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Risk of extrapelvine vascular injuries in osteosynthesis with gliding hip screws

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Abstract

Background Dynamic hip screw (DHS) osteosynthesis represents one of the most frequently performed fixation methods in orthopedic practice. The purpose of this study was to determine the potential risk of vascular damage by DHS side-plate screws (PS) and plunging instruments for individual femoral vessels and screw positions.

Methods In ten hemipelvic/leg specimens mounted with a large femur distractor, a DHS system with a four-hole side-plate was inserted. PS were inserted in 3 consecutive courses with different inclinations in the frontal plane of 0° (group 1), − 30° posterior (group 2) and + 30° anterior (group 3) in relation to the side-plate's surface, resulting in 120 PS positions. After screw tightening, the soft tissues on the medial side of the femur were dissected and investigated for vascular compromise; in each course, the effect of overshot instruments within a range of 50 mm beyond the side-plate's surface was also tested.

Results Totally, 37/120 screw positions (31%) revealed potential vascular compromise which comprised of 15/120 (13%) direct hits by screw tips and 22/120 (18%) potential impacts by plunging instruments. The deep femoral artery system (DFA) was significantly ($p = 0.007$) most often affected but no significant differences for individual vascular structures were seen. Direct vascular impacts occurred significantly more often ($p = 0.0047$) in screws with 0° inclination compared to + 30° inclination ($p = 0.017$). Significant differences among individual screw positions were only found in group − 30° with direct vessel contacts ($p = 0.038$).

Conclusions The DFA system is significantly more at risk while significant preference of a certain vessel is missing. Our data indicate that more than 30% of 120 screw positions in DHS osteosynthesis revealed a potential danger of vascular compromise, when surgical principles are denied in hip fracture fixation.

Clinical relevance Though vascular complications are infrequently encountered in DHS osteosynthesis they have to be considered as a potential complication when surgical principles are not followed in this anatomic area.

Keywords Dynamic hip screw · Intertrochanteric fractures · Vascularcomplications

Introduction

Surgical stabilization of proximal femur fractures represents one of the most commonly encountered orthopedic trauma procedures and is basically accomplished by gliding hip screw/plate or cephalomedullary systems [1]. Vascular compromise wihin these procedures can be caused by fracture fragments too [2–5], but iatrogenic reasons are most frequently found in the literature [6–9] resulting in different consequences depending on the extent of the vessel's wall damage.

Though vascular complications are reported with a low incidence between 0.2% in hip fracture surgery [10] and 0.49% in internal fixation for proximal femoral fractures [11], it is discussed that they may be more present

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in dynamic hip screw (DHS) osteosynthesis than usually anticipated [12–15]. Meta-analyses indicate that if iatrogenic impacts occur in they affect predominantly extrapelvic vessels, especially the deep femoral artery and are related to protruding screws [11, 16, 17]. However, publications covering this problem are infrequently found and represent most often small case series [12]. Especially, investigations with an experimental setting are published sporadically [3] and if so, detailed data are often missing [18].

Based on observed vascular complications with DHS fixation [7] and their increasing frequency during the last years [11], it was the intention of this study to evaluate potential risks for individual vascular structures of the thigh caused by standard DHS osteosynthesis, namely the PS of the DHS side-plate. It was also of interest to demonstrate additional risks in PS application caused by plunging instruments like an overshoting drill bit when an inadequate surgical technique is used.

Materials and methods

Ten freshly enbalmed pelvic/leg specimens from 7 male and 3 female donators (mean age: 72.4 years 39–98; 19.67), which represented 6 right and 4 left extremities, were used. Donators with prior skeletal surgery or osseous deformities as well as recognizeable bone diseases were excluded by evaluation of their medical history and fluoroscopic control. Prior to testing, a large AO femur distractor was mounted on each specimen with it is pins placed into the iliac crest and the distal femur. Then a traction force of 28.66 lb was applied to simulate extension on a fracture table (Fig. 1). The applied force was obtained as the median of intraoperative records in 50 consecutively fixed intertrochanteric fractures (min.: 6.61 lb/max.: 55.11 lb; stdev.: 4.622).

