Pseudoaneurysm of the Lateral Femoral Artery: A Systematic Review of a Rare Complication in Patients With Pertrochanteric Fractures

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ABSTRACT

Introduction: We present a case of a lateral circumflex femoral artery pseudoaneurysm associated with pertrochanteric hip fracture. **Materials and Methods:** We performed a systematic review considering all cases published in the last 15 years about this pathology (n=40). **Results:** No statistically significant associations were found between any of the variables studied. However, there seems to be some consensus in maintaining a high clinical suspicion for early intervention, thus obtaining better outcomes. Both its etiology and location are related to the morphology of the fracture, the surgical procedure, and the osteosynthesis material. Likewise, there is a greater tendency to use CT angiography for the diagnosis and localization of the pseudoaneurysm. **Conclusion:** Our patient is the first reported case of spontaneous resolution. Knowing this rare complication is essential to optimize therapeutic results. This review, the most recent on the subject, is very useful in listing and highlighting the most important aspects of the management and prevention of pseudoaneurysms secondary to hip fracture.

Key words: Hip fractures; pseudoaneurysm; femoral artery; case report; systematic review.

Level of Evidence: IV

Seudoaneurisma de la arteria femoral lateral: revisión sistemática a propósito de una complicación infrecuente en pacientes con fracturas pertrocantéricas

RESUMEN

Introducción: Se presenta un caso clínico de seudoaneurisma de la arteria femoral circunfleja lateral secundario a una fractura pertrocantérica de cadera. **Materiales y Métodos:** Como el cuadro y su localización son infrecuentes, se llevó a cabo una revisión bibliográfica sistematizada que incluyó todos los casos publicados sobre esta enfermedad (n = 40) en los últimos 15 años. **Resultados:** No se hallaron asociaciones estadísticamente significativas entre ninguna de las variables estudiadas. Sin embargo, parece existir cierto consenso en mantener una alta sospecha clínica para una intervención precoz y así obtener mejores resultados. Tanto su etiología como su localización se relacionan con la morfología de la fractura, el gesto quirúrgico y el material de osteosíntesis. Asimismo, hay una tendencia mayor a utilizar la angiotomografía para el diagnóstico y la localización del seudoaneurisma. **Conclusiones:** Nuestra paciente es el primer caso de resolución espontánea. Es fundamental conocer esta complicación tan poco frecuente para optimizar los resultados terapéuticos. Esta revisión, la más reciente sobre el tema, es muy útil para enumerar y subrayar los aspectos más importantes sobre el manejo y la prevención de los seudoaneurismas secundarios a una fractura de cadera.

Palabras clave: Fractura de cadera; aneurisma falso; arteria femoral; caso clínico; revisión sistemática.

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INTRODUCTION

Hip fractures are one of the most common fragility fractures, and their incidence is expected to increase in the future.[1] Among the possible therapeutic alternatives, fixation by trochanteric locking is a common process and widely described in the literature.[2]

Pseudoaneurysm can be defined as a repermeabilized and encapsulated pulsatile hematoma, in communication with a damaged vessel. Its origin is in the rupture of the arterial wall by inflammatory, traumatic, or iatrogenic processes. However, it is rare in the field of orthopedic surgery in general and as a complication of this technique in particular.[3] However, pseudoaneurysms have been described as the most common vascular complication associated with hip fracture. Moreover, those of the pertrochanteric region tend to have more relationship with the fracture itself; on the other hand, those in the subtrochanteric region are associated with iatrogenic causes, such as the use of retractors, the drilling of the distal screw hole, or the placement of a screw that is too long.[4]

We present a patient with a false arterial aneurysm (or pseudoaneurysm) of the femoral artery after a pertrochanteric fracture of the femur. Regarding this case, a literature review was carried out on this type of vascular complications after a hip fracture. Our objective was to determine what is the most standardized management and the common characteristics of the cases to optimize the results.

MATERIALS AND METHODS

Clinical case

An 83-year-old woman who lived in an institution arrived at our Center with rotation and shortening of the left lower extremity after suffering an accidental fall. In the general assessment in the Emergency Department, the patient was conscious, but disoriented in time and space. There were no other pathological findings. Notable personal backgrounds included a contralateral hip fracture the previous year, chronic high blood pressure, hypercholesterolemia, and moderate cognitive impairment.

In a radiographic study, a 31A2 pertrochanteric fracture of the left proximal femur, according to the AO classification, was observed. On March 21, 2018, she had undergone a closed reduction and osteosynthesis of the fracture with a TFNA™ nail (DePuy-Synthes Companies, CO, USA) of 170 mm in length, 10 mm in diameter, and a cervico-diaphyseal angle of 125º. She progressed favorably, required two transfusions of red blood cell concentrates, and was discharged five days after admission, without other complications.

At the four-week control, she had no groin pain and no complications were observed on the radiographic evaluation. However, she reported pain on palpation with swelling in the medial side of the left thigh and generalized edema in the left lower extremity, within the normal evolution of a patient undergoing surgery for hip fracture. No fluctuations, pulsatile tumors, signs of superinfection, or active exudate or thrombosis were detected.

