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System and Methods for Treating a Bifurcation

Abstract

A system for treating a bifurcation includes first and second delivery catheters, each having an expandable member and a stent. The stent on the second delivery catheter has a side hole. A portion of the first delivery catheter is disposed under a portion of the stent on second delivery catheter. The first delivery catheter is slidable relative to the second delivery catheter, and the first delivery catheter passes through the side hole.

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Background/Summary

[0001] The present application is a continuation of U.S. patent application Ser. No. 18/516,326, filed Nov. 21, 2023, which is a continuation of U.S. patent application Ser. No. 17/143,015 (Docket No. 5133.002US4) filed on Jan. 6, 2021, now issued as U.S. Pat. No. 11,857,442, which is a continuation of U.S. patent application Ser. No. 16/251,691 (Docket No. 5133.002US3) filed on Jan. 18, 2019, now U.S. Pat. No. 10,918,506, which is a continuation of U.S. patent application Ser. No. 14/621,231 (Docket No. 5133.002US2) filed on Feb. 12, 2015, now U.S. Pat. No. 10,219,927, which is a continuation of U.S. patent application Ser. No. 13/071,251 (Docket No. 5133.002US1) filed on Mar. 24, 2011, now U.S. Pat. No. 8,979,917, which is a non-provisional of, and claims the benefit of U.S. Prov. Pat. App. No. 61/317,105 (Docket No. 5133.002PRV) filed on Mar. 24, 2010, now expired; U.S. patent application Ser. No. 13/071,251 (Docket No. 5133.002US1) filed on Mar. 24, 2011, now U.S. Pat. No. 8,979,917 is also a continuation in part of International PCT Pat. App. No. PCT/US2009/058505 (Docket No. 5133.001WO1) filed on Sep. 25, 2009, which is a non-provisional of, and claims the benefit of U.S. Prov. Pat. App. No. 61/194,346 (Docket 5133.001PRV) filed on Sep. 25, 2008, now expired; the entire contents of each of the above applications is incorporated herein by reference in their entirety. [0002] The present application is related to U.S. Ser. No. 13/071,149 (now U.S. Pat. No. 8,821,562); Ser. No. 13/071,239 (now U.S. Pat. No. 8,769,796); U.S. Ser. No. 13/071,198 (now U.S. Pat. No. 8,795,347); U.S. Ser. No. 13/071,183 (now U.S. Pat. No. 8,808,347); and U.S. Ser. No. 13/071,162 (now U.S. Pat. No. 8,828,071), all of which were filed Mar. 24, 2011, and are incorporated herein by reference in their entirety for all purposes. The present application is also related to U.S. Provisional Appln. Nos. 61/317,198; 61/317,114; 61/317,121; and 61/317,130, all of which were filed on Mar. 24, 2010, and are incorporated herein by reference in their entirety for all purposes.

BACKGROUND OF THE INVENTION

[0003] The present invention relates to medical devices, and more particularly to stenting and treatment of bifurcated vessels. A stent is an implantable scaffold that is typically delivered percutaneously and deployed in a vein, artery, or other tubular body organ for treating an occlusion, stenosis, aneurysm, collapse, dissection, or weakened, diseased, or abnormally dilated vessel or vessel wall. The stent is radially expanded in situ, thereby expanding and/or supporting the vessel wall or body organ wall. In particular, stents are quite commonly implanted in the coronary, cardiac, pulmonary, neurovascular, peripheral vascular, renal, gastrointestinal and reproductive systems, and have been successfully implanted in the urinary tract, the bile duct, the esophagus, the tracheo-bronchial tree and the brain, to reinforce these body organs.

[0004] Stents are often used for improving angioplasty results by preventing elastic recoil and remodeling of the vessel wall and for treating dissections in blood vessel walls caused by balloon angioplasty of coronary arteries, as well as peripheral arteries, by pressing together the intimal flaps in the lumen at the site of the dissection. Conventional stents have been used for treating more

complex vascular problems, such as lesions at or near bifurcation points in the vascular system, where a secondary artery branches out of a typically larger, main artery, with limited success rates. [0005] Conventional stent technology is relatively well developed. Conventional stent designs typically feature a straight tubular, single type cellular structure, configuration, or pattern that is repetitive through translation along the longitudinal axis. In many stent designs, the repeating structure, configuration, or pattern has strut and connecting balloon catheter portions that can impede blood flow at vessel bifurcations.

[0006] Furthermore, the configuration of struts and connecting balloon catheter portions may obstruct the use of post-operative devices to treat a daughter vessel in the region of a vessel bifurcation. For example, deployment of a first stent in the mother lumen may prevent a physician from inserting a daughter stent through the ostium of a daughter vessel of a vessel bifurcation in cases where treatment of the mother vessel is suboptimal because of displaced diseased tissue (for example, due to plaque shifting or “snow plowing”), occlusion, vessel spasm, dissection with or without intimal flaps, thrombosis, embolism, and/or other vascular diseases. A regular stent is designed in view of conflicting considerations of coverage versus access. For example, to promote coverage, the cell structure size of the stent may be minimized for optimally supporting a vessel wall, thereby preventing or reducing tissue prolapse. To promote access, the cell size may be maximized for providing accessibility of blood flow and of a potentially future implanted daughter stent to daughter vessels, thereby preventing “stent jailing,” and minimizing the amount of implanted material. Regular stent design has typically compromised one consideration for the other in an attempt to address both. Problems the present inventors observed involving daughter jailing, fear of plaque shifting, total occlusion, and difficulty of the procedure are continuing to drive the present inventors' into the development of novel, delivery systems, which are easier, safer, and more reliable to use for treating the above-indicated variety of vascular disorders. Although conventional stents are routinely used in clinical procedures, clinical data shows that these stents are not capable of completely preventing in-stent restenosis (ISR) or restenosis caused by intimal hyperplasia. In-stent restenosis is the reoccurrence of the narrowing or blockage of an artery in the area covered by the stent following stent implantation. Patients treated with coronary stents can suffer from in-stent restenosis.

[0007] Many pharmacological attempts have been made to reduce the amount of restenosis caused by intimal hyperplasia. Many of these attempts have dealt with the systemic delivery of drugs via oral or intravascular introduction. However, success with the systemic approach has been limited.

[0008] Systemic delivery of drugs is inherently limited since it is difficult to achieve constant drug delivery to the afflicted region and since systemically administered drugs often cycle through concentration peaks and valleys, resulting in time periods of toxicity and ineffectiveness.

Therefore, to be effective, anti-restenosis drugs should be delivered in a localized manner. One approach for localized drug delivery utilizes stents as delivery vehicles. For example, stents seeded with transfected endothelial cells expressing bacterial betagalactosidase or human tissue type plasminogen activator were utilized as therapeutic protein delivery vehicles. See, e.g., Dichek, D. A. et al., “Seeding of Intravascular Stents With Genetically Engineered Endothelial Cells,” *Circulation*, 80:1347-1353 (1989), U.S. Pat. No. 5,679,400, International Patent Publication No. WO 91/12779, entitled “Intraluminal Drug Eluting Prosthesis,” and International Patent Publication No. WO 90/13332, entitled “Stent With Sustained Drug Delivery” disclose stent devices capable of delivering antiplatelet agents, anticoagulant agents, antimigratory agents, antimetabolic agents, and other anti-restenosis drugs. U.S. Pat. Nos. 6,273,913; 6,383,215; 6,258,121; 6,231,600; 5,837,008; 5,824,048; 5,679,400; and 5,609,629 teach stents coated with various pharmaceutical agents such as Rapamycin, 17-beta-estradiol, Taxol and Dexamethasone. This and all other referenced patents are incorporated herein by reference in their entirety.

Furthermore, where a definition or use of a term in a reference, which is incorporated by reference herein is inconsistent or contrary to the definition of that term provided herein, the definition of that

term provided herein applies and the definition of that term in the reference does not apply.

[0009] Therefore, given the challenges of current stent technology, a need exists for improved stent delivery systems and methods, particularly for treating bifurcated vessels. At least some of these objectives will be met by the present invention.

BRIEF SUMMARY OF THE INVENTION

[0010] The present invention relates to methods and delivery systems used to deliver stents in a bifurcated vessel. Embodiments may be configured to stent at least a portion of a mother vessel and a portion of a daughter vessel.

[0011] In a first aspect of the present invention, a system for treating a bifurcation comprises a first delivery catheter comprising a first elongate shaft with a proximal end and a distal end, a first expandable member adjacent the distal end of the first elongate shaft, and a first radially expandable stent disposed over the first expandable member. The first stent comprises a sidewall having an aperture or side hole therethrough. The first stent also has a collapsed configuration and an expanded configuration. In the collapsed configuration the first stent is coupled with the first expandable member, and in the expanded configuration the first stent supports a vessel wall. The system also includes a second delivery catheter comprising a second elongate shaft with a proximal end and a distal end, a second expandable member adjacent the distal end of the second elongate shaft, and a second radially expandable stent disposed over the second expandable member. The second stent has a collapsed configuration and an expanded configuration. In the collapsed configuration the second stent is coupled with the second expandable member, and in the expanded configuration the second stent supports a vessel wall. A portion of the second delivery catheter is disposed under a portion of the first radially expandable stent. A portion of the second delivery catheter also passes through the side hole in the first radially expandable stent. The second delivery catheter is axially slidable relative to the first delivery catheter while the first radially expandable stent is in the collapsed configuration.

[0012] In preferred embodiments, at least one stent has a sidewall with a side hole or aperture extending therethrough, and a portion of a delivery catheter may pass through the side hole. However, this is not intended to be limiting, and in any of the embodiments disclosed herein, one of skill in the art will appreciate that the stent may have another exit point. Thus the delivery catheter may pass through the exit point, whether it is a side hole in a side wall of the stent, or disposed in another portion of the stent.

[0013] The first and second expandable members may be independently expandable of one another. Either expandable member may comprise a balloon. Each of the first and second delivery catheters may comprise an inflation lumen and a guidewire lumen. The first delivery catheter may comprise a distal guidewire opening in the distal end of the first elongate shaft, and a proximal guidewire opening. The proximal guidewire opening may be spaced closer to the distal guidewire opening than the proximal end of the first elongate shaft. The proximal guidewire opening may be closer to the proximal end of the first elongate shaft than the distal guidewire opening. The guidewire lumen in the first delivery catheter may be configured to slidably receive a guidewire. The guidewire lumen may extend from the distal guidewire opening to the proximal guidewire opening.

[0014] The second delivery catheter may comprise a distal guidewire opening in the distal end of the second elongate shaft, and a proximal guidewire opening. The proximal guidewire opening may be spaced closer to the distal guidewire opening than the proximal end of the second elongate shaft. The proximal guidewire opening may be closer to the proximal end of the second elongate shaft than the distal guidewire opening. The guidewire lumen in the second delivery catheter may be configured to slidably receive a guidewire, and the guidewire lumen may extend from the distal guidewire opening to the proximal guidewire opening.

[0015] The second expandable member may be axially spaced apart from the first expandable member such that the second expandable member is distal to the first expandable member. The distal expandable member may have a cross-sectional profile smaller than a cross-sectional profile

of the other expandable member.

[0016] The first elongate shaft or the second elongate shaft may comprise a region having a guidewire lumen, an inflation lumen, and an exchange lumen. The remaining elongate shaft may be slidably disposed in the exchange lumen. The expandable member on the remaining elongate shaft may be axially spaced apart from the first elongate shaft having the exchange lumen such that the expandable member on the remaining shaft is distal to the expandable member on the elongate shaft with the exchange lumen.

[0017] The system may further comprise a capture tube having a proximal end, a distal end, a longitudinal axis, and a central channel extending therebetween. The first elongate shaft and the second elongate shaft may be disposed in the central channel, and the capture tube may prevent the first elongate shaft from tangling with the second elongate shaft. The capture tube may comprise a perforated region extending along the longitudinal axis. The perforated region may extend at least partially between the proximal and distal ends of the capture tube so that the capture tube may be peeled away from the first elongate shaft and the second elongate shaft. The capture tube may also comprise a locking mechanism for releasably holding the first elongate shaft and the second elongate shaft.

[0018] One of the first elongate shaft or the second elongate shaft may comprise a snap fitting configured to receive and retain the remaining elongate shaft. The remaining elongate shaft may be slidably movable axially through the snap fitting. The expandable member on the remaining elongate shaft may be axially spaced apart from the elongate shaft having the snap fitting such that the expandable member on the remaining elongate shaft is distal to the expandable member on the elongate shaft with the snap fitting. The system may comprise a polymer sleeve having a proximal end, a distal end, a longitudinal axis, and a central channel extending therebetween. The first elongate shaft and the second elongate shaft may be slidably disposed in the central channel. The polymer sleeve may prevent the first elongate shaft from tangling with the second elongate shaft.

[0019] The first expandable member has a working length, and the length of the first radially expandable stent may be less than or equal to the working length of the first expandable member. The length of the first radially expandable stent may be less than or equal to about half the working length of the first expandable member. The length of the first radially expandable stent may be substantially the same as the working length of the first expandable member. The first radially expandable stent may be non-uniformly crimped to the first expandable member. The first stent or the second stent may be balloon expandable.

[0020] The second radially expandable stent may be uniformly crimped to the second expandable member. The second stent may be balloon expandable. The second expandable member may have a working length, and the length of the second radially expandable stent may be less than or equal to the working length of the second expandable member.

[0021] The system may further comprise a therapeutic agent disposed on the first or the second radially expandable stent or on one or more of the expandable members. The therapeutic agent may be adapted to being eluted from the first or second stent, or from one or both of the expandable members. The therapeutic agent may comprise an anti-restenosis agent.

[0022] The first delivery catheter may comprise a first guidewire lumen that may extend at least partially between the proximal and distal ends thereof. The system may further comprise a first guidewire that is slidably positioned in the first guidewire lumen. The second delivery catheter may comprise a second guidewire lumen that may extend at least partially between the proximal and distal ends thereof. The system may further comprise a second guidewire that is slidably positioned in the second guidewire lumen.

