



Original article

Anatomy of the lateral circumflex femoral artery: Does the direct anterior approach to the hip jeopardize vascularization of the proximal femur?

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ABSTRACT

Background: Blood supply of the proximal metaphysis of the femur comes mainly from the lateral circumflex femoral artery (LCFA). Essentially, the anterior approach has gained popularity in hip surgery but routinely requires the ligation of the ascending branch of the LCFA. Until now, there is no study analysing the effect of previous hip surgery on the vascularization of the proximal femur. Notably, it might, however, have consequences on osteointegration of uncemented prosthesis as well as in the management of early complications. Therefore we conducted a retrospective study to address the following questions: (1) Is the blood supply of the trochanteric region impaired by previous hip surgery, (2) does the anterior approach alter it more than other ones?

Hypothesis: We hypothesised that the surgical approach to the hip influences blood supply of the proximal femur, as visualised by retrospective analysis of femoral digital subtraction arteriograms (FDSA).

Patients and methods: A retrospective review of 1280 FDSA, performed for vascular indications with a standard frame rate, between 07/2014 and 06/2016 in a single institution. Qualitatively sufficient FDSA were divided into 4 groups according to the history of previous hip surgery: hip replacement through an anterior approach ($n = 10$) or through a lateral approach ($n = 31$), cephalomedullary nailing for fractures of the proximal femur ($n = 5$), and a control group of 50 continuous patients without previous hip surgery. The number of frames was counted between contrast injection into the femoral bifurcation and filling of the ipsilateral vessels of the greater trochanter to measure a potential delay/impairment of its arterial perfusion. Anatomic variations of the LCFA were also recorded.

Results: The number of frames between contrast injection and visualisation of the blood supply of the greater trochanter was 3.6 ± 0.9 (mean \pm SD) in the control group ($p < 0.001$ vs. all other groups). In patients with a hip replacement, the delay was 7.0 ± 1.9 frames for the anterior approach and 5.2 ± 1.1 frames for the lateral approach, respectively. In patients after cephalomedullary nailing, a delay of 4.8 ± 1.5 frames was measured. The delay in the anterior approach group was significantly longer ($p < 0.001$) compared to all other investigated groups. The ascending branch of the LCFA could not be detected after the anterior approach. As after lateral approach or as in the control group, the transverse branch was detectable in approximately 2/3 of the patients.

Discussion: Arterial perfusion of the greater trochanter is impaired after hip surgery, particularly after an anterior approach. The clinical relevance of these findings still needs to be investigated. It might, however, explain some early aseptic failures of uncemented stems. Moreover, it should be considered in early revision surgery, because combining different approaches might critically impair femoral blood supply.

Level of evidence: III, retrospective case control study.

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1. Introduction

Branches from both circumflex femoral arteries provide the blood supply of the proximal femur. In the past, the focus has been set mainly on the terminal branches of the medial circumflex femoral artery (MCFA), which runs posteriorly to the greater trochanter, due to the essential role of its deep branch in providing blood supply to the femoral head [1–5]. Apparently, the relevance of the lateral circumflex femoral artery (LCFA), which runs anteriorly over the femur along the intertrochanteric crest, has been less studied. Majorly, it forms 3 terminal branches, which include the ascending, the transverse, and the descending branch (Fig. 1). Only a very recent study describes in more detail the blood supply originating from this artery [6]. The ascending branch supplies the joint capsule and part of the femoral neck, while the transverse branch supplies the trochanteric region. Moreover, the descending branch supplies the proximal part of the rectus femoris and the vastus lateralis muscles [6,7]. The LCFA also is a major contributor to the perfusion of the tensor fasciae latae muscle [8].

Hip surgery may be performed through various approaches [9]. Discussion of the relevance of the already mentioned deep branch of the MCFA in any joint preserving surgery is available elsewhere [1–5]. On the other hand, ligation and transection of the ascending branch of the LCFA are recommended routinely to gain appropri-

ate exposure when performing an anterior approach to the hip [10–15]. Notably, the transverse branch of the LCFA might inconveniently then be ligated too, due to possible anatomical variants [16]. However, no published data so far analysed the consequences of a ligation of branches of the LCFA, to the best of our knowledge. While large clinical experience with the anterior approach speaks in favour of the overall safety regarding vascularization of the hip region, this aspect might, however, become critical, particularly in case other approaches have to be performed later on, more specifically in case of early complications, when collateralisation of blood supply to the bone could not develop in the meantime. Essentially, the anterior approach is performed more and more frequently for hip arthroplasty. Currently, it is being chosen in over 40% of primary hip replacements in Switzerland, and more than 20% of primary hip replacements in the Netherlands [17,18]. An issue with specific complications might become relevant just by sheer numbers.