However, two months after surgery, a decrease in limb edema was observed and a mass of approximately 10 cm in diameter was identified on palpation, with a fusiform, elastic, and mobile appearance, without pulse or obvious pulsatile signs. Given these findings, it was decided to complete the evaluation with a CT scan with contrast (July 2, 2018) (Figure 1) in which a partially thrombosed pseudoaneurysm of 4 cm in diameter was detected in the anterolateral region of the left thigh, at the height of the distal locking screw of the intramedullary nail. It was in contact with a vessel, probably an arterial one due to the characteristics of the lesion, which could correspond to a descending branch of the lateral circumflex femoral artery that originates in the deep femoral artery (DFA).

The patient was sent to a referral hospital to be examined by the Vascular Surgery team. On September 28, 2018, an arteriography of the left femoral sector was performed by the right femoral route with the intention of performing an embolization of the pseudoaneurysm in the thigh; no arteriographic images compatible with aneurysms in the femoral sector were identified (Figure 2).

Subsequently, an ultrasound was performed and the thrombosis of the aneurysm was verified without Doppler signal in its interior. The patient was discharged after 24 h of rest, the right inguinal compressive bandage was removed without hematoma or pulsatile mass. After two years of follow-up, the patient has no symptoms.

Figure 1. CT angiography of the pseudoaneurysm dependent on the lateral territory of the deep femoral artery.

Figure 2. Arteriography revealing the lack of an image compatible with pseudoaneurysm and osteosynthesis with the intramedullary nail.

Systematized search

In the first quarter of 2020, we carried out a systematized literature review (Figure 3) according to the PRISMA protocol.[5] The PubMed, Embase, Scopus, Virtual Health Library (VHL), Cochrane Library, and ScienceDirect databases were reviewed. First, a search on the topic was carried out with the thesauri provided from the PubMed MeSH database, creating the search formula: ((“Femoral Artery”[MeSH]) AND (“Hip Fractures”[MeSH]) AND (“Aneurysm, False”[MeSH])). Given the few results found (29), a broader search was carried out by entering the keywords “femoral”, “pseudoaneurysm”, “hip”, and “fracture” in all the aforementioned databases.

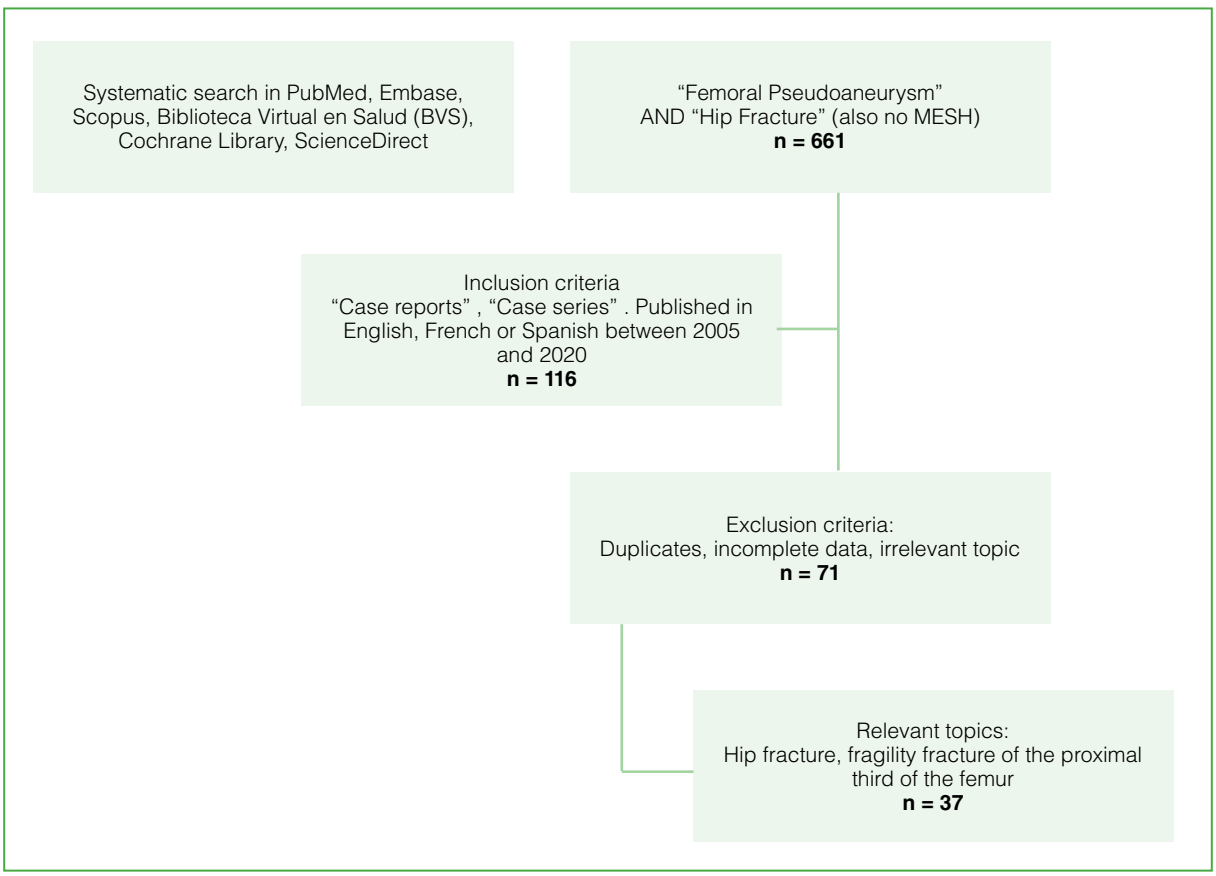

Figure 3. Algorithm of the literature review systematized according to the PRISMA protocol.

