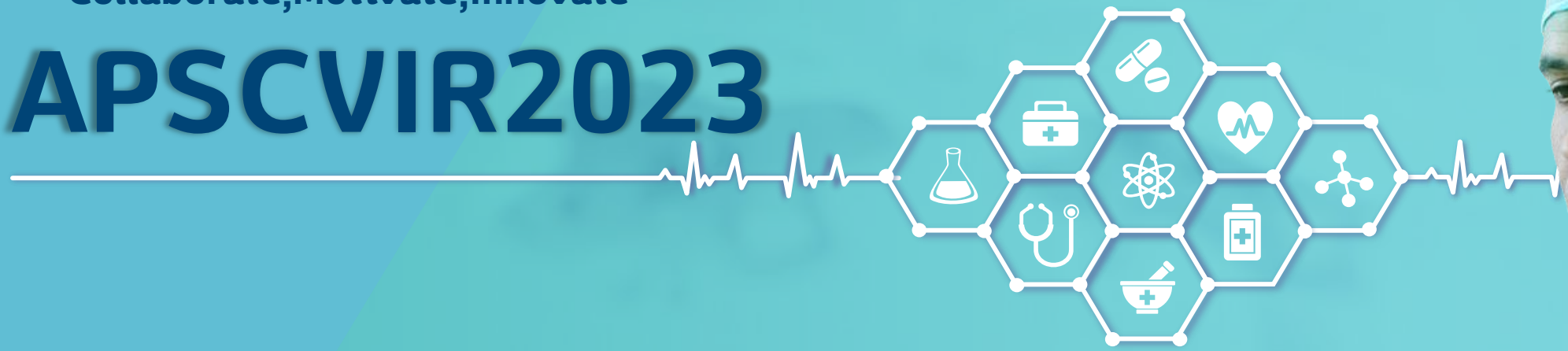
Collaborate,Motivate,Innovate

APSCVIR2023

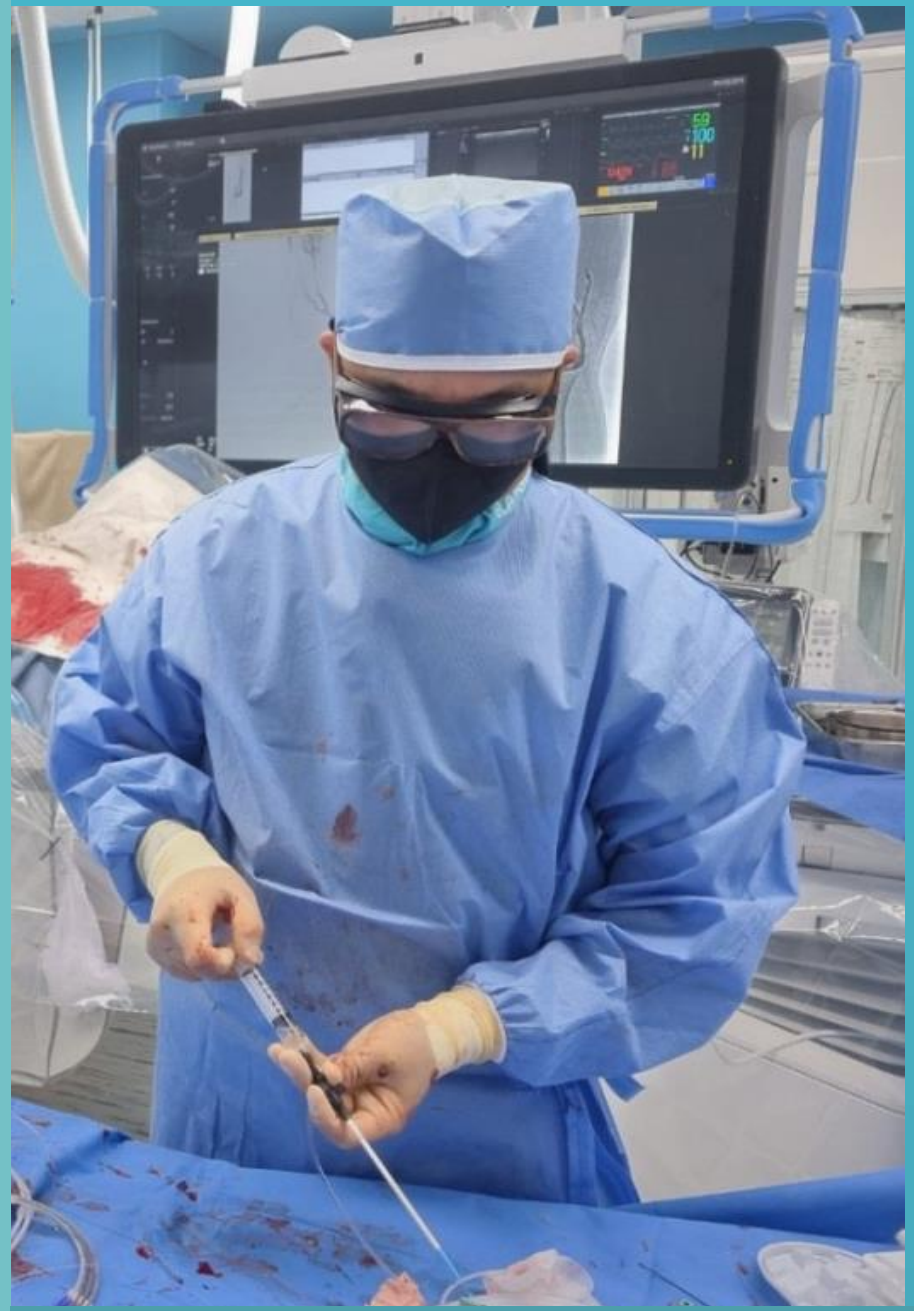


Understanding lower limb angioplasty and recent trends

Dae Jeon Health Institute of technology

Department of Radiological science

Professor. Jae Seok Kim



Content of the lecture

01 Angioplasty History & Theory

02 Procedure equipment for lower extremity angioplasty

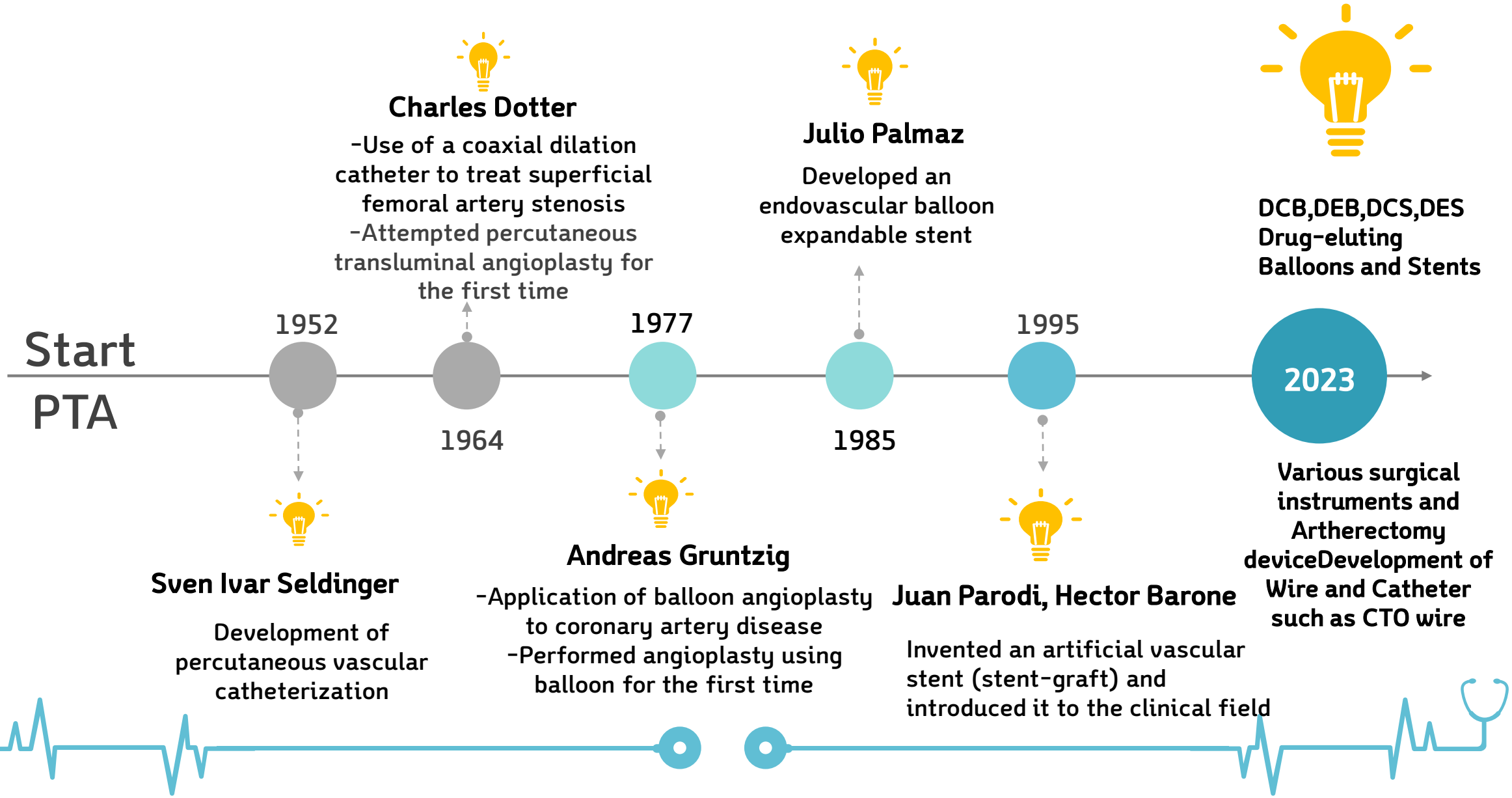
03 Treatment of lower extremity blood vessels (Atherectomy)

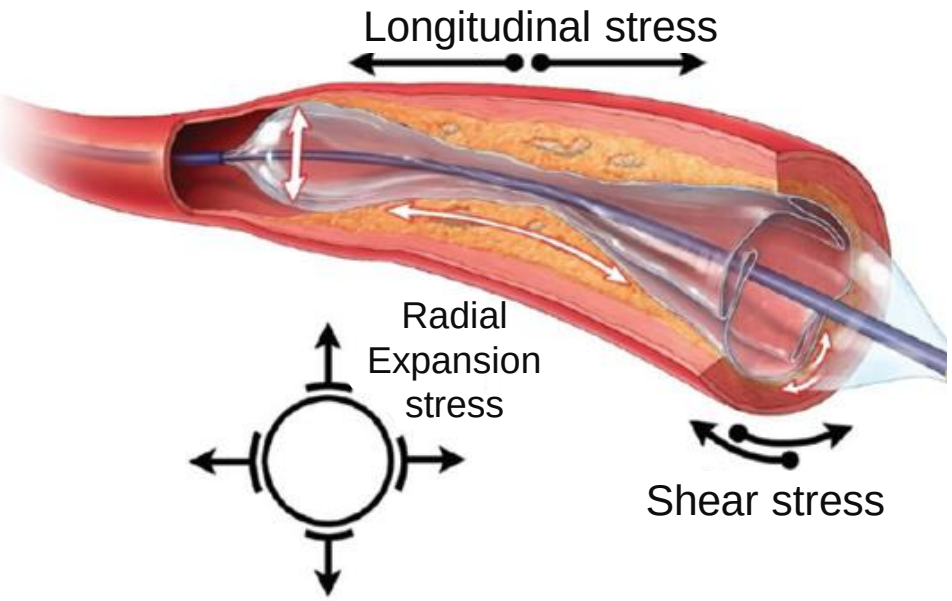
04 Measures to prevent restenosis

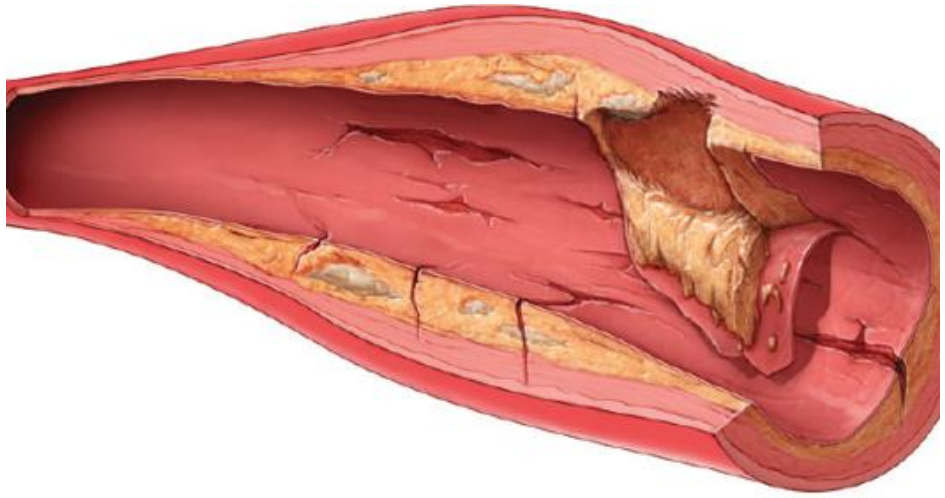
05 Lecture conclusion

History and theory of lower extremity angioplasty

PTA Past and Present







The damage to the inner wall of the vessel

Basic Theory of Angioplasty

Barotrauma

Trauma caused by pressure applied to the blood vessel wall

Shear stress

When the balloon is inflated within the vessel, damage to the vessel wall occurs during rotation of the balloon

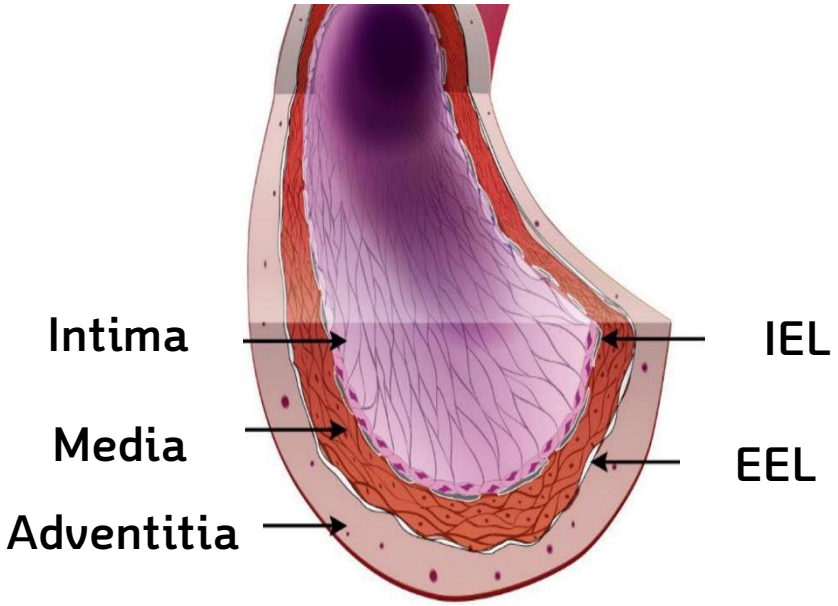
Radial expansion stress

Since pressure is applied to the blood vessel along the narrowing of the blood vessel, it causes radial damage and longitudinal damage to the inner wall of the blood vessel.

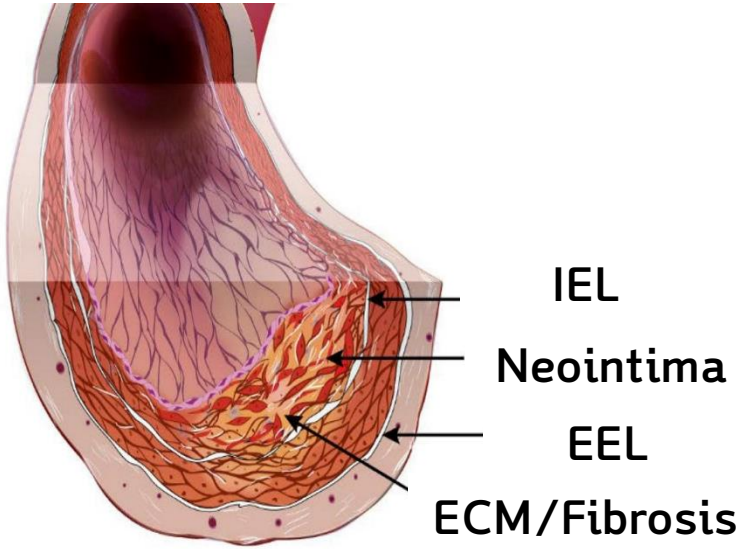
Irregular inner blood vessel wall damage

Due to the irregular shape of the atherosclerotic plate, the pressure applied to the vessel wall around the balloon during angioplasty is not uniform, and the damage to the inner wall of the vessel varies and occurs in various locations.

Basic Theory of Angioplasty



Healthy vessel



Intimal hyperplasia

Barotrauma

Trauma caused by pressure applied to the blood vessel wall

Inflammatory response

Occurs in the first few days after angioplasty (platelet and fibrin aggregation)

Migration and growth of smooth muscle cells

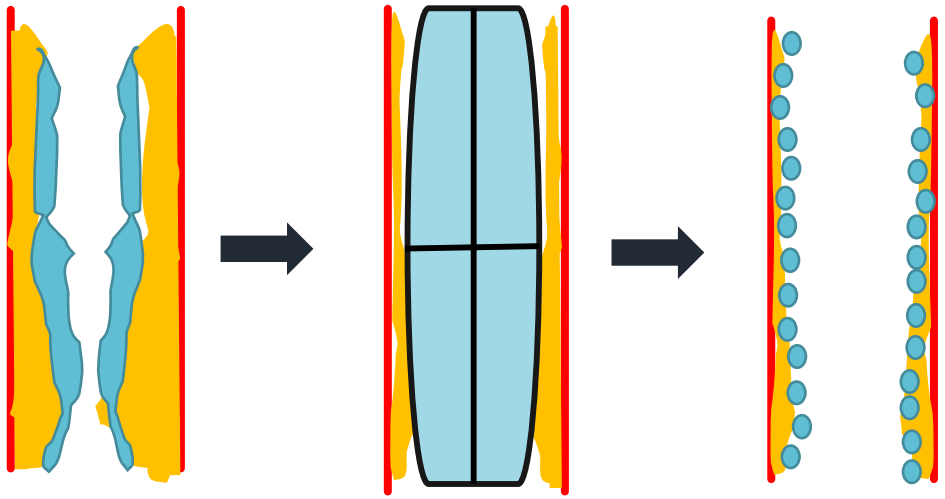
Platelet-derived growth factor and mitogenic factor induce migration and growth of smooth muscle in the vessel wall for several weeks

Blood vessel restenosis

Extracellular matrix is formed and neointimal hyperplasia proceeds

Basic Theory of Angioplasty

Lesion preparation (debulking) using Atherectomy techniques



1. Atherectomy removes atherosclerotic / calcific tissue, resulting in lumen gain with barotrauma

2. Lesion preparation is followed by low pressure balloon angioplasty, decreasing the dissection

3. Drug delivery to the vessel wall is increased, lowering the restenosis due to neointimal hyperplasia in the long term

Resolving vascular restenosis problems

Researchers are seeking alternative treatment and adjuvant treatment methods to solve the vascular restenosis problem

Alternative treatment

Metal stent, Stentgraft, Atherectomy

Adjuvant treatment

Drug-eluting balloon, drug-eluting stent

Table 1. Comparison of the principal imaging and histological features of restenotic tissue after drug-eluting stent and bare metal stent implantation.

