

## Description

### FIELD OF THE INVENTION

This invention relates generally to balloon aspiration catheters and drug coated balloon catheters. More specifically, the invention relates to the use of a balloon aspiration catheter to remove free floating non-therapeutic drug particles released from drug coated balloon catheters during treatment in order to mitigate any negative effect these drug particles poses.

### BACKGROUND OF THE INVENTION

A meta-analysis published on 6 Dec 2018 in the Journal of the American Heart Association concluded that "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." [1]

Although the exact mechanism for the increased mortality rate is not yet known, it is known that paclitaxel for chemotherapy is solvent-based and has a half-life of about six hours, the paclitaxel on medical devices has a half-life of weeks to months. Also, studies have shown that for drug coated balloons, only a small portion of drug is transferred to the vessel walls, while the majority will be released into the bloodstream. The drug transferred to the vessel walls adheres to the vessel walls and aids in preventing restenosis, thus in this article they will henceforth be referred to as therapeutic drug. The drug released into the bloodstream floats around freely as particles and does not aid in preventing restenosis, thus in this article they will be henceforth be referred to as free floating non-therapeutic drug particles.

After studying drug coated balloon catheters in an artificial vascular model, three occasions where the majority of free floating non-therapeutic drug particles are released into the blood stream were identified. The three occasions are during the process of a) tracking the drug coated balloon to a target site; b) inflating and deflating the drug coated balloon to treat a target lesion; c) retrieving the drug coated balloon through the introducer.

a) In the patent "Drug delivery balloon catheter - WO2019009809A1" it was mentioned that during the tracking process, the drug coating on the balloon will be dislodged from the balloon if the drug coated balloon is tracked to the lesion without any form of protection. This dislodgement is caused by the physical contact between the drug coating with the vessel walls and blood. The method described to overcome this issue was to use a protective sheath to protect the drug coating before the drug can reach the target site. Doing so will not only reduce the amount of free floating non-therapeutic drug particles released but also

1. Katsanos, K., Spiliopoulos, S., Kitrou, P., Krokidis, M., & Karnabatidis, D. (2018). 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. *Journal of the American Heart Association*, 7(24). e011245.

increase the amount of drug available on the balloon to transfer to the target lesion, thus, improving the efficacy of the treatment.

- b) When inflating and deflating the drug coated balloon for treatment, the drug coating on the balloon is subjected to a myriad of forces in an attempt to dislodge the drug from the balloon to transfer as much of the drug as possible to the vessel walls. However, in most cases, only a small portion of the dislodged drug will be transferred to the vessel walls as therapeutic drug while the majority of will end up as free floating non-therapeutic drug particles.
- c) To retrieve the drug coated balloon catheter from the patient, the deflated balloon will have to pass through the device used to provide access to the vessel, i.e. an introducer. After inflation and deflation has been performed in the balloon, the deflated balloon will generally have a larger profile. The larger profile is generally larger than the distal opening of the introducer. Therefore, when the deflated balloon is pulled through the introducer, the balloon will scrape against the distal opening of the introducer, leading to the majority of the drug remaining on the balloon to be dislodged as free floating non-therapeutic drug particles.

By removing free floating non-therapeutic drug particles from the body, the total amount of drug introduced into the patient will be significantly reduced, since only the therapeutic drug remains. It is believed that in doing so, the risks such as embolization, mortality, or any other risks associated with free floating non-therapeutic drug particles released from the drug coated balloon during the angioplasty procedure will be reduced.

Aspiration is a common method used to remove particles from the within vessels. Such methods that use an aspiration catheter are described in "Methods for Reducing Distal Embolization", Imran, U.S. Patent Publication 20030055398 published Mar. 20, 2003. The removal of particles through aspiration can be improved by first occluding flow within the vessel to prevent the particles generated from being immediately carried away by flowing blood. A specific example of how an occlusion can be used to improve the efficacy of aspiration to capture particles is described by Rauker and others in "Occlusion Device", U.S. Pat. No. 6,475,185 issued Nov. 5, 2002. The occlusion device includes an elongated tubular shaft having an inflatable balloon disposed near the elongate shaft distal end with a proximal seal of a sufficiently small profile to allow a second catheter to pass over the distal occlusion device while the inflatable balloon remains uninflated. One occlusion device includes an elongated fluid displacement rod within the elongated shaft of the occlusion device, providing both a fluid pressure source and a seal.