We included all articles published between January 1, 2005 and December 31, 2019, which were “case report” or “case series”. The variables were: sex and age of the patient, type of fracture and side, osteosynthesis system, time of onset of symptoms after surgery, type of symptomatology, definitive diagnostic tests, affected artery, and treatment of the pseudoaneurysm. Although they were not an indispensable condition, the following data were collected, if described: suspected diagnostic tests, previous cardiovascular risk factors, and follow-up type. Likewise, those that did not fit the topic and the criteria of description of the case were excluded: pseudoaneurysms in diaphyseal fractures due to high-energy accidents in young patients, cases of complications in orthoprosthetic procedures not due to fracture, periprosthetic fractures.

RESULTS

We included 37 articles in which 40 cases were reported (Annexes 1 and 2). The mean age of the patients was 77.88 years (standard deviation [SD] 11.205; min. 43, max. 94). Twelve (30%) patients were men and 28 (70%) were women. The mean number of days until the onset of pseudoaneurysm-related symptoms (Table 1) after hip fracture surgery was 39.970 (SD 12.68 days).

Table 1. Symptoms that triggered clinical suspicion

	Cardiovascular risk factors	Thigh symptoms	Functional pain or impairment	Pulsatile mass	Anemia that is not corrected	Hemodynamic instability
Yes	9 (22.5%)	35 (87.5)	29 (72.5)	9 (22.5%)	28 (70%)	9 (22.5%)
No	4 (10%)	3 (7.5%)	6 (15%)	27 (67.5%)	8 (20%)	31 (77.5%)
Unreported	27 (67.5%)	2 (5%)	5 (12.5%)	4 (10%)	4 (10%)	0 (0%)

Regarding the description of the fracture, in 18 (45%) cases, it was described as intertrochanteric fracture; in seven (17.5%), as unstable intertrochanteric fracture; in 13 (32.5%), as 31A2 fracture according to the AO/OTA classification; and, in two (5%), as subtrochanteric fracture. The affected side was the right in 13 cases (32.5%) and the left side in 25 (62.5%); in two (5%), no reference was made to the affected side. All were treated surgically. When the type of implant was specified, 23 (57.5%) fractures were treated with some cephalomedullary nailing device and 13 (32.5%) were treated with sliding screw or *Dynamic Hip Screw* (DHS) devices.

For the diagnosis of pseudoaneurysm, a distinction can be made between complementary tests to establish the diagnosis of suspicion in the emergency and tests for definitive diagnosis (Table 2).

Table 2. Complementary tests for suspected and definitive diagnosis

Test	Suspicious	Definitive
CT angiography	11 (27.5%)	21 (52.5%)
Angiography	2 (5%)	12 (30%)
Doppler ultrasound	18 (45%)	0 (0%)
None or other	2 (5%)	0 (0%)
Computed tomography	7 (17.5%)	0 (0%)
Direct view	0 (0%)	7 (17.5%)

The injury was located in the DFA in 8 of the 40 cases (20%), in the superficial femoral artery in four (10%), and in one branch of the DFA in seven (17.5%). The involvement of a lateral branch was specified in six other cases (15%) and the medial side in another 15 cases (37.5%). The appearance of the aneurysm was associated with the displacement of the lesser trochanter (15 cases; 37.5%), the approach (2 cases, 5%), the implant, such as the distal screw of the cephalomedullary nail (5 cases; 12.5%), or the diaphyseal proximal screw of the DHS implant in one case (2.5%).

The vascular complication had always been treated with surgery by means of a stent by catheterization (n = 7; 17.5%), embolization (n = 8; 20%), coil embolization (n = 15; 37.5%), suture or open ligation (n = 8; 20%),

or direct excision of the pseudoaneurysm and the unstable and displaced fragment of the lesser trochanter with which the pseudoaneurysm was associated (n = 1; 2.5%). The mean follow-up of patients was 183,080 days (SD 87,626 days). At the end of follow-up, the evolution was clinically favorable in 21 patients (52.5%) and with objective tests in eight (20%), there was only one death. In the rest, postoperative outcomes were not specifically mentioned.

No association was demonstrated between sex and type of fracture (p = 0.639), the presence or absence of cardiovascular risk factors (p = 0.600), the type of symptomatology, non correctable anemia despite transfusion of red blood cell concentrates (p = 0.643), hemodynamic instability (p = 0.563), the etiological mechanism of pseudoaneurysm (p = 0.427), or the affected arterial territory (p = 0.549). On the other hand, the type of fracture was not associated with the presence of anemia (p = 0.574), the arterial territory (p = 0.533), a pulsatile mass (p = 0.178), or the etiological mechanism (p = 0.283). As clinical criteria, no association was demonstrated between hemodynamic stability and the presence of a pulsatile mass (p = 0.359) or etiological mechanism (p = 0.374), nor between anemia that is not corrected and arterial territory (p = 0.174).

Finally, a hypothesis test was carried out with the chi-squared test to verify that there were no differences in the quantitative variables whether the type of fracture was stable or unstable (Table 3).