	Bare metal stent restenosis	Drug-eluting stent restenosis
Imaging features		
Angiographic morphology	Diffuse pattern more common	Focal pattern more common
OCT tissue properties	Homogenous, high signal band most common	Layered structure or heterogenous most common
Time course of late luminal loss	Late loss maximal by 6-8 months	Ongoing late loss out to 5 years
Histopathological features		
Smooth muscle cellularity	Rich	Hypocellular
Proteoglycan content	Moderate	High
Peri-strut fibrin and inflammation	Occasional	Frequent
Complete endothelialisation	3-6 months	Up to 48 months
Thrombus present	Occasional	Occasional
Neoatherosclerosis	Relatively infrequent, late	Relatively frequent, accelerated course

OCT: optical coherence tomography

Basic Theory of Angioplasty

Restenosis in the stent

Focus on alternative metal mesh stents that make up for the disadvantages of balloon angioplasty

Exist permanently

In the case of an endovascular stent, it is inserted into the blood vessel within the lesion and exists in a permanent state

Elastic recoil

Reduce the probability of elastic recoil occurring

Blood vessel dissection problem solving

Due to the expansive force of the stent, the lumen of the blood vessel can remain unobstructed even if blood vessel dissection occurs due to angioplasty

Stent factors

Underexpansion
Undersizing
Fracture/Gap
Stent type
Edge restenosis

Intra-Stent factors

Neointimal Hyperplasia
Neoatherosclerosis
Calcification
Thrombus
Hetero tissue

Extra-Stent factors

Multiple stent layers
Vessel calcification
Calcified nodules
Vessel size
Residual plaque burden

Basic Theory of Angioplasty

In-stent restenosis(ISR)

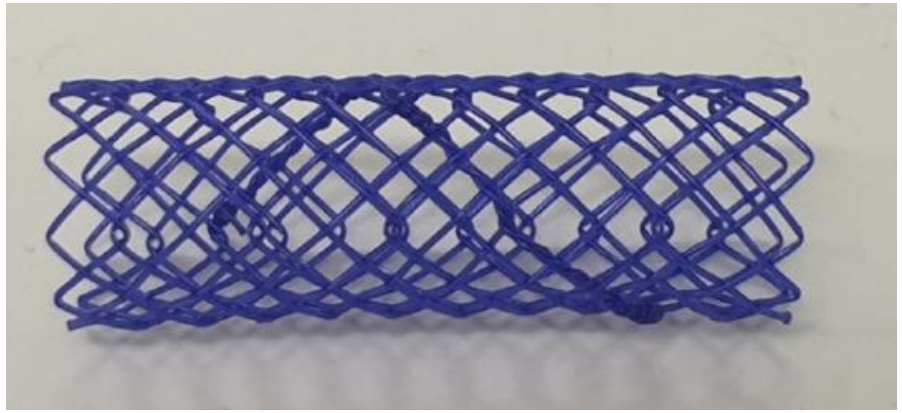
Treatment with stents is a method of permanently implanting implants, so there is controversy in terms of long-term effects.

In-stent restenosis

In-stent restenosis (ISR) occurs due to neointimal hyperplasia

Proliferation of smooth muscle cells and connective tissue cells

Pathological phenomena similar to those occurring in the intima after balloon angioplasty occur within the stent



Bundang Cha Hospital, Korea Textile Development Institute, MI Tech Co., Ltd. Development of a double-layer digestive stent that can control the biodegradation period

기존 스텐트의 단점과 부작용 획기적으로 줄인 스텐트 개발

분당차병원, 한국섬유개발원구원, (주)엠아이텍 공동 연구

생분해 기간 제어 가능한 이중층 소화기계 스텐트 개발

등록 2021-01-26 오전 9:47:41
수정 2021-01-26 오전 9:47:41

가 가

이에 연구팀은 기존 소화기계 스텐트들이 가지고 있는 문제점과 생분해성 스텐트의 한계를 극복하기 위해 스텐트에 사용되는 섬유의 생분해 기간을 달리하는 이중층 기술(sheath-core 형태)을 개발했다. 바깥층은 생분해 기간은 짧지만 스텐트 복원력에 유리한 물질을 적용하고, 중심부는 생분해 기간이 오래 유지되어 스텐트의 팽창 유지력에 유리한 물질을 삽입했다. 이렇게 해서 필라멘트(메디컬용 섬유)가 부러지는 현상을 최대한 억제하고, 생분해 과정에서 부러져도 필라멘트 조각이 얇은 중심부 구조에만 존재해 즉시 체외로 배출되거나 생분해 돼 합병증 발생 없이 사라지도록 하는데 성공했다.

Basic Theory of Angioplasty

In-stent restenosis(ISR)

If stenosis or occlusion within the stent occurs, stenosis and Treatment of obstruction requires highly sophisticated techniques.

Vascular bypass surgery

There is no possibility of future vascular bypass surgery at the site where the stent was inserted.

Disadvantages of stent treatment

As concerns about the disadvantages of stent treatment increase, techniques that can avoid the use of stents or reduce the treatment range of stents are being highlighted.

Without Drug coating stent

Klaus Bonaventura
Department of Cardiology and Angiology
Heart Thorax Vascular Center, Klinikum Ernst von Bergmann, Potsdam

With Drug coating stent

Basic Theory of Angioplasty

Current Methods to Inhibit Neointimal Hyperplasia

Paclitaxel is most often used to prevent intravascular restenosis of peripheral vessels

Techniques for binding drugs to balloon catheters and stents

It is important that the drug directly reaches the lesion site in the blood vessel without being lost in the blood vessel.

Cellular uptake

When paclitaxel reaches the blood vessel wall in the treatment area, it is rapidly absorbed by the cells of the area because of the drug's fat-soluble component.

Cessation of cell division in smooth muscle

Cell division of smooth muscle of blood vessels is stopped in the cells where the drug is absorbed, and thus neointimal hyperplasia is suppressed.

Meta-Analysis > J Am Heart Assoc. 2018 Dec 18;7(24):e011245. doi: 10.1161/JAHA.118.011245.

Risk of Death Following Application of Paclitaxel-Coated Balloons and Stents in the Femoropopliteal Artery of the Leg: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Konstantinos Katsanos [1], Stavros Spiliopoulos [2], Panagiotis Kitrou [1], Miltiadis Krokidis [3], Dimitrios Karnabatidis [1]

Affiliations + expand

PMID: 30561254 PMCID: PMC6405619 DOI: 10.1161/JAHA.118.011245

Free PMC article

Abstract

Background Several randomized controlled trials (RCT s) have already shown that paclitaxel-coated balloons and stents significantly reduce the rates of vessel restenosis and target lesion revascularization after lower extremity interventions. Methods and Results A systematic review and meta-analysis of RCT s investigating paclitaxel-coated devices in the femoral and/or popliteal arteries was performed. The primary safety measure was all-cause patient death. Risk ratios and risk differences were pooled with a random effects model. In all, 28 RCT s with 4663 patients (89% intermittent claudication) were analyzed. All-cause patient death at 1 year (28 RCT s with 4432 cases) was similar between paclitaxel-coated devices and control arms (2.3% versus 2.3% crude risk of death; risk ratio, 1.08; 95% CI, 0.72-1.61). All-cause death at 2 years (12 RCT s with 2316 cases) was significantly increased in the case of paclitaxel versus control (7.2% versus 3.8% crude risk of death; risk ratio, 1.68; 95% CI, 1.15-2.47; -number-needed-to-harm, 29 patients [95% CI , 19-59]). All-cause death up to 5 years (3 RCT s with 863 cases) increased further in the case of paclitaxel (14.7% versus 8.1% crude risk of death; risk ratio, 1.93; 95% CI , 1.27-2.93; -number-needed-to-harm, 14 patients [95% CI , 9-32]). Meta-regression showed a significant relationship between exposure to paclitaxel (dose-time product) and absolute risk of death (0.4±0.1% excess risk of death per paclitaxel mg-year; P<0.001). Trial sequential analysis excluded false-positive findings with 99% certainty (2-sided α, 1.0%). Conclusions There is increased risk of death following application of paclitaxel-coated balloons and stents in the femoropopliteal artery of the lower limbs. Further investigations are urgently warranted. Clinical Trial Registration URL : www.crd.york.ac.uk/PROSPERO . Unique identifier: CRD 42018099447.

Keywords: balloon angioplasty; paclitaxel; paclitaxel-coated balloon; paclitaxel-eluting stent.

Basic Theory of Angioplasty

Recent research results

Association with increased mortality after use of paclitaxel-containing devices

DCB & DCS

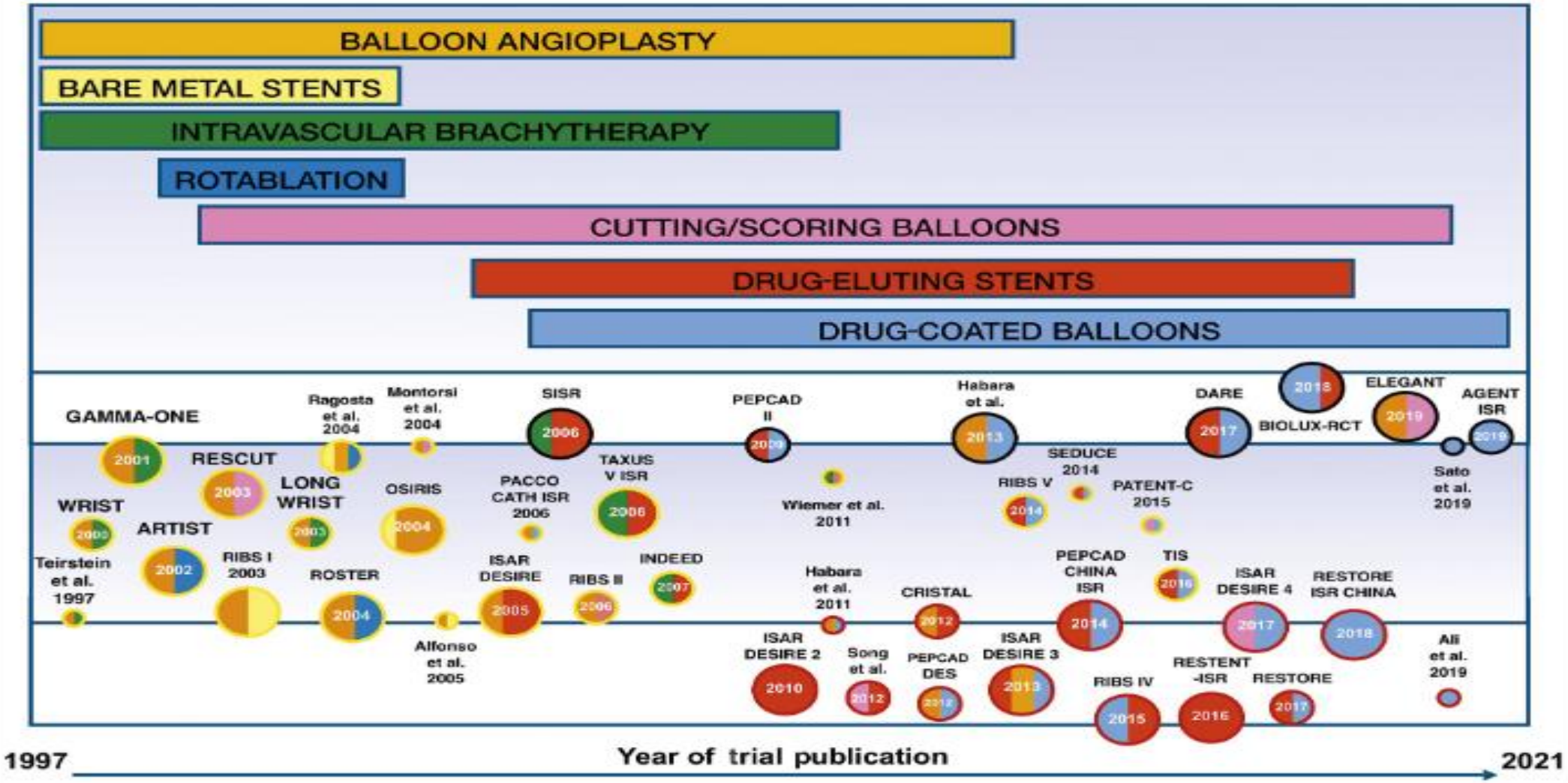
The debate about paclitaxel's safety is reigniting.

Safety

Based on the results reported so far, the evidence for the safety of the drug is poor.

Substitute material

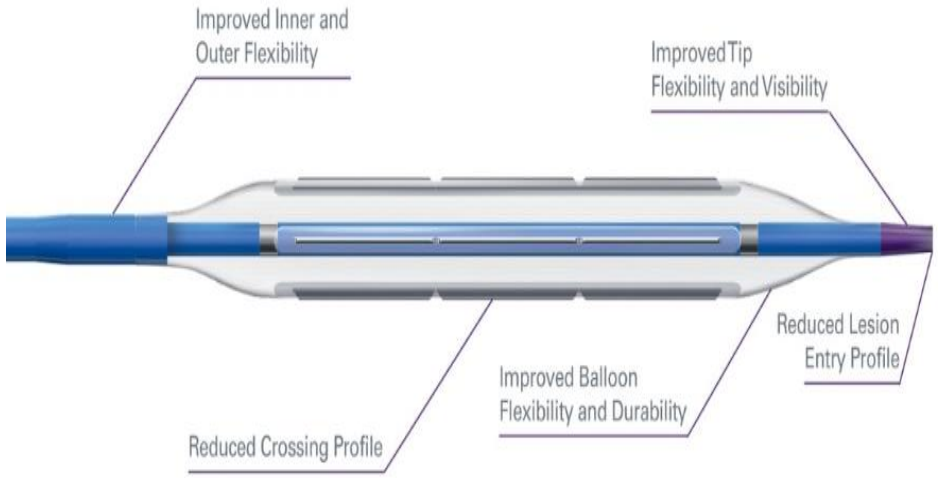
At this point, the fact that paclitaxel is the most important treatment drug for preventing restenosis remains unchanged.

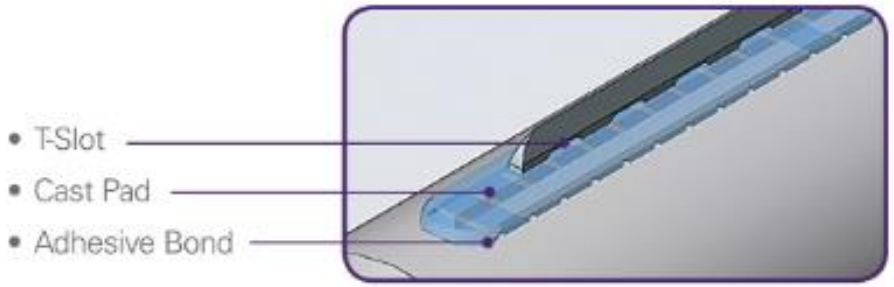


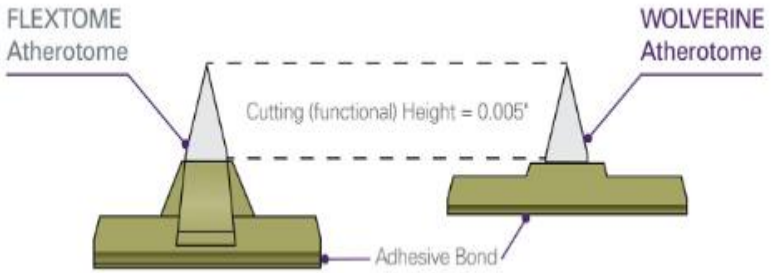
Management of in-stent restenosis EuroIntervention 2022;18:e103-e123. DOI: 10.4244/EIJ-D-21-01034

Procedure equipment for lower extremity angioplasty

Procedure equipment for lower extremity angioplasty







Cutting balloon

- It was first developed for coronary artery use by Dr. Peter Barath in the 1980s(Call it a Barath balloon)
- Cutting balloons are special balloons with three to four long blades (atherotomes) on the outer surface of the balloon

Laceration formation

Each blade forms controlled lacerations evenly on the inner surface of the vessel at the site where it is located

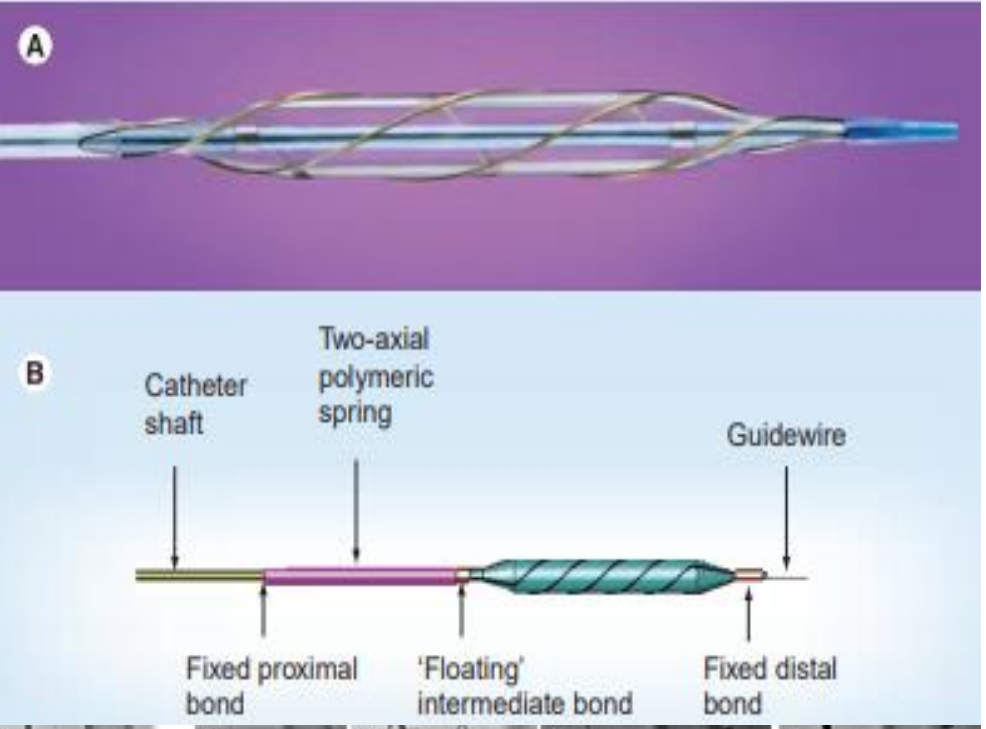
Refractory stenosis

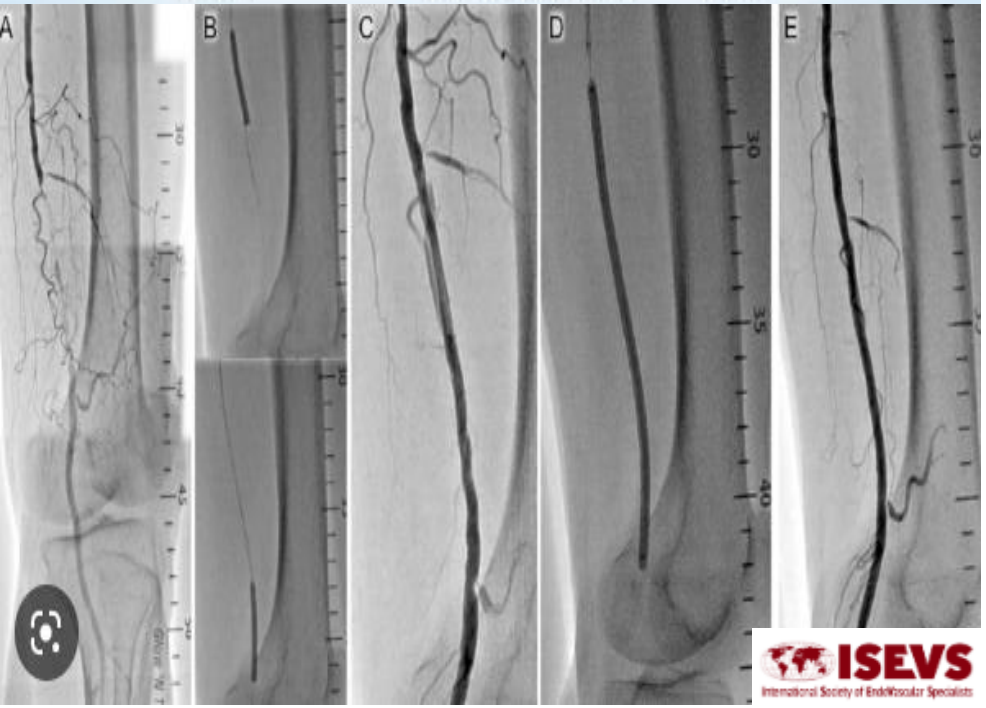
It is an effective tool when trying to expand refractory stenosis

Minimizes the risk of damage to the vascular endothelium

Inflating or deflating the balloon at a slow rate minimizes the risk of damage to the intima by the blade.

https://www.bostonscientific.com/en-US/products/balloons-cutting/wolverine-cutting-balloon.html





Procedure equipment for lower extremity angioplasty

Scoring balloon

First developed in 2003 for the treatment of complex coronary artery disease. Nitinol struts wrapped around the surface of the balloon or buddy wires parallel to the long axis of the balloon

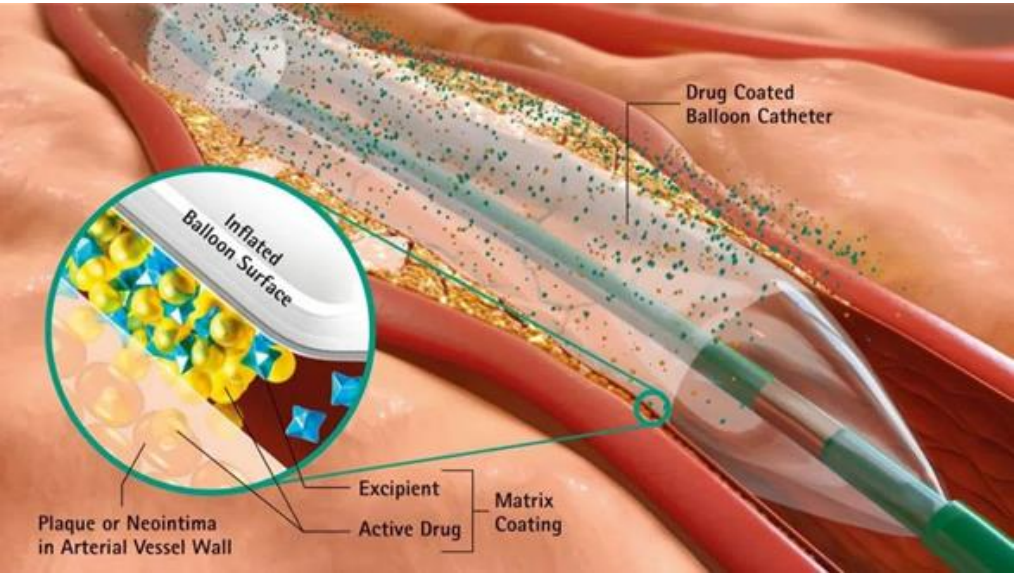
Advantages of Scoring Balloons

When angioplasty is performed using a cut-type balloon and a scoring balloon, blood vessel dissection occurs relatively less when compared to angioplasty using a general balloon catheter.

