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The learning curve of proximal femoral nailing

Burak ALTINTAS, Roland BIBER, Hermann Josef BAIL

Department of Trauma and Orthopedic Surgery, Paracelcus Medical University, Nürnberg, Germany

Objective: The aim of this study was to evaluate operation time and surgical complication rate of proximal femoral nailing during resident training.

Methods: This retrospective evaluation included 659 patients (508 females, 151 males; mean age: 80.7 years), operated by 63 supervised residents between 1998 and 2010. All patients received the same implant (Targon® PF). Fracture classification, operation time and early surgical complications causing reoperation or hospital readmission (i.e. hematoma, infection, hip perforation, nonunion, implant malpositioning) were recorded and correlated with the resident's operative experience measured by the number of operations performed.

Results: Mean operation time was 61.3 (range: 59.8 to 62.8) minutes. Mean operation time of a resident's first 15 training operations was 8.7 minutes longer than that of later operations ($p<0.001$). No further significant shortening of operation time was experienced after the first 15 training operations. Overall surgical complication rate was 9.3% (range: 7.0% to 11.5%). There were no significant differences in complication rate (9.9% vs. 8.2%; $p=0.47$), hematoma formation (2.5% vs. 0.8%; $p=0.07$), infection (2.7% vs. 3.9%; $p=0.52$), nonunion (0.7% vs. 1.6%; $p=0.51$), cut-out (1.2% vs. 2.4%; $p=0.31$), lag screw perforation (3.2% vs. 0.4%; $p=0.07$) or implant malpositioning (0.5% vs. 0.0%; $p=0.26$) between the first 10 and subsequent training operations the subsequent training operations.

Conclusion: After 15 training operations, a resident's operative speed did not significantly differ from that of more experienced collegues. Early surgical complications were not significantly affected by the resident's experience.

Key words: Complication rate; learning curve; proximal femoral nail; surgical training; trochanteric fracture.

Observing and performing operations are important parts of surgical training in orthopedic surgery. Either supervised or unsupervised by experienced surgeons, there is no doubt that training operations performed by residents themselves are the most effective means of learning. However, there are only a few publications dealing with the effects of training operations. While some studies have covered general surgery topics, they do not provide a clear view on the topic. Acun et al. analyzed 152 near-total thyroidectomies and found similar rates of temporary vocal cord paralyses and temporary hypoparathyroidism.[1] Patel et al.[2] published a study on 295 cases of bilaterally performed reduction mammoplasty. One breast was operated by an attending sur-

**B. ALTINTAS and R. BIBER had equally contributed to this work.*

Correspondence: Burak Altintas, MD. Paracelcus Medical University, Department of Trauma and Orthopedic Surgery, Nürnberg, Germany

Tel: +49-911 – 398 118206 e-mail: burak.altintas@klinikum-nuernberg.de

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geon and the other by a resident; and no significant difference in the complication rate was found. On the other hand, Wilkiemeyer et al. reported significantly shorter operative times and in patients who underwent inguinal hernia repair performed by senior residents compared to junior residents.[3] Similar results were published by Kauvar et al., who analyzed 315 laparoscopic cholecystectomies and found longer operative times and higher complication rates in operations performed by junior residents.[4]

In the field of orthopedic trauma surgery, recent literature indicates that there might be no relevant risk alteration for proximal femoral fracture patients if hemiarthroplasty or proximal femoral nailing is performed by supervised residents.[5,6]

Recent emphasis on patient safety and increasing economic pressure make clear the need for concepts combining high standards of patient safety (i.e. low complication rates) and efficient surgical education. Operation time is known to be one of the most relevant cost drivers. Therefore, the aim of our study was to analyze operation time and surgical complication rates of proximal femoral nailing during the first 40 proximal femoral nailings in resident training.

Patients and methods

All proximal femoral nails implanted in our Level 1 trauma center between 1998 and 2010 were documented prospectively in a database.