[0023] The first elongate shaft may comprise a radiopaque marker disposed thereon, and the second elongate shaft may comprise a radiopaque marker disposed thereon. When the first radiopaque marker is aligned with the second radiopaque marker a working portion of the first expandable member may be aligned with a working portion of the second expandable member.

Also, a proximal end of the second stent may be aligned with the aperture in the sidewall of the first stent, and a proximal portion of the second expandable member may be disposed under a proximal portion of the first stent.

[0024] Expansion of the second expandable member may simultaneously expand a portion of the first stent and a portion of the second stent. Either the first expandable member or the second expandable member may be differentially expandable such that a proximal portion has a larger diameter than a distal portion of the expandable member. The first or the second stent may be differentially expandable such that in the expanded configuration a first portion of the stent has a larger diameter than a second portion of the first stent. The first expandable member or the second expandable member has a working length which may include a tapered region. A proximal portion of the tapered region may have a diameter larger than a distal portion of the tapered region.

[0025] In another aspect of the present invention, a method of treating a bifurcated vessel comprises providing a first delivery catheter and a second delivery catheter. The first delivery catheter comprises a first elongate shaft, a first expandable member, and a first stent disposed over the first expandable member. The second delivery catheter comprises a second elongate shaft, a second expandable member, and a second stent disposed over the second expandable member. A portion of the first elongate shaft is disposed under the second stent and the first elongate shaft exits a side hole in the second stent. The first expandable member is distal to the second expandable member. Both the first and second delivery catheters are advanced through a main branch vessel having a lesion to a bifurcation in the main branch. The bifurcation comprises a side branch vessel having a lesion and extending from the main branch vessel. The first stent is advanced into the side branch, distal to the side branch lesion. The first elongate shaft is proximally retracted under a portion of the second stent until a proximal end of the first stent is aligned with the side hole in the second stent. The first expandable member is radially expanded, thereby simultaneously expanding the first stent into engagement with the lesion in the side branch and expanding a proximal portion of the second stent. The second expandable member is radially expanded, thereby further expanding the proximal portion of the second stent and expanding a distal portion of the second stent into engagement with a wall of the main branch.

[0026] In still another aspect of the present invention, a method for treating a bifurcated vessel comprises providing a first delivery catheter and a second delivery catheter. The first delivery catheter comprises a first elongate shaft, a first expandable member, and a first stent disposed over the first expandable member. The second delivery catheter comprises a second elongate shaft, a second expandable member, and a second stent disposed over the second expandable member. A portion of the first elongate shaft is disposed under the second stent and the first elongate shaft exits a side hole in the second stent. The first expandable member is distal to the second expandable member. Both the first delivery catheter and the second delivery catheter are advanced through a main branch vessel having a lesion adjacent a bifurcation in the main branch. The bifurcation comprises a side branch vessel having a lesion and extending from the main branch vessel. The first stent is advanced distal to the main branch lesion, and the second stent is disposed in both the main branch and the side branch. The first elongate shaft is retracted proximally under a portion of the second stent until a proximal end of the first stent is aligned with the side hole in the second stent. The first expandable member is radially expanded, thereby simultaneously expanding the first stent into engagement with the lesion in the main branch and expanding a proximal portion of the second stent into engagement with the lesion in the main branch. The second expandable member is radially expanded, thereby further expanding the proximal portion of the second stent and expanding a distal portion of the second stent into engagement with the lesion in the side branch.

[0027] The advancing may comprise advancing both the first and the second delivery catheters until resistance to further advancement is felt by an operator. The resistance may be provided by separation of the first elongate shaft from the second elongate shaft as both shafts are advanced

against a wall formed between the main branch and the side branch. The bifurcation angle may be less than about 60 to 70 degrees in some embodiments, and in other embodiments the bifurcation angle is greater than or equal to about 60 to 70 degrees.

[0028] The first delivery catheter may comprise a first radiopaque marker disposed adjacent a proximal region of the first expandable member. The second delivery catheter may comprise a second radiopaque marker disposed adjacent a proximal region of the second expandable member. The retracting may comprise retracting the first elongate shaft until the first radiopaque marker is aligned with the second radiopaque marker. The second elongate shaft may comprise an exchange lumen, and the retracting may comprise slidably retracting the first elongate shaft through the exchange lumen. The first and second elongate shafts may be disposed in a central channel of a capture tube, and the retracting comprises slidably retracting the first elongate shaft through the central channel. The capture tube may comprise a perforated region, and the method may further comprise separating the perforated region and peeling the capture tube away from the first and the second elongate shafts. The second elongate shaft may comprise a snap fitting configured to receive and retain the first elongate shaft, and the retracting may comprise slidably retracting the first elongate shaft along the snap fitting. The first and second elongate shafts may be disposed in a polymer tube having a central channel therethrough, and the retracting may comprise slidably retracting the first elongate shaft through the central channel.

[0029] The first expandable member may comprise a balloon, and the expanding of the first expandable member comprises inflating the balloon. The method may further comprise contracting the first expandable member after expansion thereof and prior to the expansion of the second expandable member. The expanding of the first stent may comprise differentially expanding the first stent so that a proximal region of the expanded first stent has a larger diameter than a distal region of the expanded first stent.

[0030] The second expandable member may comprise a balloon, and the expanding of the second expandable member comprises inflating the balloon. The expanding of the second expandable member may comprise expanding at least a portion of the second stent into engagement with the main branch lesion. The expanding of the second stent may comprise differentially expanding the second stent so that a proximal region of the expanded second stent has a larger diameter than a distal region of the expanded second stent.

[0031] The method may further comprise simultaneously expanding the first and the second expandable members into engagement with one another thereby ensuring engagement of the first stent with the side branch lesion and engagement of the second stent with the main branch lesion. This may also help ensure alignment of a proximal end of the first stent with the side hole in the second stent. In other embodiments, simultaneously expanding the first and the second expandable members into engagement with one another ensures engagement of the first stent with the main branch lesion and engagement of the second stent with the main branch lesion and the side branch lesion. In still other embodiments, simultaneous expansion of the first and second expandable members helps ensure engagement of the proximal portion of the stent with the lesion in the side branch, and also ensures alignment of the side hole in the stent with the main branch. The main branch and the side branch may have substantially the same diameter. The method may also comprise eluting a therapeutic agent from one of the first or the second stents, or one or both of the expandable members into the main branch lesion or the side branch lesion. The therapeutic agent may comprise an anti-restenosis agent.

[0032] In still another aspect of the present invention, a system for treating a bifurcation comprises a first catheter comprising a first elongate shaft with a proximal end and a distal end, a first stent receptacle adjacent the distal end of the first elongate shaft, and a first radially expandable stent disposed over the first stent receptacle. The first stent comprises a sidewall having a side hole therethrough. The first stent has a collapsed configuration and an expanded configuration, in the collapsed configuration the first stent is coupled with the first expandable member, and in the

expanded configuration the first stent supports a vessel wall. A second catheter comprises a second elongate shaft with a proximal end and a distal end, and an expandable member adjacent the distal end of the second elongate shaft. A portion of the second delivery catheter is disposed under a portion of the first radially expandable stent, and a portion of the second delivery catheter passes through the side hole in the first radially expandable stent. The second delivery catheter is axially slidable relative to the first delivery catheter while the first radially expandable stent is in the collapsed configuration.

[0033] These and other embodiments are described in further detail in the following description related to the appended drawing figures.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] FIGS. 1A-1B illustrate an exemplary embodiment of a system having an over-the-wire mother catheter and a rapid exchange daughter catheter.

[0035] FIGS. 2A-2B illustrate an exemplary embodiment of a system having an over-the-wire daughter catheter and a rapid exchange mother catheter.

[0036] FIGS. 3A-3B illustrate an exemplary embodiment of a system having a rapid exchange mother catheter and a rapid exchange daughter catheter.

[0037] FIGS. 4A-4B illustrate an exemplary embodiment of a system having an over-the-wire mother catheter and an over-the-wire daughter catheter.

[0038] FIGS. 5A-5B illustrate another exemplary embodiment of a system having a capture tube, an over-the-wire mother catheter, and a rapid exchange daughter catheter.

[0039] FIGS. 6A-6B illustrate another exemplary embodiment of a system having a capture tube, an over-the-wire daughter catheter, and a rapid exchange mother catheter.

[0040] FIGS. 7A-7B illustrate another exemplary embodiment of a system having a capture tube, a rapid exchange mother catheter, and a rapid exchange daughter catheter.

[0041] FIGS. 8A-8B illustrate another exemplary embodiment of a system having a capture tube, an over-the-wire mother catheter, and an over-the-wire daughter catheter.

[0042] FIGS. 9A-9B illustrate yet another exemplary embodiment of a system having a removable capture tube, an over-the-wire mother catheter and a rapid exchange daughter catheter.

[0043] FIGS. 10A-10B illustrate yet other exemplary embodiment of a system having a removable capture tube, an over-the-wire daughter catheter and a rapid exchange mother catheter.

[0044] FIGS. 11A-11B illustrate yet another exemplary embodiment of a system having a removable capture tube, a rapid exchange mother catheter and a rapid exchange daughter catheter.

[0045] FIGS. 12A-12B illustrate yet another exemplary embodiment of a system having a removable capture tube, an over-the-wire mother catheter and an over-the-wire daughter catheter.

[0046] FIGS. 13A-13C illustrate still another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and a rapid exchange daughter catheter.

[0047] FIGS. 14A-14C illustrate still another exemplary embodiment of a system having a snap fitting, an over-the-wire daughter catheter and a rapid exchange mother catheter.

[0048] FIGS. 15A-15C illustrate still another exemplary embodiment of a system having a snap fitting, a rapid exchange mother catheter and a rapid exchange daughter catheter.

[0049] FIGS. 16A-16C illustrate still another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and an over-the-wire daughter catheter.

[0050] FIGS. 17A-17C illustrate another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and a rapid exchange daughter catheter.

[0051] FIGS. 18A-18C illustrate another exemplary embodiment of a system having a snap fitting, an over-the-wire daughter catheter and a rapid exchange mother catheter.

[0052] FIGS. **19A-19C** illustrate another exemplary embodiment of a system having a snap fitting, a rapid exchange mother catheter and a rapid exchange daughter catheter.

[0053] FIGS. **20A-20C** illustrate another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and an over-the-wire daughter catheter.

[0054] FIGS. **21A-21B** illustrate yet another exemplary embodiment of a system having an over-the-wire mother catheter and a rapid exchange daughter catheter.

[0055] FIGS. **22A-22B** illustrate yet another exemplary embodiment of a system having an over-the-wire daughter catheter and a rapid exchange mother catheter.

[0056] FIGS. **23A-23B** illustrate yet another exemplary embodiment of a system having a rapid exchange mother catheter and a rapid exchange daughter catheter.

[0057] FIGS. **24A-24B** illustrate yet another exemplary embodiment of a system having an over-the-wire mother catheter and an over-the-wire daughter catheter.

[0058] FIGS. **25A-25B**, **26A-26B**, **27A-27B**, **28A-28B**, **29A-29B**, and **30A-30B** illustrate an exemplary method of treating a bifurcation.

[0059] FIG. **31** illustrates an exemplary embodiment of a stent.

[0060] FIG. **32** illustrates an exemplary embodiment of a system having a mother catheter and a daughter catheter.

[0061] FIG. **33** highlights the distal portion of the system illustrated in FIG. **32**.

[0062] FIG. **34** illustrates alignment of the stents in FIGS. **32-33**.

[0063] FIG. **35** illustrates a cross-section of a stent crimped over a mother catheter and a daughter catheter.

[0064] FIG. **36** illustrates a stent disposed over a mother catheter and a daughter catheter.

[0065] FIG. **37** illustrates a stent disposed over a mother catheter and a daughter catheter, and a stent disposed over the daughter catheter.

[0066] FIGS. **38A-38M** illustrate an exemplary method of treating a bifurcation.

[0067] FIGS. **39A-39M** illustrate another exemplary method of treating a bifurcation.

[0068] FIGS. **40A-40H** illustrate various stents that may be used with the systems and methods disclosed herein to treat bifurcations.

[0069] FIGS. **41A-41B** illustrate exemplary embodiments of balloon configurations.

[0070] FIGS. **42A-42C** illustrate engagement of a side branch stent with a main branch stent.

[0071] FIGS. **43A-43B** illustrate other configurations of a side branch stent engaging a main branch stent.

[0072] FIGS. **44-46** illustrate still other configurations of engagement of a side branch stent with a main branch stent.

[0073] FIGS. **47A-47D** illustrate interdigitation of a side branch stent and a main branch stent.

[0074] FIG. **48** illustrates another exemplary balloon catheter.

DETAILED DESCRIPTION OF THE INVENTION

[0075] The present invention relates to delivery systems for delivery of stents to vessel bifurcations having a main branch and a side branch, and is generally configured to at least partially cover a portion of a the side branch as well as a portion of the main branch. However, this is not intended to be limiting, and one of skill in the art will appreciate that the devices and methods described herein may be used for treating other regions of the body.

[0076] The scientific community is slowly moving away from a main branch vs. side branch model and nomenclature. It is now well accepted that a “mother” vessel bifurcates into two “daughter vessels,” the two vessels that are anatomically after the carina. The vessel that appears to be the continuation of the mother vessel is usually less angulated. The other vessel is frequently smaller in diameter and may be commonly referred to as the side branch, or a daughter vessel. Therefore, in this specification, the terms “main branch,” “trunk,” or “mother vessel” may be used interchangeably. Also in this specification, the terms “side branch vessel” and “daughter vessel” may also be used interchangeably. The terms “main branch stent,” “trunk stent,” or “mother stent”

are interchangeable, and the term “side branch stent” is also interchangeable with the term “daughter stent.” In the case where a main branch vessel bifurcates into two equally sized branches, one of the branches may still be considered to be the main branch or mother vessel, and the other branch may be considered a side branch or daughter vessel.