After distraction, a steel-made, four-hole DHS system (DePuy Synthes Austria®) was implanted in regular technique under fluoroscopic control with the hip screw placed centrally into the femoral neck in frontal and lateral view, respectively. Thereafter a four-hole side plate (SP) with an angulation of 135° was aligned along the axis of the femoral shaft and fixed with bicortical screws after predrilling of screw holes. PS were consecutively numbered proximally to distally from "1" to "4" and the distance from the tip of the greater trochanter to the center of each plate hole was measured in millimeters. The length of inserted plate screws (PS) was obtained by a depth gauge and 2 mm were added to the measured screw length. After PS's insertion, soft tissue layers at the medial side of the femur diaphysis were dissected from an additional incisionand evaluated for any contact between the screw tips and major vascular structures (Fig. 2). Then the screws were removed and a depth gauge was inserted 50 mm deep into each screw hole and blocked

Fig. 1 Laboratory set-up with mounted large femoral distractor to apply traction under radiographic control

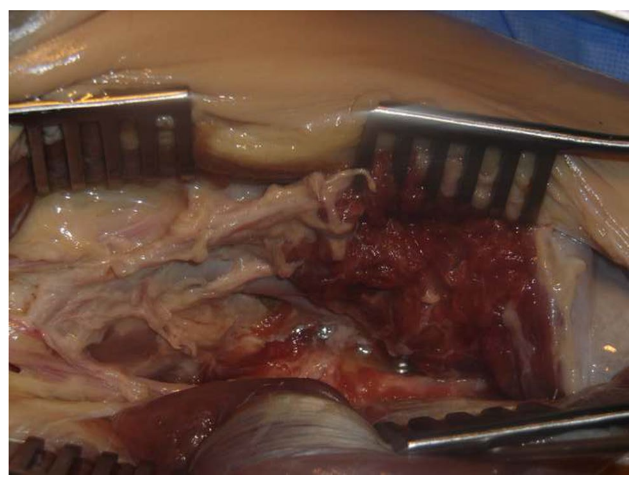

Fig. 2 Close contact of a side-plate screw tip with the DFA at the level of the first plate hole

with a clamp, thus immidating a plunging instrument (like a drill bit) and it is risk of an unintentional vascular compromise (Fig. 3), which were evaluated via the medial incision, too; by this method a protrusion of 17.9 mm on an average (13.8–24.2; ± 2.804; median: 17.3) was achieved beyond

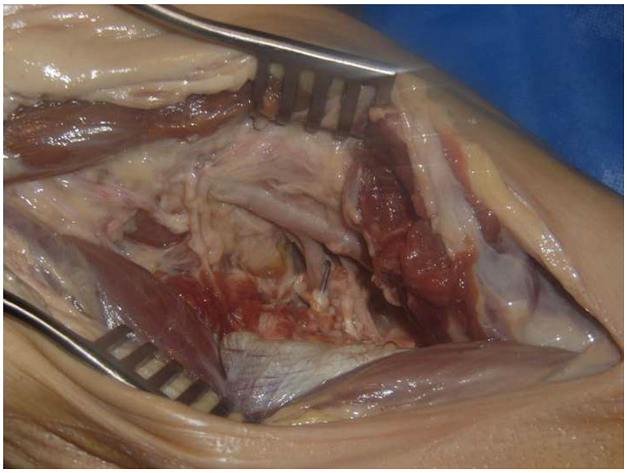

Fig. 3 Tip of depth gauge simulating a plunging instrument in close contact to the main trunk of the DFA

the medial femoral cortex depending on the width of the femoral shaft.

For each PS position, three consecutive courses representing three different inclinations of PS insertion as well as simulated protruding instruments were performed, while the DHS side-plate's position remained unchanged. In a first course, the PS/instruments were inserted perpendicular to the plate surface (group1: inclination 0°) followed by a second course in which new screws/"instruments" were inserted with a 30° posterior inclination (group 2; inclination −30°) and a third course in which 30° anteriorly inclinated screws/"instruments" (group 3; inclination +30°) were tested.

