



# Interventional Radiology for the Management of Peripheral Vascular Trauma: Case Series

Radiología intervencionista en trauma vascular periférico: Serie de casos

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## Summary

**Background:** Trauma is the third leading cause of death among the world population and the first in adults under 44 years; from this, 40-70% is represented by peripheral vascular trauma. Traditionally, surgical management has been the first choice of treatment. However, with the technological advances in interventional radiology, successful outcomes have been obtained from therapeutical options such as with stent placement. **Objective:** To present three successful experiences after stent placement for the treatment of neck, upper and lower limbs vascular trauma at a high complexity hospital from Colombia. **Clinical Cases:** Three patients presented with peripheral vascular trauma, two men were wounded by sharp weapons men and one woman by a gunshot. In two of them, there was evidence of pseudoaneurysms. In the three cases, adequate resolution and exclusion from circulation were achieved. **Conclusion:** Vascular trauma has an increased frequency in general trauma context; hence, it is important to recognize its ideal management. Currently, stent placement for the management of peripheral vascular trauma is a minimally invasive procedure with excellent outcomes for properly selected patients.

## Resumen

**Antecedentes:** El trauma es la tercera causa de mortalidad en la población mundial y la primera en el grupo etario de adultos menores de 44 años; de esta cifra, el 40-70 % se atribuyen al trauma vascular periférico. Tradicionalmente, el manejo quirúrgico ha sido la primera opción de tratamiento. No obstante, con los recientes avances tecnológicos y el auge de la radiología intervencionista, se han obtenido resultados exitosos a partir de opciones terapéuticas como las endoprótesis. **Objetivo:** Mostrar tres experiencias exitosas en el manejo con endoprótesis del trauma vascular de cuello, miembro superior e inferior, en un hospital de alta complejidad de Colombia. **Casos clínicos:** Se trata de tres pacientes con trauma vascular periférico producto de heridas por arma cortopunzante, en dos hombres, y por proyectil de arma de fuego en una mujer. En dos de los casos se evidenciaron pseudoaneurismas. En los tres casos se obtuvo adecuada resolución y exclusión de la circulación de las lesiones. **Conclusión:** El compromiso vascular ha aumentado su frecuencia en el contexto del trauma, por lo cual, es de importancia conocer su manejo óptimo. Actualmente, la reparación endovascular con endoprótesis en el trauma vascular periférico es un procedimiento mínimamente invasivo y con excelentes desenlaces para pacientes adecuadamente seleccionados.

## Antecedents

Currently, trauma represents the third cause of mortality in the world population and the first in the age group of 44 years. Of all injuries caused by trauma,

3% have a vascular component (1) and of these, 40-70% is attributed to peripheral vascular trauma, followed by blunt cerebrovascular and thoracic aortic (2, 3). Similarly, vascular lesions in extremities are

associated, especially in the polytraumatized patient, with a 10-20% risk of amputations. Therefore, timely imaging of potential lesions, coupled with adequate resuscitation with rapid bleeding control, is essential to ensure patient life and limb integrity (4).

Traditionally, management of vascular trauma has required open exploration, where sufficient tissue exposure and timely hemorrhage control are determinants of surgical success, ie, proximal and distal vascular control. Vascular wounds in the thorax and upper limbs represent a challenge for surgical management because of their complex approach, as they require extensive incisions, difficult bleeding control, long surgical time and risk of injury to neighboring structures (5, 6). Thus, rapid technological diversification has allowed the concomitant evolution of diagnostic and therapeutic approaches

(7), with a tendency to promote those minimally invasive. According to Callcut et al., since the onset of endovascular trauma management, its use has gradually increased, from 1% in 2002 to 11% in 2008; in this same sense, the interventional approach has been widely described in the correction of vascular lesions of the thoracic and carotid aorta (7). Moreover, another advantage of endovascular management is its success rate greater than 90% (8).