Although various systems and methods to remove particles have been described, they mainly focus on the removal of particles generated from the vessel itself in an attempt to prevent distal embolization. Examples include the removal of particles generated from a stenosed lesion during angioplasty using a plain old balloon catheter, stenting or atherectomy. Both the physical properties as well as the source of the aforementioned particles are vastly different from that of free floating non-therapeutic drug particles released from drug coated balloon catheters. Therefore, there is a need for systems and methods tailored to remove free floating non-therapeutic drug particles released from drug coated balloon catheters to reduce the risk posed

by free floating non-therapeutic drug particles such as increased mortality, while at least retaining the efficacy of the drug coated balloon catheter treatment.

## SUMMARY OF THE INVENTION

The present invention provides a balloon aspiration catheter and the associated systems and methods to remove free floating non-therapeutic drug particles released from a drug coated balloon catheter

A preferred variation of the inventive balloon aspiration catheter is made up of an inner elongate tubular member having an inner surface, a proximal end, and a distal end. The interior surface of the inner elongate member forms the large lumen in which a drug coated balloon catheter can be tracked through and where aspiration is performed. In this preferred variation, a balloon, preferably but not necessarily compliant, is located at the distal end and is connected to at least one fluid supply lumen that is independent of the large lumen. An outer elongate tubular member that is substantially concentric with the inner elongate tubular member forms an annular lumen between the two for supplying fluid to the balloon. The inner elongate tubular member generally contains a stiffener member situated in its wall to provide kink resistance to the balloon aspiration catheter. The stiffener member may be a coil or a braid. Ancillary features, e.g., radio-opaque marker bands distal of said inflatable member and fluid fittings, are included.

Although the inventive balloon aspiration catheter may be independent from the drug coated balloon catheter, they may be incorporated into one or more devices or kits.

For instance, a device or kit might contain, e.g., a balloon aspiration catheter described above; and a drug coated balloon.

Another desirable device or kit includes a balloon aspiration catheter described above; a protective sheath i.e. a guiding catheter; and a drug coated balloon catheter;

Another desirable device or kit includes a balloon aspiration catheter described above; and a device in which the drug coated balloon catheter is protected by a sheath;

The balloon aspiration catheter is used to remove free floating non-therapeutic drug particles released from drug coated balloon catheters from a vascular lumen, e.g., in sites as varied as the periphery, or the coronary vessels, by the steps of first tracking the balloon aspiration catheter through the vessel until distal end of the balloon aspiration catheter is positioned proximal to a lesion. The inflation of the balloon on the balloon aspiration catheter is next carried out to occlude antegrade flow in the vessel. After occlusion, the drug coated balloon catheter is then tracked through the large lumen of the balloon aspiration catheter and until the drug coated

balloon is positioned at the target lesion. The tracking of the drug coated balloon through the large lumen of the balloon aspiration catheter to position it the target lesion can cause the release of drug from the drug coating but since antegrade flow has been occluded, the dislodged drug will not flow distally. Treatment of the lesion is then done according to the instructions provided by the drug coated balloon catheter's supplier. The drug coated balloon catheter is then withdrawn from the balloon aspiration catheter and aspiration through the large lumen of the balloon aspiration catheter is conducted to remove the free floating non-therapeutic drug particles released from the drug coated balloon catheter. Finally, the balloon on the balloon aspiration catheter is deflated and the balloon aspiration catheter withdrawn. In this method, aspiration through the large lumen of the balloon aspiration catheter can also be conducted after deflation of the drug coated balloon catheter, prior to its removal. In this method, the drug coated balloon catheter can be a kit or a device which a drug coated balloon catheter is protected by a protective sheath similar but not limited to the one stated in "Drug delivery balloon catheter - WO2019009809A1". The use of said kit or device will allow the drug coating to be completely protected during tracking.