A paper on the effect of scoring balloon on the results of percutaneous angioplasty for popliteal fossa lesions

AngioSculpt® scoring balloon catheter: an atherotomy device for coronary and peripheral interventions. 10.2217/ICA.10.51 © 2010 Future Medicine Ltd Interv. Cardiol. (2010) 2(4), 469–478 ISSN 1755-5302

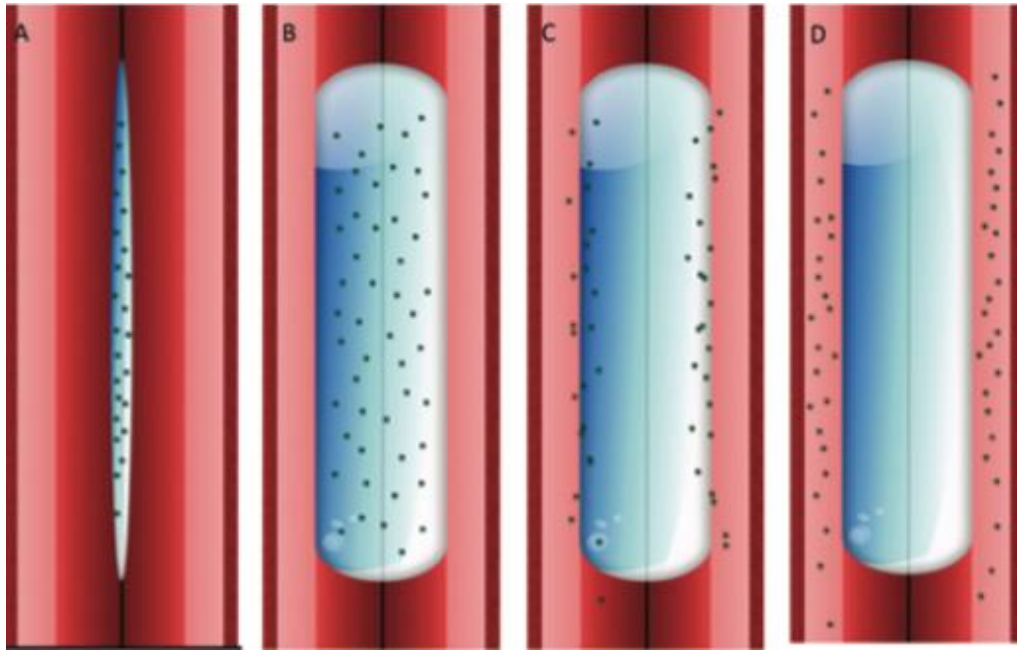
Procedure equipment for lower extremity angioplasty



https://www.kossel-medical.com/2020/08/14/drug-coated-balloon

Drug coated balloon

A drug-coated balloon or drug-eluting balloon was developed to prevent restenosis after endovascular procedures



Drug application

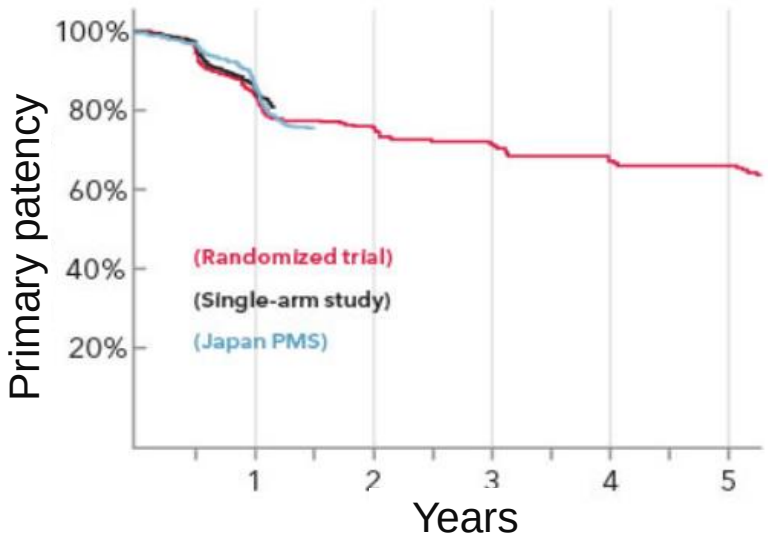
When paclitaxel is coated on the surface of the balloon, the possibility of drug loss is reduced because the drug exists between the folds of the balloon.

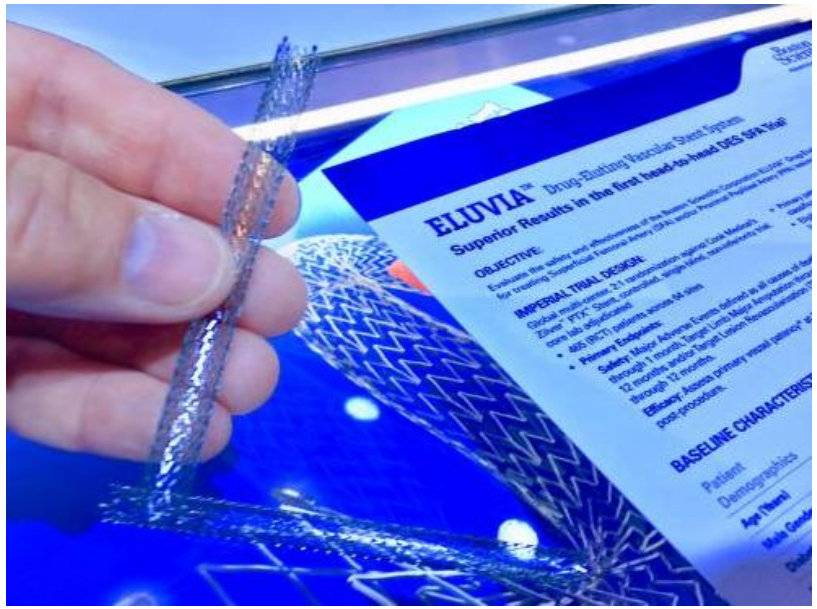
Packing method

The drug-coated balloon is wrapped in a sleeve so that the operator does not touch the drug-coated surface when holding the balloon.

https://www.hmpgloballearningnetwork.com/site/cathlab/article/drug-coated-balloon-not-just-balloon

Zilver PTX primary patency





Procedure equipment for lower extremity angioplasty

Drug-eluting stent

It is a type of stent in which a drug that inhibits neointimal overgrowth is bound to the surface of a general metal stent

Zilver PTX® drug-eluting stent (Cook Medical)

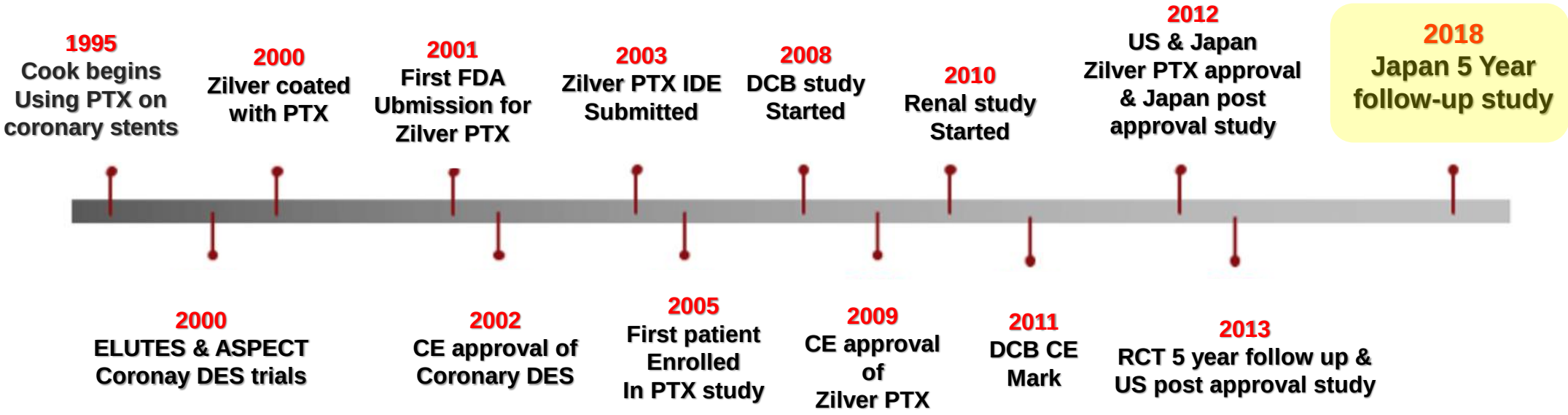
Eluvia® drug-eluting stent (Boston Scientific)

Polymer-coated stents release paclitaxel over a longer period of time.

https://www.dicardiology.com/content/cms-grants-additional-reimbursement-eluvia-vascular-stent

Cook Medical's 25 Year History with Paclitaxel

(Zilver PTX starts in the coronary artery and reaches the SFA)



A polymer-coated, paclitaxel-eluting stent (Eluvia) versus a polymer-free, paclitaxel-coated stent (Zilver PTX) for endovascular femoropopliteal intervention (IMPERIAL): a randomised, non-inferiority trial

William A Gray, Koen Keirse, Yoshimitsu Soga, Andrew Benko, Anvar Babaev, Yoshiaki Yokoi, Henrik Schroeder, Jeffery T Prem, Andrew Holden, Jeffrey Popma, Michael R Jaff, Juan Diaz-Cartelle, Stefan Müller-Hülsbeck, on behalf of the IMPERIAL investigators*

Summary

Background The clinical effect of a drug-eluting stent in the femoropopliteal segment has not been investigated in a randomised trial with a contemporary comparator. The IMPERIAL study sought to compare the safety and efficacy of the polymer-coated, paclitaxel-eluting Eluvia stent with the polymer-free, paclitaxel-coated Zilver PTX stent for treatment of femoropopliteal artery segment lesions.

Methods In this randomised, single-blind, non-inferiority study, patients with symptomatic lower-limb ischaemia manifesting as claudication (Rutherford category 2, 3, or 4) with atherosclerotic lesions in the native superficial femoral artery or proximal popliteal artery were enrolled at 65 centres in Austria, Belgium, Canada, Germany, Japan, New Zealand, and the USA. Patients were randomly assigned (2:1) with a site-specific, web-based randomisation schedule to receive treatment with Eluvia or Zilver PTX. All patients, site personnel, and investigators were masked to treatment assignment until all patients had completed 12 months of follow-up. The primary efficacy endpoint was primary patency (defined as a peak systolic velocity ratio ≤2·4, without clinically driven target lesion revascularisation or bypass of the target lesion) and the primary safety endpoint was major adverse events (ie, all causes of death through 1 month, major amputation of target limb through 12 months, and target lesion revascularisation through 12 months). We set a non-inferiority margin of −10% at 12 months. Primary non-inferiority analyses were done when the minimum sample size required for adequate statistical power had completed 12 months of follow-up. The primary safety non-inferiority analysis included all patients who had completed 12 months of follow-up or had a major adverse event through 12 months. This trial is registered with ClinicalTrials.gov, number NCT02574481.

Findings Between Dec 2, 2015, and Feb 15, 2017, 465 patients were randomly assigned to Eluvia (n=309) or to Zilver PTX (n=156). Non-inferiority was shown for both efficacy and safety endpoints at 12 months: primary patency was 86·8% (231/266) in the Eluvia group and 81·5% (106/130) in the Zilver PTX group (difference 5·3% [one-sided lower bound of 95% CI −0·66]; p<0·0001). 259 (94·9%) of 273 patients in the Eluvia group and 121 (91·0%) of 133 patients in the Zilver PTX group had not had a major adverse event at 12 months (difference 3·9% [one-sided lower bound of 95% CI −0·46]; p<0·0001). No deaths were reported in either group. One patient in the Eluvia group had a major amputation and 13 patients in each group required target lesion revascularisation.

Interpretation The Eluvia stent was non-inferior to the Zilver PTX stent in terms of primary patency and major adverse events at 12 months after treatment of patients for femoropopliteal peripheral artery disease.

Funding Boston Scientific.

Procedure equipment for lower extremity angioplasty

Drug-eluting stent (DES)

There was a recent Eluvia VS Zilver PTX® randomized controlled trial.

Primary patency

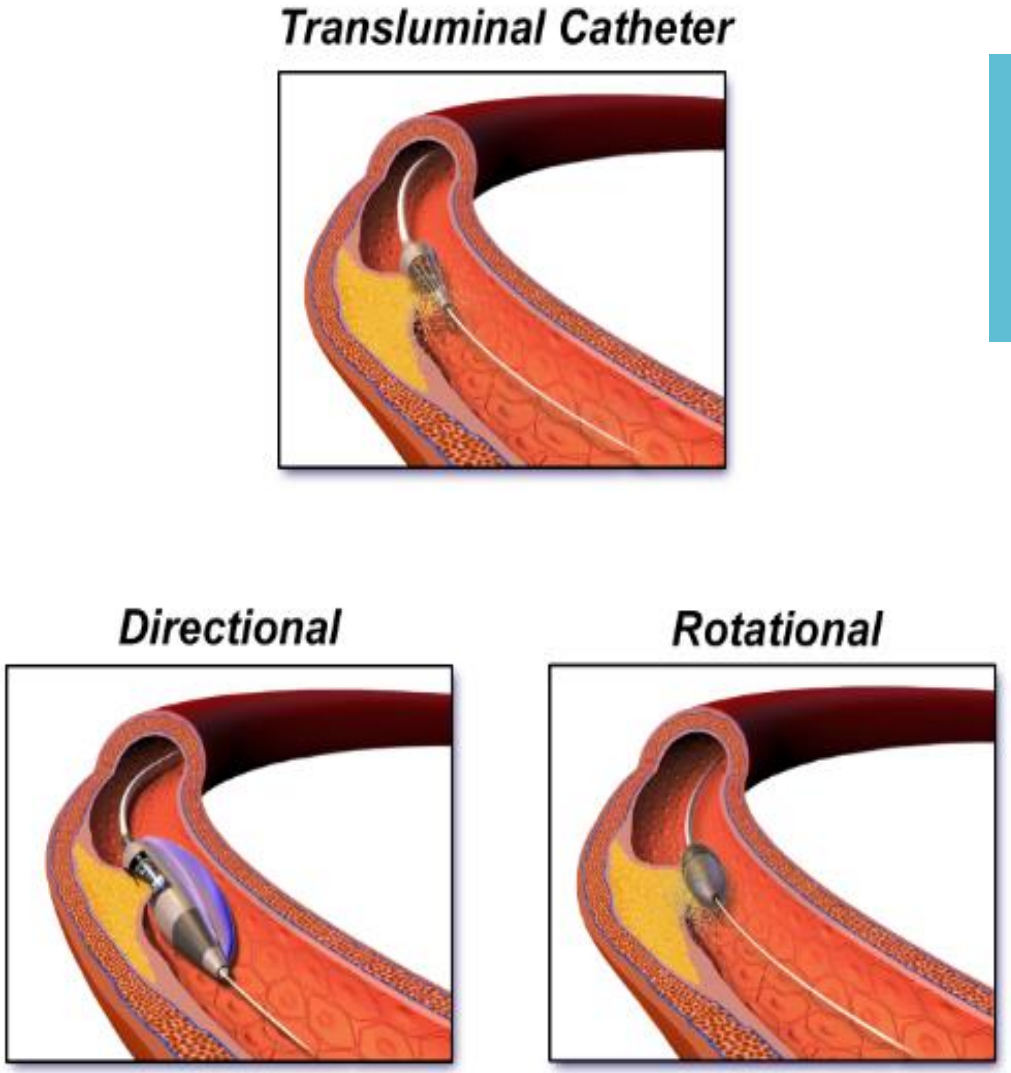
86.8% (231/266) Eluvia group vs 81.5% (106/130)

No deaths

There were no deaths in both groups during the research period

Postoperative course

Among the patients in the Eluvia group, 1 lower extremity amputation occurred.
Thirteen patients in each group underwent revascularization



Types of Atherectomy

https://en.wikipedia.org/wiki/Atherectomy

Treatment method of lower extremity angioplasty

Atherectomy

It refers to the process of mechanically removing the atherosclerotic plaque of the blood vessel using a blade embedded in the catheter

Lesion size reduction

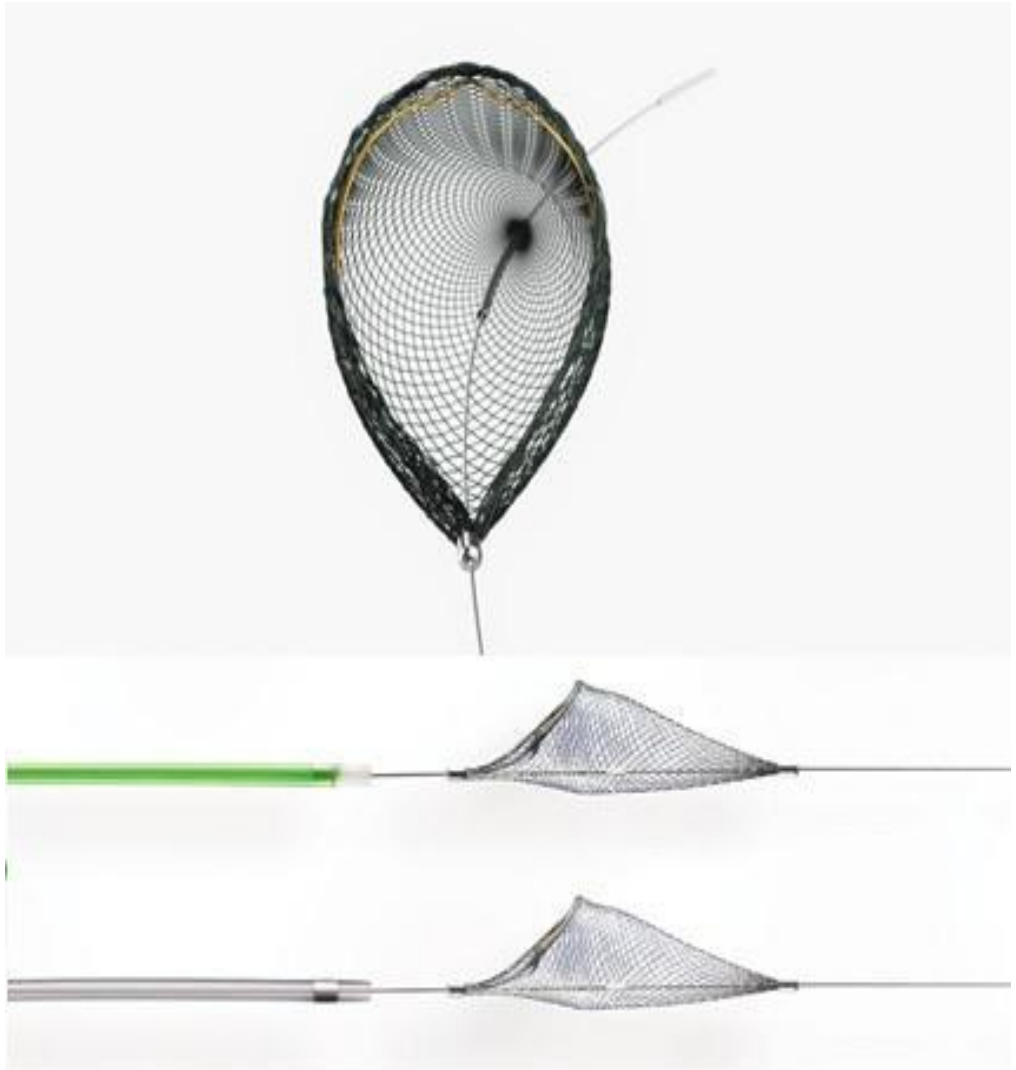
Reduces the size of stenotic or obstructive lesions through atheroma removal

Reduced vascular dissection

Decreased barotrauma during balloon dilatation, decreased probability of elastic recoil and intimal detachment

Use of a drug-eluting balloon after atherectomy

Studies using atherectomy devices and drug-eluting balloons in the superficial femoral artery and popliteal artery are being actively conducted.