However, there are few reports of endovascular repair with endoprosthesis in peripheral vascular trauma, especially in the context of the urgent patient. The clinical cases presented here correspond to three successful experiences in the management by interventional radiology of vascular trauma of the neck, upper and lower limbs, in a highly complex hospital in Colombia (Table 1).

Table 1. Related variables in the three exposed cases of peripheral vascular trauma\*

Variable	Patient I	Patient II	Patient III
Age	40 years	29 years	21 years
Sex	Male	Male	Female
Etiology	HACP	HPAF	HPAF
Signs of certainty	Yes	No	Yes
Signs of doubt	Yes	Yes	Yes
Diagnosis	Arteriography	Angiotomography	Angiotomography
Artery	Subclavia	Humeral	Superficial femoral
Third	Medium	Proximal	Proximal
Half body	Left	Left	Right
Injury	Laceration	Pseudoaneurysm and arteriovenous fistula	Pseudoaneurysm
Instability	Yes	No	No
Comorbidity	Hemoneumothorax	Soft tissue trauma	Acute anemia
Intrahospital Postoperative	6 days	2 days	2 days

\* Patient characteristics and traumatic injuries included. HACP: Short stab weapon wound; HPAF: Firearm projectile wound.

## Clinical case 1

A 40-year-old male patient, apparently under effects of psychoactive substances, who is transferred by the police as a vital emergency. On admission, the patient is hemodynamically unstable, hypotensive (80/60 mm Hg), with low oxygen saturation (89%) and tending to tachycardia (100 bpm) and tachypnea (20 rpm). At the initial physical examination, the patient had diminished respiratory sounds in the left hemithorax and four sharps injuries (knife) located in zone I of left hemineck, right posterior hemithorax at the seventh intercostal space with right posterior axillary line, distal third of left thigh (bleeding) and middle third of right thigh. As for the cervical wound, there was an expansive, pulsatile and blowing hematoma as a sign of vascular injury, besides ipsilateral jugular engorgement and dyspnea.

Immediately, water resuscitation is initiated with 2000 cm<sup>3</sup> of Ringer's milk, which improves the tension figures (100/70 mm

Hg), after which a chest x-ray is taken, confirming suspicion of left hemoneumothorax; is transferred to the interventional radiology service for diagnosis and treatment of possible peripheral vascular trauma.

During the procedure, active bleeding was evidenced by extravasation of the contrast medium in the left subclavian artery. Therefore, Roadrunner<sup>®</sup> (Cook<sup>®</sup>) hydrophilic guide distal to the lesion was passed, bleeding was controlled with Viabahn<sup>®</sup> (Gore<sup>®</sup>) coated stent; control was performed with contrast medium injection, to observe the resolution of the alteration of the vascular path (Figure 1). In addition, left inferior arteriography was performed in which the distal vessel was identified, without other vascular alterations. Finally, he was transferred to the operating room where a left thoracostomy was performed, which resulted in the resolution of the hemoneumothorax. At the sixth day of hospitalization the patient is discharged without complications.