This study aims to determine the influence of different surgical approaches to the hip on the blood supply of the proximal femur by retrospectively analysing femoral digital subtraction arteriograms (FDSA) performed in our hospital. Originally, this was evaluated by answering the following study questions.

- Does previous surgery impair the blood supply to the greater trochanter, as assessed by measuring the delay between injection of contrast media into the femoral bifurcation until perfusion of bone?
- Are the branches of the LCFA altered by previous surgery, as identifiable during FDSA?

We hypothesised that the surgical approach to the hip influences blood supply of the proximal femur, as visualised by retrospective analysis of femoral digital subtraction arteriograms (FDSA).

2. Patients and methods

2.1. Patients

FDSA performed at our institution between 07/2014 and 06/2016 have been identified in the picture archiving and communication system (IMPAX version 6.6, Agfa HealthCare, Dübendorf, Switzerland) of the inhouse Institute of Radiology through appropriate labelling of the study. It allowed the identification of 1280 FDSA, which had been all performed for vascular indications. Exclusion criteria were a related relevant vascular disease of, or previous surgery or interventional procedures on, or in the vicinity of, the femoral arterial division. Studies with an insufficient field of view or without injection of the LCFA were excluded as well. Patients were finally grouped by previous surgery of the hip, be it arthroplasty, and then considering the approach used, or cephalomedullary nailing for fractures of the proximal femur. A patient flowchart is provided in Fig. 2. A continuous control group with 50 patients without previous hip surgery was selected, counting backward from 06/2016.

The median age of the 46 patients with previous hip surgery was 78.3 years (range 63–94 years). Among the 10 FDSA performed after an anterior approach, 3 patients were female and 7 were males. The median age was 81.2 years (range 75–89 years). In the group of 31 FDSA with a lateral approach, there were 14 female and 17 male patients, with a median age of 76.7 years (range 63–90 years). In general, all arthroplasties had been performed for degenerative joint disease. The 5 patients with cephalomedullary nailing were all female, aged 85.4 years median (range 74–94 years). In the control group enclosing 50 continuous patients without previous hip

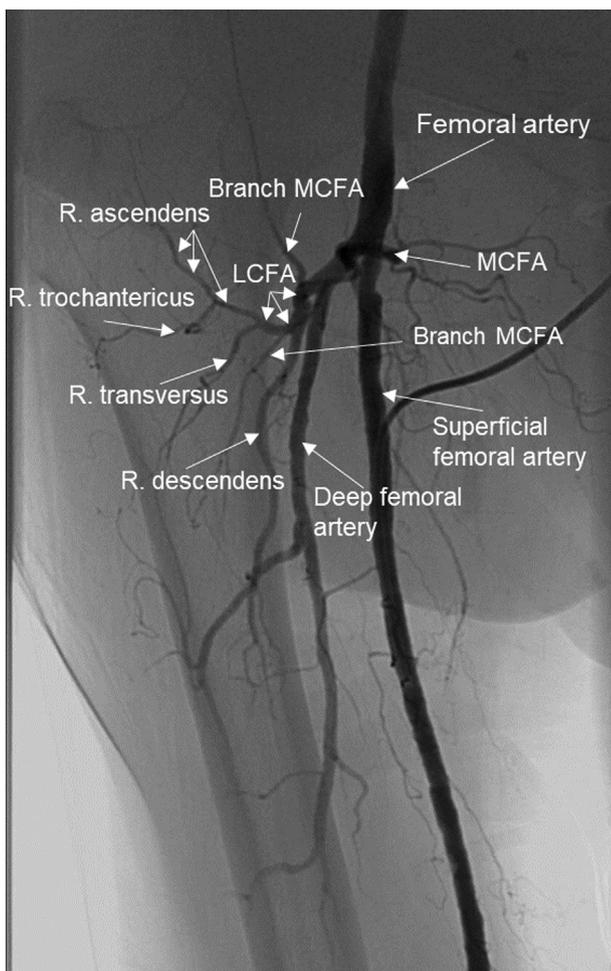


Fig. 1. Femoral digital subtraction arteriogram (FDSA) documenting the perfusion of a proximal femur from a case without previous hip surgery, to illustrate normal anatomy. MCFA – medial circumflex femoral artery, LCFA – lateral circumflex femoral artery. Note the faster filling of the branches of the LCFA than of those from the MCFA. Branch MCFA marks an unnamed branch of the MCFA that forms an anastomosis with acetabular branches.