[0077] A variety of catheter designs may be employed to deploy and position the mother and daughter stents. Such catheters may be used in connection with multiple guidewires that terminate in the mother and daughter vessels. These guidewires may be used to facilitate introduction of the catheter, any angioplasty balloons, any stents, and/or to properly orient the stent or balloon within the vessel.

[0078] In general, the methods disclosed herein may utilize a catheter system comprising a catheter body having a mother vessel guidewire lumen and a daughter vessel balloon that is independently operable and coupled to the catheter body. The daughter balloon catheter portion has a daughter vessel guidewire lumen. The catheter system further includes a mother catheter balloon, and a stent is disposed over the balloon. The daughter catheter portion extends into the proximal opening of the mother stent and exits the mother stent through a side passage of the mother stent.

[0079] According to one method, a mother vessel guidewire is inserted into the mother vessel until a distal end of the mother vessel guidewire passes beyond the ostium of the daughter vessel, and a daughter vessel guidewire is inserted into the mother vessel until a distal end of the daughter vessel guidewire passes into the daughter vessel. To prevent the crossing of guidewires, the two vessels are wired through a guidewire catheter with two lumens to keep the guidewires separate and untangled.

[0080] The guidewire catheter is then removed and a wire separator is placed on the wires to keep the guidewires unwrapped. The catheter system is then advanced over the mother and daughter vessel guidewires, with the mother and daughter vessel catheters passing over the mother vessel guidewire and the daughter vessel guidewire. The catheter system is advanced on both wires with the daughter vessel balloon catheter portion distal to the mother balloon catheter portion, leading the system. As the catheter system advances over the wires, the daughter vessel balloon will enter the daughter vessel and may be positioned after or simultaneously with placement of the mother vessel balloon. The mother balloon catheter portion of the catheter system is then advanced distally as far as it can be advanced where it is stopped by the carina. It cannot be advanced beyond the bifurcation site because the tension of the daughter catheter on the mother stent will prevent the mother catheter from moving distally. At this time the distal portion of the mother stent is beyond the carina in the mother vessel and cannot be advanced any further. This method facilitates advancement of the catheter system to the bifurcation, which may be necessary for tortuous or calcified coronaries. Once the catheter system is in place the daughter vessel balloon catheter portion is then pulled back relative to the mother catheter so that the proximal part of the daughter balloon is partially within the mother stent. Alignment can be performed with radiopaque markers, in that the proximal markers on the two balloons are next to each other. The operator can then gently push the catheter system distal to maximize apposition to the carina. The daughter balloon which is now partially under the mother stent is then inflated to ensure proper alignment of the mother stent. The daughter balloon may also have a stent on its distal portion, which would result in the proximal portion of the mother stent and the daughter stent to expand simultaneously. The daughter balloon is then deflated.

[0081] The mother balloon is then inflated which deploys the mother stent. Kissing, reinflation, of the two balloons is performed if necessary or for shifting plaque. The catheter system may be removed while the wires remain in place. In this embodiment, or any of the other embodiments disclosed herein, an angioplasty catheter may be used to predilate the vessel and lesion prior to stenting. In some embodiments, primary stenting is employed where the stent is deployed without the predilation. The two vessels may be angioplastied separately if predilatation is indicated on occasion.

[0082] In an alternative method, the mother catheter can be mounted on the daughter vessel guidewire and the daughter catheter can be mounted on the mother vessel guidewire. In daughter vessels with a high degree of angularity, for example, when the bifurcation angle is greater than about 60-70°, the friction between catheters is lower when the operator needs to draw the daughter stent proximally along the main branch and into the mother stent, as opposed to the prior configuration where the daughter stent is drawn along the side branch into the mother stent. The catheter system is advanced so the daughter balloon catheter leads the system and passes the ostium of the daughter vessel, while remaining in the mother vessel. As the catheter system is advanced further, the mother balloon catheter will enter the daughter vessel. The catheter system can only be advanced a certain distance toward the bifurcation, until it is stopped by the carina. It cannot be advanced beyond the bifurcation site because the tension of the daughter catheter on the mother stent will prevent the mother catheter from moving distally. At this time the distal portion of the mother stent is beyond the ostium of the daughter vessel and cannot be advanced any further. While the mother catheter is held in place, the daughter catheter is drawn back such that the proximal portion of the daughter balloon is partially in the mother stent. Alignment can be performed with radiopaque markers, in that the proximal markers on the two balloons are next to each other. The operator can then gently push the catheter system distally to maximize apposition to the carina. A stent on the daughter balloon (which is now partially under the mother stent) is aligned so that when the daughter balloon is inflated the daughter stent and the proximal portion of the mother stent expand simultaneously and give complete coverage of the mother vessel. The daughter vessel balloon is then deflated. The mother vessel balloon is then inflated and the distal portion of the mother stent is expanded. A kissing procedure can also be performed if required.

[0083] The mother vessel can be stented if necessary with any commercially available stent. A balloon on a wire could be used as an alternative to the daughter catheter. In an alternative embodiment, the catheter system can be arranged with the daughter balloon portion proximal to the mother balloon portion and advanced over the guidewires to the bifurcation. In the case of the mother catheter on the mother guidewire, the alignment of the mother stent with the ostium of the daughter vessel occurs because tension between the daughter guidewire and mother stent on the mother catheter prevents further advancement of the mother catheter. In the alternative case of the mother catheter on the daughter guidewire, the alignment of the mother stent with the ostium of the mother vessel occurs because tension between the mother guidewire and mother stent on the mother catheter (on the daughter guidewire) prevents further advancement of the mother catheter. In both cases the daughter stent is advanced into alignment with the mother stent and expanded. In preferred embodiments, the mother catheter is an over-the-wire (OTW) design and the daughter catheter is a rapid-exchange (RX) design with daughter catheter portion preferably distal thereto. The daughter balloon is placed just distal to the tip of the mother catheter, this arrangement minimizes the overall profile of the catheter system and allows maximal tracking of the arteries. The system may additionally have stents crimped over the balloons. The daughter stent may be any length, but in preferred embodiments is approximately half the length of the daughter balloon or mother stent. The proximal end of the mother stent may be crimped only slightly to allow the daughter catheter balloon portion to operate independently so that it may be pushed or pulled without dislodging the mother stent.

[0084] An exemplary method comprises the following steps: [0085] 1. Advance the catheter system to bifurcation, daughter balloon catheter portion and mother balloon catheter portion in their respective vessels. [0086] 2. The mother catheter is no longer able to advance because of the tension between the mother stent and daughter catheter. [0087] 3. The daughter balloon proximal portion is drawn back into the mother stent and aligned with radiopaque markers. [0088] 4. While holding both the mother and daughter catheters tightly, the operator pushes forward lightly. [0089] 5. Inflate the daughter balloon and expand the daughter stent, approximately half of the daughter balloon distal portion will expand the “half-stent,” and half of the daughter balloon proximal

portion will expand inside the mother vessel and partially expand the proximal portion of the mother stent. Expansion of the proximal portion of the mother stent and the daughter stent preferably occur simultaneously. [0090] 6. Once the daughter stent is fully deployed, then the mother balloon can be fully expanded to deploy the distal portion of the mother stent. [0091] 7. A conventional kissing procedure may be utilized to ensure full apposition. In one particular aspect, the daughter balloon catheter portion may be used without a stent. This allows perfect alignment of the mother stent around the ostium of the daughter vessel. The daughter balloon would be used for the alignment as outlined in step three above, and expands the proximal portion of the mother stent. [0092] In an alternative embodiment, the mother catheter is an over-the-wire (OTW) design and the daughter catheter is a rapid-exchange (RX) design with daughter catheter portion distal thereto. The system may additionally have stents crimped over the balloons. The daughter stent is preferably less than the length of the mother balloon or stent, although this is not intended to be limiting, and the daughter stent may be any length. The proximal end of the mother stent may be partially crimped to allow the daughter catheter balloon portion to operate independently, so that it may be pushed or pulled without restriction and minimum friction, and without dislodging or affecting the mother stent. An exemplary method comprises the following steps: [0093] 1. Looping the OTW so that one operator can hold both guide wires with one hand and then push both catheters with the other. [0094] 2. Advance the catheter system to bifurcation, daughter balloon catheter portion and mother balloon catheter portion aligned in their respective vessels, as disclosed in steps two through three in the above embodiment. [0095] 3. While holding both the mother and daughter catheters tightly, push the catheter system forward until the mother balloon catheter portion is stopped at the carina. [0096] 4. Inflate the daughter balloon and expand the daughter stent, approximately half of the daughter balloon distal portion will expand the “half-stent,” and half of the daughter balloon proximal portion will expand inside the mother vessel and partially expand the proximal portion of the mother stent. [0097] 5. Once the daughter stent is fully deployed, then the mother balloon can be fully expanded to deploy the distal portion of the mother stent. [0098] 6. A conventional kissing procedure may be utilized to ensure full apposition.

[0099] In one particular aspect, the daughter balloon catheter portion may be used without a stent. This would allow perfect alignment of the mother stent around the ostium of the daughter vessel. The daughter balloon would be used for the alignment as outlined in step three above, and expand the proximal portion of the mother stent.

[0100] In an alternative embodiment, the mother catheter is an over-the-wire design and the daughter catheter is a rapid-exchange design with daughter catheter portion distal thereto. The system may additionally have stents crimped over the balloons. The daughter stent may be approximately half the length of the mother balloon or stent, but this is not intended to be limiting, and the daughter stent may be any length. The proximal end of the mother stent may be partially crimped to allow the daughter catheter balloon portion to operate independently, so that it may be pushed or pulled without dislodging the mother stent. An exemplary method comprises the following steps: [0101] 1. Place the daughter catheter over the guidewire in the daughter vessel and slide the system into the guide catheter without placing the mother balloon over a guidewire at this time. After the leading daughter catheter enters the coronary artery and just before the mother catheter exits the guide catheter, insert the mother guidewire through the mother catheter and into the mother vessel, then push the system out of the guide catheter over the two guidewires. This method mitigates wire wrap. [0102] 2. Advance the catheter system to the bifurcation, daughter balloon catheter portion and mother balloon catheter portion aligned in their respective vessels. [0103] 3. Advance the catheter system to bifurcation, daughter balloon catheter portion and mother balloon catheter portion aligned in their respective vessels, as disclosed in step two in the above embodiment. Pull the daughter catheter back until the proximal markers on both balloons are aligned. [0104] 4. Inflate the daughter balloon and expand the daughter stent, approximately half of the daughter balloon distal portion will expand the “half-stent,” and half of the daughter balloon

proximal portion will expand inside the mother vessel and partially expand the proximal portion of the mother stent. [0105] 5. Once the daughter stent is fully deployed, then the mother balloon can be fully expanded to deploy the distal portion of the mother stent. [0106] 6. A conventional kissing procedure may be utilized to ensure full apposition. In one particular aspect, the daughter balloon catheter portion may be used without a stent. This would allow perfect alignment of mother stent around the ostium of the daughter vessel. The daughter balloon would be used for the alignment as outlined in step three above, and expand the proximal portion of the mother stent.

[0107] In an alternative embodiment the mother and daughter systems balloons are aligned. This embodiment could include the mother stent and daughter stent or either stent. When there is both a mother stent and a daughter stent, the daughter stent is preferably shorter than the mother stent, although it may be any length, and in preferred embodiments is approximately half the length of the mother stent so that the daughter stent could be mounted on the distal half of the daughter balloon. Furthermore, the proximal portion of the daughter catheter shaft is positioned under the non-uniformly crimped mother stent. The dual stent arrangement reduces the profile compared to a full length stent that covers the entire length of the daughter balloon.

[0108] The methods described herein could alternatively include the step of flushing the catheters and the guidewire port to assist with maneuverability. The methods described herein could alternatively include the step of a couple of snap-on couplers that lock the two catheters together. In another particular aspect, each balloon catheter portion may include at least one radiopaque marker. With such a configuration, separation of the markers may be conveniently observed using fluoroscopy to indicate that the balloon catheter portions have passed beyond the ostium and the daughter balloon catheter portion has passed into the daughter vessel, thus aligning the passage of the stent with the ostium of the daughter vessel. In another particular aspect, the catheter systems design is contemplated to cover combinations of rapid exchange and over the wire; for visualization purposes the hybrid versions are preferred because they are easier to distinguish while using fluoroscopy.

[0109] In another particular aspect, the proximal balloon may be differentially expandable, such that one end of the balloon may expand prior to the other end. In another particular aspect, the proximal balloon catheter portion may receive a stent that can be crimped under variable pressure to allow the distal balloon catheter portion freedom of movement.

[0110] In another particular aspect, a stent may be crimped over the proximal balloon catheter portion and the stent may be designed to deploy with variable profile to better oppose the patient anatomy.

[0111] In another particular aspect, the distal balloon catheter portion may be delivered via a pull away or peel away capture tube. All of the above embodiments may utilize mother vessel stents having any diameter, with diameter preferably ranging from about 2.5 to about 5 millimeters, and daughter vessel stent having any diameter, preferably ranging from about 2 to about 5 millimeters. The length of the stents may be any length, preferably in the range of about 4 to about 40 millimeters. The position of a stent on a catheter need not be fixed and may be positioned on either or both catheters.

