Precise nail tip positioning after tibial intramedullary nailing prevents anterior knee pain

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Abstract

Purpose Anterior knee pain (AKP) is a common complication following intramedullary nailing of tibial shaft fractures. Our aim was, by analysing the postoperative lateral knee X-rays and clinical status (VAS score), to find the best intramedullary tip position of a non protruded nail that will provide the best postoperative outcome avoiding AKP.

Methods We evaluated the postoperative outcome of 221 patients, from the last four years, with healed fractures initially treated with intramedullary reamed nails with two or three interlocking screws proximally and distally through a medial paratendinous incision for nail entry portal. Our aim was to analyse a possible relationship between AKP according to the VAS scale, and nail position marked as a distance from tip of nail to tibial plateau (NP) and to tibial tuberosity (NT), measured postoperatively on lateral knee X-rays.

Results Two groups of patients were formed on the basis of presence of pain related to AKP (the level of pain was neglected): group A were patients with pain and group B without pain. The difference between the two groups concerning NP and NT measurements appeared to be statistically significant concerning NT measurement ($p < 0.05$), with high accuracy according to the classification tree.

Conclusions We presume that the position of the proximal tip of the nail and its negative influence on the innervation pattern of the area dorsal to patellar tendon could be the key factor of AKP. We conclude that the symptoms of AKP will not appear if the tip of the nail position is more than 5.5 mm

from the tibial plateau (NP) and more than 2.5 mm from the tibial tuberosity (NT).

Introduction

Intramedullary nailing (IN) is the gold standard treatment option for displaced closed or open tibial diaphyseal fractures [1–4]. It acts as an internal splint and permits early weight bearing along with fracture healing. Current nails have different degrees of proximal curvature and various location of locking screws. The best way to insert the nail is via the standard medial parapatellar approach. The location of the starting point varies depending on the type of nail used. The appropriate starting point of a slotted nail is 1–1.5 cm distal to the knee joint in line with the medullary canal on AP radiographs, at the level of the fibular head.

Anterior knee pain (AKP) is one of the most common complaints after tibial IN [5–10]. This has a significant economic impact, since the majority of tibial fractures that require nailing are sustained by men with an average age of 31 years. Court-Brown et al. [11] found the incidence of AKP to be 56 %. AKP has a multifactorial aetiology. Recent studies have confirmed an association between AKP and nail position [12], but the ideal placement of the nail entry point has not yet been precisely defined. The presumption is that the position of the proximal tip of the nail and its negative influence on the innervation pattern of the area dorsal to the patellar tendon could be the key factor of AKP. Altered sensory-sympathetic innervation has implications in the pathophysiology of AKP. Explanations for this include nail protrusion leading to soft tissue irritation or damage to the gliding tissues in front of the knee during nail insertion. Still, there is no published randomised control trial regarding the tip position of non protruded nail inside the tibial medullary canal observed on the lateral X-rays in a relation to AKP.

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Our aim was, by analysing the postoperative lateral knee X-rays of tibial shaft fractures in 221 patients with IM osteosynthesis and their postoperative clinical status (VAS score), to find the best intramedullary tip position of a non protruded nail that will provide the best postoperative outcome avoiding AKP. We analysed a possible relationship between AKP according to the VAS scale, and nail position marked as a distance from tip of nail to tibial plateau (NP) and to the tibial tuberosity (NT), measured postoperatively on lateral knee X-rays, and calibrated using known standard sizes of the of the nail tips.

Materials and methods

In this prospective study 221 patients were treated. This trial was conducted over a period of 60 months; the first patient was enrolled in 2006 and the last patient completed follow-up in 2011.

Each patient was fully informed about the purpose of the trial, expected benefits, possible risks, and all the other details pertaining to the study. All participants signed an informed consent. Approval for this study was obtained from the Ethical Board, School of Medicine, University of Zagreb, prior to performing the study.

Eligible patients were older than 18 years. Prior to each operation, traumatic tibial diaphyseal fracture was diagnosed on the basis of a clinical examination and confirmed by X-ray. The study included patients with the same preoperative diagnosis of a traumatic tibial diaphyseal fracture, without any neural or vascular injury.

Exclusion criteria were poor general health as judged by the orthopaedic surgeon; concomitant painful or disabling disease of the spine, hips, knees or lower limbs that would interfere with evaluation of the afflicted extremity; any inflammatory and infectious diseases; alcohol/drug abuse and morbid obesity; or a extramedullary canal position of the nail tip.

Surgical intervention

The data used in this study are from the records of the patient's operative and postoperative protocols. The subjects underwent osteosynthesis of tibial diaphyseal fracture with intramedullary reamed nails with two or three interlocking screws proximally and distally (static positions), through a medial paratendinous incision for nail entry. In the trial, procedures were equal in all patients. We used two types of intramedullary nails, which have different diameters of their proximal end. The first type, produced by TREU-Instrumente GmbH, Tuttlingen, Germany has a proximal end diameter of 12.0 mm for sizes eight to 11, and 13.0 mm for sizes 13 and 14. The other type of nail was produced by Stryker Corporate,

Michigan, USA., with tip diameter of 11.5 mm for sizes eight to 11, while the diameter of sizes 12–14 is 14 millimetres for all. Postoperative cast-immobilisation was not used. Postoperatively, patients were allowed partial weight bearing for 12 weeks, and after that time a full weight load. All patients were given postoperative instructions for thigh muscle rehabilitation and the same physiotherapy was performed after IM nailing during their stay in hospital.