Of a total of 1,516 patients treated with the implant, attending surgeons performed surgery on 857 patients and supervised residents (training operations) on 659. The 659 patients (508 female, 77.1% and 151 male, 22.9%) in the latter group were included in this study. Patient age ranged from 21 to 103 years (mean: 80.7±11.0 years). On average, male patients were considerably younger (mean: 72.4 years, range: 70.1-74.7) than females (mean: 83.2 years, range: 82.5-83.9).

Patient age, gender, fracture type and surgical complications occurring during the initial hospital stay or causing readmission were recorded. Complications included wound infection, hematoma, intraoperative malreduction or implant malpositioning causing revision, excessive postoperative pain, cut-out, and nonunion.

Resident experience was evaluated by the number of proximal femoral nailing operations performed. The first 40 proximal femoral nailings in the career of each resident were analyzed and classified in intervals of five (1 to 5, 6 to 10, etc.).

Targon® PF nails (Aesculap AG, Tuttlingen, Germany), a biaxial fixation system offering a unique telescoping system consisting of a lag screw able to glide within a sleeve, were used in all patients. As is usual in proximal femoral nailing, the operative procedure is highly standardized. Patients were mobilized postoperatively with full weight-bearing of the affected side if they were capable of walking before fracture formation. There was no difference in postoperative rehabilitation protocols between the training and other operations.

Statistical analysis was performed using IBM® SPSS® v.19.0.0 software. All confidence intervals in this article are 95%. For detection of significantly different complication frequencies between operations performed by residents of different experience levels, we used the χ^2 test in cases with all expected values greater than 5 and the two-sided Fisher's exact test for others. The t-test for independent samples was used to compare the means of continuous data (operation time).[7]

Results

The 659 training operations were performed by 63 residents supervised by a board-certified attending surgeon. Depending on their duration of stay in our hospital or their date of board-certification, residents performed between 1 and 42 (mean: 10.5±9.7) proximal femoral nailings for training purposes. Four hundred and three operations were performed by residents with experience of 1 to 10 previous proximal femoral nailings and 163 by residents who had performed 11 to 20 previous operations. In 66 cases, the resident had experience of 21 to 30 operations, in 24 cases 31 to 40 operations and in 2 cases the residents had performed more than 40 nailings.

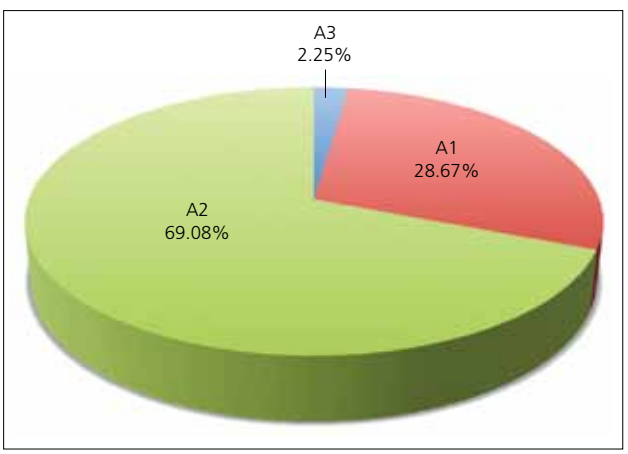

Fig. 1. The high proportion of trochanteric fracture types A1 and A2 may be characteristic for training operations. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Teaching operations were performed predominantly for trochanteric fracture types A1 and A2 according to the AO/ASIF classification (Fig. 1).[8] Operation time was significantly shorter in A1 fractures (57.0 min vs. 62.9 min; p<0.001). While the overall complication rate was lower in A1 fractures (8.4% vs. 9.6%), this difference was not significant (p=0.63). However, in A1 fractures cut-out (0.0% vs. 2.3%; p=0.001) and nonunion (0.0% vs. 1.5%; p=0.05) was less frequent. Revision rates were 12.4% (range: 9.6% to 15.3%) in operations performed by the residents and 11.6% (range: 9.0% to 14.1%) in operations performed by board-certified surgeons.