Catheter Configurations:

[0112] FIG. 1A illustrates an exemplary embodiment of the catheter system **100** with a distal daughter balloon catheter portion comprising a balloon with a daughter stent crimped thereon. The daughter stent may be shorter than the mother stent, and it may not be centered on its corresponding balloon in this as well as any other embodiments disclosed herein. Thus, in preferred embodiments, a proximal portion of the daughter balloon remains uncovered by a stent, as will be discussed in greater detail below. In a particular embodiment the daughter stent is preferably about half the length of the mother stent. The distal daughter stent is crimped under standard conditions known in the art. The proximal mother balloon catheter portion comprises a mother balloon and a mother stent. The mother stent is crimped differentially along the longitudinal direction and

circumferentially. In this exemplary embodiment, the distal half of the mother stent is crimped under typical conditions to ensure that the mother stent is not dislodged during the alignment with the distal daughter balloon. Further, the proximal portion of the mother stent is crimped under non-standard, relatively loose, conditions to allow the distal daughter balloon catheter portion freedom of movement even though a portion of the daughter balloon catheter portion is circumferentially enclosed. The mother and daughter catheters are slidably attached to each other via a hollow exchange port. The exchange port is embedded in the side of the mother over the wire catheter and has an inner diameter just large enough to allow the insertion of the rapid exchange daughter catheter and balloon. The exchange port may be any length that extends between a proximal portion of the balloons and a distal portion of the catheter connectors, and in this embodiment is about 10 centimeters long, but in preferred embodiments varies from about 1 centimeter to about 30 centimeters, and in more preferred embodiments is about 5 cm to about 10 cm long. The entry for the daughter catheter on the exchange port is proximal and the exit for the daughter catheter is on the distal end of the exchange port. The daughter catheter is loaded through the exchange port and the daughter balloon extends distally from the exit of the exchange port, preferably about 5 centimeters. However, it is possible to have the exchange port any distance from the mother balloon, but preferably about 1 to about 30 centimeters proximal to the mother balloon. The daughter stent can be crimped on to the balloon after it has been loaded through the exchange port. The exchange port preferably has a tight fit to reduce catheter profile and preferably has low friction to allow the operator to easily slide the catheters relative to each other.

[0113] FIG. 1B more clearly illustrates the features of the catheter system **100** in FIG. 1A. The stent delivery system **100** includes a first catheter **102**, and a second catheter **130**. The first catheter **102** includes an elongate shaft **104** with a radially expandable balloon **106** disposed near a distal end of the elongate shaft **104**. A stent **108** having a proximal portion **122**, a distal portion **114** and a side hole **120** is disposed over the balloon **106**. The distal portion **114** is crimped to the balloon **106** to prevent ejection during delivery, while the proximal portion **122** is partially crimped to the balloon **106** so the second catheter **130** may be slidably advanced or retracted under the proximal portion **122** of stent **108**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **112** extending from the distal guidewire port **110** at the distal end of the elongate shaft **104** to the proximal end of the elongate shaft **104** into Y-adapter **114** having a connector **116**. The connector **116** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **112** exits via connector **116**. A second connector **118**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **106** via an inflation lumen (not shown) in the elongate shaft **104**. The first catheter **102** also includes a hollow exchange port tube **124** coupled to the elongate shaft **104**. The hollow exchange port tube **124** may be coextruded with the first shaft **104**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **132**. The hollow exchange port tube **124** includes a central channel **126** extending therethrough and is sized to slidably receive a portion of the second catheter **130**. Radiopaque markers may be placed at different locations along the shaft **104**, often near the balloon **106** and/or stent **108**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0114] The second catheter **130** includes an elongate shaft **132** with a radially expandable balloon **140** disposed near a distal end of the elongate shaft **132**. A stent **142** is disposed over balloon **140**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **142** is shorter than the working length of the balloon **140** so that a proximal portion of the balloon **140** is unconstrained by the stent **142** and this unconstrained portion of the balloon **140** may be slidably

advanced or retracted through side hole **120** and under proximal portion **122** of stent **108** as will be discussed below. Stent **142** is crimped to balloon **140** to prevent ejection during delivery. At least a portion of balloon **140**, and stent **142** are distally offset relative to balloon **106** and stent **108** so as to minimize profile of the device. In this embodiment the distal stent **142** may be deployed in a main branch of the vessel and the other stent **108** may be deployed in a side branch of the vessel. Alternatively, the distal stent **142** may be deployed in a side branch of a vessel and the other stent **108** may be deployed in the main branch of a vessel. The second catheter **130** is a rapid exchange catheter (RX) having a guidewire lumen **134** extending from the distal guidewire port **138** at the distal end of the elongate shaft **132** to a proximal guidewire port **136** which is closer to the distal port **138** than the proximal end of the catheter shaft **132**. The proximal guidewire port **136** is also unobstructed by the hollow exchange tube **124** and preferably proximal thereto. A connector **144**, preferably a Luer connector is connected to the proximal end of the elongate shaft **132** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **132** for inflation of balloon **140**. A portion of shaft **132** is disposed in the central channel **126** of the hollow exchange tube **124** and this helps keep the two catheter shafts **104**, **132** parallel and prevents tangling during delivery and as shaft **132** is slidably advanced or retracted relative to shaft **104**. Also, another portion of shaft **132** is disposed under proximal portion **122** of stent **108**. The second catheter **130** may also be slidably advanced or retracted under the proximal portion **122** of stent **108** so that the shaft **132** passes through the side hole **120** in stent **108**. Radiopaque markers may be placed at different locations on the shaft **132**, often near the balloon **140** or stent **142**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0115] FIG. 2A illustrates a cross sectional view of one embodiment of a catheter system **200** with the daughter catheter balloon portion distal to the mother balloon portion utilizing the same exchange port as described in FIG. 1A. The mother balloon is preferably at least about 5 centimeters distal from the exit of the exchange port. As disclosed above the mother balloon could be distal from the exchange port from about 1 cm to about 30 centimeters.

[0116] FIG. 2B more clearly illustrates the features of the catheter system **200** in FIG. 2A. The stent delivery system **200** includes a first catheter **202**, and a second catheter **230**. The first catheter **202** includes an elongate shaft **204** with a radially expandable balloon **206** disposed near a distal end of the elongate shaft **204**, and a stent **208** disposed over the balloon **206**. The stent **208** may be the same length as the working length of the balloon **208**, or it may be shorter. In preferred embodiments, the stent **208** is shorter than the working length of balloon **206** such that a proximal portion of balloon **206** remains unconstrained by stent **208**. The proximal portion of balloon **206** may be slidably advanced and retracted under stent **242** via side hole **220**. Stent **208** is crimped to the balloon **206** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **212** extending from the distal guidewire port **210** at the distal end of the elongate shaft **204** to the proximal end of the elongate shaft **204** into Y-adaptor **214** having a connector **216**. The connector **216** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **212** exits via connector **216**. A second connector **218**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **206** via an inflation lumen (not shown) in the elongate shaft **204**. The first catheter **202** also includes a hollow exchange port tube **224** coupled to the elongate shaft **204**. The hollow exchange port tube **224** may be coextruded with the first shaft **204**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **232**. The hollow exchange port tube **224** includes a central channel **226** extending therethrough and is sized to slidably receive a portion of the second catheter **230**. Radiopaque markers may be placed at different locations along the shaft **204**, often near the balloon **206** and/or stent **208**, to help mark the proximal and distal ends of the

stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0117] The second catheter **230** includes an elongate shaft **232** with a radially expandable balloon **240** disposed near a distal end of the elongate shaft **232**. A stent **242** having a proximal portion **222**, a distal portion **214**, and a side hole **220** is disposed over balloon **240**. The distal portion **214** is crimped to balloon **240** to prevent ejection during delivery, while the proximal portion **222** is partially crimped to balloon **240** so elongate shaft **204** may be slidably advanced or retracted under the proximal portion **222** of stent **242**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **206**, and stent **208** are distally offset relative to balloon **240** and stent **242** so as to minimize profile of the device. In this embodiment the distal stent **208** may be deployed in a main branch of the vessel and the other stent **242** may be deployed in a side branch of the vessel. Alternatively, the distal stent **208** may be deployed in a side branch of a vessel and the other stent **242** may be deployed in the main branch of a vessel. The second catheter **230** is a rapid exchange catheter (RX) having a guidewire lumen **234** extending from the distal guidewire port **238** at the distal end of the elongate shaft **232** to a proximal guidewire port **236** which is closer to the distal port **238** than the proximal end of the catheter shaft **232**. The proximal guidewire port **236** is also unobstructed by the hollow exchange tube **224** and preferably proximal thereto. A connector **244**, preferably a Luer connector is connected to the proximal end of the elongate shaft **232** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **232** for inflation of balloon **240**. A portion of shaft **232** is disposed in the central channel **226** of the hollow exchange tube **224** and this helps keep the two catheter shafts **204**, **232** parallel and prevents tangling during delivery and as shaft **232** is slidably advanced or retracted relative to shaft **204**. Also, a portion of shaft **204** is disposed under proximal portion **222** of stent **242**. The first catheter **202** may be slidably advanced or retracted under the proximal portion **222** of stent **242** so that the shaft **204** passes through the side hole **220** in stent **242**. Radiopaque markers may be placed at different locations on the shaft **232**, often near the balloon **240** or stent **242**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0118] FIG. 3A illustrates a cross sectional view of one embodiment of a catheter system **300** with the mother and daughter catheters both having a rapid exchange design. In this particular embodiment one of the catheters has a hollow exchange port embedded in its side and the other catheter is loaded through the exchange port. Typically, the catheter is loaded prior to having a stent crimped over the balloon portion.

[0119] FIG. 3B more clearly illustrates the features of the catheter system **300** in FIG. 3A. The delivery system **300** includes a first catheter **302**, and a second catheter **330**. The first catheter **302** includes an elongate shaft **304** with a radially expandable balloon **306** disposed near a distal end of the elongate shaft **304**. A stent **308** having a proximal portion **322**, a distal portion **314** and a side hole **320** is disposed over the balloon **306**. The distal portion **314** is crimped to the balloon **306** to prevent ejection during delivery, while the proximal portion **322** is partially crimped to the balloon **306** so the second catheter **330** may be slidably advanced under the proximal portion **322** of stent **308**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **312** extending from the distal guidewire port **310** at the distal end of the elongate shaft **304** to a proximal guidewire port **311** which is closer to the distal port **310** than the proximal end of the catheter shaft **304**. A connector **316** is coupled with the proximal end of the elongate shaft **304**. The connector **316** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **306**. The first catheter **302** also includes a hollow exchange port tube **324** coupled to the elongate shaft **304**. The hollow exchange port tube **324** may be coextruded with the first shaft **304**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft

332. The hollow exchange port tube **324** includes a central channel **326** extending therethrough and is sized to slidably receive a portion of the second catheter **330**. Radiopaque markers may be placed at different locations along the shaft **304**, often near the balloon **306** and/or stent **308**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0120] The second catheter **330** includes an elongate shaft **332** with a radially expandable balloon **340** disposed near a distal end of the elongate shaft **332**. A stent **342** is disposed over balloon **340**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **342** is shorter than the working length of the balloon **340** so that a proximal portion of the balloon **340** is unconstrained by the stent **342** and this unconstrained portion of the balloon **340** may be slidably advanced or retracted through side hole **320** and under proximal portion **322** of stent **308** as will be discussed below. Stent **342** is crimped to balloon **340** to prevent ejection during delivery. At least a portion of balloon **340**, and stent **342** are distally offset relative to balloon **306** and stent **308** so as to minimize profile of the device. In this embodiment the distal stent **342** may be deployed in a main branch of the vessel and the other stent **308** may be deployed in a side branch of the vessel. Alternatively, the distal stent **342** may be deployed in a side branch of a vessel and the other stent **308** may be deployed in the main branch of a vessel. The second catheter **330** is a rapid exchange catheter (RX) having a guidewire lumen **334** extending from the distal guidewire port **338** at the distal end of the elongate shaft **332** to a proximal guidewire port **336** which is closer to the distal port **338** than the proximal end of the catheter shaft **332**. The proximal guidewire port **336** is also unobstructed by the hollow exchange tube **324** and may be distal thereto. A connector **344**, preferably a Luer connector is connected to the proximal end of the elongate shaft **332** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **332** for inflation of balloon **340**. A portion of shaft **332** is disposed in the central channel **326** of the hollow exchange tube **324** and this helps keep the two catheter shafts **304**, **332** parallel and prevents tangling during delivery and as shaft **332** is slidably advanced or retracted relative to shaft **304**. Also, another portion of shaft **332** is disposed under proximal portion **322** of stent **308**. The second catheter **330** may also be slidably advanced or retracted under the proximal portion **322** of stent **308** so that the shaft **332** passes through the side hole **320** in stent **308**. Radiopaque markers may be placed at different locations on the shaft **332**, often near the balloon **340** or stent **342**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0121] FIG. 4A illustrates a cross sectional view of one embodiment of a catheter system **400** with the mother and daughter catheters both having an over the wire design. In this particular embodiment one of the catheters has a hollow exchange port embedded in its side and the other catheter does not have a hollow exchange port. The catheter without the exchange port is loaded onto the catheter with an exchange port. Typically, the catheter would have to be loaded prior to having a stent crimped over the balloon portion.