Treatment method of lower extremity angioplasty

Atherectomy

Although it has the advantage of reducing the size of the lesion or increasing drug absorption, there is a possibility of vascular blockage due to the distal outflow of the removed atheroma.

Distal vascular embolization

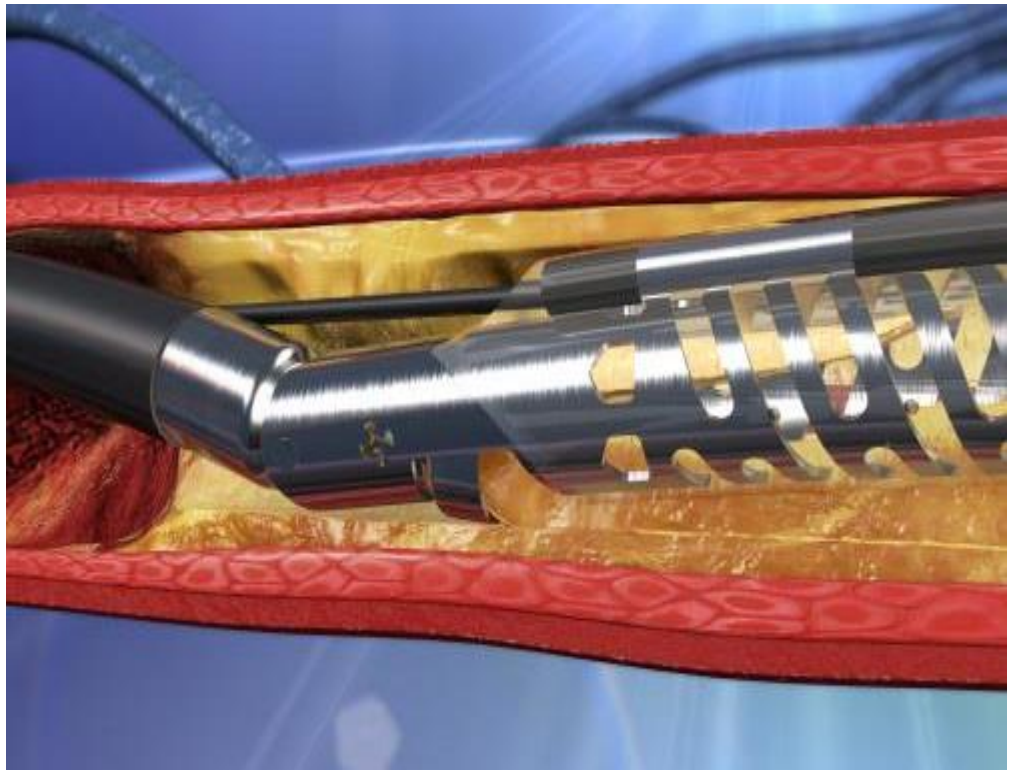
High risk of embolism in distal vessels after atherectomy.

Efforts to prevent embolism

Use of filter wire during atherectomy to reduce the risk of developing an embolus

(SpiderFX™ Medtronic SpiderFX Embolic Protection Device - SpiderFX Embolic Protection Device, 4 mm Filter, 320 cm Wire - SPD2-US-040-190)

https://europe.medtronic.com/xd-en/healthcare-professionals/products/cardiovascular/embolic-protection-devices/spiderfx.html



Treatment method of lower extremity angioplasty

Directional atherectomy

Silverhawk -> Turbohawk-> Hawkone

HawkOne® (Medtronic, Minneapolis, MN)

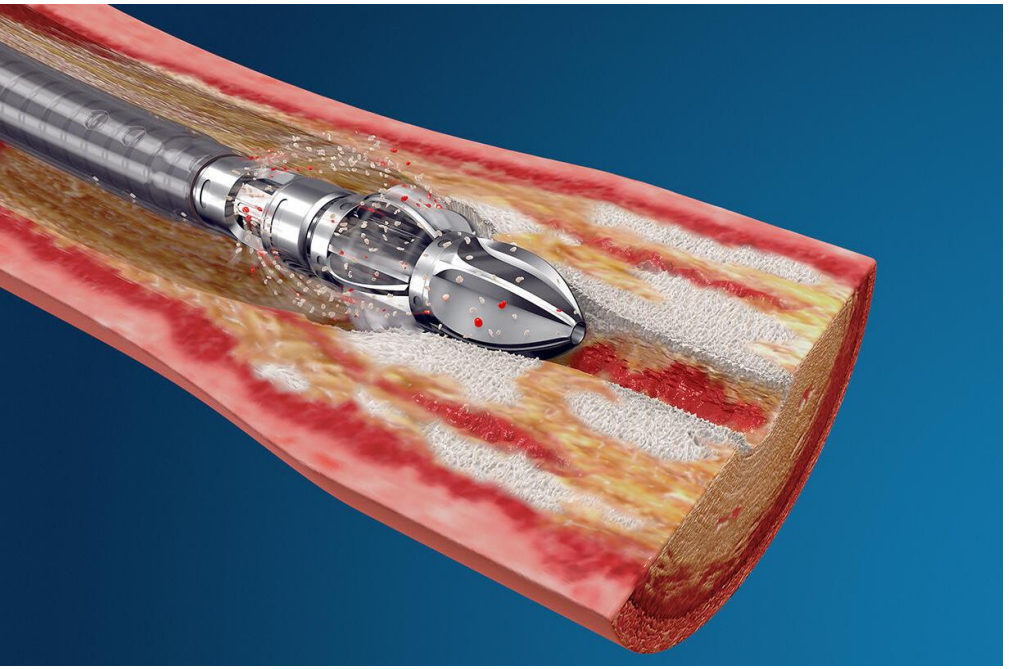
Cutting blade adjustment

Since the cutting blade is located on only one side of the catheter, direct the blade towards the plaque

plaque storage

Severed pieces of plaque are deposited on the nosecone of the instrument

https://europe.medtronic.com/xd-en/healthcare-professionals/products/cardiovascular/directional-atheterectomy-systems/hawkone.html



Treatment method of lower extremity angioplasty

Rotational atherectomy

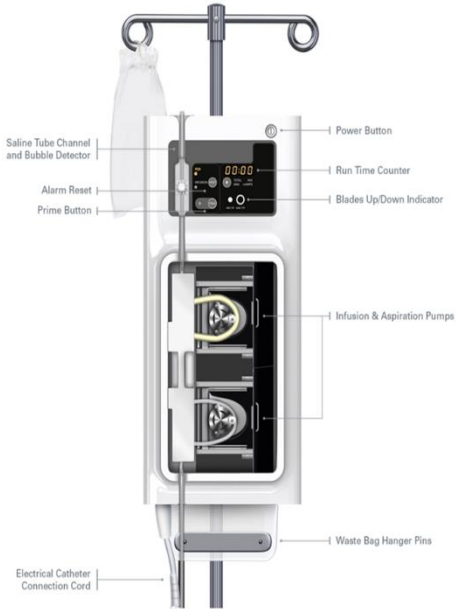
Jetstream® (Boston Scientific, Natick, MA), Rotarex® (BD, Franklin Lakes, NJ)

Plaque removal

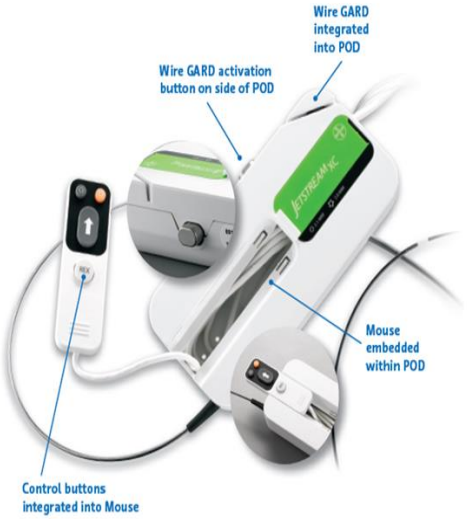
The rotating blade is located at the distal end of the catheter and removes it by breaking up the plaque like a power drill.

Absorption of residual plaque

The electric drill serves to secure the lumen of the blood vessel and at the same time remove residual plaque fragments.



CONSOLE

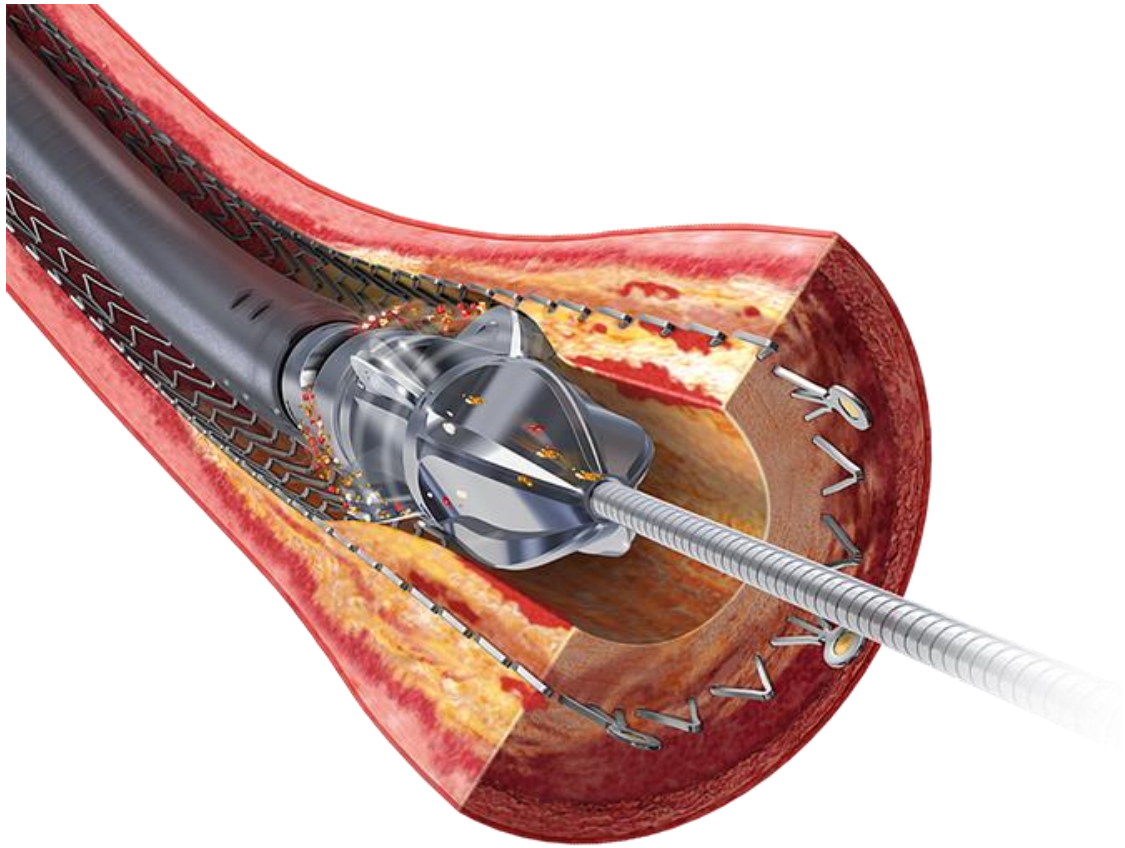


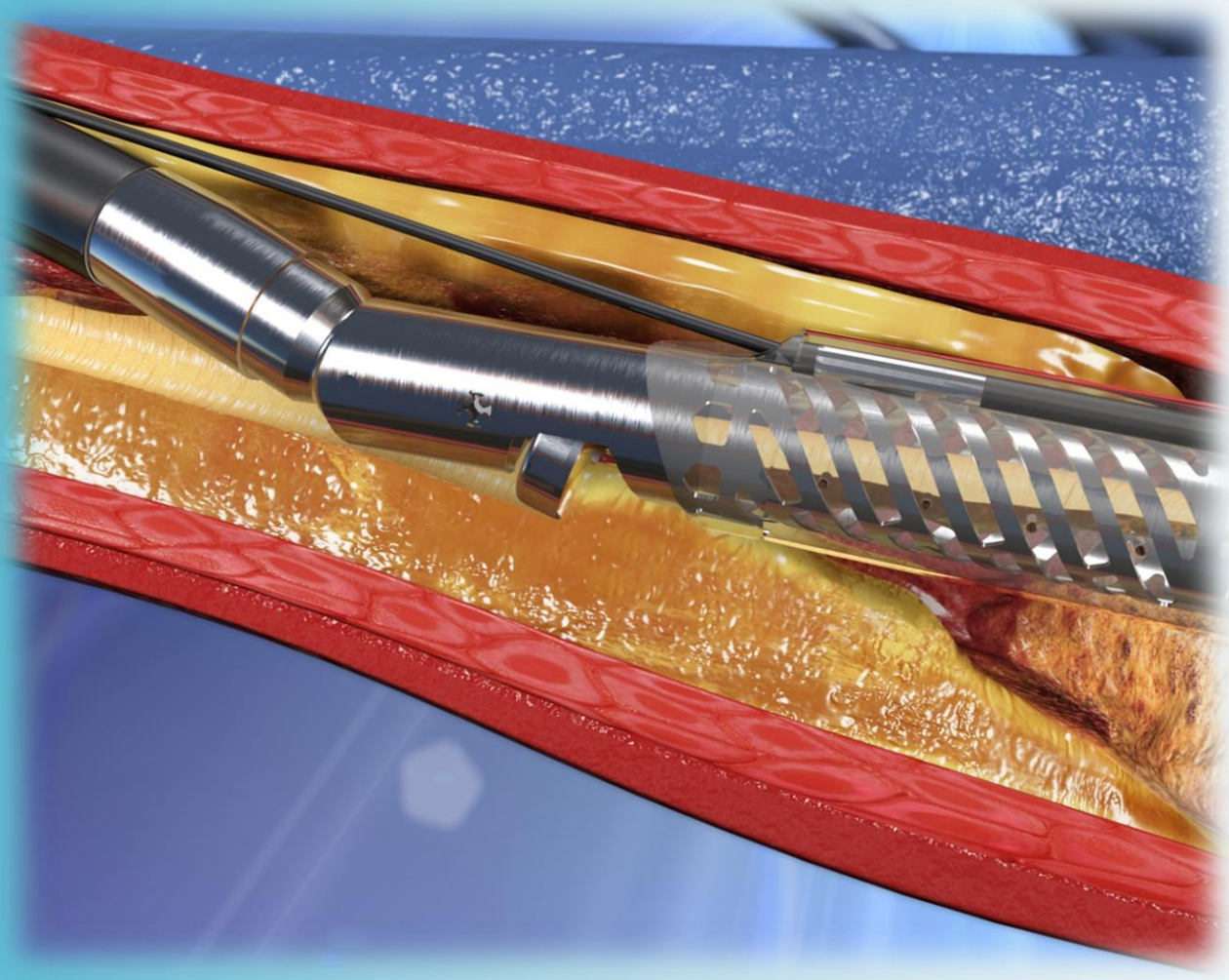
CATHETER/ DISPOSABLE

https://www.bostonscientific.com/en-EU/products/atherectomy-systems/jetstream-atherectomy-system.html