Radiological intervention

At a date of 12–13 months postoperatively, proof of the healed bone fracture was confirmed by radiological examination. At the same time, a standard lateral view of the knee was used to measure the nail position distances: NP (length between the tip of the intramedullary nail to tibial plateau), and NT (distance between the tip of the intramedullary nail and the tibial tuberosity) (Fig. 1). Measured distances were calibrated using known standard sizes of the of the nail tips. Two independent radiologists (intra- and interobserver) performed the measurements on lateral radiographs using measurement tools on our PACS workstation (Issa). The measurements were obtained in millimetres. The analysis of reliability between first and second radiologist revealed excellent interobserver reliability (ICC 0.95; 95 % CI 0.87–0.97).

Statistical analysis

In this analysis we used two proportional scales (NT and NP) and one (VAS_ORG) ordinal (10 categories), which is documented in binary variables as VAS (0=no pain, 1=any position on the subjective scale of pain) for analysis of two different groups: with and without pain.

Fig. 1 Assessment of the nail position distances: NP (length between the tip of the intramedullary nail to tibial plateau), and NT (distance between the tip of the intramedullary nail and the tibial tuberosity) on a standard lateral view of the knee

We used the program system SAS EG (Statistical Application System Enterprise Guide ver.4.1) for a data processing. Also, we used a RIDIT system of VAS_ORG scale transformation in variable VAS_RID, that gives the monotone distribution with arithmetic median $M=0.50$. Next, we used a Kolmogorov-Smirnov normality test to check our hypothesis that our results follow a normal shape of distribution. Upon a positive test we used a parametric method of data analysis. Regarding the NT and NP differences we used a simple univariate test to assess significant differences between the two groups. Hypothesis of mean arithmetic equivalence was tested with Student t-test. We used a discriminative analysis to reclassify patients according to their group affiliation defined by VAS variable (0,1). The percentage of compliance between the reclassification and original values is a degree of discriminative function efficacy.

Results

Among 221 patients evaluated in this study, one hundred were female, mean age 49 (range 19–69), and 121 male, mean age 45 (range 18–68). Four patients were excluded from further analysis: one because of alcohol/drug abuse, one because of morbid obesity, and two because of the extra-medullary canal position of the nail tip. Apart from these, no other patients had complications, such as deep or superficial infections, compartment syndrome, broken hardware, or neurovascular lesion.

A distance from the proximal tip of the nail to the tibial plateau varied from 35 mm to 3 mm below the plateau with a mean value of 11.6 mm below the tibial plateau. The distance from the tip of the nail to the tibial tuberosity varied from 11 mm to one mm below the cortical bone of the tibial tuberosity with a mean value of 1.3 mm below the cortical bone of the tibia (Table 1).

Two groups of patients were formed on the basis of presence of pain related to AKP (the level of pain was neglected): group A had pain and group B had no pain.

Kolmogorov-Smirnov test shows that the risk for the rejection of the hypothesis of equality of the normal and the resulting distribution for NP and NT variables is greater than 1 and 5 %. Therefore, the conclusion is that the distribution of the analysed variables are normal.

The coefficient of correlation between variables NT and NP is low ($r=0.23$) but statistically significant at a significance level of $P<0.01$. It is obvious that these two measures of nail position have very few common sources of variability.

T-test showed that patients who reported pain significantly differ in mean nail position distances in both variables compared to those who did not suffer the pain. Significance in both calculated t-tests is so great (risk of rejecting the null hypothesis of equality of arithmetic means in both cases less than 1 %) that it can be concluded that the position is an important factor determining whether or not there is pain in the operated limb.

Since the confidence intervals of the estimated mean scores for NT and NP variables for group A and group B are separated, it is obvious that the groups differ in the way that high values are typical of those who do not have pain, and significantly lower values of those who experienced postoperative pain.

Multiple linear regression analysis, which used NP and NT as predictor variables, and VAS_RID as a criterion variable, showed that the prediction of results in the criterion variable is significant on a level of less than 0.01.

Pooled variance shared by the predictor and the criterion variables (coefficient of multiple determination is 31 %) suggests that the position of the nail is an important factor in predicting the incidence of pain in the operated limb. In the analysis of the importance of individual measures, through the size of the standardised regression coefficient, it is indicated that the position marked as NT is a much more important indicator ($SB=-0.47$). Furthermore, the analysis confirms what was indicated using the t-test for binarised independent variables, namely, the level of pain, expressed on a subjective scale transformed into a form suitable for statistical analysis, is lower as both variables are registered numerically higher values.