[0122] FIG. 4B more clearly illustrates the features of the catheter system **400** in FIG. 4A. The stent delivery system **400** includes a first catheter **402**, and a second catheter **430**. The first catheter **402** includes an elongate shaft **404** with a radially expandable balloon **406** disposed near a distal end of the elongate shaft **404**. A stent **408** having a proximal portion **422**, a distal portion **414** and a side hole **420** is disposed over the balloon **406**. The distal portion **414** is crimped to the balloon **406** to prevent ejection during delivery, while the proximal portion **422** is partially crimped to the balloon **406** so the second catheter **430** may be slidably advanced under the proximal portion **422** of stent **408**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **412** extending from the distal guidewire port **410** at the distal end of the elongate shaft **404** to the proximal end of the elongate shaft **404** into Y-adaptor **414** having a connector **416**. The connector **416** is preferably a Luer connector and this allows easy coupling with a syringe or other device for

lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **412** exits via connector **416**. A second connector **418**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **406** via an inflation lumen (not shown) in the elongate shaft **404**. The first catheter **402** also includes a hollow exchange port tube **424** coupled to the elongate shaft **404**. The hollow exchange port tube **424** may be coextruded with the first shaft **404**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **432**. The hollow exchange port tube **424** includes a central channel **426** extending therethrough and is sized to slidably receive a portion of the second catheter **430**. Radiopaque markers may be placed at different locations along the shaft **404**, often near the balloon **406** and/or stent **408**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0123] The second catheter **430** includes an elongate shaft **432** with a radially expandable balloon **440** disposed near a distal end of the elongate shaft **432**. A stent **442** is disposed over balloon **440**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **442** is shorter than the working length of the balloon **440** so that a proximal portion of the balloon **440** is unconstrained by the stent **442** and this unconstrained portion of the balloon **440** may be slidably advanced or retracted through side hole **420** and under proximal portion **422** of stent **408** as will be discussed below. Stent **442** is crimped to balloon **440** to prevent ejection during delivery. At least a portion of balloon **440**, and stent **442** are distally offset relative to balloon **406** and stent **408** so as to minimize profile of the device. In this embodiment the distal stent **442** may be deployed in a main branch of the vessel and the other stent **408** may be deployed in a side branch of the vessel. Alternatively, the distal stent **442** may be deployed in a side branch of a vessel and the other stent **408** may be deployed in the main branch of a vessel. The second catheter **430** is an over-the-wire (OTW) catheter having a guidewire lumen **434** extending from the distal guidewire port **438** at the distal end of the elongate shaft **432** to the proximal end of the elongate shaft **432** into Y-adaptor **446** having a connector **448**. The connector **448** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **434** exits via connector **448**. A second connector **444**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **440** via an inflation lumen (not shown) in the elongate shaft **432**. A portion of shaft **432** is disposed in the central channel **426** of the hollow exchange tube **424** and this helps keep the two catheter shafts **404**, **432** parallel and prevents tangling during delivery and as shaft **432** is slidably advanced or retracted relative to shaft **404**. Also, another portion of shaft **432** is disposed under proximal portion **422** of stent **408**. The second catheter **430** may also be slidably advanced or retracted under the proximal portion **422** of stent **408** so that the shaft **432** passes through the side hole **420** in stent **408**. Radiopaque markers may be placed at different locations on the shaft **432**, often near the balloon **440** or stent **442**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0124] FIGS. 5A, 6A, 7A, and 8A illustrate an end to end capture tube that connects the catheters together. The capture tube keeps the catheters from tangling. The capture tube preferably remains in place during the entire clinical procedure. In these exemplary embodiments, the capture tube is a thin polymer hollow straw that covers the mother and daughter catheters from a point about 10 centimeters distal to the Indeflator attachment to a distal point that is about 10 centimeters proximal from the rapid exchange catheter's proximal rapid exchange port.

[0125] FIG. 5A illustrates a catheter system **500** having a distal daughter catheter with a rapid exchange configuration and a proximal mother catheter with an over-the-wire configuration. FIG. 5B more clearly illustrates the features of the catheter system **500** seen in FIG. 5A. The stent

delivery system **500** includes a first catheter **502**, and a second catheter **530**. The first catheter **502** includes an elongate shaft **504** with a radially expandable balloon **506** disposed near a distal end of the elongate shaft **504**. A stent **508** having a proximal portion **522**, a distal portion **514** and a side hole **520** is disposed over the balloon **506**. The distal portion **514** is crimped to the balloon **506** to prevent ejection during delivery, while the proximal portion **522** is partially crimped to the balloon **506** so the second catheter **530** may be slidably advanced under the proximal portion **522** of stent **508**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **512** extending from the distal guidewire port **510** at the distal end of the elongate shaft **504** to the proximal end of the elongate shaft **504** into Y-adapter **514** having a connector **516**. The connector **516** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **512** exits via connector **516**. A second connector **518**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **506** via an inflation lumen (not shown) in the elongate shaft **504**. The first catheter **502** is disposed in the central channel **526** of a capture tube **524**. Central channel **526** is sized to fit both shafts **504**, **532** and allow slidable movement thereof. Shaft **504** is slidable in the central channel **526**, or it may be locked with a locking collar **525** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **504**, often near the balloon **506** and/or stent **508**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0126] The second catheter **530** includes an elongate shaft **532** with a radially expandable balloon **540** disposed near a distal end of the elongate shaft **532**. A stent **542** is disposed over balloon **540**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **542** is shorter than the working length of the balloon **540** so that a proximal portion of the balloon **540** is unconstrained by the stent **542** and this unconstrained portion of the balloon **540** may be slidably advanced or retracted through side hole **520** and under proximal portion **522** of stent **508** as will be discussed below. Stent **542** is crimped to balloon **540** to prevent ejection during delivery. At least a portion of balloon **540**, and stent **542** are distally offset relative to balloon **506** and stent **508** so as to minimize profile of the device. In this embodiment the distal stent **542** may be deployed in a main branch of the vessel and the other stent **508** may be deployed in a side branch of the vessel. Alternatively, the distal stent **542** may be deployed in a side branch of a vessel and the other stent **508** may be deployed in the main branch of a vessel. The second catheter **530** is a rapid exchange catheter (RX) having a guidewire lumen **534** extending from the distal guidewire port **538** at the distal end of the elongate shaft **532** to a proximal guidewire port **536** which is closer to the distal port **538** than the proximal end of the catheter shaft **532**. The proximal guidewire port **536** is also unobstructed by the capture tube **524** and may be distal thereto. A connector **544**, preferably a Luer connector is connected to the proximal end of the elongate shaft **532** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **532** for inflation of balloon **540**. A portion of shaft **532** is disposed in the central channel **526** of the capture tube **524** and this helps keep the two catheter shafts **504**, **532** parallel and prevents tangling during delivery and as shaft **532** is slidably advanced in the central channel **526**. Compression fitting **525** may be used to lock elongate shafts **504**, **532** in the capture tube **524** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **532** is disposed under proximal portion **522** of stent **508**. The second catheter **530** may also be slidably advanced or retracted under the proximal portion **522** of stent **508** so that the shaft **532** passes through the side hole **520** in stent **508**. Radiopaque markers may be placed at different locations on the shaft **532**, often near the balloon **540** or stent **542**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0127] FIG. 6A illustrates a catheter system **600** having a distal daughter catheter with an over the wire design and a proximal mother catheter with a rapid exchange design. FIG. 6B more clearly illustrates the features of the catheter system **600** in FIG. 6A. The stent delivery system **600** includes a first catheter **602**, and a second catheter **630**. The first catheter **602** includes an elongate shaft **604** with a radially expandable balloon **606** disposed near a distal end of the elongate shaft **604**, and a stent **608** disposed over the balloon **606**. The stent **608** may be the same length as the working length of the balloon **608**, or it may be shorter. In preferred embodiments, the stent **608** is shorter than the working length of balloon **606** such that a proximal portion of balloon **606** remains unconstrained by stent **608**. The proximal portion of balloon **606** may be slidably advanced and retracted under stent **642** via side hole **620**. Stent **608** is crimped to the balloon **606** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **612** extending from the distal guidewire port **610** at the distal end of the elongate shaft **604** to the proximal end of the elongate shaft **604** into Y-adapter **614** having a connector **616**. The connector **616** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **612** exits via connector **616**. A second connector **618**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **606** via an inflation lumen (not shown) in the elongate shaft **604**. The first catheter **602** is disposed in the central channel **626** of a capture tube **624**. Central channel **626** is sized to fit both shafts **604**, **632** and allow slidable movement thereof. Shaft **604** is slidable in the central channel **626**, or it may be locked with a locking collar **625** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **604**, often near the balloon **606** and/or stent **608**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0128] The second catheter **630** includes an elongate shaft **632** with a radially expandable balloon **640** disposed near a distal end of the elongate shaft **632**. A stent **642** having a proximal portion **622**, a distal portion **614**, and a side hole **620** is disposed over balloon **640**. The distal portion **614** is crimped to balloon **640** to prevent ejection during delivery, while the proximal portion **622** is partially crimped to balloon **640** so elongate shaft **604** may be slidably advanced or retracted under the proximal portion **622** of stent **642**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **606**, and stent **608** are distally offset relative to balloon **640** and stent **642** so as to minimize profile of the device. In this embodiment the distal stent **608** may be deployed in a main branch of the vessel and the other stent **642** may be deployed in a side branch of the vessel. Alternatively, the distal stent **608** may be deployed in a side branch of a vessel and the other stent **642** may be deployed in the main branch of a vessel. The second catheter **630** is a rapid exchange catheter (RX) having a guidewire lumen **634** extending from the distal guidewire port **638** at the distal end of the elongate shaft **632** to a proximal guidewire port **636** which is closer to the distal port **638** than the proximal end of the catheter shaft **632**. The proximal guidewire port **636** is also unobstructed by the capture tube **624** and may be distal thereto. A connector **644**, preferably a Luer connector is connected to the proximal end of the elongate shaft **632** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **632** for inflation of balloon **640**. A portion of shaft **632** is disposed in the central channel **626** of the capture tube **624** and this helps keep the two catheter shafts **604**, **632** parallel and prevents tangling during delivery and as shaft **604** is slidably advanced in the central channel **626**. Compression fitting **625** may be used to lock elongate shafts **604**, **632** in the capture tube **624** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, a portion of shaft **604** is disposed under proximal portion **622** of stent **642**. The first catheter **602** may be slidably advanced or retracted under the proximal portion **622** of stent **642** so that the shaft **604** passes through the

side hole **620** in stent **642**. Radiopaque markers may be placed at different locations on the shaft **632**, often near the balloon **640** or stent **642**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0129] FIG. 7A shows a catheter system **700** having dual rapid exchange mother and daughter catheters so the end point of the capture tube is preferably about 10 centimeters proximal from the rapid exchange port on the distal most catheter. FIG. 7B more clearly illustrates the features of the catheter system **700** in FIG. 7A. The stent delivery system **700** includes a first catheter **702**, and a second catheter **730**. The first catheter **702** includes an elongate shaft **704** with a radially expandable balloon **706** disposed near a distal end of the elongate shaft **704**. A stent **708** having a proximal portion **722**, a distal portion **714** and a side hole **720** is disposed over the balloon **706**. The distal portion **714** is crimped to the balloon **706** to prevent ejection during delivery, while the proximal portion **722** is partially crimped to the balloon **706** so the second catheter **730** may be slidably advanced under the proximal portion **722** of stent **708**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **712** extending from the distal guidewire port **710** at the distal end of the elongate shaft **704** to a proximal guidewire port **711** which is closer to the distal port **710** than the proximal end of the catheter shaft **704**. A connector **716** is coupled with the proximal end of the elongate shaft **704**. The connector **716** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **706**. The first catheter **702** is disposed in the central channel **726** of a capture tube **724**. Central channel **726** is sized to fit both shafts **704**, **732** and allow slidable movement thereof. Shaft **704** is slidable in the central channel **726**, or it may be locked with a locking collar **725** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **704**, often near the balloon **706** and/or stent **708**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0130] The second catheter **730** includes an elongate shaft **732** with a radially expandable balloon **740** disposed near a distal end of the elongate shaft **732**. A stent **742** is disposed over balloon **740**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **742** is shorter than the working length of the balloon **740** so that a proximal portion of the balloon **740** is unconstrained by the stent **742** and this unconstrained portion of the balloon **740** may be slidably advanced or retracted through side hole **720** and under proximal portion **722** of stent **708** as will be discussed below. Stent **742** is crimped to balloon **740** to prevent ejection during delivery. At least a portion of balloon **740**, and stent **742** are distally offset relative to balloon **706** and stent **708** so as to minimize profile of the device. In this embodiment the distal stent **742** may be deployed in a main branch of the vessel and the other stent **708** may be deployed in a side branch of the vessel. Alternatively, the distal stent **742** may be deployed in a side branch of a vessel and the other stent **708** may be deployed in the main branch of a vessel. The second catheter **730** is a rapid exchange catheter (RX) having a guidewire lumen **734** extending from the distal guidewire port **738** at the distal end of the elongate shaft **732** to a proximal guidewire port **736** which is closer to the distal port **738** than the proximal end of the catheter shaft **732**. The proximal guidewire port **736** is also unobstructed by the capture tube **724** and may be distal thereto. A connector **744**, preferably a Luer connector is connected to the proximal end of the elongate shaft **732** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **732** for inflation of balloon **740**. A portion of shaft **732** is disposed in the central channel **726** of the capture tube **724** and this helps keep the two catheter shafts **704**, **732** parallel and prevents tangling during delivery and as shaft **732** is slidably advanced in the central channel **726**. Compression fitting **725** may be used to lock elongate shafts **704**, **732** in the capture tube **724** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **732** is disposed

under proximal portion 722 of stent 708. The second catheter 730 may also be slidably advanced or retracted under the proximal portion 722 of stent 708 so that the shaft 732 passes through the side hole 720 in stent 708. Radiopaque markers may be placed at different locations on the shaft 732, often near the balloon 740 or stent 742, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0131] FIG. 8A embodies a catheter system 800 with dual over the wire designs, therefore the capture tube ending point ends preferably about 30 centimeters proximal from the balloon portion of the most distal catheter. FIG. 8B more clearly illustrates the features of the catheter system 800 in FIG. 8A. The stent delivery system 800 includes a first catheter 802, and a second catheter 830. The first catheter 802 includes an elongate shaft 804 with a radially expandable balloon 806 disposed near a distal end of the elongate shaft 804. A stent 808 having a proximal portion 822, a distal portion 814 and a side hole 820 is disposed over the balloon 806. The distal portion 814 is crimped to the balloon 806 to prevent ejection during delivery, while the proximal portion 822 is partially crimped to the balloon 806 so the second catheter 830 may be slidably advanced under the proximal portion 822 of stent 808. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen 812 extending from the distal guidewire port 810 at the distal end of the elongate shaft 804 to the proximal end of the elongate shaft 804 into Y-adapter 814 having a connector 816. The connector 816 is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen 812 exits via connector 816. A second connector 818, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon 806 via an inflation lumen (not shown) in the elongate shaft 804. The first catheter 802 is disposed in the central channel 826 of a capture tube 824. Central channel 826 is sized to fit both shafts 804, 832 and allow slidable movement thereof. Shaft 804 is slidable in the central channel 826, or it may be locked with a locking collar 825 such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft 804, often near the balloon 806 and/or stent 808, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0132] The second catheter 830 includes an elongate shaft 832 with a radially expandable balloon 840 disposed near a distal end of the elongate shaft 832. A stent 842 is disposed over balloon 840. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent 842 is shorter than the working length of the balloon 840 so that a proximal portion of the balloon 840 is unconstrained by the stent 842 and this unconstrained portion of the balloon 840 may be slidably advanced or retracted through side hole 820 and under proximal portion 822 of stent 808 as will be discussed below. Stent 842 is crimped to balloon 840 to prevent ejection during delivery. At least a portion of balloon 840, and stent 842 are distally offset relative to balloon 806 and stent 808 so as to minimize profile of the device. In this embodiment the distal stent 842 may be deployed in a main branch of the vessel and the other stent 808 may be deployed in a side branch of the vessel. Alternatively, the distal stent 842 may be deployed in a side branch of a vessel and the other stent 808 may be deployed in the main branch of a vessel. The second catheter 830 is an over-the-wire (OTW) catheter having a guidewire lumen 834 extending from the distal guidewire port 838 at the distal end of the elongate shaft 832 to the proximal end of the elongate shaft 832 into Y-adapter 846 having a connector 848. The connector 848 is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen 834 exits via connector 848. A second connector 844, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon 840 via an inflation lumen (not shown) in the elongate shaft 832. A portion

of shaft **832** is disposed in the central channel **826** of the capture tube **824** and this helps keep the two catheter shafts **804**, **832** parallel and prevents tangling during delivery and as shaft **832** is slidably advanced in the central channel **826**. Compression fitting **825** may be used to lock elongate shafts **804**, **832** in the capture tube **824** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **832** is disposed under proximal portion **822** of stent **808**. The second catheter **830** may also be slidably advanced or retracted under the proximal portion **822** of stent **808** so that the shaft **832** passes through the side hole **820** in stent **808**. Radiopaque markers may be placed at different locations on the shaft **832**, often near the balloon **840** or stent **842**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0133] FIGS. **9A**, **10A**, **11A**, and **12A** illustrate a removable capture tube that is fitted over the dual catheters as described above but the capture tube has a polymer appendage. Once the operator has the catheter system placed near the bifurcation the operator can grab hold of the polymer appendage and pull the capture tube off of the catheters.