Table 3. Comparison of quantitative variables according to the type of fracture

		n	X	SD	Significance	CI
Average age at diagnosis (years)	S	18	75.110	2.973	0.161	-12.140; 2.089
	U	22	80.140	2.051		
Average number of days from surgery to onset of symptoms	S	18	53.330	26.165	0.336	-26.762; 76.381
	U	21	28.520	7.372		
Follow-up (days)	S	12	301.330	176.991	0.201	-130.005; 584.825
	U	13	73.920	30.938		

SD = standard deviation, CI = confidence interval.

DISCUSSION

Pertrochanteric fractures of the proximal femur are a very prevalent entity. The first published case of pseudoaneurysm after a hip fracture is that of Dameron et al. in 1964.[6] In more recent research, the incidence of vascular injuries following a hip fracture has been estimated to range from 0.2% to 0.49%.[7,8] In a series in which more than 7,000 cases of hip fracture were retrospectively reviewed, only four cases with pseudoaneurysm as a complication were found.[4]

The lateral territory of the deep system of the femoral artery is much less frequently involved than the medial territory. We have only found three cases in the last 15 years, in addition to our own. The first case of acute involvement of this territory was published by Rajaesparan et al., in 2008,[9] and is related to the incision by the scalpel or to the beginning of the entry of the osteosynthesis material. Our patient would be, therefore, the second published case of acute presentation and involvement of the lateral side. In addition, we were able to appreciate a change in the involvement of proximal vessels in favor of the more distal vessels, perhaps due to the popularization of intramedullary locking instead of extramedullary fixation, which underlines that the type of implant seems to be related to the affected territory.

In a 2015 systematic review,[10] the authors also found that of the 64 cases published in the previous 50 years, half had occurred in the 10 years before the article had been written. This also highlights the increase in reports of clinical cases of pseudoaneurysms related to a hip fracture in recent years. This is probably due to different reasons, such as the greater instrumentation and manipulation in the reduction,[8] the greater fragility of older patients with more risk factors, and the greater sensitivity of the topic that leads to diagnose and communicate it more frequently.

In that same year, Barquet et al.[8] conducted a systematic review and meta-analysis of all types of vascular lesions associated with orthopedic surgery. They analyzed 182 cases and the most frequent vascular complication was pseudoaneurysm (122 cases) followed by hemorrhagic laceration (42 cases). They collected the frequencies of the affected arterial regions: 8.24% in the pelvis. Outside the pelvis, 78.31% had involvement of the superficial femoral artery and 10.64%, of the DFA, within them, there were only four cases with involvement of the lateral territory like our patient. In contrast, in a 2018 review,[8] the superficial territory was much less frequent than the deep territory. In our review, it was revealed that the deep femoral artery territory is the most often affected.

It has been determined that the most common type of associated fracture is the 31A2 AO/OTA pertrochanteric fracture with medial or proximal displacement of the lesser trochanter.[8,9] This is most often associated with the affected region, the type and time of clinical presentation, and severity. In our systematic review, the involvement was also related to this particular event in about a third of the cases. However, they found no statistically significant differences in the type of osteosynthesis performed. The most frequent mechanisms related to instrumentation were the placement of the third and fourth screws of the plate, and the distal screw of a short nail. This can occur during surgery when the vessel is injured with the drill bit[11] or by chronic irritation of the vessel by a screw that is too long.[12] The risk would increase[6] due to the increased handling and need for instrumentation, poor placement of retractors,[13] or the use of Kirschner pins for reduction. Figure 4 schematically describes the pathophysiology.

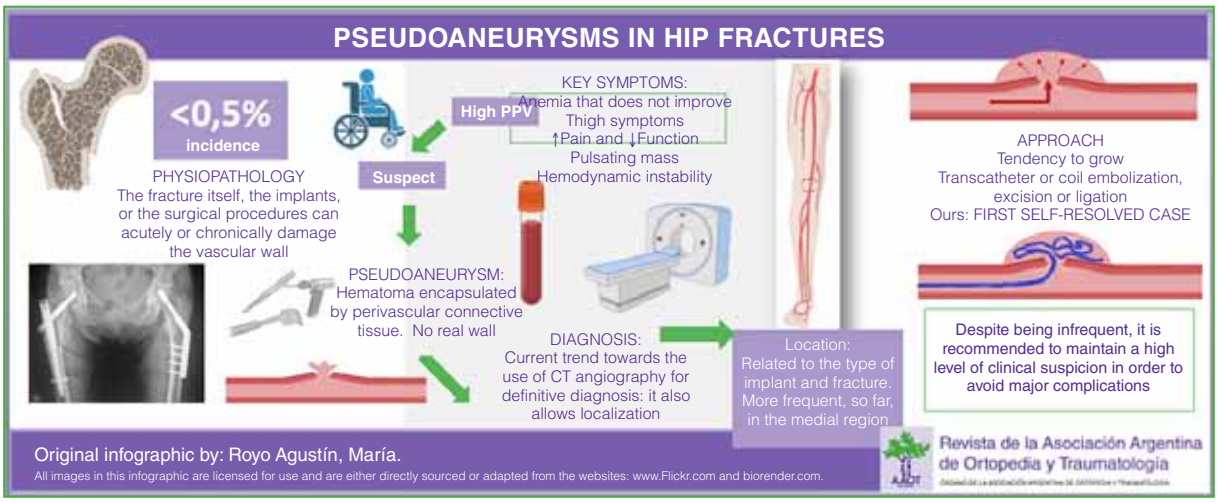

Figure 4. Pseudoaneurysms in hip fractures.