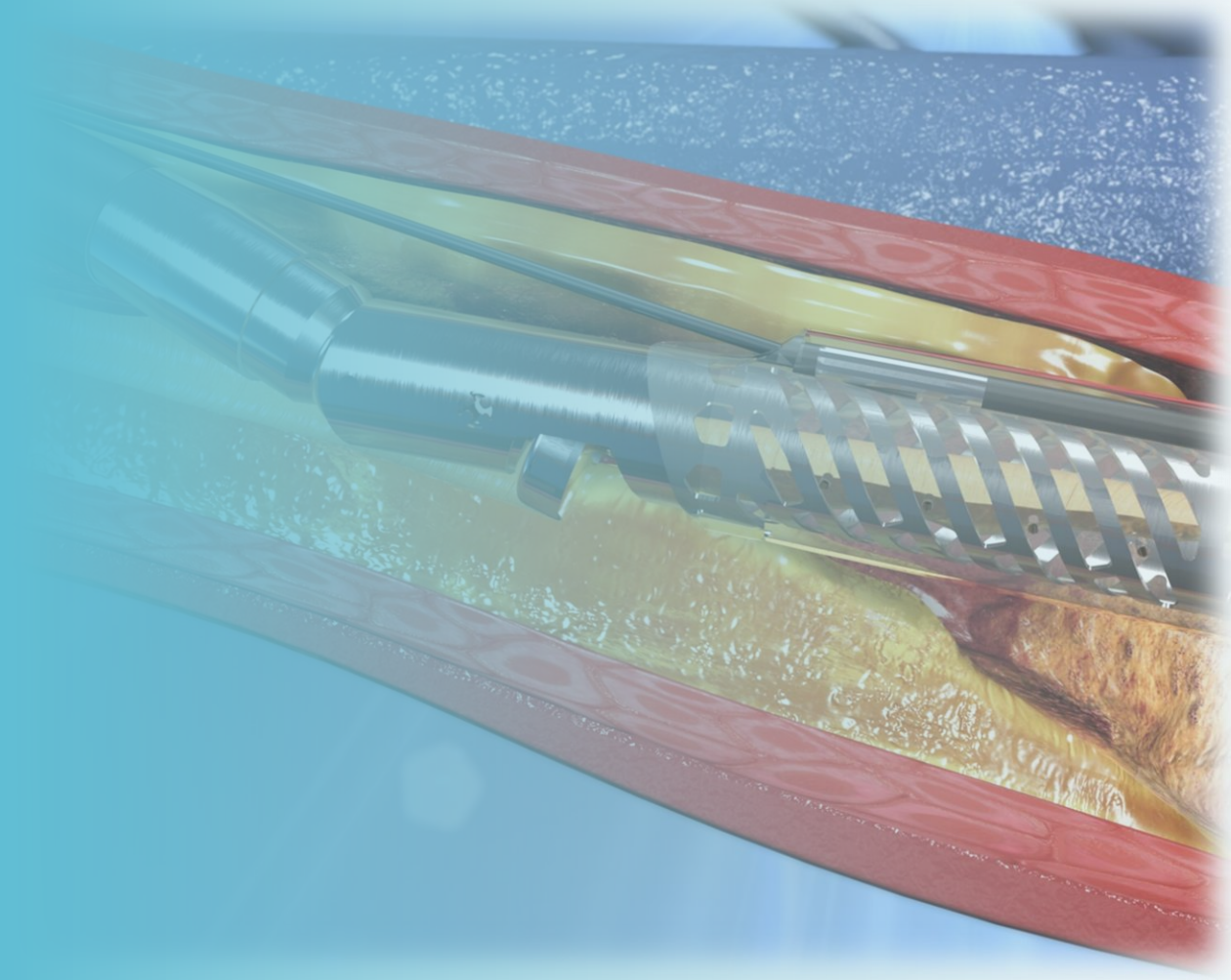
Atherectomy

Recent trend treatment case





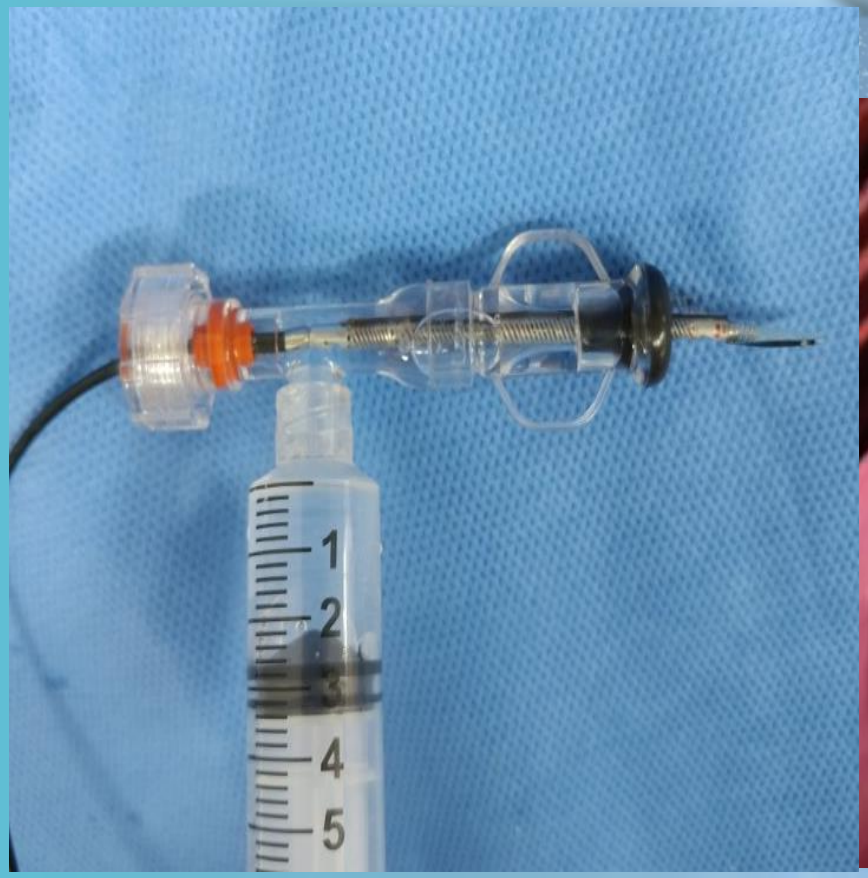
HawkOne

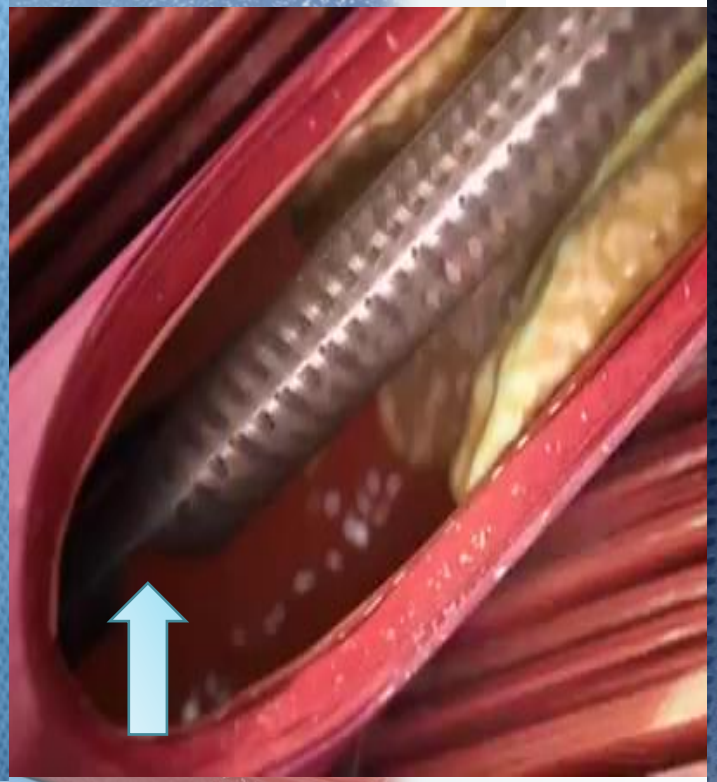


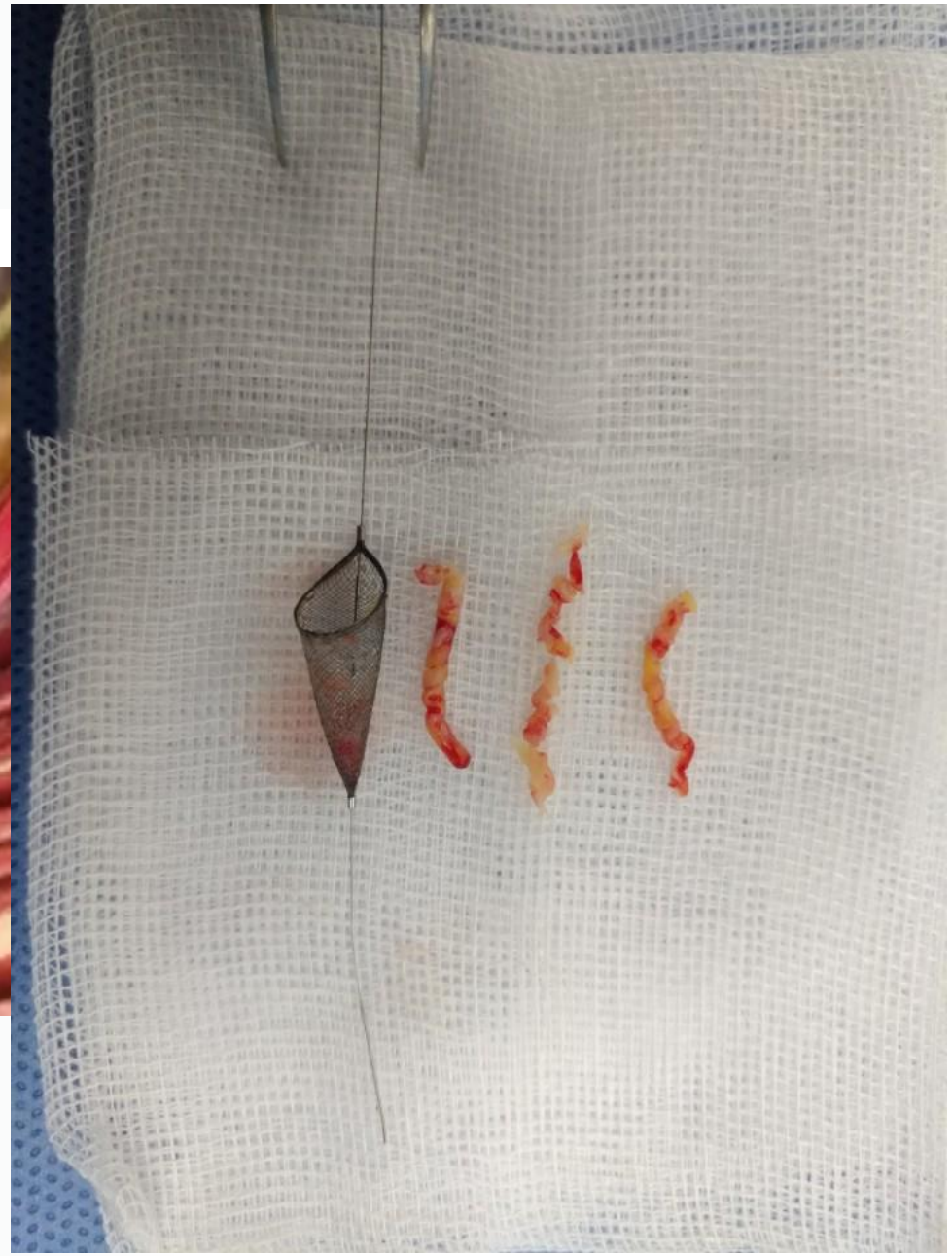
Medtronic

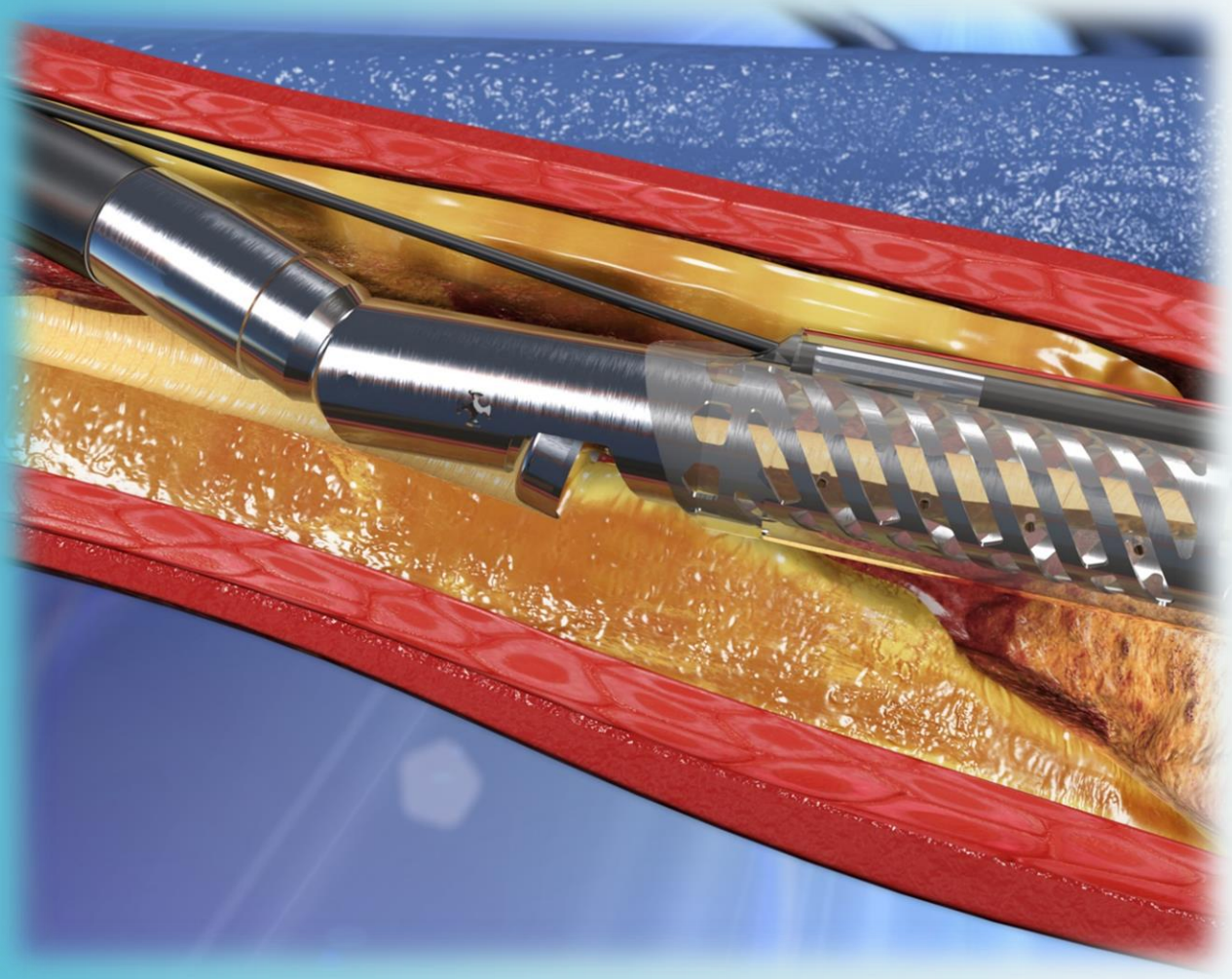
Directional Atherectomy

One Device All Morphology


1
2
3
4
5







Recent trend treatment case

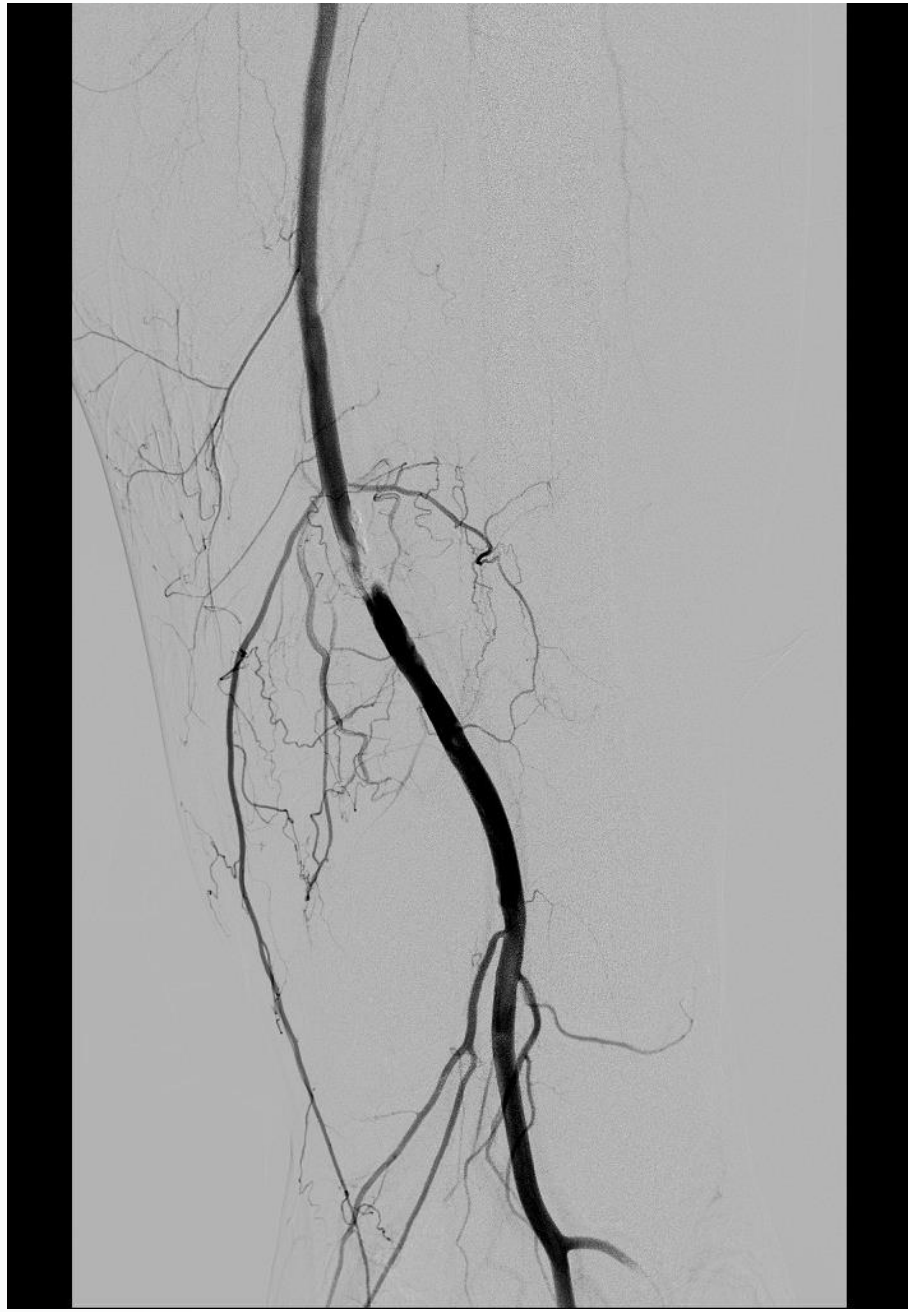
Recent trend treatment case

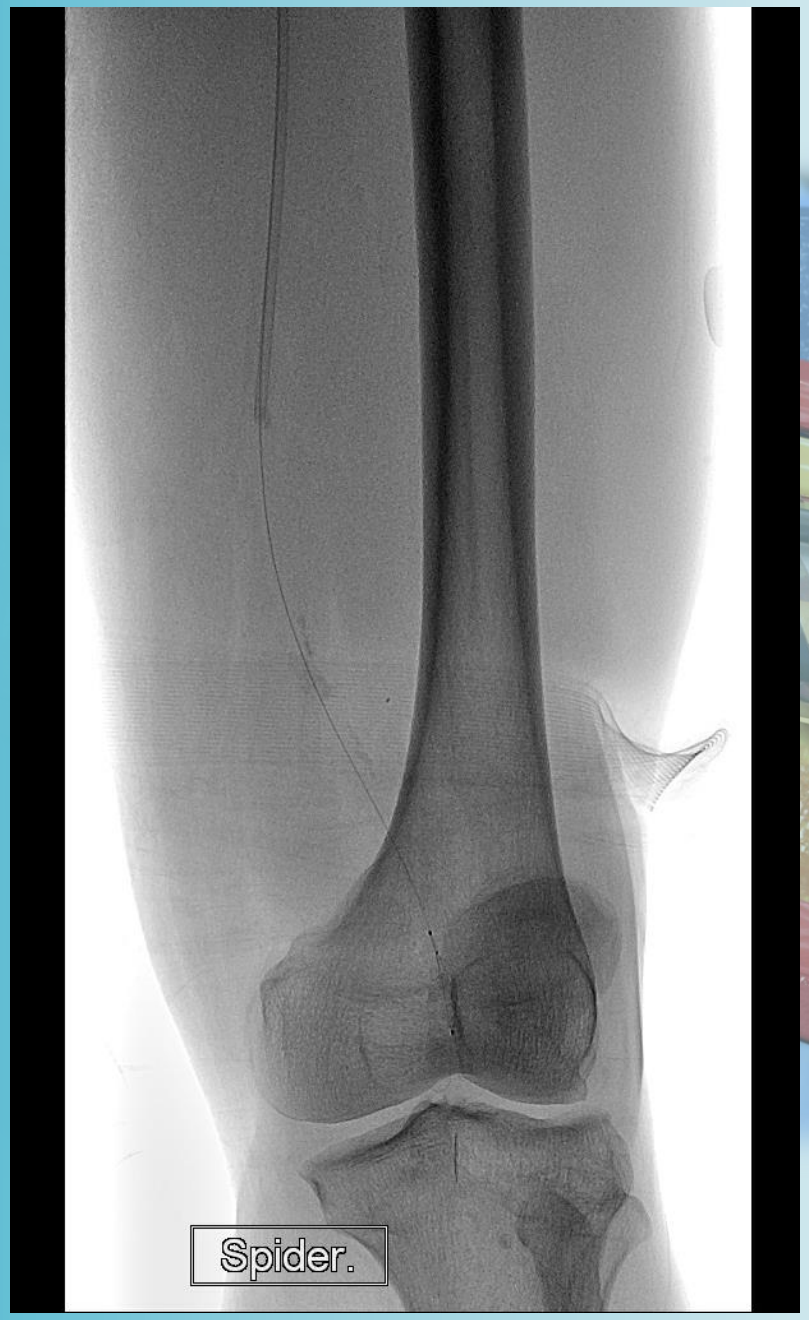
Problem