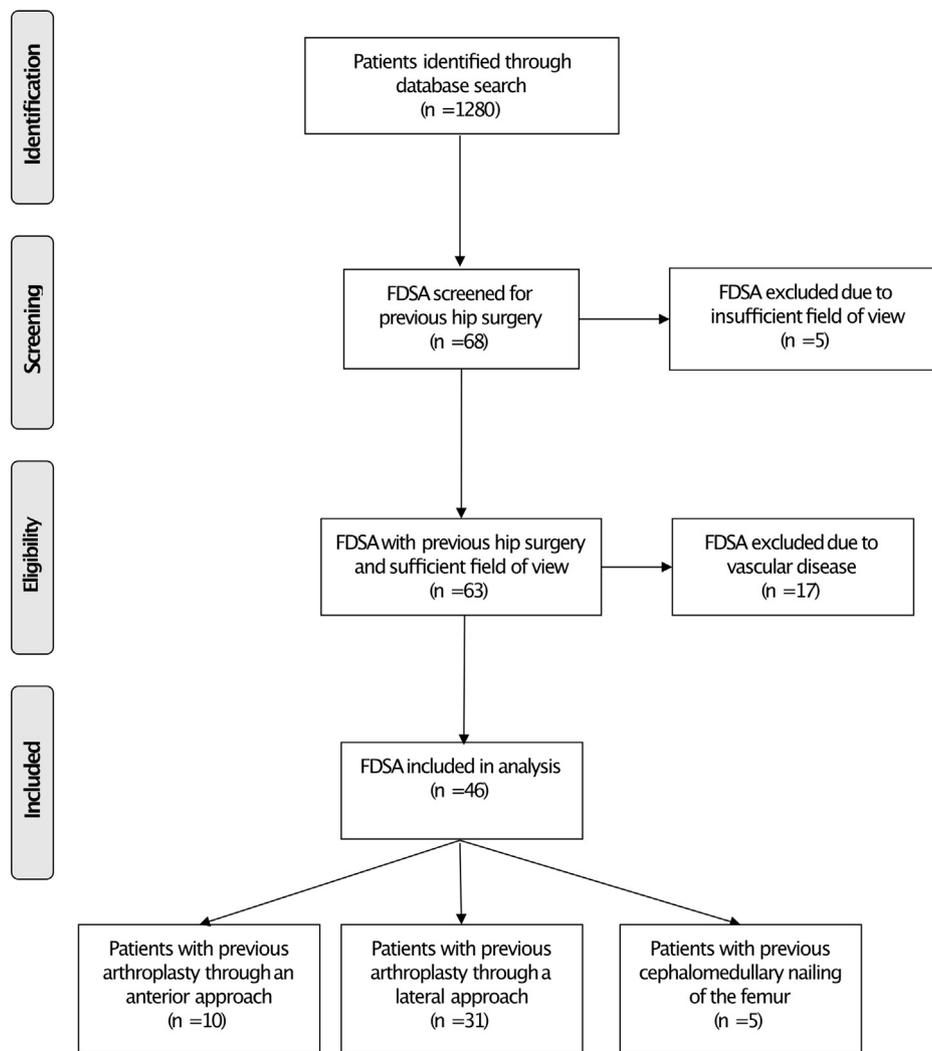


Fig. 2. Flowchart illustrating the patient selection and showing the number of patients excluded.

surgery, 17 of them were female and 33 were males. The median age was 75.0 years (range 43–96 years).

Time was also noted between hip surgery and the date the FDSA was performed. In the anterior approach group, the median time was 42 months (range 1–146 months), whereas in the lateral approach group, it was 150 months (range 62–342 months). The delay between internal nail fixation and FDSA was 32 months (range 8–70 months).

2.2. Methods

The internal review board approved the study protocol. No submission to an external ethical committee was required, as no intervention was performed for study purposes. The technique used for all FDSA was standardised, following an inhouse protocol. The frame rate was identical for all studies, with images taken after every 250 ms.

2.3. Methods of assessment

The analysis of the FDSA was performed on the images including the proximal femur in the field of view. Firstly, the division of the common femoral artery (CFA) into the superficial femoral artery (SFA) and the deep femoral artery (DFA) was identified. The vascularization of the bone of the greater trochanter was evaluated as follows. It started from the injection of contrast medium (Visipaque,

GE Healthcare, Glattbrugg, Switzerland) at the division of the CFA, time until perfusion of the bone was quantified by counting the number of frames until filling of the capillary network of the greater trochanter (Fig. 3). Finally, the LCFA and MCFA and their terminal branches were identified according to Tomaszewski et al. [19]. Any variants regarding branch ramification were noted. Branches of the MCFA were identified to distinguish them from the LCFA branches (Fig. 1).

2.4. Statistical analysis

Continuous variables are presented as means \pm standard deviation (SD) and comparison among groups were performed using the t-test, when normal distribution could be assumed. If data distribution was skewed, then description was done using median and range, with comparison done using a non-parametric test. Dichotomous variables are presented as the number of cases and percentages, comparison among groups being performed using Fisher's exact test. Statistical significance was accepted at $p < 0.05$. Statistical analysis was performed with Excel 2010 (Microsoft, Redmond, WA, USA) with the statistical package.