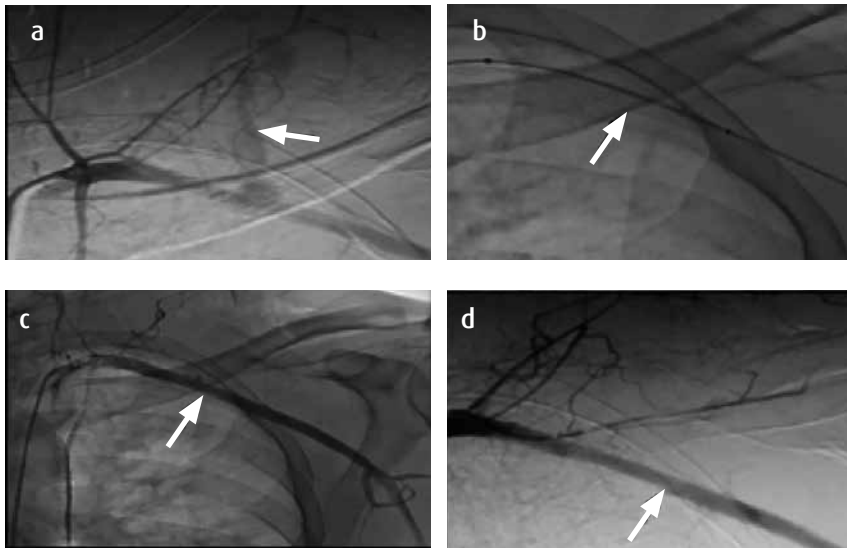


Figure 1. Correction of left subclavian traumatic lesion. a) Subclavian artery catheterization. Contrast extravasation due to sharp-blade injury is observed. b) Placement of covered stent in the affected segment. c) Total control of vascular injury. d) Permeable artery without extravasation of contrast or leaks (endoleak) (arrows).

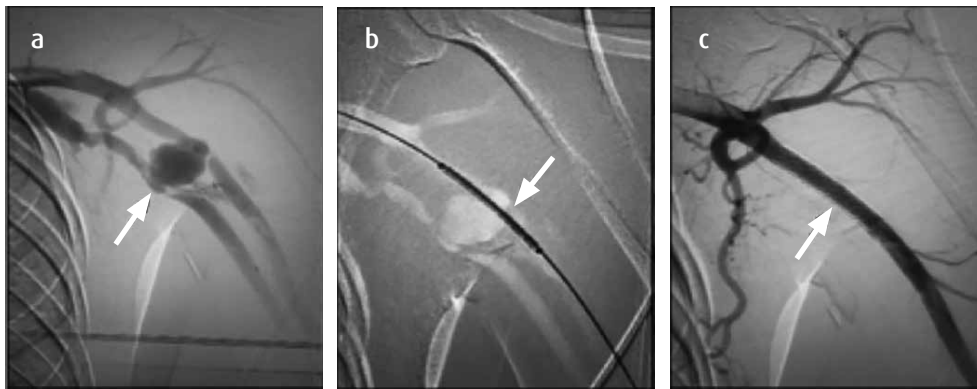


Figure 2. Correction of traumatic vascular injury of the left humeral artery. a) Pseudoaneurysmal dilatation of the humeral artery with formation of arteriovenous fistula (AV). b) A stent is placed covered at the level of the artery. c) Postdilation with balloon, with adequate permeabilization of the vessel. In the control, there is no evidence of pseudoaneurysm nor arteriovenous fistula (arrows).