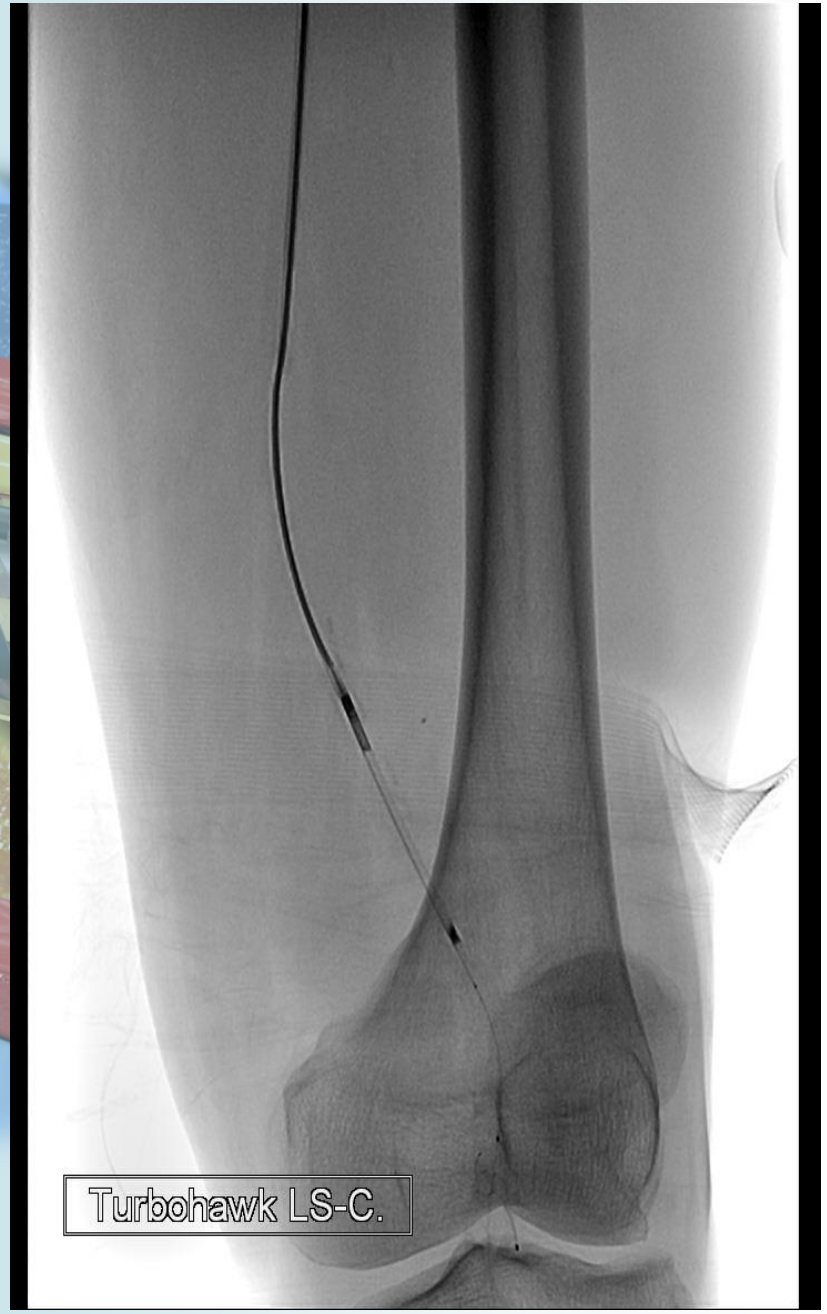
PAOD, Claudication M/69 2023.01

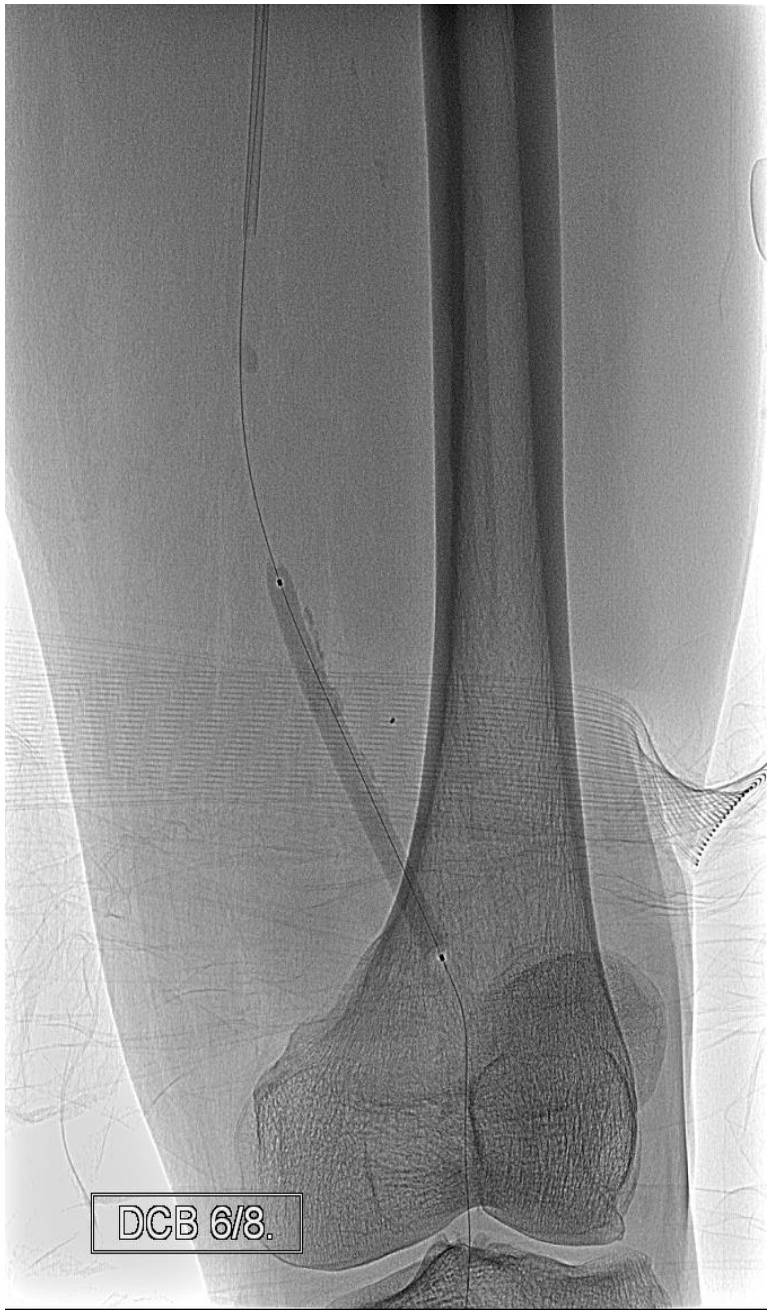
Procedure

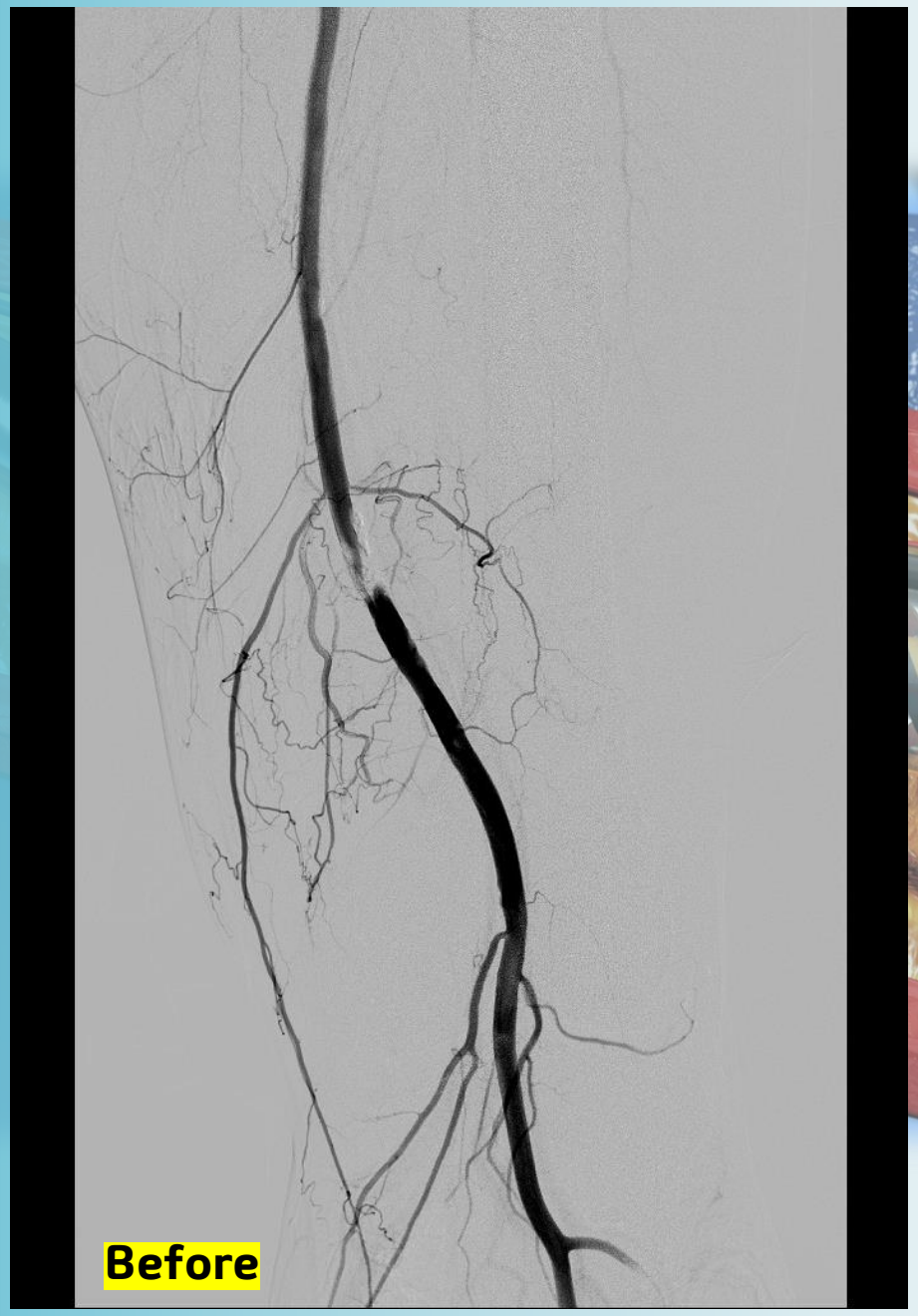
- Procedure : L/E Angio & PTA
- Access / Side : Left antegrade
- Target artery : Left SFA
- Lesion : <3 Focal eccentric calcified stenosis(>75%)
- Treatment :
  Turbohawk directional atherectomy in stenosis segment. Angioplasty using DCB 6mm/8cm.

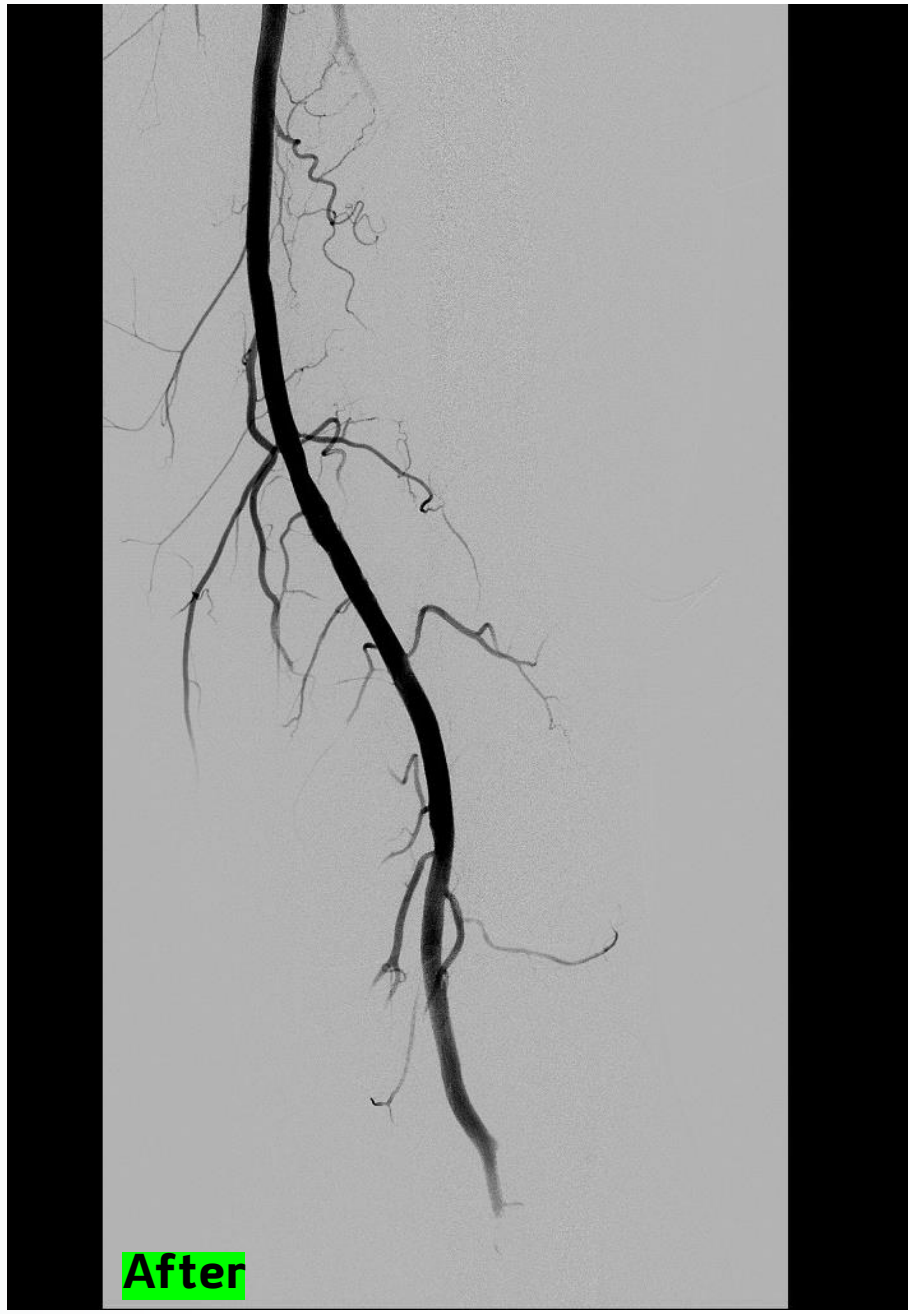



Spider.


Turbohawk LS-C.


DCB 6/8.