3. Results

The number of frames until the contrast medium reached and filled the greater trochanter was 5.0 ± 1.6 (mean \pm SD) for all FDSA

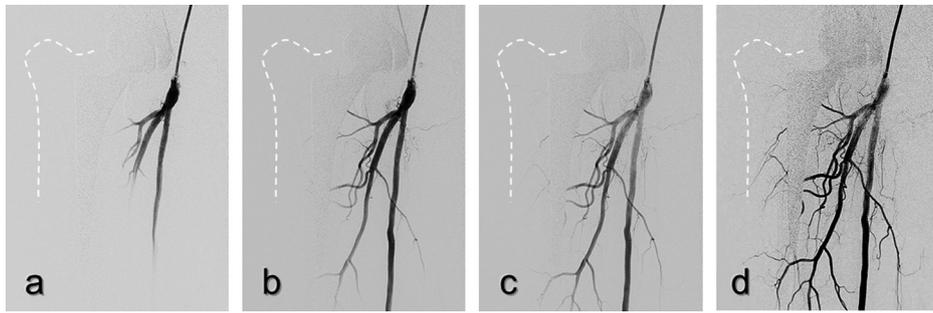


Fig. 3. Femoral digital subtraction arteriogram (FDSA) of a patient with a previous hip replacement through a lateral approach. The dashed white line shows the lateral contours of the proximal femur. Starting from (a) to (d) the vascularization of the bone of the greater trochanter was evaluated as follows. Beginning from the injection of contrast medium at the femoral arterial division (a), time until perfusion of the bone was quantified by counting the number of frames until the greater trochanter was obviously perfused. In (d) a faint contrast uptake of the bone is visible, due to the filling of the capillaries.

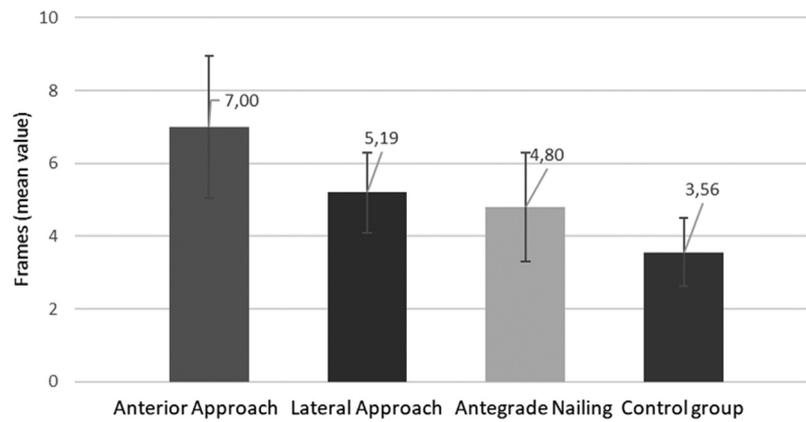


Fig. 4. Mean number of frames until perfusion of the greater trochanter. The count starts when the contrast medium reaches the femoral arterial bifurcation. Results are provided for each subgroup. The mean value is indicated at the top of each histogram. Error bars indicate standard deviation.