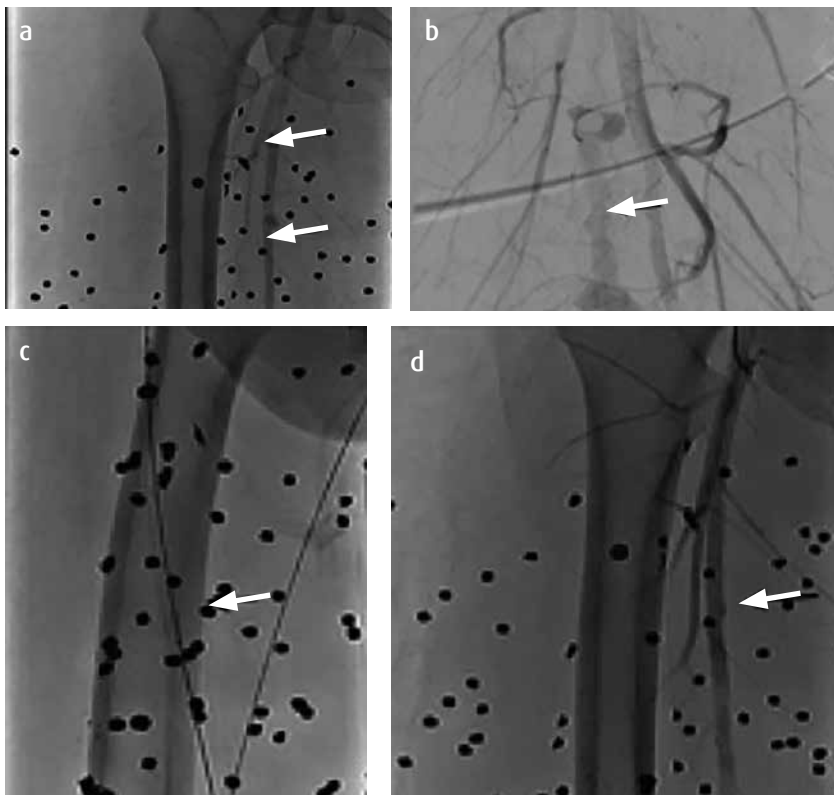


Figure 3. Correction of traumatic vascular injury of the right superficial femoral artery. a) Traumatic vascular injury and multiple pellets in soft tissues. b) Pseudoaneurysmal lesions in the territory of the right superficial femoral artery. c) Hydrophilic Radifocus® (Terumo®) guide to the superficial femoral artery. d) In the control, there are exclusions of pseudoaneurysmal lesions of the circulation after stent placement (arrows).

## Clinical case 2

A 29-year-old male patient was referred from a less complex hospital with a gunshot wound to the left shoulder. It entered normotensive (100/74 mm Hg) and normocardial (68 bpm), with arterial oxygen saturation of 97% and 18 breaths per minute. Upon physical examination, a gunshot wound, transfixed, with an opening in the posterior region of the left shoulder and exiting the ipsilateral axillary fossa accompanied by hematoma, non-pulsatile or expansive, and layered bleeding with pulses distally diminished. In addition, the patient reported pain in the lower left limb, with no evidence of certainty for vascular injury. At admission, the patient had a blood pressure index (IPA) with a result of 0.9.

An angiotomography is performed, where the lesion of the left proximal humeral artery (3,3 cm distal to the origin of the circumflex artery) is identified with a 1.6 cm pseudoaneurysm formation. Subsequently, it was evaluated by the interventional radiology service, where a Viabahn® graft stent (Gore®) and an Agiltrac® angioplasty balloon (Abbott®) 5 × 60 mm were inserted under a fluoroscopic guide, thus achieving control and exclusion of the pseudoaneurysmal lesion (Figure 2). The patient was transferred to the hospitalization floor, with adequate clinical evolution and discharge to the second.

## Clinical case 3

A 21-year-old female patient referred from a hospital of lower level of complexity, after being victim of multiple gunshot wounds (shotgun shot) in thighs and hypogastrum. At admission, it is normotensive (115/68 mm Hg), tachycardic (104 bpm), respiratory rate (14 rpm) and oxygen saturation within normal limits (94%). On physical examination, multiple gun and / or mid-thigh firearm projection inlets were observed, with filiform pedal pulse, distal ipsilateral coldness, and blood pressure index of 1.03. In view of the possibility of visceral perforation in the pelvis and vascular trauma, flexible rectosigmoidoscopy and angiotomography of lower limbs are performed.

With the results of the diagnostic aids, the visceral involvement was ruled out, but two pseudoaneurysmal lesions were evident in the middle third of the right superficial femoral artery, in addition to metallic splinters in the soft tissues. Subsequently, the patient is assessed by interventional radiology who consider performing arteriography and embolization of pseudoaneurysmal lesions.

During the procedure two pseudoaneurysmal lesions were evident in the proximal territory of the right superficial femoral artery, with 5 cm of separation, with risk of rupture. Under the fluoroscopic guidance, Viabahn® peripheral covered stent (Gore®) was introduced, which was positioned excluding the two described lesions from the circulation. In angiographic control adequate vessel filling was observed, without extravasation of the contrast medium (Figure 3). After adequate clinical evolution, hospital discharge is given 48 hours after the procedure.

## Review and discussion

### *General and trauma assessment peripheral vascular*

Peripheral vascular trauma remains a complex problem, while its prevalence depends on the violent events that afflict contemporary

society. According to Jiménez et al., This is a public health problem (9), especially for developing countries, which warrants a comprehensive approach.