Statistical evaluation was performed using SPSS software version 20.0 (IBM, Chicago, IL, USA). Data were expressed as frequencies or percentages for discrete variables and as mean ± standard deviation for continuous variables. Comparisons between two groups were performed with the chi-squared test for categorical variables, and unpaired *t* test for continuous variables, comparisons between variables in more than two categorial groups were made using the Kruskal–Wallis test. p values < 0.05 were considered as statistically significant.

Results

The average distance between the tip of the major trochanter and the center of the first plate hole was 105.2 mm (94–116 mm; ± 0.693) which consecutively resulted in average distances of 121.2 mm (110–132 mm; ± 6.93) for the second hole, 137.2 mm (126–148 mm; ± 6.93) for the third hole and 153.2 mm (142–164 mm; ± 6.93) for the fourth hole according to the geometry of DHS plates. Screw lengths of inserted PS decreased proximally to distally in all given inclination angles according to the anatomy of the proximal femur (see Table 1).

Direct impact of screw tips with some major vascular structure of the thigh was observed in 15/120 of inserted PS (12.5%). On the other hand, vascular contact by plunging instruments was seen in 22/120 PS (18.3%) within a range of 17.9 mm on an average beyond the medial cortex of the femoral shaft. Overall, among 37/120 potential compromises (30.8%) the system of the deep femoral artery ($n = 26/120$) was significantly more often endangered than the system of the superficial femoral artery ($n = 11/120$) ($p = 0.007$) (see Table 2). In respect to a certain vascular structure, the main trunk of the deep femoral artery revealed most often contacts with implants ($n = 13/120$),

Table 1 Vascular contacts in relation to length and position of plate screws (PS) ($n = 37/120$)

Screw inclination	Screw position	Screw length (mm)	Direct vascular impact	Vascular impact in projection
0°	1	**36.2** ± 2.44 (34–40)	2	3
	2	**34.4** ± 3.32 (28–40)	2	2
	3	**34.4** ± 3.32 (28–40)	2	2
	4	**31.3** ± 4.19 (24–38)	1	4
−30°	1	**32.4** ± 5.35 (22–42)	4	1
	2	**28.8** ± 5.81 (20–38)	0	3
	3	**28.8** ± 5.15 (20–38)	1	2
	4	**25.8** ± 4.51 (18–34)	0	0
+30°	1	**34.4** ± 3.66 (30–42)	0	2
	2	**33.8** ± 3.15 (30–40)	2	1
	3	**33.2** ± 3.91 (28–40)	1	1
	4	**32.0** ± 3.68 (26–38)	0	1

Bold = mean value ± std. dev. (min–max); values = millimeters

Table 2 37/120 screw positions with potential extrapelvine vascular impact of the femoral artery vessel system

	SFA	DFA	*p* value
Direct contact	4	11	0.62
In projection	7	15	0.74
Total	11	26	0.007

SFA superficial femoral artery, *DFA* deep femoral artery

followed by the superficial femoral artery ($n = 11/120$), the first perforator ($n = 7/120$) and the second perforator ($n = 6/120$) of the deep femoral artery (see Table 3). However, these differences showed no statistical significance ($p = 0.281$), which was also mirrored in the subgroups for direct vessel contacts ($n = 15/120$; $p = 0.728$) and potential contacts by overshoting drill bits ($n = 22/120$; $p = 0.357$).

In respect to individual screw holes (1–4) of the femoral side-plate, the contacts with vascular structures decreased constantly from proximal to distal as in position 1 contacts were seen in 12/120, followed by position 2 ($n = 10/120$), position 3 ($n = 9/120$) and position 4 (6/120). This trend was not statistically significant even when PS positions were split up into "proximal" (position 1 + 2) and "distal" group (position 3 + 4) (see Table 1). Neutral inclination (0°) of PS gave highest risks of vascular contact ($n = 18/120$), followed by the screws/"instruments" in − 30° posterior inclination ($n = 11/120$) and those in + 30° anterior inclination ($n = 8/120$), but significant differences could only be detected between 0° and + 30° anterior inclination ($p = 0.017$), while no significant differences could be evaluated between 0° and − posterior 30° inclination ($p = 0.104$) or between − posterior 30° and + anterior 30° inclination ($p = 0.431$). In addition, the analysis of subgroups of PS ($p = 0.404$) and "plunging instruments" ($p = 0.181$) revealed no significant differences in respect to inclinations and vessel contacts.