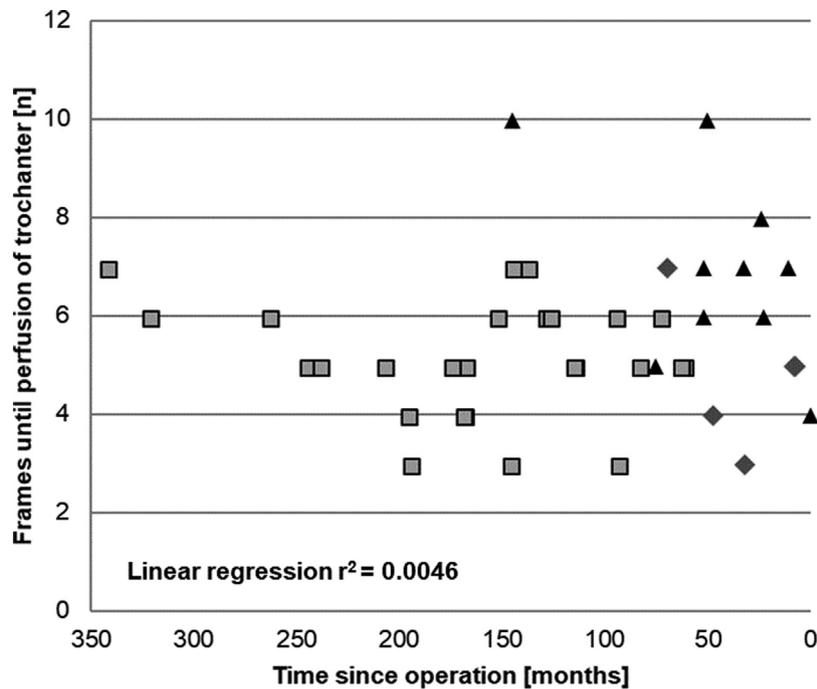


Fig. 5. Graphical illustration of the relation between time passed since previous hip surgery and the perfusion delay of the proximal femur, as measured in numbers of frames between injection of contrast medium into the femoral arterial bifurcation and perfusion of the trochanteric region. No statistically significant correlation could be observed between both variables. The following marking has been used: triangles for cases with hip replacement performed through an anterior approach, squares for cases with hip replacement performed through a lateral approach, and diamonds for cases of cephalomedullary nailing of the femur. Note the differing timely distribution of the approaches used for hip replacement, corresponding to a change in regional practice.

performed after a previous hip surgery. After arthroplasty, the delay was 5.5 ± 1.5 frames, while it was 4.8 ± 1.5 frames after cephalomedullary nailing of the femur. In the control group without previous hip operation, 3.6 ± 0.9 frames were counted. Perfusion of the greater trochanter was significantly delayed in all previously operated patients, compared to the control group ($p < 0.001$). Results are detailed in Fig. 4.

Among the patients who had undergone hip arthroplasty, the number of frames was 7.0 ± 1.9 after a previous anterior approach for hip replacement surgery, while after a lateral approach it was 5.2 ± 1.1 frames ($p < 0.001$). While there was no significant difference in the perfusion time when comparing the previous arthroplasty through a lateral approach with previous cephalomedullary nailing ($p = 0.48$), the difference in the delay between anterior approach and internal fixation was barely at the limit of statistical significance ($p = 0.045$). When comparing the previous anterior approach for hip arthroplasty with all other patients, the difference was statistically highly significant ($p < 0.001$).

The relation between the timeframe of previous hip surgery and delay until perfusion of the greater trochanter is illustrated in Fig. 5. No statistically significant correlation could be identified (linear regression $r^2 = 0.0046$). For 5 patients in the group of the lateral approach (16%), the date of the hip replacement could not be traced with enough precision, thus these cases had to be excluded from this analysis.

In all patients who had hip replacement through an anterior approach ($n = 10$), the ascending branch of the LCFA was stunted or undetectable (Fig. 6). In the patients who had undergone hip replacement through a lateral approach ($n = 31$), the ascending branch was identifiable in 27 cases (87%) (Fig. 7). After cephalomedullary nailing ($n = 5$), the ascending branch could always be identified (100%). In the control group ($n = 50$), the ascending branch was detected in all but one case (98%). There was a transverse branch detectable in 6 (60%) of the 10 patients in the anterior approach group. Among the 31 patients in the group of hip arthroplasty through the lateral approach, the transverse branch was identifiable in 19 cases (61%), but it always originated from the ascending branch of the LCFA. In the control group, this was the case in 36 patients (72%). In the cephalomedullary nail group all transverse branches were detectable (Fig. 8).

4. Discussion

This study aims at evaluating the effect of previous hip surgery on the vascularization of the proximal femur. For this purpose, perfusion time was assessed, as it could be documented retrospectively in FDSA performed for vascular indications. The first observation is that any previous surgery, be it arthroplasty or cephalomedullary nailing of femoral fractures, does disturb perfusion of the proximal femur to a certain degree. It might well be argued that an increase in the delay of 1–3 angiography frames (taken every 250 ms, corresponding to an additional delay of 250–750 ms) might not be clinically relevant. The second observation is that an anterior approach causes the most considerable disturbance of the blood supply to the proximal femur. On balance, the perfusion delay appears to be twice as long in this group as observed in the control group (Fig. 4). Both the patients with previous hip surgery, as well as the patients from the control group, suffered from peripheral vascular disease, which indicated FDSA. Differences in perfusion might as well be less pronounced in the absence of vascular disease.