As a pathological phenomenon, vascular trauma causes ischemia secondary to the decrease of adenosine triphosphate, which in turn induces a response in the endothelium (tissue factor production), platelets (hemostatic plug consolidation) and smooth muscle vascular (proliferation) (10). In addition, there is an increase in vascular tone due to increased requirements of acetylcholine, prostaglandin production and reduction of nitric oxide concentration, with deleterious effects on tissue that persist until vessel reperfusion. Once the flow has been restored, the lesion may be prolonged following reperfusion ischemia dependent on the conversion of xanthine dehydrogenase to xanthine oxidase (10).

In the clinical evaluation, despite the presence of sophisticated radiological methods, the probable diagnosis of peripheral vascular trauma must be made in the emergency department from the physical examination. Classification in the so-called definite or hard signs (expansive hematoma, pulsatile bleeding, poikilothermia and distal pallor, tactile thrill and absence of distal pulses) and doubtful or soft (wound in arterial pathway, peripheral neurological deficit, diminished pulses and antecedent of arterial bleeding) is determinant for defining therapeutic behavior (11). Thus, there is no doubt that, in patients with signs of certainty, vascular exploration is unavoidable.

Previously, diagnostic studies have shown how the signs of certainty offer a predictive value and a 95% sensitivity for vascular trauma requiring surgical exploration (12). In addition, in series of vascular trauma after posterior knee dislocation, the prevalence of signs of certainty reaches up to 18% of patients, in whom surgical exploration is performed in 72%; On the other hand, in those patients without these signs, the rate of surgery is zero (13). Regarding the signs of doubt, there are studies in our country that do not prove useful for the diagnosis of vascular injury (12).

Another consideration in the physical examination of peripheral vascular trauma is the ankle-brachial index in which figures less than 0.9 are suggestive of this lesion. Although, according to Feliciano, this diagnostic method is a sign of doubt (soft) (11), reviews of the literature show a high discriminative capacity when compared to arteriography (14). Studies performed at our University Hospital have identified an area under the ROC curve of 0.97 (95% CI, 0.94-1.00). In the same cohort of patients, the ankle-ankle index was proposed as a new diagnostic strategy, with an area under the curve similar to that of the ankle-arm index and concordance with it in 98% (12).

In addition, one of the aspects that should be taken into account by the emergency doctor is the possibility of finding bleeding contents. According to Soto et al., This is of particular importance in vascular trauma of the thorax, abdomen and pelvis, including wounds that compromise compartments of soft tissues such as buttocks and thighs (15). For example, in another case treated with embolization with coils in the same hospital, in addition to a pseudoaneurysm in the gluteal artery, a hematoma resulting from injury to the vessels that irrigate the retroperitoneum was present.

With regards to radiological aids, duplex ultrasonography has limitations due to its being a dependent operator (16) (which affects its reproducibility) and false negatives in cases of gunshot wounds (17)

or prominent vascular collaterals (18). At the same time, the literature proposes angiotomography as the image of choice in that it presents a performance close to that of angiography, without the inherent risks of vascular intervention (19). Thus, although angiography is the gold diagnostic standard (15, 20) (sensitivity 99% and specificity 97%), Márquez explains how up to 95% of studies could be negative in patients with no signs of certainty hard), which defines therapeutic behavior only in 1.3% (12). However, in cases where the arteriography is positive, it allows an endovascular intervention to be performed simultaneously with this procedure (19).

It is worth clarifying that in the patients studied, in whom the vascular lesion was diagnosed from angiography, there was enough clinical evidence to implement this method. In the first case, the patient showed signs of certainty of vascular lesion and recovered his hemodynamic stability after water resuscitation, which, together with the difficult open vascular access, made him an ideal candidate for the diagnostic and therapeutic endovascular procedure.