Mean operation time was 61.3 (range: 59.8-62.8) minutes. Operation time decreased with resident's experience (Fig. 2). Mean operation time of a resident's first 15 training operations was significantly longer than that of subsequent operations (63.6 min vs. 54.9 min; p<0.001). There was no significant difference in operative time between residents with experience of 11 to 20 surgeries and more experienced residents (58.3 min vs. 57.2 min; p=0.72). Mean operation time in complication cases was longer (71.3 min vs. 56.0 min; p=0.06).

Overall surgical complication rate was 9.3% (range: 7.0%-11.5%). The complication rate changed with increasing experience (Fig. 3). However, there was no significant difference in complication rates between the first 10 operations and subsequent training operations (9.9% vs. 8.2%; p=0.47). The same was true for all specific complications: hematoma formation (2.5% vs. 0.8%; p=0.07), infection (2.7% vs. 3.9%; p=0.52), nonunion (0.7% vs. 1.6%; p=0.51), cut-out (1.2% vs. 2.4%; p=0.31), lag screw perforation (3.2% vs. 0.4%; p=0.07) and implant malpositioning (0.5% vs. 0.0%; p=0.26).

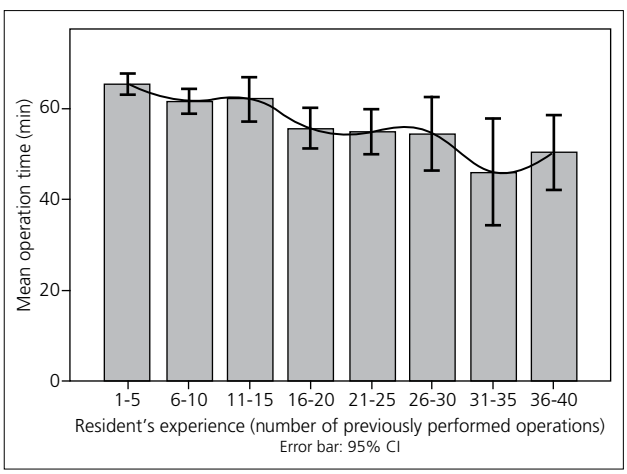

Fig. 2. Operation time seems to decrease throughout the training process. However, a statistically significant change was detected after the first 10 operations only.

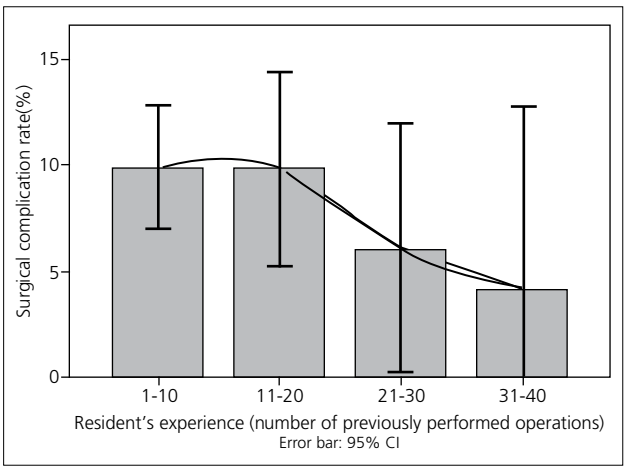

Fig. 3. Complication rate seems to decrease after 20 operations of training. However, due to the low complication rates, the confidence intervals are wide and the level of statistical significance is not achieved.

Discussion

Although there have been some reports on learning curves in recent orthopedic literature, there is limited data on how many training operations are necessary to educate junior doctors. There is some evidence in the literature suggesting that teaching total hip replacement in an elective setting may not increase the complication rate.[9,10] On the other hand, there is also evidence that learning curves might be influenced by the type of operative procedure,[11] which indicates that additional studies are needed about different types of operations in order to understand the effects of learning curves. Moreover, what might be right in the elective setting of orthopedic surgery may be wrong for trauma surgery, especially if elderly patients are involved.