Before


After

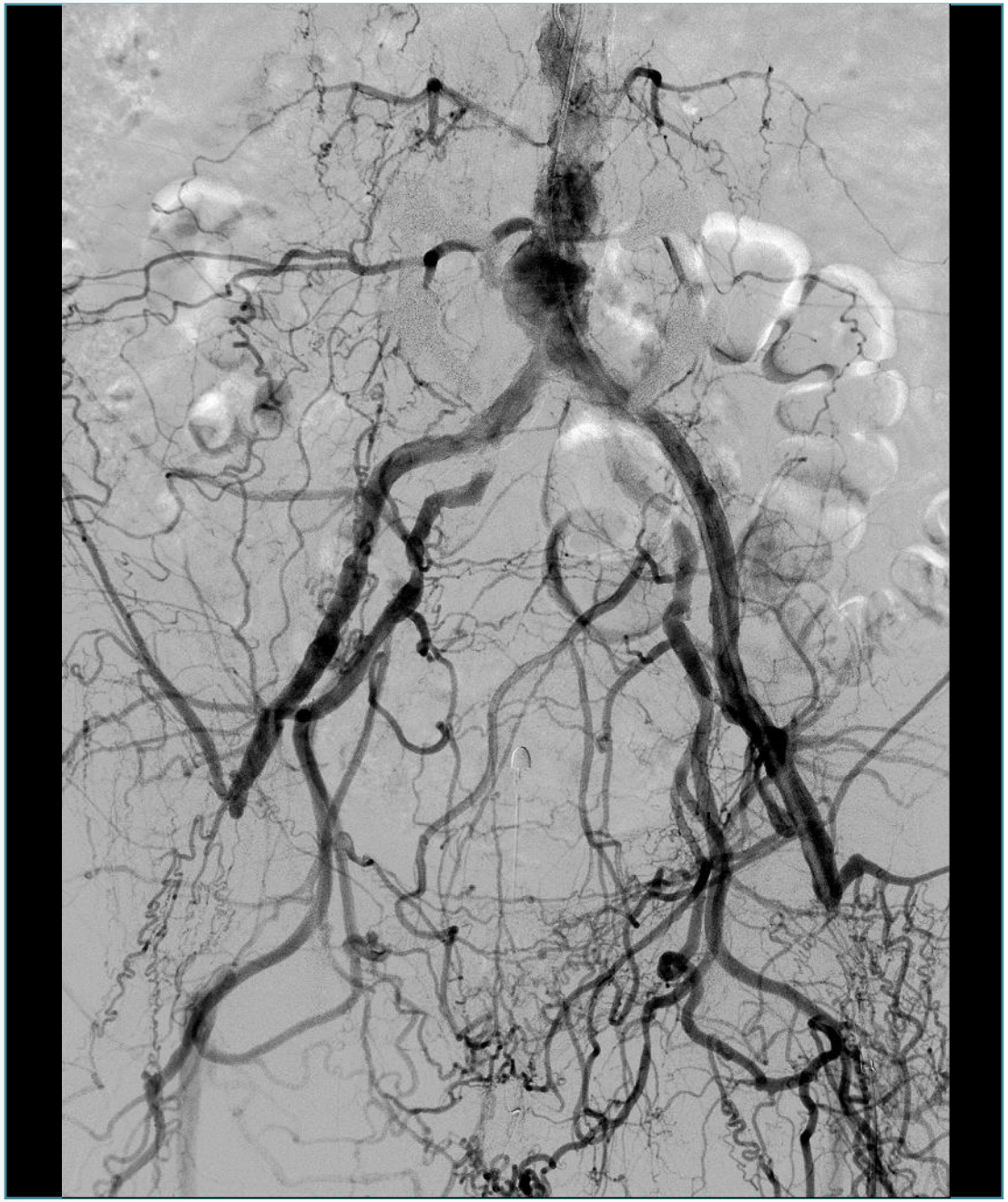
Recent trend treatment case

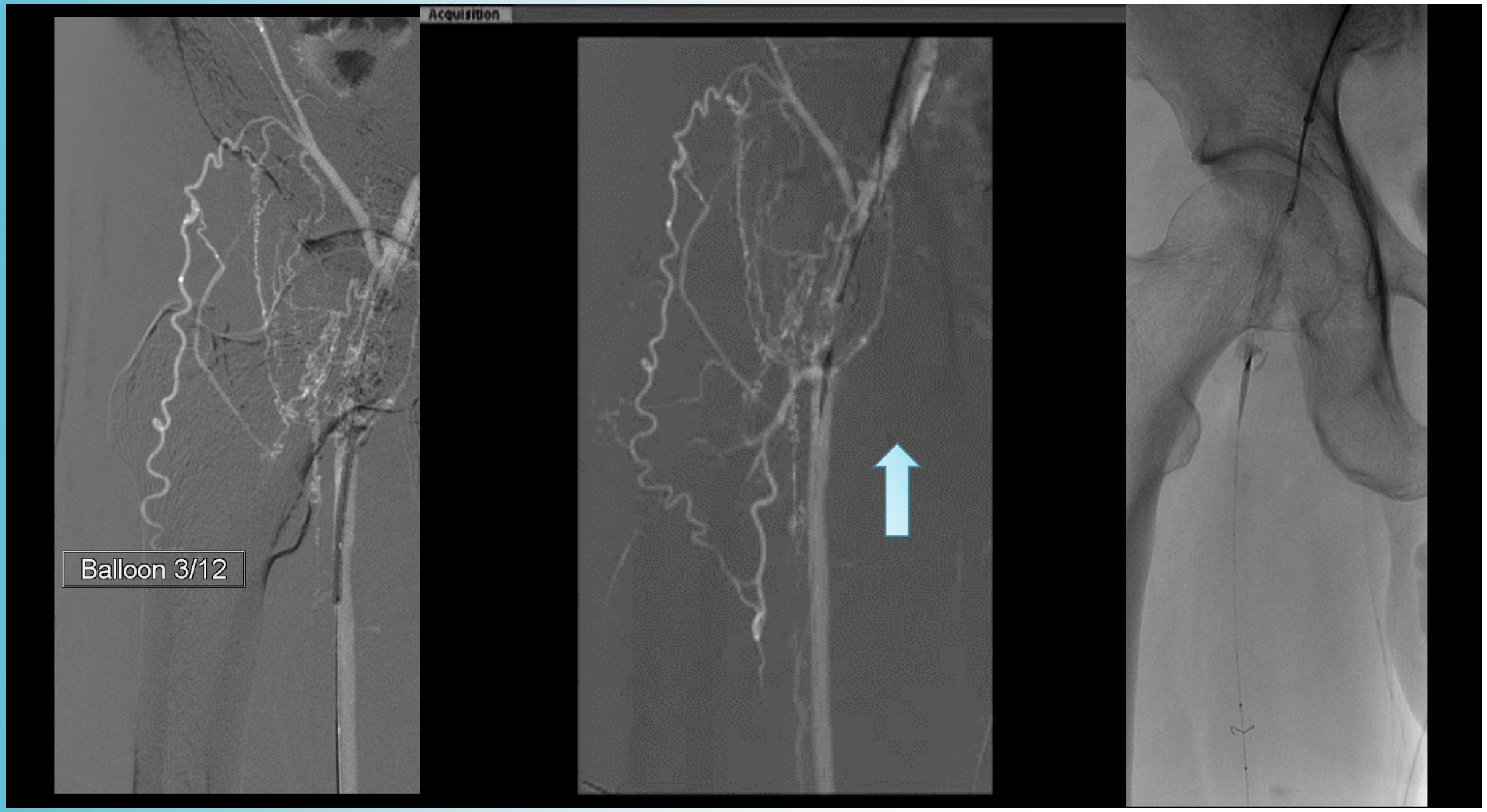
Problem

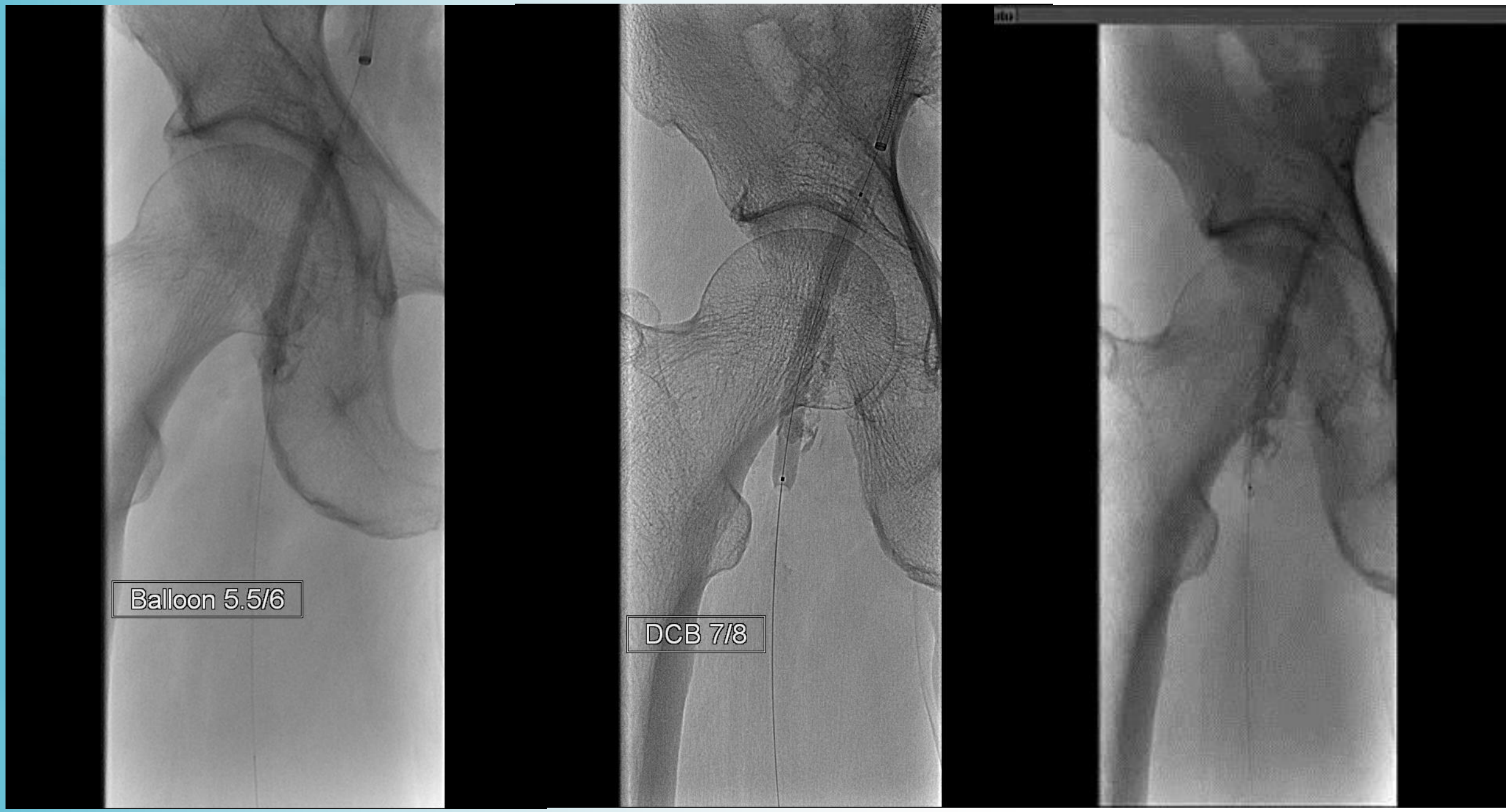
Claudication M/63 2023.01

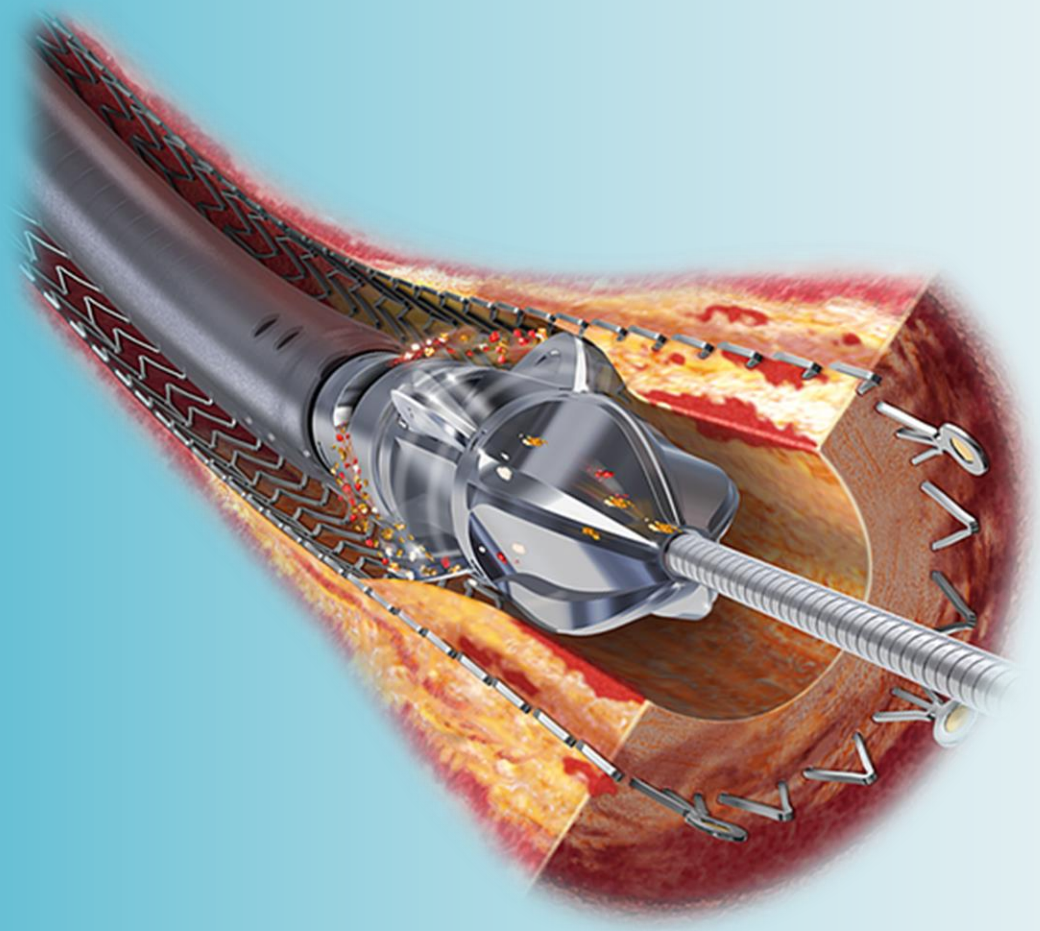
Procedure

- Procedure : L/E Angio & PTA
- Access / Side : Left retrograde
- Target artery : Right SFA
- Lesion : <10 Segmental complete occlusion
- Treatment :
  Pre Ballooning with 3mm
  Directional atherectomy with Hawkone under Emboshield filter.
  Post Ballooning with 5.5mm and DCB 7mm/8cm.




Acquisition
Balloon 3/12


Balloon 5.5/6
DCB 7/8

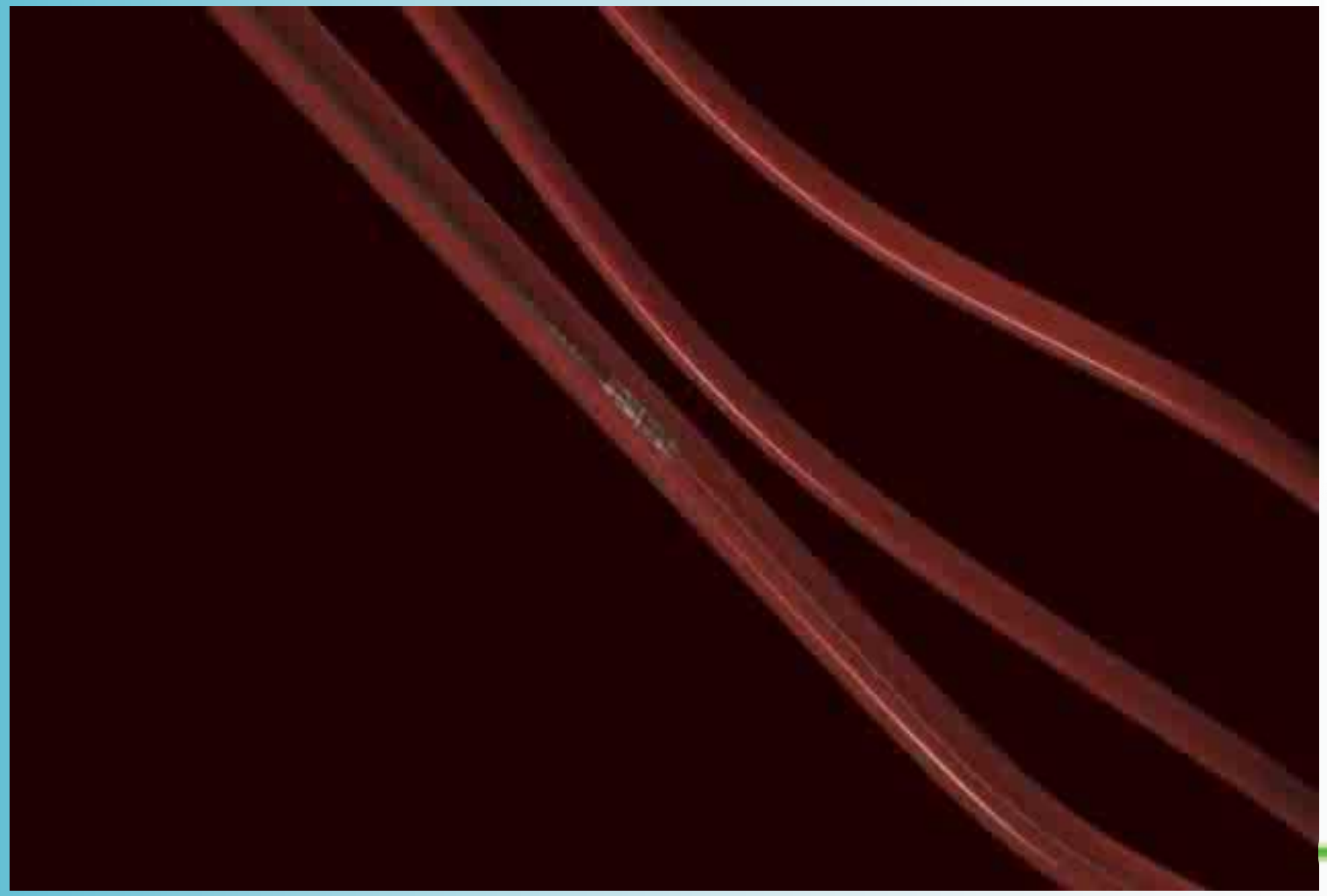


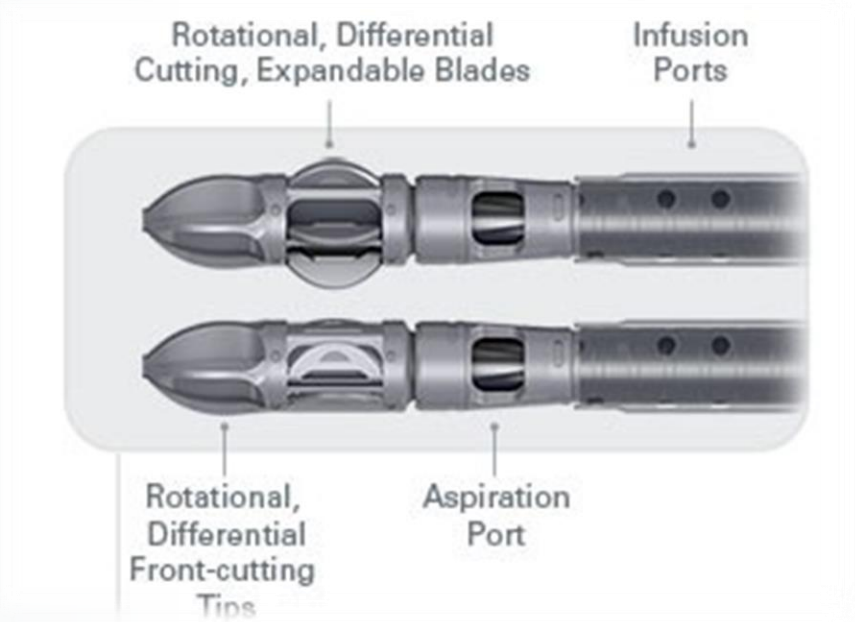
Jetstream

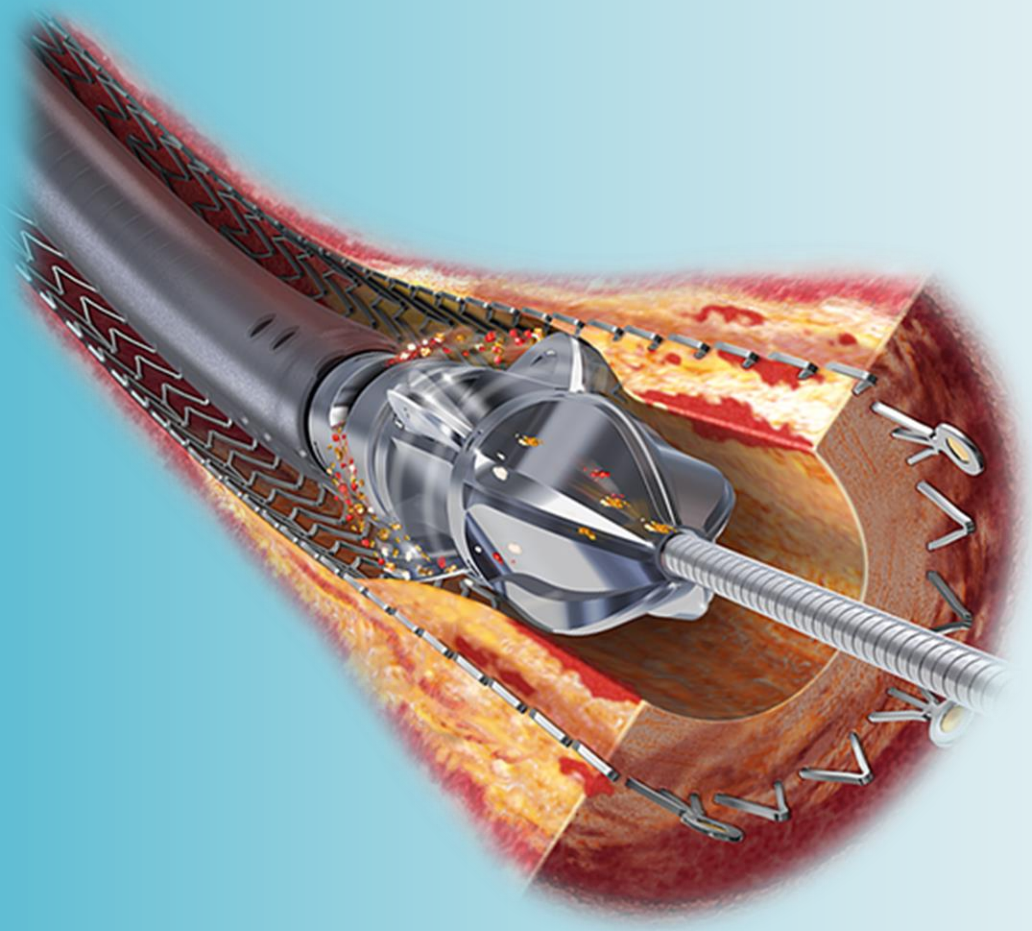
Boston Scientific

Multi Function

ISR




Rotational, Differential
Cutting, Expandable Blades
Infusion
Ports
Rotational,
Differential
Front-cutting
Tips
Aspiration
Port