### Endovascular approach by interventional radiology

Endovascular therapy has evolved from a diagnostic modality to a useful therapy in several vascular pathologies (1). In recent years, with the help of emerging technology, endovascular repair in the context of trauma has increased (21). Thus, angiography is not only useful for determining the specific nature of the lesion, but also for planning the diagnostic approach and optimal treatment for the patient (21). Also, the angiographic findings in peripheral vascular trauma are multiple, typical of the same classification of lesions mentioned by Soto et al. (15) (Table 2). It is noteworthy that in patients II and III, the finding of pseudoaneurysm developed within 24-48 hours after trauma, so the denomination of late may be confusing.

Table 2. Classification of peripheral vascular trauma

Classification	Injuries
Penetrating injuries	Laceration
	Partial transection
	Complete transection
Blurred injuries	Intimal disruption
	Lateral disruption
Late Complications	Arteriovenous fistula
	Pseudoaneurysms

As for the access site, Carrick et al. propose that the territories of the brachial, axillary and femoral arteries are optimal for endovascular therapy because they prevent large surgical dissections (21). Stents are usually coated with materials that allow adequate vessel permeability such as dacron or polytetrafluoroethylene. In addition to the endoprosthesis, the inventory used in the endovascular approach to peripheral vascular trauma includes coils, catheters, balls and microguides, making it less complex than the one required for

management of other types of vascular pathologies (22).

In particular, the literature has defined the type of endovascular repair candidate patient, with emphasis on the requirement of hemodynamic stability. Authors such as Rachapalli (8), Jiménez (9) and Desai (23) have established the following scenarios:

- » Patients with penetrating lesions of low velocity, in an area requiring extensive or difficult surgical access for open repair (23).
- » Unstable patients with a high probability of complications resulting from surgery (9) or anesthesia (23).
- » Trauma in complex access sites due to risk of neurological injury, as in the case of carotid or popliteal lesions (9).
- » Temporary control of hemorrhage prior to vascular exploration or in a patient susceptible to a combined approach (9).
- » Management of postoperative complications or the impossibility to achieve hemostasis during surgical exploration (8).

It is necessary to clarify that despite the advantages of endovascular techniques in the repair of up to 50% of vascular lesions (24), these are not exempt from contraindications and complications. First, the use of this therapeutic modality in patients with hemodynamic instability (persistent hypotension due to uncontrolled hemorrhage) (25) and vascular section is considered inappropriate. Subsequent to the procedure, the most frequent complication are hematomas, thrombosis of the stent or formation of pseudoaneurysms at the site of vascular access, although arteriovenous fistulas, stenosis, lesions of the nerve plexus may also occur, among others (26).

### Characterization and outcome after endovascular management

In relation to the available literature, unfortunately there are predominantly series and case presentations. In Latin America, there are some experiences published in countries such as Colombia (9), Chile (27) and Brazil (28), which, like this, collect groups of less than 10 patients. However, this type of work is relevant in that it shares experiences that have been scarcely quantified by studies of greater scientific evidence, a situation that has previously been commented by authors such as Furtado de Medeiros et al. (28).

When compiling the Latin American series mentioned (9, 27, 28) together with the cases reported here, 21 patients were found in whom 10 pseudoaneurysms, 6 arteriovenous fistulas, 3 lacerations and 4 postconclusion thrombosis were found as angiographic findings. The lesions were located predominantly in the lower limbs, and as for the involved vessel, the popliteal, subclavian and axillary arteries were the most frequent. In these series, endovascular stent repair is the most frequently performed intervention (77%, 17 cases). As for angiographic success, it reached 100% of cases, with no evidence of recurrence of lesions or complications in subsequent follow-up up to 3 years, for one of the cases (27).