On the other hand, in many cases, the cardiovascular history of the patients is collected or the atherosclerotic disease of the treated vessel is highlighted as a factor associated with the mechanism of formation of a pseudoaneurysm. Therefore, it is recommended to moderate traction due to the fragility of blood vessels with atherosclerosis that we often find in elderly patients.[4] Adduction and internal rotation in the placement of the distal screw of the intramedullary interlock must also be avoided, since in that position, the branches of the DFA seem to be more vulnerable. This was demonstrated by Yang et al. in 2004,[3] in a study with 59 thighs that underwent a color Duplex computed tomography to study the anatomical position of the femoral artery according to the placement of the limb. It was observed that the ideal position is that of neutral rotation, moving the femoral artery or its branches away from the femur and avoiding its injury when placing the distal locking screw. Therefore, we could prevent these injuries if we remembered to place the lower limb in a neutral position before this surgical step.[3,11]

In the same review by Barquet et al.,[8] a differentiation is made in terms of clinical presentation. Chronologically, a distinction is made between acute, subacute, and chronic symptoms. Severity increases according to chronicity, it presents with anemia, clinical or radiological signs of active bleeding, severe hemodynamic instability, or even death. Vande Voorde et al.[11] established an etiological relationship with the chronology of the clinical presentation. They established that, in cases of late presentation, the cause is usually related to friction by mobilization of the fracture fragment, usually the lesser trochanter. In fact, it is the most frequent cause in our review. On the other hand, early symptoms are associated with unprotected drilling, which causes the safe zone to be exceeded. However, we have not observed statistically significant differences between the time of presentation and the stability of the fracture.

The diagnosis is made with the same type of complementary tests that we have collected. It should be noted that our review highlights the greater tendency to use computed tomography that, in its version of CT angiography, has been able to displace angiography in recent years. As in our case, it offers multiple advantages, such as studying the rest of the tissues, the bone, the fracture, observing with what etiological mechanism it can be related and allowing a three-dimensional reconstruction to locate the pseudoaneurysm.

Being able to carry out an adequate therapeutic approach implies knowing the clinical presentation that guides us in an appropriate way. Hanna et al. have already described the classic symptoms of presentation that should make us suspect this condition: pain; pulsatile mass (not essential); the audible murmur is characteristic, although not constant; subcutaneous hematoma; and progressive decrease in hemoglobin levels that does not respond to transfusions.[14] It is recommended to maintain a high level of suspicion when faced with a patient who has anemia that is not justified by the clinical evolution and that is not corrected despite transfusions, without active bleeding, who suffers disabling pain in the thigh that delays rehabilitation, or who presents signs of distal ischemia with pulses or consolidation defects.[12] It may happen that not all symptoms manifest themselves, as in the case published by Kim et al.[15], in which the patient had pronounced anemia without clinical signs of thigh involvement, and, despite this, was diagnosed early and complications were avoided. In most of the cases in our review, except for one, the outcome of a timely intervention with adequate treatment was satisfactory.

Different treatment algorithms have been proposed.[7,10] If the patient is asymptomatic and the pseudoaneurysm measures <3 cm, it can be treated conservatively and we can wait between 4 and 6 weeks for spontaneous resolution to occur.[16] If it does not meet these criteria, it is recommended to repair it by open surgery or transcutaneous embolization.

One technique that can be applied is ultrasound-guided compression, which consists of compression of the neck of the pseudoaneurysm to cause thrombosis.[17] It has a success rate of 65%. The limitations are discomfort for the patient, a recurrence rate of 20%, or difficulties if there is an organized hematoma, among others. Another therapeutic alternative is thrombin injection,[18] a percutaneous method that uses thrombin administered intravenously into the peripheral artery. It can be performed through a catheter[16] and has a 93% success rate. It requires a known and viable vascular tract, something sometimes difficult to find in elderly patients with vascular disease (diabetes, hypertension) so it is not always the first choice in our cases. Thrombin injection can also be ultrasound-guided. It is a technique described by Kang in 1998[19] which has achieved superior outcomes to those of ultrasound-guided compression in a 2020 comparative study.[17] Embolization, usually with coils, is a useful technique and seems to have gained more popularity in recent years, as can be seen in different publications[20] and also in our review. Other devices, such as balloons or stents, can also be used.[21] If embolization techniques are not possible,[10] the surgeon can opt for aneurysmectomy, and arterial repair and DFA ligation. In any case, it is recommended to embolize both the distal and proximal level to completely exclude pseudoaneurysm from circulation, given the high collateral circulation that develops in this territory.

In our case, no symptoms were observed that led to suspicion of this condition in the immediate postoperative period, but they appeared in a subacute stage of the postoperative period. In addition, the patient had hypertension and dyslipidemia. The postoperative radiological control also did not show an overly long distal screw. All this has led us to the conclusion that the injury occurred at the time of drilling, which was performed in a guided but unprotected manner, as described in a clinical case published in 2018.[11]

Another exceptional feature is that it is the first case of spontaneous resolution of a pseudoaneurysm, which was even visualized with angiography. None of the other studies reviewed reported such results; we have only found one case of spontaneous resolution in another vascular territory.[22] This may be due to the fact that there are more cases in which this complication occurs almost asymptomatically, resolves spontaneously, and goes unnoticed. If this therapeutic decision is made, we recommend, as in our case, a close follow-up of the patient and a consensus on the management, the alarm symptoms, and the assessment of risks and benefits of the diagnostic-therapeutic orientation.