Only in screws with − 30° posterior inclination, an individual screw position (number 1) revealed significantly more impacts by screw tips than others ($p = 0.031$), while in screws with 0° and + 30° anterior inclination no significant differences concerning idividual screw positions.

Discussion

Sliding hip screw systems are an established treatment concept of intertrochanteric fractures and provide early mobilization with improved functional outcome as well as reduction of morbidity and fatal complications [1]. Though a low incidence of vascular complications in hip fracture stabilization is reported [10, 11] they represent for the individual patient a potential risk for long-term functional deficits or even fatal outcome [19]. Iatrogenic damage accounts for the majority of these cases [6, 16, 20] and has been observed for almost all kinds of implants but due to their frequent use, it is most often reported in gliding hip screw and caphalomedullary nailing systems [6, 21] predominantly related to the tips of sideplate screws or distal locking bolts [16].

Our results demonstrate that potential danger for extrapelvine vascular compromise in DHS osteosynthesis related to PS insertion exists in about one-third of procedures (30.7%) with a significant predominance of the DFA system. This finding comes up with the literature [7, 10, 11, 22] and is considered due to its anatomic location within the medial intermuscular septum between the femoral shaft, the vastus medialis and the adductor muscles [17]. The DFA originates 2.2–5 cm distally to the inguinal ligament at the latero-dorsal circumference of the common femoral artery. In its course it is situated dorsally and laterally to the SFA releasing the Aa. circumflexae femoris lat. et med. at the level of the femoral neck and the intertrochanteric area. Distally, three perforating branches emerge from the main trunc's lateral side and pierce the tendon of the adductor magnus muscle [23]. The first perforator pierces at the distal edge of the pectineus muscle, while the second is vanishing at the upper rim of the adductor longus muscle. The third perforator, which represents the end branch of the profunda femoris, runs dorsally to the adductor longus before piercing to the posterior side. Along with the DFA 's neighbourhood to the medial femoral cortex the perforators contribute to an additional vulnerability by fixing the vessel near the femur shaft [8]. Additional danger can result intraoperatively from the tightened muscle envelope when traction is applied on a traction table [13] and from the extended leg's position, especially in internal rotation [3]. However, it has to be emphasized that

Table 3 Direct vascular contacts of PS ($n = 15/120$) and potential impacts of plunging instruments ($n = 22/120$) in relation to inclination and affected anatomic structures

	0°		− 30°		+ 30°	
	Direct in	Projection	Direct in	Projection	Direct in	Projection
Superficial femoral artery	4	5	0	0	0	2
Profound femoral artery	1	3	3	2	1	3
First perforator	1	0	1	3	2	0
Second perforator	1	3	1	1	0	0
Total	7	11	5	6	3	5

DHS is a globally used and reliable implant providing excellent results. Our data do not indicate vascular compromise in 30% in any case, but emphasizes a close vicinity of the implant to vascular structures, which is especially important in situations with unintentional blunging of instruments and/or when surgical techniques are not correctly applied.

In our investigation we found no significant prevalence for any individual arterial branch to be at special risk, but in all modes (direct PS contact, potential contact by plunging instrument) the trunc of the deep femoral artery was most often affected due to it's anatomic position next to the medial femoral cortex. Lesions of DFA's most proximal branches—the circumflex femoral arteries—are reported occasionally [24] but were not seen in our investigation. They can be injured when K-wires are employed along the femoral neck for determination of its antetorsion or used for additional temorary fixation.