The results of the series of the region do not seem to differ from the North American one published by Desai and collaborators in 2014 (23), where in 28 patients with peripheral vascular trauma



handled with stent placement, the most frequent lesions were pseudoaneurysms (32%) and extravasations by laceration (32%). In these cases, the usual arterial pathways were femoropopliteal (32%), subclavian (25%) and axillary (22%), with a median follow-up of 13 months. In these patients, the complication rate reached 21%, requiring conversion by thrombosis of the stent in four cases (all with concomitant fractures), without it being possible to establish specific risk factors for this condition. At the same time, the authors commented that the complications described could have as a possible cause the variability in the use of anticoagulation after the procedure (23). Similarly, there are two other series published by the Carrick (21) and Brandt (29) groups reporting 2 cases of penetrating lesions and 3 cases of blunt trauma in the subclavian artery area, treated with endovascular techniques with stents and with successful follow up of up to 20 months.

In the European scenario, the Italian series by Piffaretti et al. Reports 10 patients with blunt peripheral vascular trauma treated by interventional radiology with endoprosthesis. As often, the arteries involved by pseudoaneurysms and dissections were the common femoral, subclavian, axillary, and internal iliac (30). The imaging follow-up was performed at 6, 12 and > 12 months (mean follow-up of 16 months), reporting in turn absence of major perioperative complications and an average hospital stay of 13 days. In their protocol, they describe the systematic use of 2,500 IU preoperative and 22,000 IU postoperative of unfractionated heparin (30), a variable not shown in the Desai series (23). Because it is only a blunt trauma, the rates of perioperative complications in this series may not be comparable with those reported for penetrating trauma. Therefore, studies that provide a better level of evidence (e.g. cases and controls) could be useful to determine which patient benefits the most from the interventional approach, with the lowest risk of complications.

It is worth mentioning that, for the patients studied here, it was not possible to perform clinical or radiological follow-up after hospital discharge to assess the occurrence of possible complications because they did not attend the outpatient visits. In addition, it was identified as a barrier to access to health services inability to contact patients, which is probably associated with their status as street dwellers and users of psychoactive substances.

As mentioned above, after the endovascular approach with stents there is the possibility of restenosis and thrombosis in vascular areas of low caliber. Unfortunately, although the literature mentions these complications (31), the figure referenced by the sources (14%) is calculated in the study by Desai et al. (23). Likewise, most of the studies are followed up in the medium term where patients are asymptomatic and retain functionality, which methodically prevents the occurrence of complications in a longer period of time. Recently published in vitro models suggest that these events are associated with upregulation of microribonucleic RNA (miR-21) that induce vascular remodeling and inflammation, so modulation of such response could have a positive impact on functional viability of the stent (32).

On the other hand, when a systematic search was made in the PubMed database, it was only possible to find a multicenter clinical trial that evaluated "hard outcomes" such as mortality and complications in patients treated with surgical exploration versus those taken to endovascular management. This study by White et

al. Compared 62 patients treated with the Wallgraft® stent (53.2% with iliac artery lesions) versus the historical controls reported in the literature. Bayesian analysis revealed a significant reduction in perioperative complications (21.21% vs. 57.70%) and late mortality from any cause (15.15% vs. 33, 86%) (33).

Moreover, there are two meta-analyses that approach the specific theme of this discussion. The first one corresponds to the contribution of Sinha et al., Who compared open surgical procedures (n = 23) with endovascular procedures (n = 25) in patients with thoracic vascular trauma. The results suggest that although there are no statistically significant differences in mortality (OR 0.67, 95% CI, 0.11-4.05), there is a shorter surgical time (differential of 58.34 minutes, 95% CI %, 17,82-98,85) in favor of endovascular management (24). Finally, the meta-analysis carried out by Joshi and colleagues for the Cochrane Library, coincides with the results of Sinha's work and adds a shorter hospital stay (4.3 vs. 7.7 days, p <0.001) for those treated by interventional radiology with endoprosthesis for the correction of asymptomatic aneurysms of the popliteal artery (34).

## Conclusion

Vascular trauma has increased in frequency in the context of trauma, which is why the knowledge about the ideal management for this type of injury is of great importance. Endovascular endovascular repair in the management of peripheral vascular trauma is currently a minimally invasive procedure, which with adequate patient selection can be performed in a shorter time than open vascular exploration, with good success rates, and shorter hospital stay for the patient.

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