No correlation between time since previous surgery and perfusion delay could be identified in our data ($r^2 = 0.0046$), as illustrated in Fig. 4. A different distribution over time between the lateral and the anterior approach for hip replacement is obvious. Majorly, this is because the anterior approach has become the standard approach

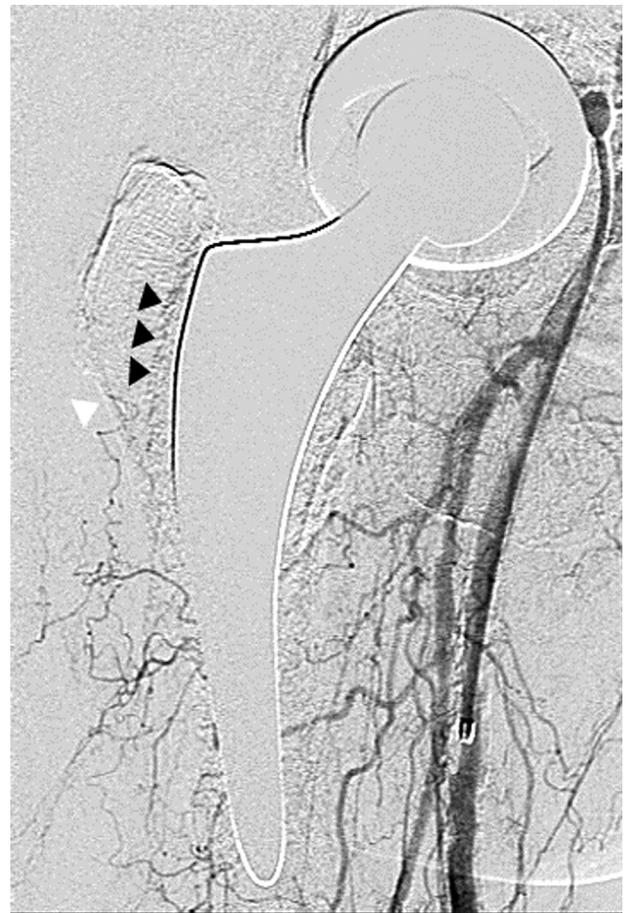


Fig. 6. Femoral digital subtraction angiogram (FDSA) image of a patient with previous hip replacement through an anterior approach. The injection was performed in the superficial femoral artery, but retrograde filling allowed good visualisation of the deep and circumflex femoral arteries. The catheter is in place and projects over the arterial axis. Note the reduced contrast uptake in the greater trochanter (proximally to the white arrowhead), compared to the rest of the femur. Black arrowheads mark bone cement lateral to the stem of the prosthesis.

for primary hip replacement in our region some years ago. Potential revascularization of the bone can, however, be discarded as an explanation. Not only considering the distribution of the observed data but also as bone repair is a process that evolves over months, even if remodelling happens over a timeframe of many years [20]. Stem design evolved in the study population, but is not expected to have any influence on the perfusion of the bone of the greater trochanter.

The morbidity of the surgical approach to the hip regarding impairment of blood supply to the proximal femur has been a neglected issue in clinical research. Bony integration of uncemented implants might become compromised in the presence of insufficient blood supply, and this might be an unrecognized cause of early aseptic loosening or failed integration, particularly if using short stems, which rely more on fixation in the metaphysis. Considering the fact that the anterior approach and uncemented femoral stems have become increasingly popular in hip arthroplasty [17,18], the problem might well become relevant just by sheer numbers. To investigate this hypothesis, a thorough comparison of hip register data regarding the implantation of an identical stem through different surgical approaches would be necessary, focussing on early revision rates. However, such data are not available yet. Neither the Australian nor the Swiss arthroplasty register could provide any data following our inquiry. No uncemented stem

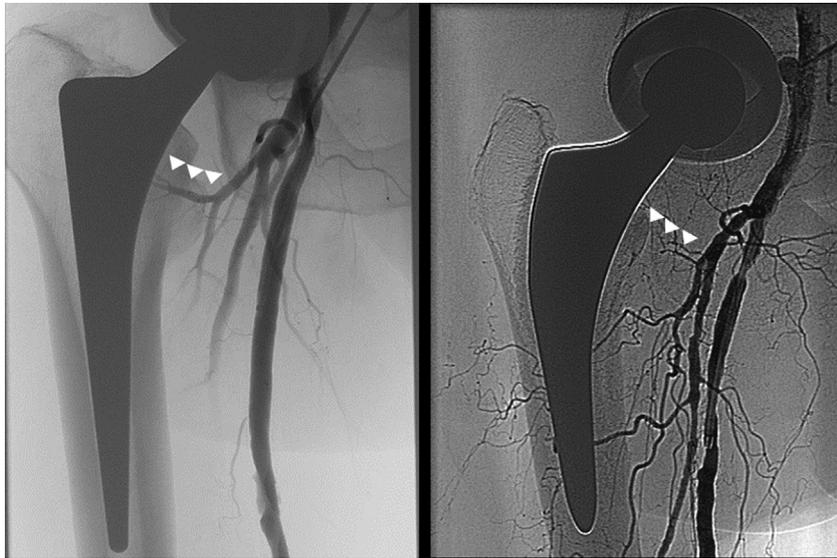


Fig. 7. Examples of femoral digital subtraction angiograms (FDSA) from patients with a previous hip replacement, performed through a lateral approach (on the left, after 4 frames) and through an anterior approach (on the right, after 6 frames). The ascending branch (white arrowheads) of the LCFA is well perfused on the image on the left, whereas it is stunted on the image on the right, after an anterior approach. Note the absence of contrast medium in the greater trochanter after anterior approach, on the right, despite a delay of 6 frames from the injection of the femoral bifurcation, whereas the subtrochanteric and diaphyseal region is well-perfused.