[0134] FIG. **9A** illustrates a catheter system **900** having a distal daughter catheter with a rapid exchange configuration and a proximal mother catheter with an over the wire configuration. FIG. **9B** more clearly illustrates the features of the catheter system **900** seen in FIG. **9A**. The stent delivery system **900** includes a first catheter **902**, and a second catheter **930**. The first catheter **902** includes an elongate shaft **904** with a radially expandable balloon **906** disposed near a distal end of the elongate shaft **904**. A stent **908** having a proximal portion **922**, a distal portion **914** and a side hole **920** is disposed over the balloon **906**. The distal portion **914** is crimped to the balloon **906** to prevent ejection during delivery, while the proximal portion **922** is partially crimped to the balloon **906** so the second catheter **930** may be slidably advanced under the proximal portion **922** of stent **908**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **912** extending from the distal guidewire port **910** at the distal end of the elongate shaft **904** to the proximal end of the elongate shaft **904** into Y-adapter **914** having a connector **916**. The connector **916** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **912** exits via connector **916**. A second connector **918**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **906** via an inflation lumen (not shown) in the elongate shaft **904**. The first catheter **902** is disposed in the central channel **926** of a capture tube **924** having a perforated region **945** along its longitudinal length. Central channel **926** is sized to fit both shafts **904**, **932** and allow slidable movement thereof. Shaft **904** is slidable in the central channel **926**, or it may be locked with a locking collar **925** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **904**, often near the balloon **906** and/or stent **908**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **945** along the capture tube **924** allows the capture tube to be easily peeled away from both catheter shafts **904**, **932** once the catheters have been properly positioned and when no longer needed.

[0135] The second catheter **930** includes an elongate shaft **932** with a radially expandable balloon **940** disposed near a distal end of the elongate shaft **932**. A stent **942** is disposed over balloon **940**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **942** is shorter than the working length of the balloon **940** so that a proximal portion of the balloon **940** is unconstrained by the stent **942** and this unconstrained portion of the balloon **940** may be slidably advanced or retracted through side hole **920** and under proximal portion **922** of stent **908** as will be discussed below. Stent **942** is crimped to balloon **940** to prevent ejection during delivery. At least a portion of balloon **940**, and stent **942** are distally offset relative to balloon **906** and stent **908** so as

to minimize profile of the device. In this embodiment the distal stent **942** may be deployed in a main branch of the vessel and the other stent **908** may be deployed in a side branch of the vessel. Alternatively, the distal stent **942** may be deployed in a side branch of a vessel and the other stent **908** may be deployed in the main branch of a vessel. The second catheter **930** is a rapid exchange catheter (RX) having a guidewire lumen **934** extending from the distal guidewire port **938** at the distal end of the elongate shaft **932** to a proximal guidewire port **936** which is closer to the distal port **938** than the proximal end of the catheter shaft **932**. The proximal guidewire port **936** is also unobstructed by the capture tube **924** and may be distal thereto. A connector **944**, preferably a Luer connector is connected to the proximal end of the elongate shaft **932** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **932** for inflation of balloon **940**. A portion of shaft **932** is disposed in the central channel **926** of the capture tube **924** and this helps keep the two catheter shafts **904**, **932** parallel and prevents tangling during delivery and as shaft **932** is slidably advanced in the central channel **926**. Compression fitting **925** may be used to lock elongate shafts **904**, **932** in the capture tube **924** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **932** is disposed under proximal portion **922** of stent **908**. The second catheter **930** may also be slidably advanced or retracted under the proximal portion **922** of stent **908** so that the shaft **932** passes through the side hole **920** in stent **908**. Capture tube **924** may be peeled away from shaft **932** by severing the perforated region **945**. Radiopaque markers may be placed at different locations on the shaft **932**, often near the balloon **940** or stent **942**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0136] FIG. **10A** illustrates a catheter system **1000** having a distal daughter catheter with an over the wire design and a proximal mother catheter with a rapid exchange design. FIG. **10B** more clearly illustrates the features of the catheter system **1000** in FIG. **10A**. The stent delivery system **1000** includes a first catheter **1002**, and a second catheter **1030**. The first catheter **1002** includes an elongate shaft **1004** with a radially expandable balloon **1006** disposed near a distal end of the elongate shaft **1004**, and a stent **1008** disposed over the balloon **1006**. The stent **1008** may be the same length as the working length of the balloon **1008**, or it may be shorter. In preferred embodiments, the stent **1008** is shorter than the working length of balloon **1006** such that a proximal portion of balloon **1006** remains unconstrained by stent **1008**. The proximal portion of balloon **1006** may be slidably advanced and retracted under stent **1042** via side hole **1020**. Stent **1008** is crimped to the balloon **1006** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1012** extending from the distal guidewire port **1010** at the distal end of the elongate shaft **1004** to the proximal end of the elongate shaft **1004** into Y-adapter **1014** having a connector **1016**. The connector **1016** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1012** exits via connector **1016**. A second connector **1018**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1006** via an inflation lumen (not shown) in the elongate shaft **1004**. The first catheter **1002** is disposed in the central channel **1026** of a capture tube **1024** having perforated region **1045**. Central channel **1026** is sized to fit both shafts **1004**, **1032** and allow slidable movement thereof. Shaft **1004** is slidable in the central channel **1026**, or it may be locked with a locking collar **1025** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **1004**, often near the balloon **1006** and/or stent **1008**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **1045** along the capture tube **1024** allows the capture tube to be easily peeled away from both catheter shafts **1004**, **1032** once the catheters have been properly positioned and when no longer needed.

[0137] The second catheter **1030** includes an elongate shaft **1032** with a radially expandable balloon **1040** disposed near a distal end of the elongate shaft **1032**. A stent **1042** having a proximal portion **1022**, a distal portion **1014**, and a side hole **1020** is disposed over balloon **1040**. The distal portion **1014** is crimped to balloon **1040** to prevent ejection during delivery, while the proximal portion **1022** is partially crimped to balloon **1040** so elongate shaft **1004** may be slidably advanced or retracted under the proximal portion **1022** of stent **1042**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **1006**, and stent **1008** are distally offset relative to balloon **1040** and stent **1042** so as to minimize profile of the device. In this embodiment the distal stent **1008** may be deployed in a main branch of the vessel and the other stent **1042** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1008** may be deployed in a side branch of a vessel and the other stent **1042** may be deployed in the main branch of a vessel. The second catheter **1030** is a rapid exchange catheter (RX) having a guidewire lumen **1034** extending from the distal guidewire port **1038** at the distal end of the elongate shaft **1032** to a proximal guidewire port **1036** which is closer to the distal port **1038** than the proximal end of the catheter shaft **1032**. The proximal guidewire port **1036** is also unobstructed by the capture tube **1024** and may be distal thereto. A connector **1044**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1032** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1032** for inflation of balloon **1040**. A portion of shaft **1032** is disposed in the central channel **1026** of the capture tube **1024** and this helps keep the two catheter shafts **1004**, **1032** parallel and prevents tangling during delivery and as shaft **1032** is slidably advanced in the central channel **1026**. Compression fitting **1025** may be used to lock elongate shafts **1004**, **1032** in the capture tube **1024** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, a portion of shaft **1004** is disposed under proximal portion **1022** of stent **1042**. The first catheter **1002** may be slidably advanced or retracted under the proximal portion **1022** of stent **1042** so that the shaft **1004** passes through the side hole **1020** in stent **1042**. Capture tube **1024** may be peeled away from shaft **1032** by severing the perforated region **1045**. Radiopaque markers may be placed at different locations on the shaft **1032**, often near the balloon **1040** or stent **1042**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0138] FIG. **11A** illustrates a catheter system **1100** having dual rapid exchange design with a removable capture tube. FIG. **11B** more clearly illustrates the features of the catheter system **1100** in FIG. **11A**. The stent delivery system **1100** includes a first catheter **1102**, and a second catheter **1130**. The first catheter **1102** includes an elongate shaft **1104** with a radially expandable balloon **1106** disposed near a distal end of the elongate shaft **1104**. A stent **1108** having a proximal portion **1122**, a distal portion **1114** and a side hole **1120** is disposed over the balloon **1106**. The distal portion **1114** is crimped to the balloon **1106** to prevent ejection during delivery, while the proximal portion **1122** is partially crimped to the balloon **1106** so the second catheter **1130** may be slidably advanced under the proximal portion **1122** of stent **1108**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **1112** extending from the distal guidewire port **1110** at the distal end of the elongate shaft **1104** to a proximal guidewire port **1111** which is closer to the distal port **1110** than the proximal end of the catheter shaft **1104**. A connector **1116** is coupled with the proximal end of the elongate shaft **1104**. The connector **1116** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **1106**. The first catheter **1102** is disposed in the central channel **1126** of a capture tube **1124** having a perforated region **1145**. Central channel **1126** is sized to fit both shafts **1104**, **1132** and allow slidable movement thereof. Shaft **1104** is slidable in the central channel **1126**, or it may be locked with a locking collar **1125** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **1104**, often near the balloon **1106** and/or stent **1108**, to

help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **1145** along the capture tube **1124** allows the capture tube to be easily peeled away from both catheter shafts **1104**, **1132** once the catheters have been properly positioned and when no longer needed.

[0139] The second catheter **1130** includes an elongate shaft **1132** with a radially expandable balloon **1140** disposed near a distal end of the elongate shaft **1132**. A stent **1142** is disposed over balloon **1140**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1142** is shorter than the working length of the balloon **1140** so that a proximal portion of the balloon **1140** is unconstrained by the stent **1142** and this unconstrained portion of the balloon **1140** may be slidably advanced or retracted through side hole **1120** and under proximal portion **1122** of stent **1108** as will be discussed below. Stent **1142** is crimped to balloon **1140** to prevent ejection during delivery. At least a portion of balloon **1140**, and stent **1142** are distally offset relative to balloon **1106** and stent **1108** so as to minimize profile of the device. In this embodiment the distal stent **1142** may be deployed in a main branch of the vessel and the other stent **1108** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1142** may be deployed in a side branch of a vessel and the other stent **1108** may be deployed in the main branch of a vessel. The second catheter **1130** is a rapid exchange catheter (RX) having a guidewire lumen **1134** extending from the distal guidewire port **1138** at the distal end of the elongate shaft **1132** to a proximal guidewire port **1136** which is closer to the distal port **1138** than the proximal end of the catheter shaft **1132**. The proximal guidewire port **1136** is also unobstructed by the capture tube **1124** and may be distal thereto. A connector **1144**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1132** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1132** for inflation of balloon **1140**. A portion of shaft **1132** is disposed in the central channel **1126** of the capture tube **1124** and this helps keep the two catheter shafts **1104**, **1132** parallel and prevents tangling during delivery and as shaft **1132** is slidably advanced in the central channel **1126**. Compression fitting **1125** may be used to lock elongate shafts **1104**, **1132** in the capture tube **1124** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **1132** is disposed under proximal portion **1122** of stent **1108**. The second catheter **1130** may also be slidably advanced or retracted under the proximal portion **1122** of stent **1108** so that the shaft **1132** passes through the side hole **1120** in stent **1108**. Capture tube **1124** may be peeled away from shaft **1132** by severing the perforated region **1145**. Radiopaque markers may be placed at different locations on the shaft **1132**, often near the balloon **1140** or stent **1142**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0140] FIG. **12A** illustrates a catheter system **1200** having dual over the wire design with a removable capture tube. FIG. **12B** more clearly illustrates the features of the catheter system **1200** in FIG. **12A**. The stent delivery system **1200** includes a first catheter **1202**, and a second catheter **1230**. The first catheter **1202** includes an elongate shaft **1204** with a radially expandable balloon **1206** disposed near a distal end of the elongate shaft **1204**. A stent **1208** having a proximal portion **1222**, a distal portion **1214** and a side hole **1220** is disposed over the balloon **1206**. The distal portion **1214** is crimped to the balloon **1206** to prevent ejection during delivery, while the proximal portion **1222** is partially crimped to the balloon **1206** so the second catheter **1230** may be slidably advanced under the proximal portion **1222** of stent **1208**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1212** extending from the distal guidewire port **1210** at the distal end of the elongate shaft **1204** to the proximal end of the elongate shaft **1204** into Y-adaptor **1214** having a connector **1216**. The connector **1216** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media.