Recent trend treatment case

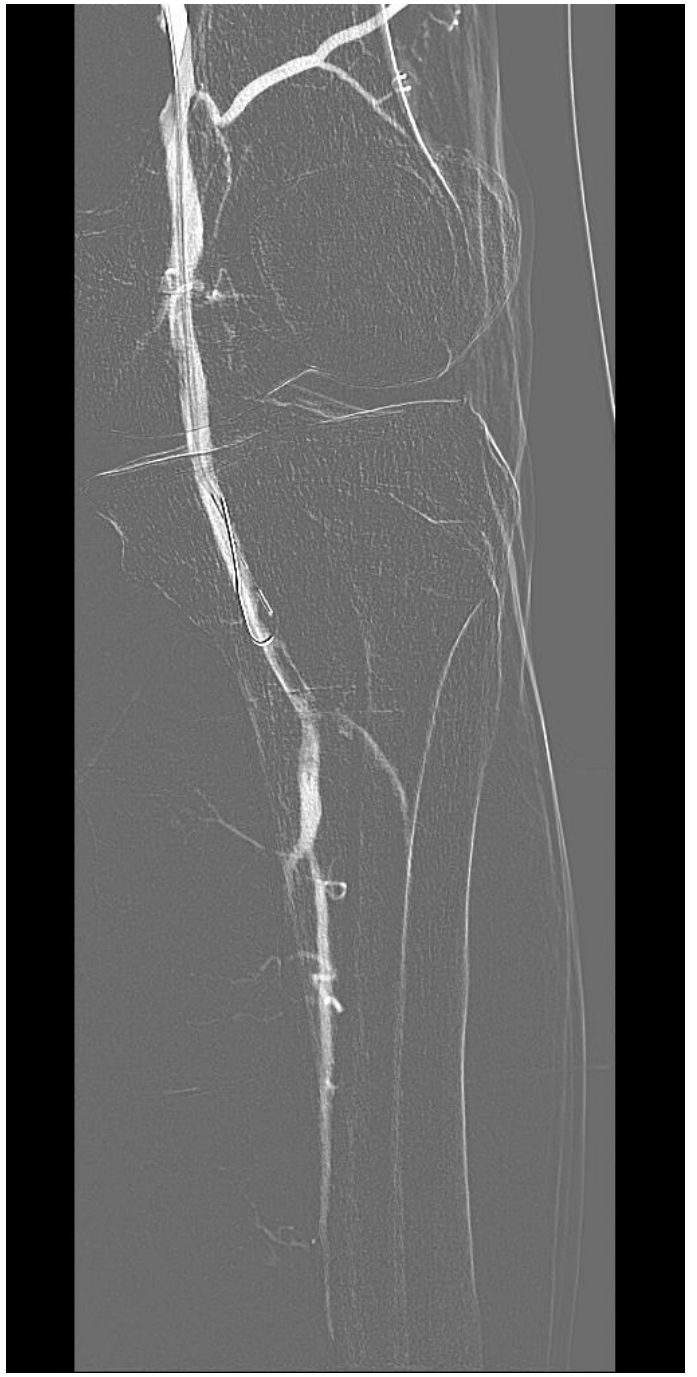
Recent trend treatment case

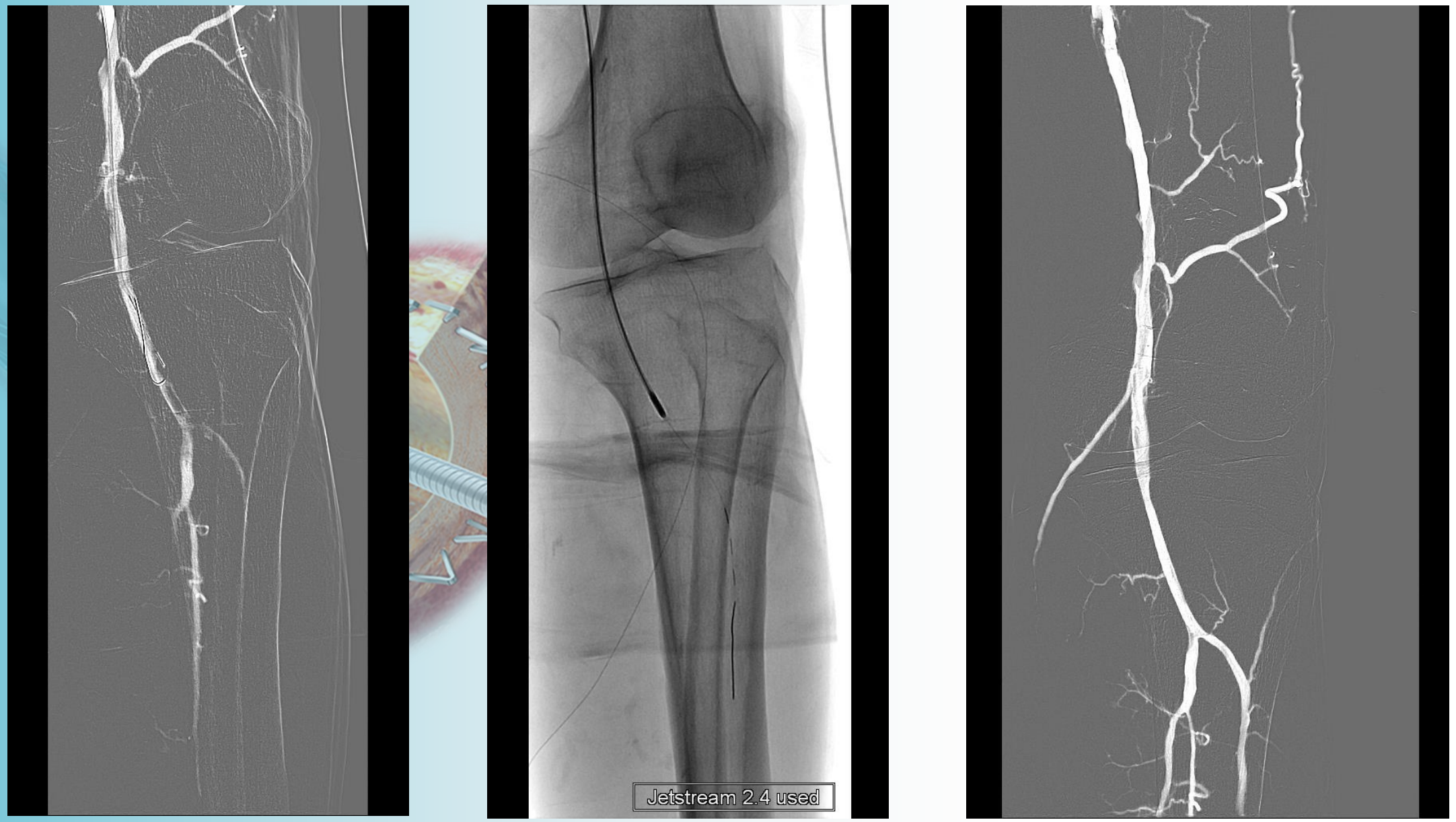
Problem

Acute limb ischemia. M/64 2022.12

Procedure

- Procedure : L/E Angio & PTA
- Access / Side : contralateral
- Target artery : Left PoA
- Lesion : Chronic total complete occlusion (>10 cm)
- Primary treatment
  distal SFA-popliteal artery: thrombosis with total occlusion Jetstream atherectomy




Jetstream 2.4 used

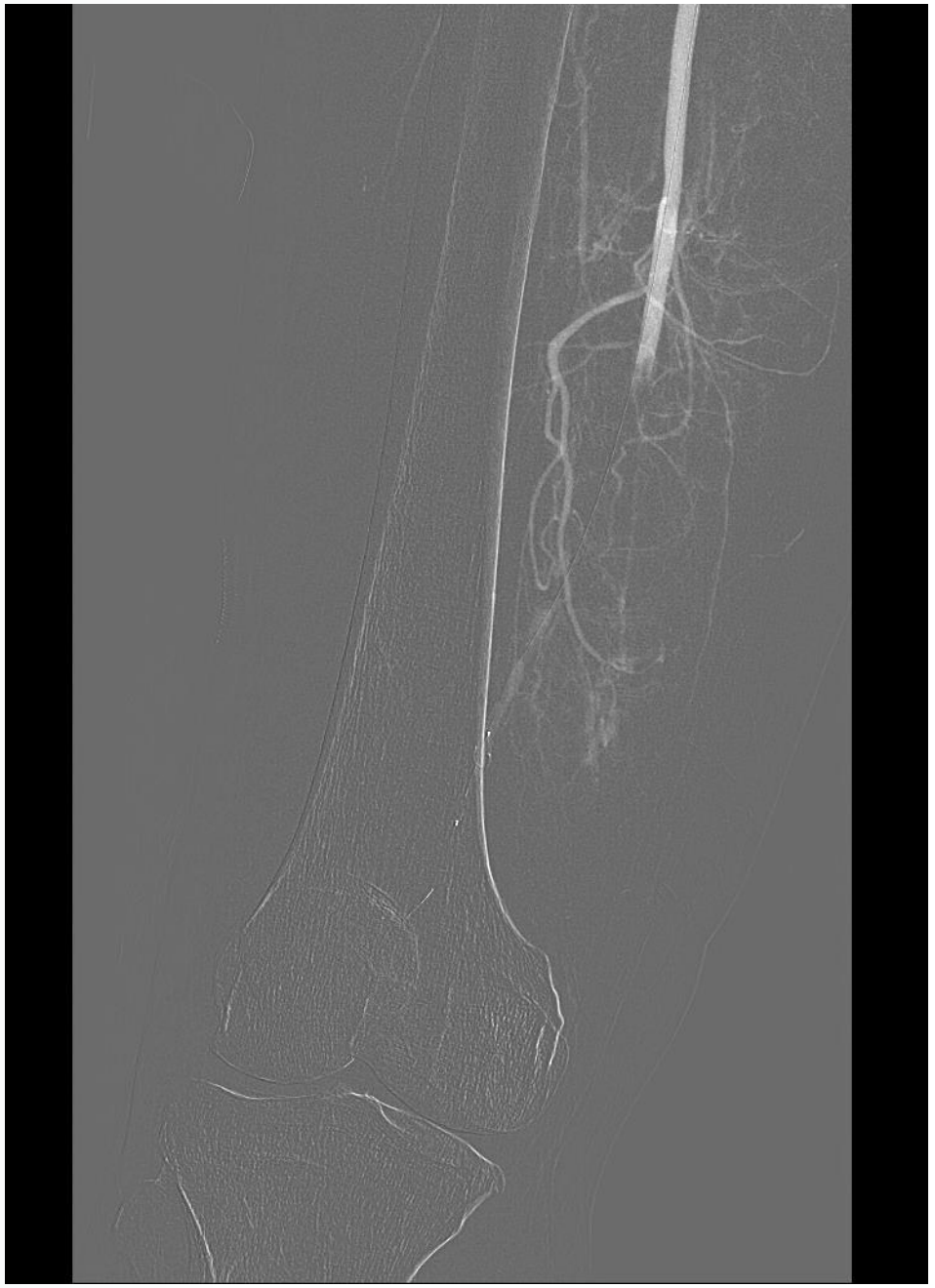
Recent trend treatment case

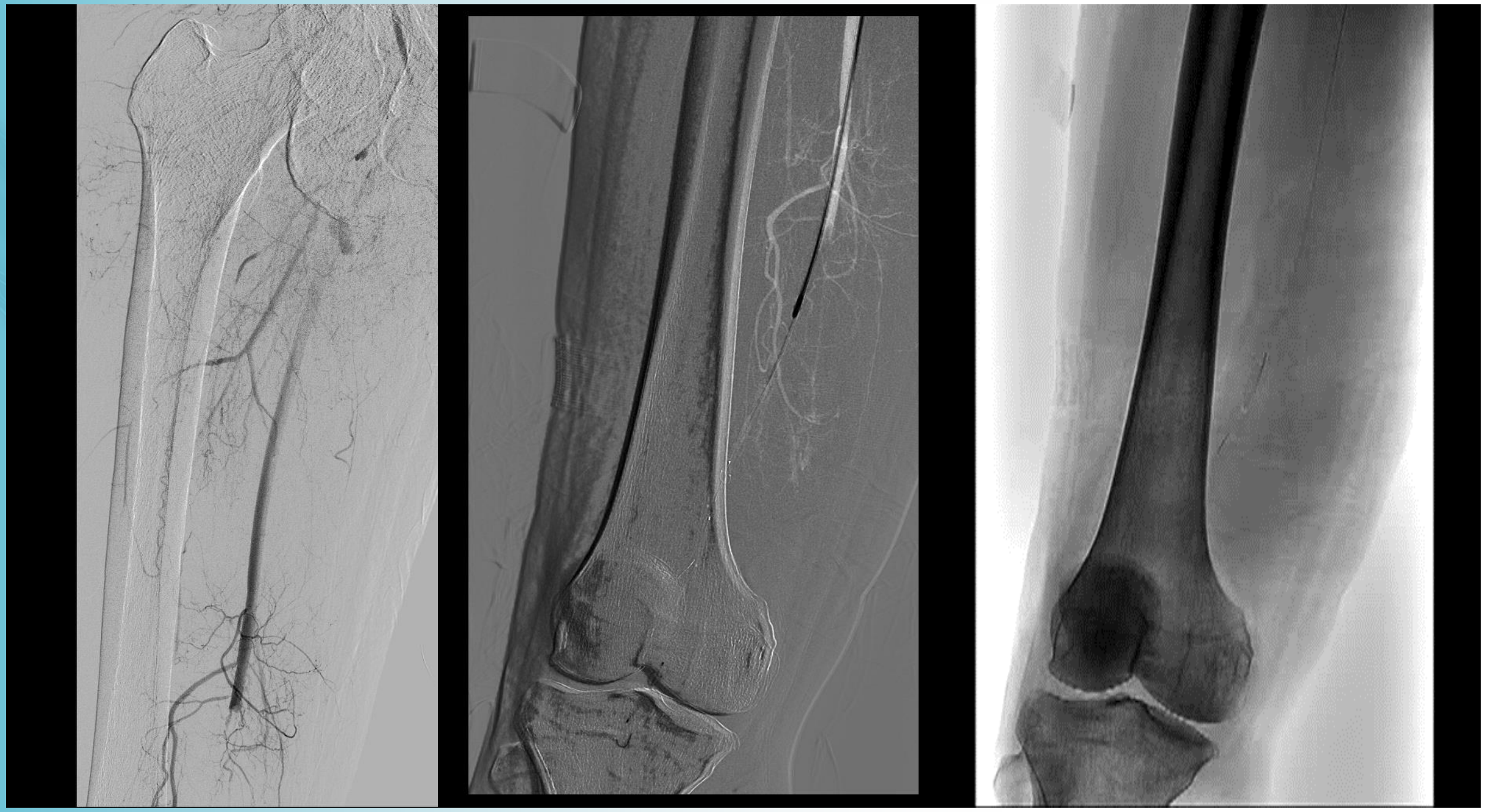
Problem

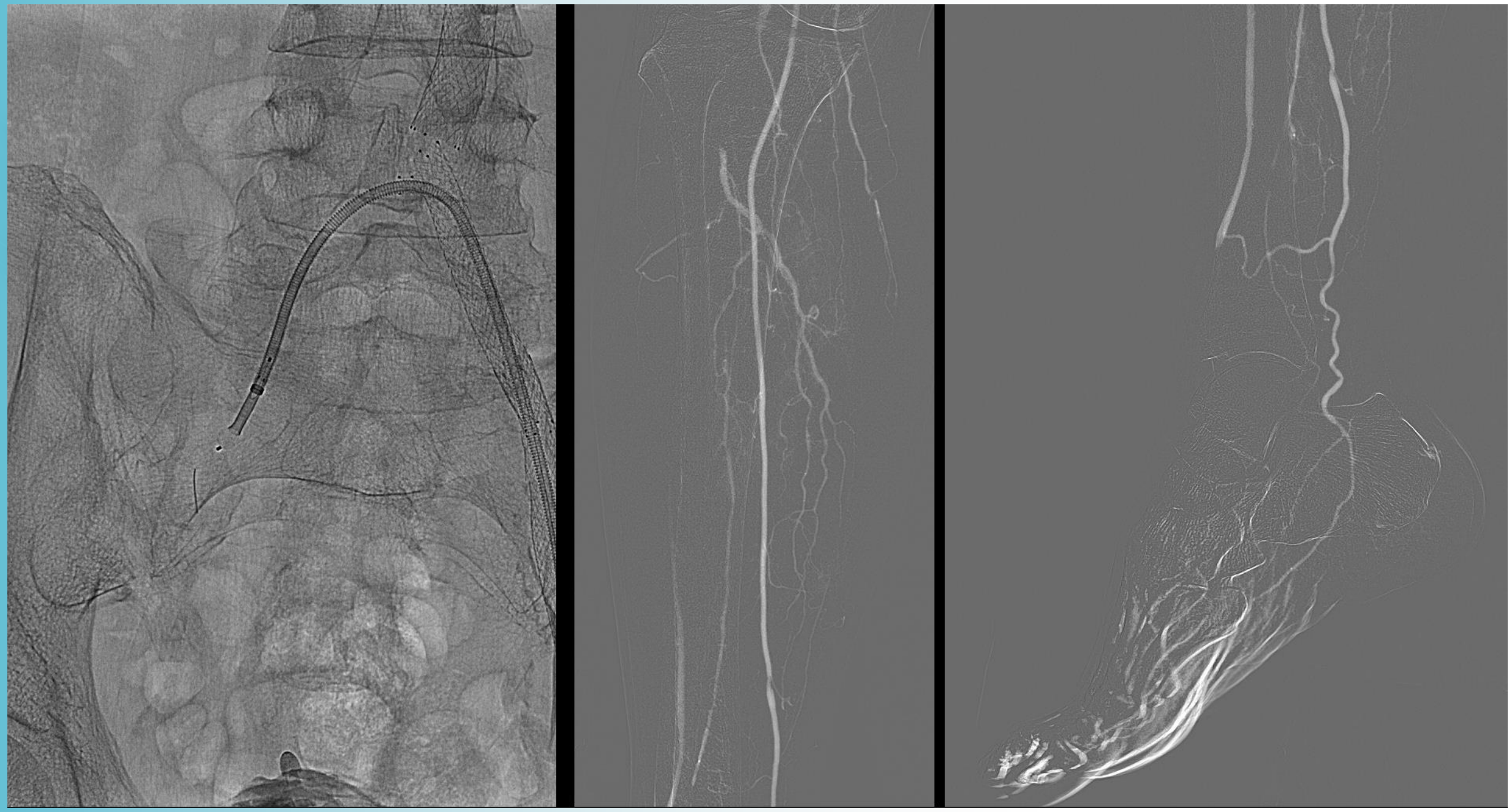
Claudication. M/61 2022.10

Procedure

- Procedure : L/E Angio & PTA
- Access / Side : Bilateral retrograde
- Target artery : Right SFA
- Lesion : Segmental complete occlusion (<10 cm)
- Primary treatment;
  -Rotational atherectomy using JetStream device.
  -Distal embolus was caught in embolic protection device pre-positioned in PoA. Embolus was removed.





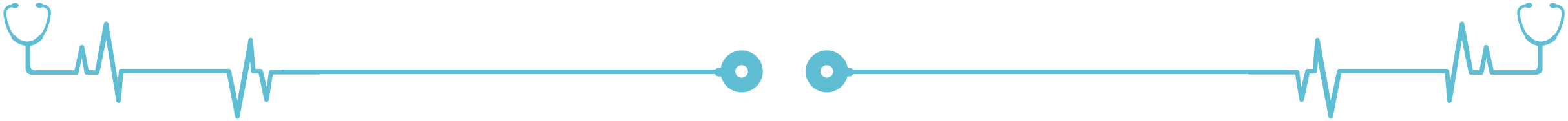


Restenosis Prevention Measures

1. **Determine whether the vessel lumen will fit a drug-coated balloon or a drug-eluting stent.**

2. After inserting a drug-coated balloon into the sheath of the femoral artery, the balloon catheter is quickly delivered to the lesion site along the guide wire so that the drug is not lost to the bloodstream.

(About 10% of the drug is lost before reaching the treatment site, and less than 20% of the drug is effectively delivered to the treatment site in the blood vessel)



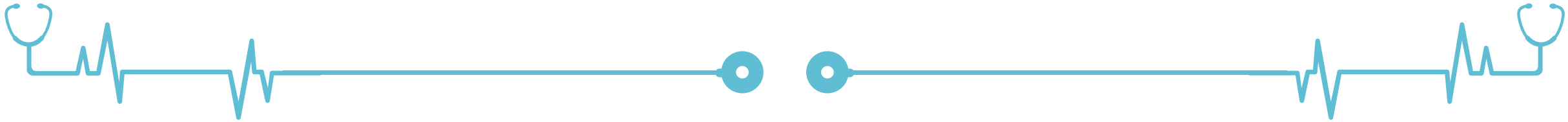
Restenosis Prevention Measures

1. Depending on the product, in order for the drug to be well absorbed into the treatment area, expand the balloon for at least 60 to 180 seconds.

(most of the drug is absorbed into the inner wall of the blood vessel during the first 60 seconds)

2. When using multiple drug-coated balloons in long lesions, care must be taken to avoid geographic misses.

3. In order to avoid geographic miss, the drug treatment sections overlap each other by 10 mm (Overlap).

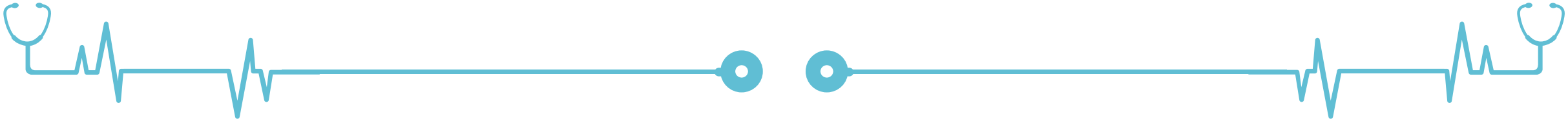


Restenosis Prevention Measures

1. When a stent is inserted after using a drug-coated balloon, the stent must be placed within the drug-treated area.

2. Drug-eluting stents can be used as an alternative treatment to drug-coated balloons in anti-restenosis treatment.

3. Compared to drug-coated balloons, drug-eluting stents have the advantage of being able to perform a scaffolding function that physically maintains the space in the lumen of blood vessels.
   (especially useful when elastic recoil or blood vessel dissection occurs)



conclusion

- In the past, interventional procedures such as balloon angioplasty, atherectomy, and stent insertion were performed as a single procedure.
- Recent trends are thought to focus on reducing vascular long patency and mortality by using together with drugs that prevent the growth of neointimal hyperplasia, such as DCB, DES or DCS, after atherectomy.
- There have been technological advances in alternative procedures to rule out lower extremity amputations.
- If I have a chance next time, I will introduce alternative techniques.