Proximal femoral nailing is a highly standardized procedure and is often to younger surgeons for training purposes. However, proximal femoral fractures are typical fragility fractures. Patient morbidity, osteoporosis and the trauma setting are often challenging problems. There is much experience but little evidence on how much surgical education is necessary and how to effectively and safely perform training operations. Orthopedic trauma surgery performed by supervised and unsupervised trainees does not appear to have different complication rates.[12] However, the most common method of teaching is to allow residents to perform operative procedures under the supervision of attending surgeons, which is also the setting of our study.

Studies on learning curves often evaluate operation time or radiographic outcome as a surrogate marker for learning success and operative excellence.[13] Although

operation time was found to be correlated with complication rates, we consider operation time not to be of primary importance in proximal femoral nailing. In the orthogeriatric setting, outcome is predominantly determined by complications delaying rehabilitation. Therefore, our study concentrated on inhouse complications. In addition, from an economic standpoint, both operation time and hospital length of stay are relevant cost drivers. Comparing the first 15 training operations in a resident's career to later operations, we found that mean operation time was prolonged by only 8.7 minutes. Although statistically significant, this difference obviously has a very limited economic impact, which is an additional reason to focus on complications which might be economically more relevant.

Currently, no convincing evidence that complication rates in proximal femoral nailing are associated with resident's experience has been presented. Thus, the goal of our study was to explore such a potential association. If the risk of complication differs in different stages of surgical education, this might influence patient safety when proximal femoral nailing is performed by a trainee. Therefore, we analyzed the complication rates among patients operated by residents of different operative experience.

Our study reports on a respectable number of training operations collected with a single implant during a 12-year period. Age and gender proportion are typical for orthogeriatrics. Fracture classification showed an overrepresentation of the more simple trochanteric fractures, indicating that easier fractures were routinely selected for teaching. However, this seems adequate and can be assumed to be a common and reasonable approach.

There was a significantly longer operation time for a resident's first 15 training operations (63.6 min vs. 54.9 min; $p<0.001$). At later stages of a resident's surgical education, the decrease was minimal and no longer significant. The average difference of 8.7 minutes per operation makes a total extra 130 minutes for the 15 training operations. In other words, 130 minutes of operation time may be considered an estimate for the price of instruction of a surgical beginner. After this initial investment, the resident will likely be able to perform proximal femoral nailing at the same speed as an experienced surgeon.

Overall surgical complication rate decreased somewhat with increasing numbers of operations performed by the resident. However, this decrease was far from significant and may therefore be interpreted as a random effect. Although operation time and complication rate were associated in our collective, the significantly higher operation time during a resident's first 10-operations-series was not reflected by a significantly higher complication rate.

However, hematoma formation (2.5% vs. 0.8%; $p=0.07$) and lag screw perforation (3.2% vs. 0.4%; $p=0.07$) were more frequent in the first 10 training operations. These differences were remarkable, but not quite statistically significant. All other types of complications were not significant. One might hypothesize that hematoma formation and lag screw perforation may be especially dependent on the operator's surgical experience. We recommend that the attending surgeon should be particularly aware of hemostasis and lag screw positioning when assisting inexperienced residents.

Further investigations should be undertaken to explore the potentially increased rate of lag screw perforation in training operations. This problem is known to be associated with lag screw placement: cut-out becomes more likely when the the lag screw deviates from the axis of the femoral neck in the axial radiologic view.[14,15] One might hypothesize that more experienced surgeons may need less attempts to place the lag screw more centrally, thus reducing the risk of later lag screw perforation.

In conclusion, proximal femoral nailing is a suitable procedure for teaching residents. Operation time is prolonged only during the first 15 training operations; approximately 130 minutes of operation time must be invested until the residents have gained the same operative speed as the more experienced surgeons. There were no significant differences in complication rates between more or less experienced residents. By tendency, there might be a higher rate of hematoma formation and lag screw perforation after teaching operations performed by inexperienced trainees. We recommend attending surgeons assisting younger colleagues to focus on these aspects.

Conflicts of Interest: No conflicts declared.

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