When unconnected, the guidewire lumen **1212** exits via connector **1216**. A second connector **1218**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1206** via an inflation lumen (not shown) in the elongate shaft **1204**. The first catheter **1202** is disposed in the central channel **1226** of a capture tube **1224** having a perforated region **1245**. Central channel **1226** is sized to fit both shafts **1204**, **1232** and allow slidable movement thereof. Shaft **1204** is slidable in the central channel **1226**, or it may be locked with a locking collar **1225** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **1204**, often near the balloon **1206** and/or stent **1208**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **1245** along the capture tube **1224** allows the capture tube to be easily peeled away from both catheter shafts **1204**, **1232** once the catheters have been properly positioned and when no longer needed.

[0141] The second catheter **1230** includes an elongate shaft **1232** with a radially expandable balloon **1240** disposed near a distal end of the elongate shaft **1232**. A stent **1242** is disposed over balloon **1240**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1242** is shorter than the working length of the balloon **1240** so that a proximal portion of the balloon **1240** is unconstrained by the stent **1242** and this unconstrained portion of the balloon **1240** may be slidably advanced or retracted through side hole **1220** and under proximal portion **1222** of stent **1208** as will be discussed below. Stent **1242** is crimped to balloon **1240** to prevent ejection during delivery. At least a portion of balloon **1240**, and stent **1242** are distally offset relative to balloon **1206** and stent **1208** so as to minimize profile of the device. In this embodiment the distal stent **1242** may be deployed in a main branch of the vessel and the other stent **1208** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1242** may be deployed in a side branch of a vessel and the other stent **1208** may be deployed in the main branch of a vessel. The second catheter **1230** is an over-the-wire (OTW) catheter having a guidewire lumen **1234** extending from the distal guidewire port **1238** at the distal end of the elongate shaft **1232** to the proximal end of the elongate shaft **1232** into Y-adapter **1246** having a connector **1248**. The connector **1248** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1234** exits via connector **1248**. A second connector **1244**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1240** via an inflation lumen (not shown) in the elongate shaft **1232**. A portion of shaft **1232** is disposed in the central channel **1226** of the capture tube **1224** and this helps keep the two catheter shafts **1204**, **1232** parallel and prevents tangling during delivery and as shaft **1232** is slidably advanced in the central channel **1226**. Compression fitting **1225** may be used to lock elongate shafts **1204**, **1232** in the capture tube **1224** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **1232** is disposed under proximal portion **1222** of stent **1208**. The second catheter **1230** may also be slidably advanced or retracted under the proximal portion **1222** of stent **1208** so that the shaft **1232** passes through the side hole **1220** in stent **1208**. Capture tube **1224** may be peeled away from shaft **1232** by severing the perforated region **1245**. Radiopaque markers may be placed at different locations on the shaft **1232**, often near the balloon **1240** or stent **1242**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0142] FIGS. **13A**, **14A**, **15A**, and **16A** illustrates a zipper that allows one catheter to snap in to the other catheter. The zipper is essentially a groove that forms a concave receiving cross section and is carved into a catheter's outer surface in a straight line. The groove can be a single groove over a certain portion of a catheter or it can run from end to end. Alternatively, the catheter can have a

series of short grooves of 1 to 10 centimeters in length that run the length of the catheter or only a certain portion. Full length end to end zippers will have reduced profile and reduced friction with the vessel. The resulting groove can receive another catheter and prevent the catheters from dislodging while the operator is advancing the catheters to the bifurcation. Once at the site the operator can still slidably move the catheters forward and back relative to each other. Mother catheters that utilize the groove can have fully crimped stents as described in several of the embodiments above; however, it is possible to allow operators to choose any commercially available catheter with or without a stent and mount the commercially available catheter via the zipper. The mother catheters with an empty zipper would have a mother stent fully crimped on the distal balloon portion. After loading the commercially available catheter the operator would have to crimp the proximal portion of the mother stent in situ prior to beginning the clinical procedure. This option may be extremely valuable to operators who can reduce their total inventory of catheters but have more options for treating bifurcated lesions.

[0143] FIG. 13A illustrates a catheter system **1300** having a distal daughter catheter with an over the wire design and a proximal mother catheter with a rapid exchange design and a short zipper. FIG. 13B more clearly illustrates the features of the catheter system **1300** in FIG. 13A. The stent delivery system **1300** includes a first catheter **1302**, and a second catheter **1330**. The first catheter **1302** includes an elongate shaft **1304** with a radially expandable balloon **1306** disposed near a distal end of the elongate shaft **1304**. A stent **1308** having a proximal portion **1322**, a distal portion **1314** and a side hole **1320** is disposed over the balloon **1306**. The distal portion **1314** is crimped to the balloon **1306** to prevent ejection during delivery, while the proximal portion **1322** is partially crimped to the balloon **1306** so the second catheter **1330** may be slidably advanced under the proximal portion **1322** of stent **1308**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1312** extending from the distal guidewire port **1310** at the distal end of the elongate shaft **1304** to the proximal end of the elongate shaft **1304** into Y-adapter **1314** having a connector **1316**. The connector **1316** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1312** exits via connector **1316**. A second connector **1318**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1306** via an inflation lumen (not shown) in the elongate shaft **1304**. The first catheter **1302** also includes a zipper or snap fitting **1324** coupled to the elongate shaft **1304**. The snap fit tube **1324** may be coextruded with the first shaft **1304**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1324** may alternatively be coupled with the other shaft **1332**. The snap fitting **1324** includes a central channel **1326** extending therethrough and is sized to slidably receive a portion of the second catheter **1330**. An elongate slot **1345** extends along the entire length of the snap fitting **1324** and is sized so that shaft **1336** may snapped into the central channel **1326**. FIG. 13C illustrates a partial cross-section of FIG. 13B taken along the line C-C and shows shaft **1304** with the snap fitting **1324**. Radiopaque markers may be placed at different locations along the shaft **1304**, often near the balloon **1306** and/or stent **1308**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0144] The second catheter **1330** includes an elongate shaft **1332** with a radially expandable balloon **1340** disposed near a distal end of the elongate shaft **1332**. A stent **1342** is disposed over balloon **1340**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1342** is shorter than the working length of the balloon **1340** so that a proximal portion of the balloon **1340** is unconstrained by the stent **1342** and this unconstrained portion of the balloon **1340** may be slidably advanced or retracted through side hole **1320** and under proximal portion **1322** of stent **1308** as will be discussed below. Stent **1342** is crimped to balloon **1340** to prevent ejection during delivery. At least a portion of balloon **1340**, and stent **1342** are distally offset relative to

balloon **1306** and stent **1308** so as to minimize profile of the device. In this embodiment the distal stent **1342** may be deployed in a main branch of the vessel and the other stent **1308** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1342** may be deployed in a side branch of a vessel and the other stent **1308** may be deployed in the main branch of a vessel. The second catheter **1330** is a rapid exchange catheter (RX) having a guidewire lumen **1334** extending from the distal guidewire port **1338** at the distal end of the elongate shaft **1332** to a proximal guidewire port **1336** which is closer to the distal port **1338** than the proximal end of the catheter shaft **1332**. The proximal guidewire port **1336** is also unobstructed by the snap fitting **1324** and preferably proximal thereto. A connector **1344**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1332** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1332** for inflation of balloon **1340**. A portion of shaft **1332** is snapped into the central channel **1326** of the snap fitting **1324** via slit **1345**, and thus shaft **1332** may slide in channel **1326**. This helps keep the two catheter shafts **1304**, **1332** parallel and prevents tangling during delivery and as shaft **1332** is slidably advanced or retracted relative to shaft **1304**. Also, another portion of shaft **1332** is disposed under proximal portion **1322** of stent **1308**. The second catheter **1330** may also be slidably advanced or retracted under the proximal portion **1322** of stent **1308** so that the shaft **1332** passes through the side hole **1320** in stent **1308**. Radiopaque markers may be placed at different locations on the shaft **1332**, often near the balloon **1340** or stent **1342**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0145] FIG. **14A** illustrates a catheter system **1400** having a proximal mother catheter with a rapid exchange configuration and a distal daughter catheter having an over-the-wire configuration and a short zipper or snap fitting. FIG. **14B** more clearly illustrates the features of the catheter system **1400** in FIG. **14A**. The stent delivery system **1400** includes a first catheter **1402**, and a second catheter **1430**. The first catheter **1402** includes an elongate shaft **1404** with a radially expandable balloon **1406** disposed near a distal end of the elongate shaft **1404**, and a stent **1408** disposed over the balloon **1406**. The stent **1408** may be the same length as the working length of the balloon **1408**, or it may be shorter. In preferred embodiments, the stent **1408** is shorter than the working length of balloon **1406** such that a proximal portion of balloon **1406** remains unconstrained by stent **1408**. The proximal portion of balloon **1406** may be slidably advanced and retracted under stent **1442** via side hole **1420**. Stent **1408** is crimped to the balloon **1406** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1412** extending from the distal guidewire port **1410** at the distal end of the elongate shaft **1404** to the proximal end of the elongate shaft **1404** into Y-adapter **1414** having a connector **1416**. The connector **1416** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1412** exits via connector **1416**. A second connector **1418**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1406** via an inflation lumen (not shown) in the elongate shaft **1404**. The first catheter **1402** also includes a zipper or snap fitting **1424** coupled to the elongate shaft **1404**. The snap fit tube **1424** may be coextruded with the first shaft **1404**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1424** may alternatively be coupled with the other shaft **1432**. The snap fitting **1424** includes a central channel **1426** extending therethrough and is sized to slidably receive a portion of the second catheter **1430**. An elongate slot **1445** extends along the entire length of the snap fitting **1424** and is sized so that shaft **1436** may be snapped into the central channel **1426**. FIG. **14C** illustrates a partial cross-section of FIG. **14B** taken along the line C-C and shows shaft **1404** with the snap fitting **1424**. Radiopaque markers may be placed at different locations along the shaft **1404**, often near the balloon **1406** and/or stent **1408**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two

catheters during stent deployment, as discussed elsewhere in this specification.

[0146] The second catheter **1430** includes an elongate shaft **1432** with a radially expandable balloon **1440** disposed near a distal end of the elongate shaft **1432**. A stent **1442** having a proximal portion **1422**, a distal portion **1414**, and a side hole **1420** is disposed over balloon **1440**. The distal portion **1414** is crimped to balloon **1440** to prevent ejection during delivery, while the proximal portion **1422** is partially crimped to balloon **1440** so elongate shaft **1404** may be slidably advanced or retracted under the proximal portion **1422** of stent **1442**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **1406**, and stent **1408** are distally offset relative to balloon **1440** and stent **1442** so as to minimize profile of the device. In this embodiment the distal stent **1408** may be deployed in a main branch of the vessel and the other stent **1442** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1408** may be deployed in a side branch of a vessel and the other stent **1442** may be deployed in the main branch of a vessel. The second catheter **1430** is a rapid exchange catheter (RX) having a guidewire lumen **1434** extending from the distal guidewire port **1438** at the distal end of the elongate shaft **1432** to a proximal guidewire port **1436** which is closer to the distal port **1438** than the proximal end of the catheter shaft **1432**. The proximal guidewire port **1436** is also unobstructed by the snap fitting **1424** and preferably proximal thereto. A connector **1444**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1432** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1432** for inflation of balloon **1440**. A portion of shaft **1432** is snapped into the central channel **1426** of the snap fitting **1424** via slit **1445**, and thus shaft **1432** may slide in channel **1426**. This helps keep the two catheter shafts **1404**, **1432** parallel and prevents tangling during delivery and as shaft **1432** is slidably advanced or retracted relative to shaft **1404**. Also, a portion of shaft **1404** is disposed under proximal portion **1422** of stent **1442**. The first catheter **1402** may be slidably advanced or retracted under the proximal portion **1422** of stent **1442** so that the shaft **1404** passes through the side hole **1420** in stent **1442**. Radiopaque markers may be placed at different locations on the shaft **1432**, often near the balloon **1440** or stent **1442**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0147] FIG. 15A illustrates a catheter system **1500** having dual rapid exchange design with a short zipper or snap fitting. FIG. 15B more clearly illustrates the features of the catheter system **1500** in FIG. 15A. The stent delivery system **1500** includes a first catheter **1502**, and a second catheter **1530**. The first catheter **1502** includes an elongate shaft **1504** with a radially expandable balloon **1506** disposed near a distal end of the elongate shaft **1504**. A stent **1508** having a proximal portion **1522**, a distal portion **1514** and a side hole **1520** is disposed over the balloon **1506**. The distal portion **1514** is crimped to the balloon **1506** to prevent ejection during delivery, while the proximal portion **1522** is partially crimped to the balloon **1506** so the second catheter **1530** may be slidably advanced under the proximal portion **1522** of stent **1508**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **1512** extending from the distal guidewire port **1510** at the distal end of the elongate shaft **1504** to a proximal guidewire port **1511** which is closer to the distal port **1510** than the proximal end of the catheter shaft **1504**. A connector **1516** is coupled with the proximal end of the elongate shaft **1504**. The connector **1516** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **1506**. The first catheter **1502** also includes a zipper or snap fitting **1524** coupled to the elongate shaft **1504**. The snap fit tube **1524** may be coextruded with the first shaft **1504**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1524** may alternatively be coupled with the other shaft **1532**. The snap fitting **1524** includes a central channel **1526** extending therethrough and is sized to slidably receive a portion of the second catheter **1530**. An elongate slot **1545** extends along the entire length of the snap fitting **1524** and is