Though the risk of thread cutting decreased during the last decade with the invention of self cutting screw designs, the danger of injuries by protruding screw tips or an unintentional plunging drill bit still exists, especially in blunt instruments [25]. Eggert [8] observed unintentional drilling beyond the medial femoral cortex up to 35 mm and reported an average protrusion length 10 mm, which was mostly underestimated by the treating surgeons. Clement [26] emphasized that over drilling of 6.3 mm on an average occurred independently of the surgeons experience. Our findings indicate that plunging instruments might represent a potential risk of vascular injury in the proximal femur with a rate of 18.3% ($n=22/120$ PS) within an average range of 17.9 mm beyond the medial femoral cortex. This would support the hypothesis that small vessel lesions or false aneurysms are more common than estimated but may to some extent occlude sponanteously [12, 13, 15, 20, 27]. Asmus [28] found in an investigation of 6615 cases treated with DHS fixation that local hematoma was by far the most frequent complication with a rate of 5.43%. Toursarkissian [27] reported on 147 cases of pseudoaneurysms and arteriovenous fistulae smaller than 3 cm in diameter that occluded spontaneously in 86% under sonographic control.

Some authors consider the level of the third and fourth screws in DHS side-plate especially prone for vascular compromise [3, 17, 21, 29] and gave proposals for intramedullary stabilization instead of DHS osteosynthesis [13] or to use two hole DHS side plates [21]. Our data does not suggest an increased risk for vascular damage in distal screw positions [6] as we observed here the lowest impact rate. It seems reasonable for us to refrain from the use of shorter DHS side plates in intertrochanteric fractures to avoid unnecessary loss of fixation stability. On the other hand, vascular compromise has also been reported in intramedullary osteosynthesis [22]. Signifcant preference of an individual screw position and vascular impact were only found within the group of $-30°$ inclination.

Inclinations of PS have also been considered responsible for vascular impact and especially posteromedial screw positions are referred to in the literature [17]. This is supported by our data as we found the least vascular contacts at $+30°$anterior inclination. Significant differences among inclination groups and vascular contacts extsited only between 0° and +anterior 30° (18/120 vs. 8/120; $p=0.017$). However, it is noteable that vascular contacts of screw tips and potential contacts of overshot drills were observed in all PS positions and inclinations and that different screw positioning does not extinct the danger of vascular injury. This fact and possible variations in vascular anatomy require a very careful operative technique when using these implants to avoid unintentional damage by plunging instruments or wrong lengths of PS [30, 31].

Our study has some limitations, as we did not perform an osteotomy of the proximal femur to immitate an intertrochanteric fracture, which we considered not relevant for the discussed aim of our experimental setting. We could also not simulate vascular compromise caused by malpositioned retractors. Because of conservation conditions of the specimens, the coefficient of elasticity was different to tissues alive so we could not dissect vessels beyond 1 mm in diameter. Finally, the drilling for bone screws was not performed in a save "feel and touch"-technique (drilling, pulling back and smoothly re-advancing of the drilling machine when reaching the opposite cortex) which we use in clinical practice as drilling techniques were not the topic of our investigation.

Conclusions

Our data indicate that fixation of intertrochanteric fractures with well established implants, namely a gliding hip screw systems like the DHS, may inherit an overall potential danger of vascular complications in 30.7%, especially when an adequate surgical technique is ignored. The system of the DFA is significantly more endangered than the SFA ($p=0.007$) due to anatomic local conditions. Our data 230 include potential danger by overshot drilling devices which contritbute in 18% to potential vascular compromise within an average range of 17.9 mm beyond the medial femoral cortex. Most vascular impacts were found in neutral and posterior screw inclination, but significant differences in inclination were only found between PS at 0° inclination those at $+30°$ inclination ($p=0.017$). However, no significant preference for any individual arterial structure and the majority of PS positions was found in our data. Especially, the level of the distal PS was not affected but offered the lowest incidence of impact rates.

Technical improvements of osteosynthesis techniques, such as self drilling screws or locking head screw systems with the option of monocortical screw insertion and allowing only one screw direction may help to reduce the iatrogenic risk of vascular damage. On the other hand, with the developement of angular stable implants with variable inclinated PS this advantage cannot be used when bicortical PS are inserted. If in doubt, the use of intramedullary stabilization systems may reduce the potential danger due to the less number of distal screws/polts used the proximal femur. However, care must also be taken not to cause damage to vascular structures by malpositioned retractors, brisk reduction maneuvers, plunging drill bits and incorrect screw length. Thus, a thorough operative technique has to be accomplished by the surgeon, who should consider vascular compromise as a rare but potential source of complication in DHS osteosynthesis.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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