Another aspect of the method comprises first pre-loading the drug coated balloon catheter into the large lumen of the balloon aspiration catheter. The pre-loading step consists of inserting the distal end of the drug coated balloon catheter through the proximal end of the large lumen of the balloon aspiration catheter. The drug coated balloon catheter is then pushed through the large lumen of the balloon aspiration catheter until the distal end of the drug coated balloon catheter is close to the distal end of the balloon aspiration catheter. Said unit of the balloon aspiration catheter and drug coated balloon catheter is then tracked through the vessel and finally positioned such that the drug coated balloon is at a lesion to be treated. While maintaining the position of the drug coated balloon catheter, the balloon aspiration catheter is shifted proximally relative to the drug coated balloon to expose the drug coated balloon. By keeping the balloon aspiration catheter and drug coated balloon catheter as a unit until the drug coated balloon is positioned at the target lesion, the balloon aspiration catheter is able to act as a protective sheath. The inflation of the balloon on the balloon aspiration catheter is then carried out to occlude antegrade flow in the vessel. Treatment of the lesion is then done according to the instructions provided by the drug coated balloon catheter's supplier. The drug coated balloon catheter is then withdrawn from the balloon aspiration catheter. Aspiration through the large lumen of the balloon aspiration catheter is then conducted to remove the free floating non-therapeutic drug particles released from the drug coated balloon catheter. Finally, the balloon on the balloon aspiration catheter is deflated and the balloon aspiration catheter withdrawn. In this method, aspiration through the large lumen of the balloon aspiration catheter can be conducted after deflation of the drug coated balloon catheter, prior to its removal.

Another aspect of the method comprises first pre-loading the drug coated balloon catheter into the large lumen of the balloon aspiration catheter. The pre-loading step consists of inserting the distal end of the drug coated balloon catheter through the proximal end of the large lumen of the balloon aspiration catheter, the drug coated balloon catheter is then pushed through the large lumen of the balloon aspiration catheter until the distal end of the drug coated balloon catheter is close to the distal end of the balloon aspiration catheter. Said unit of the balloon aspiration catheter and drug coated balloon is then tracked through the vessel and finally positioned such that the distal end of the balloon aspiration catheter is proximal to the lesion. By keeping the

balloon aspiration catheter and drug coated balloon catheter as a unit for the majority of the tracking process, the balloon aspiration catheter is able to act as a protective sheath during the majority of the tracking process. The inflation of the balloon on the balloon aspiration catheter is then carried out to occlude antegrade flow in the vessel before the drug coated balloon catheter is shifted distally relative to the balloon aspiration catheter to expose the drug coated balloon and until the drug coated balloon is positioned at the target lesion. The tracking of the drug coated balloon outside the balloon aspiration catheter to position it the target lesion can cause the dislodgement of drug from the drug coating but since antegrade flow has been occluded, the dislodged drug will not flow distally. Treatment of the lesion is then done according to the instructions provided by the drug coated balloon catheter's supplier. The drug coated balloon catheter is then withdrawn from the balloon aspiration catheter. Aspiration through the large lumen of the balloon aspiration catheter is then conducted to remove the free floating non-therapeutic drug particles released from the drug coated balloon catheter. Finally, the balloon on the balloon aspiration catheter is deflated and the balloon aspiration catheter withdrawn. In this method, aspiration through the large lumen of the balloon aspiration catheter can be conducted after deflation of the drug coated balloon catheter, prior to its removal. In this method, the drug coated balloon catheter can be a kit or a device which a drug coated balloon catheter is protected by a protective sheath similar but not limited to the one stated in "Drug delivery balloon catheter - WO2019009809A1". The use of said kit or device will allow the drug coating to be completely protected during tracking.

Another aspect of the method comprises first pre-assembling a drug coated balloon catheter, a protective sheath, and a balloon aspiration catheter into one unit. The pre-assembly consists of first inserting the distal end of the drug coated balloon catheter through the proximal end of the protective sheath until the distal end of the drug coated balloon catheter is close to the distal end of the protective sheath. Next, said unit of drug coated balloon catheter and protective sheath is inserted through the proximal end of the large lumen of the balloon aspiration catheter via its distal end and pushed through the large lumen of the balloon aspiration catheter until the proximal end of the drug coated balloon is distal to the distal end of the balloon aspiration catheter. Said unit of the balloon aspiration catheter, protective sheath and drug coated balloon is then tracked through the vessel and finally positioned such that the drug coated balloon catheter is at a lesion to be treated before the inflation of the balloon on the balloon aspiration catheter is carried out to occlude antegrade flow in the vessel. While maintaining the position of the drug coated balloon catheter, the protective sheath is pulled back to exposed the drug coated balloon. Treatment of the lesion is then done according to the instructions provided by the drug coated balloon catheter's supplier and the drug coated balloon catheter and protective sheath is withdrawn from the balloon aspiration catheter as a unit. Aspiration through the large lumen of the balloon aspiration catheter is then conducted to remove the free floating non-therapeutic drug particles released from the drug coated balloon catheter. Finally, the balloon on the balloon aspiration catheter is deflated and the balloon aspiration catheter withdrawn. In this method, aspiration through the large lumen of the balloon aspiration catheter can also be conducted after deflation of the drug coated balloon catheter, prior to its removal. In this method, the drug coated balloon catheter and protective sheath can be a kit or a device. In this method, the drug coated balloon, protective sheath, and balloon aspiration catheter can be incorporated into a single device.