CONCLUSIONS

Trochanteric nailing is a very useful solution in the treatment of pertrochanteric fractures. It is necessary to reduce the risk of complications by optimizing the surgical technique. Knowing the clinical presentation of vascular complications allows an early diagnosis and treatment, significantly reducing the occurrence of major adverse events.

Conflict of interests: The authors declare they do not have any conflict of interests.

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Annex 1. List of clinical cases of pseudoaneurysm as a complication of pertrochanteric hip fracture published in the last 15 years

Article	Number of cases	Clinical case	Fracture fixation	Clinical suspicion of pseudoaneurysm	Diagnosis of pseudoaneurysm (time since surgery and technique)	Affected artery and possible trigger (if reported)	Treatment of pseudo-aneurysm	Evolution (if reported)
Anderson et al.[23] (2005)	1	82-year-old female, intertrochanteric fracture (right)	DHS	2 months: pain when walking, pulsatile thigh mass	Radiograph: osteo-synthesis failure Doppler ultrasound Angiography	DFABM pseudoaneurysm in relation to proximal material	Angio-embolization	Clinically stable
Chandrasenan et al.[20] (2005)	2	94-year-old woman, intertrochanteric fracture	DHS	Anemia that was not corrected with transfusions Intraoperative decrease of Hb Pulsatile mass (ultrasound)	Day 9: Doppler ultrasound	Pseudoaneurysm of a DFAB	Angio-embolization with spiral coils	No recurrence at 3 months
Alwhouhayb et al.[24] (2005)	3	82-year-old female, intertrochanteric fracture (left)	DHS	Day 6: thigh pain, edema, warmth and redness, anemia (Hb 7.8 g/dl)	Doppler ultrasound Active bleeding	DFAB in the fracture fragment	Direct suture with 5/0	Clinically stable post-surgery
Ryzewicz et al.[25] (2006)	4	94-year-old female, comminuted intertrochanteric fracture	Gottfried percutaneous nail	10 h post-surgery: hypotension, tachycardia, preserved pulses, anemia	Angiography	Medial DFAB Aberrant branch distal to the osteos-ynthesis material	Coil embolization	Day 4: mobilization hemodynamic stability
Cowley et al.[26] (2007)	5	76-year-old female, intertrochanteric fracture (right)	DHS	Week 6: pain, increase in volume, functional impairment. Week 8: anemia not corrected by transfusions	Resection, active bleeding	Pseudoaneurysm of DFA in relation to the lesser trochanter	Coil embolization	Post-embolization angiography, no bleeding point
Rajaesparan et al.[9] (2008)	6	81-year-old female, unstable intertrochanteric fracture (right)	Gamma locking nail	Intraoperative bleeding at the incision. Hypotension and dizziness, thigh pain, edema, anemia that was not corrected with transfusions. Pulsatile mass at the lateral distal femoral level	Day 30 post-surgery: Doppler ultrasound, angio-CT localization	Lateral DFAB pseudoaneurysm in relation to the entry of the material	Coil embolization	Doppler ultrasound at one month
Navarrete et al.[27] (2009)	7	78-year-old female, intertrochanteric fracture (left)	Percutaneous 240 mm PFNA nail	Day 7: pain, temperature increase, and diffuse swelling of the inner thigh	Doppler ultrasound Angiography	SFA pseudoaneurysm	Endovascular stent repair	Satisfactory Doppler ultrasound 6 months: clinically and radiologically healed
Grimaldi et al.[28] (2009)	8	85-year-old female, intertrochanteric fracture (31A2-1 AO)	Short Gamma nail	24 h post-surgery: anteromedial thigh pain and swelling	48 h post-surgery: Doppler ultrasound	SFA Laceration	Direct suture	Doppler ultrasound at one month