Discriminant analysis was performed for the original values of the variables NP and NT, and variable VAS was used as the dependent variable. It should be noted that, with the strong possibility of group discrimination ($p<0.01$), in the process of subjects reclassification in the initial groups based on discriminant function, correct affiliation to the group with no pain reached 90 %, and correct affiliation to the group with no pain reached 74 %. This data indicates that the use of discriminant functions significantly improved initial classification (60 % and 40 %).

Table 1 Simple statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
NP	214	13.18734	7.80613	2822	-17.78000	35.12000	np
NT	212	4.60764	4.89827	976.82000	-8.21000	23.00000	nt
VAS_ORG	215	1.56279	2.22024	336.00000	0	8.00000	vas_org
VAS_RID	215	0.49993	0.25822	107.48600	0.29300	0.99100	VAS_RID

Discussion

Intramedullary nailing of tibial fractures has evolved since the 1940s. The classic parapatellar and transtendon approaches are associated with postoperative knee pain [5–10]. The aetiology of this pain is likely to be multifactorial, including stretching the tendon intraoperatively, damage and scarring to the soft tissues, and infrapatellar nerve injury. This pain has a significant impact on patient outcome, particularly in young manual labourers, who are, after all, most commonly affected by tibial shaft fractures.

In this study, we used the medial parapatellar approach for nail insertion in all patients. In this approach, a medial longitudinal incision is made, with care being taken not to damage the patellar tendon or its sheath. The patellar tendon, the retropatellar fat pad and paratendinous tissue are retracted and, theoretically there would be no tissue injury [13]. Therefore, it was our belief that by this approach the patellar tendon would be protected from any additional trauma, as much as it is reasonably achievable. Furthermore, we used a stainless steel protective sleeve to prevent patellar contact with the nail during its introduction and to maintain protection between the nail itself and the cartilaginous surface of the trochlear knee. A potential criticism for this approach is that the trauma caused by the retractors during reaming could cause knee pain [14].

Innervation of patellar tendon is confined to the loose paratendinous connective tissue, which is rather richly innervated by nerve structures. These consist of large nerve fascicles, with perivascular innervation in the walls of some of the larger arteries and smaller blood vessels. Part of these nerve structures correspond to sensory afferents, and some conform to cholinergic and, especially, sympathetic nerve fibres. The tendon tissue proper is strikingly less innervated than the paratendinous tissue. The sparse innervation found in the tendon tissue proper is seen in narrow zones of loose connective tissue and blood vessels, interspersed between the collagen bundles [15]. The infrapatellar fat pad, also known as Hoffa's fat pad (intracapsular, extrasynovial structure that fills the anterior knee compartment), is also richly vascularised and innervated. Its degree of innervation, the proportion of substance-P-containing fibres and close relationship to its posterior synovial lining implicates that the infrapatellar fat pad has important clinical implications regarding the variety of possible pain patterns [16].

In our study NP value represents the distance between the nail tip and the tibial plateau tuberosity. As shown before, higher NP values are associated with lower incidence of AKP. Following that, a conclusion can be made that, if the nail tip is located too close to the tibial plateau, there is a greater danger of intra-articular penetration and injury of articular cartilage, meniscus and transverse ligament.

NT value stands for the distance between nail tip and tibial tuberosity. As shown earlier, in the analysis of the importance of individual measures, through the size of the standardised regression coefficient, and using the t-test for binarised independent variables, it is indicated to be a much more important factor for prediction of AKP than NP. According to our results, to avoid AKP, the NT value should be as high as possible. In other words, the nail tip should be as remote from tibial tuberosity as reasonably achievable. We consider that through this, the possibility of injury or damage to the well innervated structures including patellar tendon, peritendinous tissue, the infrapatellar branch of the saphenous nerve and the infrapatellar fat pad is minimised.

According to these results, during placement of the tibial nail, both NP and NT values should be as high as possible. However, if a nail tip is located too distant from the tibial plateau, it approaches the tibial tuberosity too much, and, vice versa, if it is located too proximally, there is a risk of intra-articular penetration and chondral injury. So to have it reduced to a realistic framework, and in accordance with the results, we consider that the symptoms of AKP will not appear if a nail tip is located more than 5.5 mm from the tibial plateau (NP) and more than 2.5 mm from the tibial tuberosity (NT).

Conclusion

We presume that a position of the proximal tip of the nail and its negative influence on the innervation pattern of the area dorsal to the patellar tendon could be the key factor of AKP. We conclude that the symptoms of AKP will not appear if the tip of the nail position shall be more than 5.5 mm from the tibial plateau (NP) and more than 2.5 mm from the tuberositas tibiae (NT).

We consider the medial paratendinous incision is a good approach for nailing tibial fractures. We emphasise that special care should be taken not to damage the patellar tendon or its sheath. Therefore, the use of protective sleeves and a trocar is recommended.

However, the pain generator in AKP is still not clearly identified. A cadaver study comparing pathohistological changes in patellar tendon, retropatellar fat pad and paratendinous tissue, regarding the degree of innervation and the proportion of substance-P-containing fibres, would be helpful.

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