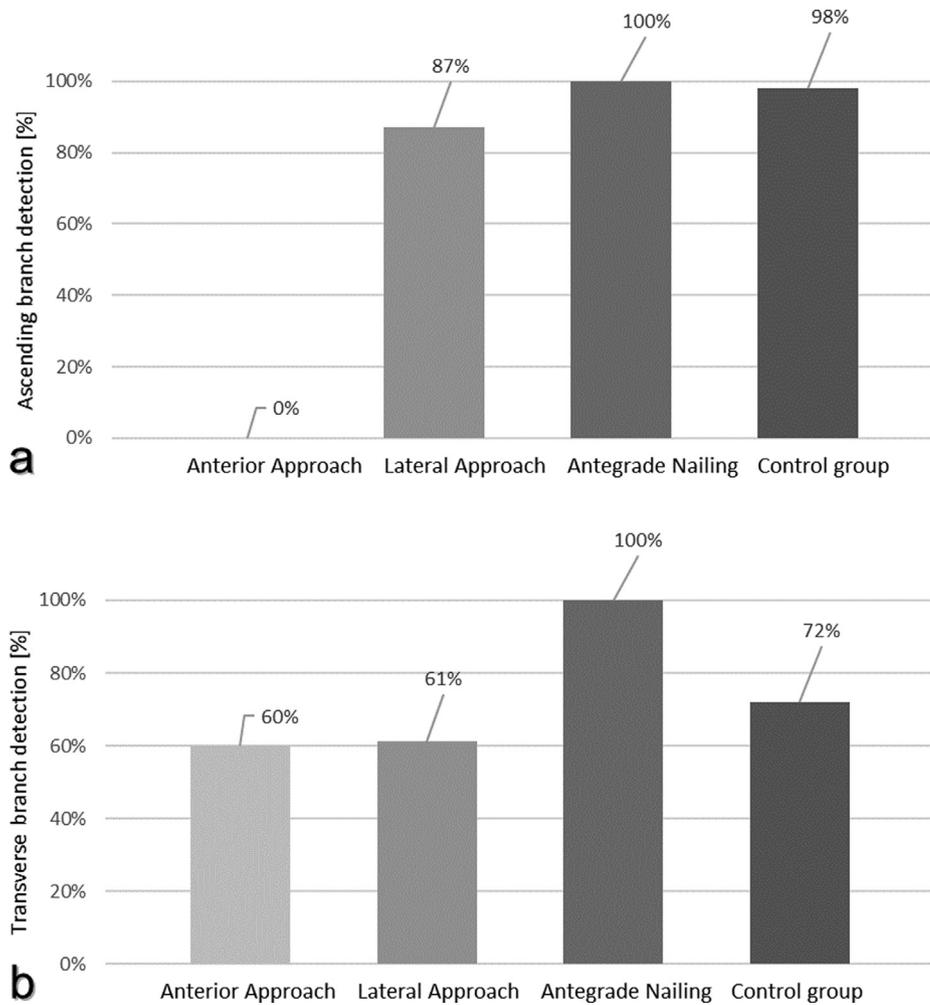


Fig. 8. Detection of the ascending (a) and transverse (b) branch of the lateral circumflex femoral artery, measured and displayed in percent by subgroup (anterior approach $n = 10$, lateral approach $n = 31$, antegrade nailing $n = 5$, control group $n = 50$).

with sufficient numbers implanted through both anterior and other approaches could be identified to be suitable for analysis.

Early femoral complications after hip arthroplasty, such as periprosthetic fractures, instability or infection, might require revision through a transfemoral approach [21,22]. As the trochanteric branch and the corresponding vascularization of the greater trochanter originating from the MCFA have to be sacrificed for the transfemoral approach [21,22], blood supply to the proximal femur might be critically jeopardized if hip surgery has been performed initially through an anterior approach, as the primary blood supply from the LCFA already has been sacrificed [6]. Also, a transfemoral approach or a periprosthetic fracture interrupts the blood supply through the bone itself, leaving only residual perfusion through supra-acetabular branches of the superior gluteal artery [2].