Hamoui et al.[29] (2009)	9	57-year-old female, intertrochanteric fracture (left)	DHS	Day 2 post-surgery: hematoma on medial thigh In rehabilitation: dizziness, anemia (Hb 8.5 g/dl) Month 2: persistent fatigue	Month 2: Doppler ultrasound Pulsatile hematoma Arteriography to confirm	DFA perforating branch	Coil embolization	48 h: Doppler ultrasound and, at 3 months, partial clinical remission
Kizilates et al.[30] (2010)	10	87-year-old female, intertrochanteric fracture (31A2 AO) (left)	Gamma Nail	Day 2: displacement of the lesser trochanter Post-surgery week 3: thigh pain and pulsatile mass Uncorrected anemia (Hb 3.9 mmol/l)	CT scan: hematoma, extravasation of contrast. Definitive: open surgery	DFA at the level of the lesser trochanter	Direct suture and excision of the lesser trochanter	Clinically stable at 7 days
	11	86-year-old female, intertrochanteric fracture (31A2 AO) (left)	Gamma Nail	Day 12 post-surgery: edema with severe hematoma, anemia that was not corrected with transfusions	Day 14: CT	DFAB	Endovascular stent repair	
Chan et al.[31] (2010)	12	83-year-old female, intertrochanteric fracture (right)	DHS	Day 11: increase in thigh circumference, anemia Day 23: increase in anemia and edema, hemodynamic instability	Day 23: Doppler ultrasound: hematoma and pseudoaneurysm Angio-CT (confirmation)	DFA Perforating branch	Drainage of the hematoma (large bleeding) and emergent open excision of the pseudo-aneurysm	After ICU and 9 transfusions, clinically stable after 1 year
Li et al.[32] (2010)	13	88-year-old female, unstable intertro-chanteric fracture (left),	K-wire reduction Trochanteric long nail	Week 2: weakness, dizziness, loss of strength and subjective edema, anemia	Doppler ultrasound	DFA	Coil embolization	Tolerance and rehabilitation
Tomčovčík et al.[33] (2011)	14	79-year-old male, intertrochanteric fracture with displacement of the lesser trochanter (31A2 AO) (left)	Gamma Nail	Week 5: edema and pain in thigh, pulsatile mass	CT: hematoma Open surgery: definitive diagnosis	SFA at the level of the displaced lesser trochanter	Direct suture, open surgery	19 days without complications
Sharma et al.[34] (2013)	15	72-year-old male intertrochanteric fracture (31A2 AO/OTA) (left)	DHS	Day 2 of admission (before surgery): increased edema and anemia that was not corrected, tense pulsatile mass	Doppler ultrasound: high probability of pseudoaneurysm Angio-CT: definitive	SFA at the level of the lesser trochanter	Endovascular with endoprosthesis. At the same stage, osteosynthesis	One year of follow-up without complications
Singh et al.[35] (2013)	16	65-year-old female, intertrochanteric fracture (left)	DHS	Day 3 post-surgery: edema, anemia, pain, functional impairment	Doppler ultrasound, angio-CT	DFA	Coils	18 months without symptoms
Rana et al.[36] (2014)	17	48-year-old male, epileptic, unstable intertrochanteric fracture (right)	Delay due to neurological status	14 days: pain and edema 2 months: progressive Hb decrease	2.5 months after fracture: Doppler ultrasound	Posteromedial to posterolateral pseudoaneurysm of DFABM at the level of the lesser trochanter fragment	1º. Endovascular embolization 2º. DHS and cerclage	Post-embolization angiography Clinically stable at follow-up
Osagie et al.[37] (2014)	18	79-year-old female, intertrochanteric fracture (right)	Stryker® Gamma nail	Hb 9.6 g/dL post-surgery to 6.7 g/dL on day 10 post-surgery which was not corrected with red blood cell concentrates	Day 10 post-surgery: arteriography	DFABM pseudoaneurysm at the level of the lesser trochanter spicule	Endoprosthesis placement	Clinical. 15 days

Raherinante-naina et al.[10] (2015)	19	55-year-old female, without fracture	Hematoma drainage (without fracture)	Painful swelling after a direct blow to the anterolateral aspect of the thigh. Days later: pulsatile mass and murmur	Day 9 post-surgery: Doppler ultrasound	SFAB pseudoaneurysm, femoropopliteal, tibiofibular	Open surgery Saphenous vein graft reinforcement	13 months without symptoms and Doppler ultrasound
Regus et al.[38] (2015)	20	85-year-old female, unstable pertrochanteric fracture (left)	Gamma Nail	Week 3: edema, pulsatile thigh mass	CT: hematoma and arterial involvement	DFA at the level of the displaced lesser trochanter	Open arteriotomy and excision of lesser trochanter	Discharge on day 9 without complications
Yoon et al.[39] (2016)	21	79-year-old male, pertrochanteric fracture (right) CVRF	Zimmer® Cephalomedu-llary nail	Day 1 post-surgery: pain, uncorrected anemia, volume gain	Day 7: angio-CT	DFAB rupture (lateral) at the level of the distal locking screw	Coil embolization	Negative Doppler ultra-sound at week 4 and beginning of weight-bearing
Roy et al.[40] (2016)	22	55-year-old female, intertrochanteric fracture (right)	DHS	Intraoperative: bleeding due to overdrilling of the 2nd diaphyseal screw, res-ponded to compression Day 1 post-surgery: wound bleeding Day 4: Hb 5.9 g/dl	Day 4: Doppler ultrasound Confirmation with angiography	DFA	Coil embolization	Week 3: clinically stable
Raaff et al.[41] (2016)	23	78-year-old female, intertrochanteric fracture with displa-cement of the lesser trochanter	Gamma Nail	Month 5: pain, thigh edema (suspicion of deep vein thrombosis)	Doppler ultrasound Angio-CT scan to confirm	Proximal DFA at the level of the lesser trochanter	Endoscopic grafting	Heart failure, death
Potenza et al.[42] (2016)	24	81-year-old male, intertrochanteric fracture		Immediate postoperative anemia that was not corrected by transfusion of red blood cell con-centrates (shock at 24 h with Hb 6.4 g/dl)	24 h: angio-CT	DFABM pseudoaneurysm at the level of the lesser trochanter spicule	Transcatheter embolization	1 month clinically stable and Hb 12.4 g/dl
Toyota et al.[43] (2017)	25	76-year-old female, pertrochanteric fracture (Evans 1-3)	Intertrochan-teric nail (ASIANS-IMHS, Smith & Nephew)	Month 4: thigh pain, edema, increased circumference, non-clotted blood on as-piration of collection. Non-pulsatile	Radiograph: lateral cortical erosion Angio-CT: confirmation	DFA perforating branch, near the locking screw	Open surgery: suture and screw excision	6-year follow-up: no clinical/ imaging recurrence
Piolanti et al.[44] (2017)	26	90-year-old female, intertrochanteric fracture (31A2-1 AO)	Locked Gamma nail	Day 16 post-surgery: anemia (Hb 7.7 g/dl), edema, pain	Day 16: Doppler ultrasound. After: confirmation arteriography	Proximal DFABM pseudoaneurysm at the level of the lesser trochanter spicule	Endoprosthesis placement	Clinical 3 months after surgery
Lee et al.[45] (2017)	27	75-year-old male, intertrochanteric fracture (31A2 AO)	Percutaneous fixation with long Gamma nail	No anemia until postoperative day 14 (Hb 7 g/dL), hypotension and large edema requiring CPR	Day 14: angio-CT (1st study)	Proximal DFABL pseudoaneurysm, active bleeding	Embolization	Ambulation and clinically stable at 24 h
Mayura-sakorn et al.[46] (2017)	28	70-year-old female, intertrochanteric fracture (31A2 AO/ OTA) (left)	PFNA nail (Depuy-Synthes)	Day 6: incisional pain and bleeding, anemia, loss of reduction on radiographs	CT: hematoma Angio-CT Definitive: open surgery	DFA	Open surgery: ligation, excision of hematoma	-
Nadal et al.[47] (2017)	29	87-year-old female, pertrochanteric fracture of left femur	Gamma 3 Nail	Day 15 after discharge: hypotension, increase in thigh circumference, increase in previous hematoma	Angio-CT	DFA, in relation to the lesser trochanter	Coil embolization	Discharge: painless ambulation