The present invention is illustrated by the accompanying drawings of various embodiments and the detailed description given below. The drawings should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding. The detailed description and drawings are merely illustrative of the invention rather than limiting, the scope of the invention being defined by the appended claims and equivalents thereof. The foregoing aspects and other attendant advantages of the present invention will become more readily appreciated by the detailed description taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the present invention are illustrated by the accompanying figures, wherein:

FIG. 1 is a longitudinal cross-sectional view of a balloon aspiration catheter having a central lumen and an occlusion balloon;

FIG. 2 shows one method for using a balloon aspiration catheter to remove free floating non-therapeutic drug particles released from a drug coated balloon catheter

## DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is depicted an embodiment of the balloon aspiration catheter of the present invention. Although depicted and described as a two lumen catheter, it should be appreciated that the present invention may also be adapted to catheters having more than two lumen. The manner of adapting the present invention to these various treatments and structures will become readily apparent to those of skill in the art in view of the description which follows.

FIG. 1 shows a balloon aspiration catheter **100** for removal of free floating non-therapeutic drug particles **212**.

The balloon aspiration catheter **100** generally comprises a balloon **111** with a distal and proximal end, a hub **121**, an outer elongate tubular member **131** with a distal and proximal end, and an inner elongate tubular member **132** with a distal end proximal end. The balloon **111** is positioned at the distal end of the catheter **100**. The hub **121** is positioned at the proximal end of the catheter **100**. The distal end of the outer tubular member **131** is coupled to the proximal end of the balloon **111**, while the proximal end of the outer tubular member **131** is coupled to the hub **121**. The inner tubular member **132** is substantially concentric with the outer tubular member **131**. The distal end of the inner tubular member **132** is coupled to the distal end of the balloon **111**, while the proximal end of the inner tubular member **132** is coupled to the hub **121**.

The inner surface of the inner tubular member forms the large lumen 141. The large lumen 141 is accessed from the working port 122 of the hub 121. The large lumen 141 is used to track a drug coated balloon catheter 211 as well as for aspiration of the free floating non-therapeutic drug particles 212. An inflation lumen 142 is formed between the inner surface of the outer elongate tubular member 131 and the outer surface of the inner elongate tubular member 132. The inflation lumen 142 is independent of the large lumen 141 and is accessed from the inflation port 123 of the hub 121 and is in fluid communication with the balloon 111. The inflation lumen 142 is used to control the inflation and deflation of the balloon 111.

Referring to FIG. 2, there is depicted a method to use the balloon aspiration catheter of the present invention to remove free floating non-therapeutic drug particles released from drug coated balloon catheters. The specific method in FIG. 2 is not intended to limit the invention in any way. Additionally, to the extent that there are variations of the invention that are within the spirit of the disclosure and yet are equivalent to the inventions found in the claims, it is our intent that this patent cover those variations as well.

FIG. 2 shows a four-step method for utilizing the balloon aspiration catheter 100 in a vessel for removal of free floating non-therapeutic drug particles 212 released from a drug coated balloon catheter 211.

In Step (I), the balloon aspiration catheter 100 is placed in the stenosed vessel 201. The balloon 111 is then inflated close to a target lesion 202. Inflation of balloon 111 prevents blood from carrying the free floating non-therapeutic drug particles close to a target lesion 202 distally which will prevent their removal. In Step (II), the drug coated balloon catheter 211 is advanced through the large lumen 141 to the reach target lesion 202 and treatment of the target lesion 202 in the stenosed vessel 201 is conducted using the drug coated balloon catheter 211. After treatment, the drug coated balloon catheter 211 is withdrawn from the treated vessel 203, leaving behind the free floating non-therapeutic drug particles 212 released from the drug coated balloon catheter 211. In Step (III), aspiration is carried out through the large lumen 141 to remove the free floating non-therapeutic drug particles 212 from the treated vessel 203. In step (IV), the balloon 111 is deflated and the balloon aspiration catheter is withdrawn from the treated vessel 203.