In this study, the blood supply to the proximal femur was assessed by measuring the time delay (number of frames) between injection of contrast medium at the femoral bifurcation and contrast medium uptake in the capillaries of the bone of the greater trochanter. No perfusion pressure or oxygen partial pressure could be measured in the tissues of interest. Minimal metabolic requirements of the bone are unknown. Minimal perfusion pressure and oxygen partial pressure needed for healing of soft tissue wounds have been discussed in the literature, and threshold values of 35–40 mmHg have been recommended [23,24]. However, these cut off values do not reach broad international consensus in the treatment of peripheral vascular insufficiency and chronic wounds. Anyway, these threshold values cannot be transposed directly to the bone, considering the architectural and metabolic differences between the tissues. However, performing an angiography of the proximal femur might have to be considered when investigating cases with delayed healing of the proximal femur, if an anterior approach has been performed previously.

The ascending branch of the LCFA does have a relevant size, and it is not surprising that sacrificing such a vessel may impair local blood supply. Ligation is mostly preferred over coagulation due to the diameter of this vessel [14,15]. The literature shows that the LCFA also is a major contributor to the perfusion of the tensor fasciae latae muscle [16,25]. As the transverse branch, which is going to the greater trochanter, originates from the ascending branch in 36/50 (72%) of the patients of the control group in our study, an unintentional or accidental ligation of both branches might be possible. Our findings support this hypothesis as no transverse branch could be detected in 4/10 (40%) patients in whom an anterior hip approach had been performed. One could derive from these observations that the two most important arteries of the trochanteric region [6,7] might be sacrificed in a high number of patients operated on the hip through an anterior approach. Local blood supply might be impaired even more when cable passers are used to place a subtrochanteric cerclage [26,27]. The blood supply to the muscles surrounding the proximal femur is not relevantly compromised, mostly due to the presence of perforators of the descending branch in up to 80% [28]. Damage to the nerve supply of muscles during an anterior hip approach is also possible, especially the tensor fasciae latae with its superior gluteal nerve lying in close correlation to the ascending branch of the LCFA [8,29,30], potentially worsened by impairment of the perfusion of this muscle. If muscle impairment or reduced proprioception also contributes to a higher dislocation rate after an anterior approach remains unclear [26]. However, patients operated through an anterior approach often use more energy resources to maintain static balance [30].

The LCFA is also indispensable as a contributor to the collateral circulation in patients with peripheral vascular disease, mainly through its descending branch [8]. It might also be relevant in vascular reconstruction surgery [8]. The descending branch of the LCFA has also served as an alternative arterial graft for coronary bypass grafting [31,32]. In the field of plastic surgery, the LCFA is often

used as a supplying artery for an anterolateral thigh flap [33]. These elements are mostly neglected in orthopaedic surgery but should be taken into consideration when choosing the most appropriate approach to the hip.

This study has limitations.

The main limitation concerns the assessment of perfusion, as it was performed as available on FDSA. All been made for vascular indications, not specifically to evaluate perfusion of the proximal femur. A large proportion of FDSA had to be excluded from analysis for technical reasons, such as inadequate field of view or insufficient filling of the proximal femoral vessels. Some variants of the DFA or SFA [16–24] or long variants of the LCFA [24] might not have been documented. But this would not influence the time until filling of the greater trochanter and the main outcome measure used to evaluate perfusion.

Also, despite a rather large number of FDSA scanned, only a relatively small number of patients had previous hip surgery with technically sufficient depiction of the zone of interest. Small numbers available for analysis represent a notable limitation of the study. Indeed, this fact explains the relatively large variability in the results, with overlapping values between groups, ± 2 SD representing approximately a 95% confidence interval in normally distributed data. This notably weakens the clinical relevance of the conclusions, even if appropriate statistical tests indicate highly significant differences.

Exclusion of 5 patients from the group of the lateral approach from the analysis of the relation between time since previous surgery and perfusion delay was because of inadequate documentation of the date of arthroplasty, but should not have a significant impact on the results. The vast majority of patients (63/68, 84%) were still available, and the variability of results was smallest in this subgroup.

5. Conclusion

Arterial perfusion of the proximal femur is impaired after any previous hip surgery, but particularly after an anterior approach. The clinical relevance of these findings still needs to be investigated. It might however explain some early aseptic failures of uncemented stems. Anatomy of the vascularization of the proximal femur should be considered in early revision surgery, as combining different approaches might critically impair femoral blood supply.

Disclosure of interest

The authors declare that they have no competing interest.

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Authors' contributions

Christoph Hartog (conceptualization, study protocol, literature review, data collection, statistical analysis, data analysis and interpretation, manuscript redaction).

Christoph Metzler (study protocol, data analysis and interpretation).

Christoph Meier (data analysis and interpretation, revising manuscript, supervision).

Fabian Kalberer (data analysis and interpretation, revising manuscript, supervision).

Peter Wahl (conceptualization, study protocol, statistical analysis, data analysis and interpretation, manuscript redaction and critical review, supervision).

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