Kim et al.[15] (2017)	30	85-year-old female, intertrochanteric fracture (31A2 AO)	PFNA-2 nail (Depuy Synthes)	Postoperative severe anemia that was not corrected	CT, angio-CT	DFA, in relation to the lesser trochanter	Coil embolization	Discharge after 15 days
Pandey et al.[48] (2018)	31	85-year-old male, intertrochanteric fracture (right)	DHS	Month 6 post-surgery: increase in thigh volume (progressive growth)	Doppler ultrasound, angio-CT	DFA lateral branch	Coil embolization	-
Vande Voorde et al.[11] (2018)	32	78-year-old male, intertrochanteric fracture (31A2 AO) (right)	PFNA nail (Depuy-Synthes)	Month 8 post-surgery: increase in thigh volume, with pain. No systemic symptoms	Doppler ultrasound: calcified hematoma Angio-CT	Medial DFAB pseudoaneurysm in relation to the distal locking screw	Direct suture	No follow-up complications
Kinoshita et al.[35] (2018)	33	80-year-old male, trochanteric fracture (left)	Zimmer Natural Nail	Day 1 post-surgery: Hb 12 g/dl to 6 g/dl, not corrected with red cell concentrates	Day 12 post-surgery: 1º. MRI: hematoma 2º. Angio-CT with 3D reconstruction	DFABM pseudoaneurysm at the level of the distal locking screw	Immediate transcatheter embolization	Post-embolization angiography Clinically stable after one month
Zhang et al.[4] (2018)	34	85-year-old male, subtrochanteric fracture	-	Clinical onset on day 3	All angio-CT	DFABM pseudoaneurysm	Embolization	-
	35	80-year-old female, trochanteric fracture (left)	-	Clinical onset at 48 h post-surgery				
	36	43-year-old male, trochanteric fracture	Gotfield plate	Common clinical presentation from day 1: edema, pain, ecchymosis in thigh or leg, and anemia. Clinical onset on day 1 post-surgery				
Arbeloa-Gutierrez et al.[49] (2019)	37	80-year-old male, intertrochanteric fracture (31A2 AO/OTA) (left)	Gamma 3 Nail	Day 18: syncope Month 1: edema, increased thigh circumference, worsening of anemia	Radiograph: displacement of the lesser trochanter Doppler ultrasound: hypoechoic lesion, turbulent flow Angio-CT: confirmation	DFA lateral branch in relation to the lesser trochanter	Coil embolization	Clinically stable after 24 h
Nossa et al.[51] (2019)	38	69-year-old male, intertrochanteric fracture (31A2 AO/OTA) (left)	Cephalome-dullary nail	Day 8: pain, difficulty in ambulation Week 6: radiograph: migration of the lesser trochanter and soft tissue edema	CT, MRI, angio-CT	DFA branch	Endovascular stent	Aggravation at one week: open ligation and excision of the lesser trochanter
Lidder et al.[12] (2019)	39	72-year-old male intertrochanteric fracture (left)	DHS	Month 15: pain, increased volume, progressive functional impairment	CT, angio-CT	DFA branch	Coil embolization	Month 3: complete recovery. Stable at 2.5 years
Labronici et al.[52] (2019)	40	87-year-old female, intertrochanteric fracture (31A2 AO/OTA) (left)	DHS	Day 23 post-surgery: thigh enlargement, pain, functional impairment, anemia	Doppler ultrasound, angio-CT	Medial branch of the DFA in relation to the lesser trochanter	Placement of 2 percutaneous endoprostheses	Relapse after 6 months. Excision of the lesser trochanter

DHS = Dynamic Hip Screw; PFNA = proximal femoral nail antirotation; CT = computed tomography, MRI = magnetic resonance imaging, DFAB(M)/(L) = deep femoral artery branch (medial)/(lateral), DFA = deep femoral artery, SFA = superficial femoral artery, SFAB = superficial femoral artery branch, ICU = intensive care unit, CPR = cardiopulmonary resuscitation, CVRF = cardiovascular risk factors.

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