient volume was based on recruitment of patients into SPRINT, which may have been only loosely correlated with overall volumes of patients with tibial fracture treated with tibial nailing. In addition, other surgical procedure volumes are likely to affect the quality of surgery for intramedullary nailing of the tibia. For example, intramedullary nailing of femoral

fractures and overall use of intraoperative radiographic imaging for insertion of implants are both likely to affect the quality of surgical care when inserting an interlocking tibial nail, but these outcomes were not assessed in this study. Low patient numbers also limited our analyses.

## CONCLUSION

There appears to be no significant additional patient benefit of treatment at a higher-volume centre versus a lower-volume centre for intramedullary fixation of tibial shaft fractures. For this reason, we cannot conclude that centres with high volume perform better than lower-volume centres managing tibial shaft fractures. The odds of reoperation were significantly lower among patients treated by moderate- and higher-volume surgeons compared to very-low-volume surgeons. Our findings suggest that high- and moderate-volume surgeons may perform better in regard to odds of reoperation than very-low-volume surgeons; however, more high-quality evidence is required to confirm this finding.

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overall content and integrity of the manuscript. M. Swiontkowski, D. Teague, M. Bhandari and E. Schemitsch designed the study. M. Swiontkowski, D. Teague, A. Dowrick, S. Sprague, D. Heels-Ansdell, M. Bhandari, E. Schemitsch, G. Guyatt, D. Sanders, P. Tornetta III and S. Walter analyzed the data. M. Swiontkowski, D. Teague, A. Dowrick, S. Sprague and D. Heels-Ansdell wrote the article, which G. Guyatt, M. Bhandari, D. Sanders, E. Schemitsch, M. Swiontkowski, P. Tornetta III and S. Walter critically reviewed. All authors approved the article for publication.

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