sized so that shaft **1536** may snapped into the central channel **1526**. FIG. **15C** illustrates a partial cross-section of FIG. **15B** taken along the line C-C and shows shaft **1504** with the snap fitting **1524**. Radiopaque markers may be placed at different locations along the shaft **1504**, often near the balloon **1506** and/or stent **1508**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0148] The second catheter **1530** includes an elongate shaft **1532** with a radially expandable balloon **1540** disposed near a distal end of the elongate shaft **1532**. A stent **1542** is disposed over balloon **1540**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1542** is shorter than the working length of the balloon **1540** so that a proximal portion of the balloon **1540** is unconstrained by the stent **1542** and this unconstrained portion of the balloon **1540** may be slidably advanced or retracted through side hole **1520** and under proximal portion **1522** of stent **1508** as will be discussed below. Stent **1542** is crimped to balloon **1540** to prevent ejection during delivery. At least a portion of balloon **1540**, and stent **1542** are distally offset relative to balloon **1506** and stent **1508** so as to minimize profile of the device. In this embodiment the distal stent **1542** may be deployed in a main branch of the vessel and the other stent **1508** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1542** may be deployed in a side branch of a vessel and the other stent **1508** may be deployed in the main branch of a vessel. The second catheter **1530** is a rapid exchange catheter (RX) having a guidewire lumen **1534** extending from the distal guidewire port **1538** at the distal end of the elongate shaft **1532** to a proximal guidewire port **1536** which is closer to the distal port **1538** than the proximal end of the catheter shaft **1532**. The proximal guidewire port **1536** is also unobstructed by the snap fitting **1524** and may be distal thereto. A connector **1544**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1532** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1532** for inflation of balloon **1540**. A portion of shaft **1532** is snapped into the central channel **1526** of the snap fitting **1524** via slit **1545**, and thus shaft **1532** may slide in channel **1526**. This helps keep the two catheter shafts **1504**, **1532** parallel and prevents tangling during delivery and as shaft **1532** is slidably advanced or retracted relative to shaft **1504**. Also, another portion of shaft **1532** is disposed under proximal portion **1522** of stent **1508**. The second catheter **1530** may also be slidably advanced or retracted under the proximal portion **1522** of stent **1508** so that the shaft **1532** passes through the side hole **1520** in stent **1508**. Radiopaque markers may be placed at different locations on the shaft **1532**, often near the balloon **1540** or stent **1542**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0149] FIG. **16A** illustrates a catheter system **1600** having a dual over the wire design with a short zipper or snap fitting. FIG. **16B** more clearly illustrates the features of the catheter system **1600** in FIG. **16A**. The stent delivery system **1600** includes a first catheter **1602**, and a second catheter **1630**. The first catheter **1602** includes an elongate shaft **1604** with a radially expandable balloon **1606** disposed near a distal end of the elongate shaft **1604**. A stent **1608** having a proximal portion **1622**, a distal portion **1614** and a side hole **1620** is disposed over the balloon **1606**. The distal portion **1614** is crimped to the balloon **1606** to prevent ejection during delivery, while the proximal portion **1622** is partially crimped to the balloon **1606** so the second catheter **1630** may be slidably advanced under the proximal portion **1622** of stent **1608**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1612** extending from the distal guidewire port **1610** at the distal end of the elongate shaft **1604** to the proximal end of the elongate shaft **1604** into Y-adaptor **1614** having a connector **1616**. The connector **1616** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1612** exits via connector **1616**. A second connector **1618**,

also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **1606** via an inflation lumen (not shown) in the elongate shaft **1604**. The first catheter **1602** also includes a zipper or snap fitting **1624** coupled to the elongate shaft **1604**. The snap fit tube **1624** may be coextruded with the first shaft **1604**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1624** may alternatively be coupled with the other shaft **1632**. The snap fitting **1624** includes a central channel **1626** extending therethrough and is sized to slidably receive a portion of the second catheter **1630**. An elongate slot **1645** extends along the entire length of the snap fitting **1624** and is sized so that shaft **1636** may be snapped into the central channel **1626**. FIG. **16C** illustrates a partial cross-section of FIG. **16B** taken along the line C-C and shows shaft **1604** with the snap fitting **1624**. Radiopaque markers may be placed at different locations along the shaft **1604**, often near the balloon **1606** and/or stent **1608**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0150] The second catheter **1630** includes an elongate shaft **1632** with a radially expandable balloon **1640** disposed near a distal end of the elongate shaft **1632**. A stent **1642** is disposed over balloon **1640**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1642** is shorter than the working length of the balloon **1640** so that a proximal portion of the balloon **1640** is unconstrained by the stent **1642** and this unconstrained portion of the balloon **1640** may be slidably advanced or retracted through side hole **1620** and under proximal portion **1622** of stent **1608** as will be discussed below. Stent **1642** is crimped to balloon **1640** to prevent ejection during delivery. At least a portion of balloon **1640**, and stent **1642** are distally offset relative to balloon **1606** and stent **1608** so as to minimize profile of the device. In this embodiment the distal stent **1642** may be deployed in a main branch of the vessel and the other stent **1608** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1642** may be deployed in a side branch of a vessel and the other stent **1608** may be deployed in the main branch of a vessel. The second catheter **1630** is an over-the-wire (OTW) catheter having a guidewire lumen **1634** extending from the distal guidewire port **1638** at the distal end of the elongate shaft **1632** to the proximal end of the elongate shaft **1632** into Y-adapter **1646** having a connector **1648**. The connector **1648** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1634** exits via connector **1648**. A second connector **1644**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **1640** via an inflation lumen (not shown) in the elongate shaft **1632**. A portion of shaft **1632** is snapped into the central channel **1626** of the snap fitting **1624** via slit **1645**, and thus shaft **1632** may slide in channel **1626**. This helps keep the two catheter shafts **1604**, **1632** parallel and prevents tangling during delivery and as shaft **1632** is slidably advanced or retracted relative to shaft **1604**. Also, another portion of shaft **1632** is disposed under proximal portion **1622** of stent **1608**. The second catheter **1630** may also be slidably advanced or retracted under the proximal portion **1622** of stent **1608** so that the shaft **1632** passes through the side hole **1620** in stent **1608**. Radiopaque markers may be placed at different locations on the shaft **1632**, often near the balloon **1640** or stent **1642**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0151] FIG. **17A** illustrates a catheter system **1700** having a distal daughter catheter with a rapid exchange configuration a proximal mother catheter with an over-the-wire configuration and an end to end zipper, or snap fitting. This embodiment is similar to that shown in FIGS. **13A-13B**, with the major difference being the length of the snap fitting and the location of one of the guidewire ports. FIG. **17B** more clearly illustrates the features of the catheter system **1700** in FIG. **17A**. The stent delivery system **1700** includes a first catheter **1702**, and a second catheter **1730**. The first catheter

1702 includes an elongate shaft **1704** with a radially expandable balloon **1706** disposed near a distal end of the elongate shaft **1704**. A stent **1708** having a proximal portion **1722**, a distal portion **1714** and a side hole **1720** is disposed over the balloon **1706**. The distal portion **1714** is crimped to the balloon **1706** to prevent ejection during delivery, while the proximal portion **1722** is partially crimped to the balloon **1706** so the second catheter **1730** may be slidably advanced under the proximal portion **1722** of stent **1708**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1712** extending from the distal guidewire port **1710** at the distal end of the elongate shaft **1704** to the proximal end of the elongate shaft **1704** into Y-adapter **1714** having a connector **1716**. The connector **1716** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1712** exits via connector **1716**. A second connector **1718**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **1706** via an inflation lumen (not shown) in the elongate shaft **1704**. The first catheter **1702** also includes a zipper or snap fitting **1724** coupled to the elongate shaft **1704**. The snap fit tube **1724** may be coextruded with the first shaft **1704**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1724** may alternatively be coupled with the other shaft **1732**. The snap fitting **1724** includes a central channel **1726** extending therethrough and is sized to slidably receive a portion of the second catheter **1730**. An elongate slot **1745** extends along the entire length of the snap fitting **1724** and is sized so that shaft **1736** may snapped into the central channel **1726**. The snap fitting **1724** may extend from the distal end of connectors **1714**, **1744** to the proximal end of balloon **1706**, or it may be shorter, extending only partially between the connectors **1714**, **1744** and the balloon **1706**. FIG. 17C illustrates a partial cross-section of FIG. 17B taken along the line C-C and shows shaft **1704** with the snap fitting **1724**. Radiopaque markers may be placed at different locations along the shaft **1704**, often near the balloon **1706** and/or stent **1708**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0152] The second catheter **1730** includes an elongate shaft **1732** with a radially expandable balloon **1740** disposed near a distal end of the elongate shaft **1732**. A stent **1742** is disposed over balloon **1740**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1742** is shorter than the working length of the balloon **1740** so that a proximal portion of the balloon **1740** is unconstrained by the stent **1742** and this unconstrained portion of the balloon **1740** may be slidably advanced or retracted through side hole **1720** and under proximal portion **1722** of stent **1708** as will be discussed below. Stent **1742** is crimped to balloon **1740** to prevent ejection during delivery. At least a portion of balloon **1740**, and stent **1742** are distally offset relative to balloon **1706** and stent **1708** so as to minimize profile of the device. In this embodiment the distal stent **1742** may be deployed in a main branch of the vessel and the other stent **1708** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1742** may be deployed in a side branch of a vessel and the other stent **1708** may be deployed in the main branch of a vessel. The second catheter **1730** is a rapid exchange catheter (RX) having a guidewire lumen **1734** extending from the distal guidewire port **1738** at the distal end of the elongate shaft **1732** to a proximal guidewire port **1736** which is closer to the distal port **1738** than the proximal end of the catheter shaft **1732**. The proximal guidewire port **1736** is also unobstructed by the snap fitting **1724** and preferably distal thereto. A connector **1744**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1732** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1732** for inflation of balloon **1740**. A portion of shaft **1732** is snapped into the central channel **1726** of the snap fitting **1724** via slit **1745**, and thus shaft **1732** may slide in channel **1726**. This helps keep the two catheter shafts **1704**, **1732** parallel and prevents tangling during delivery and as shaft **1732** is slidably advanced or retracted relative to

shaft **1704**. Also, another portion of shaft **1732** is disposed under proximal portion **1722** of stent **1708**. The second catheter **1730** may also be slidably advanced or retracted under the proximal portion **1722** of stent **1708** so that the shaft **1732** passes through the side hole **1720** in stent **1708**. Radiopaque markers may be placed at different locations on the shaft **1732**, often near the balloon **1740** or stent **1742**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0153] FIG. **18A** illustrates a catheter system **1800** having a proximal mother catheter with a rapid exchange configuration and a distal daughter catheter with an end to end zipper or snap fitting. FIG. **18A** is similar to the embodiment of FIGS. **14A-14B**, with the major difference being the length of the snap fitting and the location of one of the guidewire ports. FIG. **18B** more clearly illustrates the features of the catheter system **1800** in FIG. **18A**. The stent delivery system **1800** includes a first catheter **1802**, and a second catheter **1830**. The first catheter **1802** includes an elongate shaft **1804** with a radially expandable balloon **1806** disposed near a distal end of the elongate shaft **1804**, and a stent **1808** disposed over the balloon **1806**. The stent **1808** may be the same length as the working length of the balloon **1808**, or it may be shorter. In preferred embodiments, the stent **1808** is shorter than the working length of balloon **1806** such that a proximal portion of balloon **1806** remains unconstrained by stent **1808**. The proximal portion of balloon **1806** may be slidably advanced and retracted under stent **1842** via side hole **1820**. Stent **1808** is crimped to the balloon **1806** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1812** extending from the distal guidewire port **1810** at the distal end of the elongate shaft **1804** to the proximal end of the elongate shaft **1804** into Y-adapter **1814** having a connector **1816**. The connector **1816** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1812** exits via connector **1816**. A second connector **1818**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1806** via an inflation lumen (not shown) in the elongate shaft **1804**. The first catheter **1802** also includes a zipper or snap fitting **1824** coupled to the elongate shaft **1804**. The snap fit tube **1824** may be coextruded with the first shaft **1804**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1824** may alternatively be coupled with the other shaft **1832**. The snap fitting **1824** includes a central channel **1826** extending therethrough and is sized to slidably receive a portion of the second catheter **1830**. An elongate slot **1845** extends along the entire length of the snap fitting **1824** and is sized so that shaft **1836** may be snapped into the central channel **1826**. FIG. **18C** illustrates a partial cross-section of FIG. **18B** taken along the line C-C and shows shaft **1804** with the snap fitting **1824**. The snap fitting **1824** may extend from the distal end of connectors **1814**, **1844** to the proximal end of balloon **1840**, or it may be shorter, extending only partially between the connectors **1814**, **1844** and the balloon **1806**. Radiopaque markers may be placed at different locations along the shaft **1804**, often near the balloon **1806** and/or stent **1808**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0154] The second catheter **1830** includes an elongate shaft **1832** with a radially expandable balloon **1840** disposed near a distal end of the elongate shaft **1832**. A stent **1842** having a proximal portion **1822**, a distal portion **1814**, and a side hole **1820** is disposed over balloon **1840**. The distal portion **1814** is crimped to balloon **1840** to prevent ejection during delivery, while the proximal portion **1822** is partially crimped to balloon **1840** so elongate shaft **1804** may be slidably advanced or retracted under the proximal portion **1822** of stent **1842**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **1806**, and stent **1808** are distally offset relative to balloon **1840** and stent **1842** so as to minimize profile of the device. In this embodiment the distal

stent **1808** may be deployed in a main branch of the vessel and the other stent **1842** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1808** may be deployed in a side branch of a vessel and the other stent **1842** may be deployed in the main branch of a vessel. The second catheter **1830** is a rapid exchange catheter (RX) having a guidewire lumen **1834** extending from the distal guidewire port **1838** at the distal end of the elongate shaft **1832** to a proximal guidewire port **1836** which is closer to the distal port **1838** than the proximal end of the catheter shaft **1832**. The proximal guidewire port **1836** is also unobstructed by the snap fitting **1824** and preferably distal thereto. A connector **1844**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1832** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1832** for inflation of balloon **1840**. A portion of shaft **1832** is snapped into the central channel **1826** of the snap fitting **1824** via slit **1845**, and thus shaft **1832** may slide in channel **1826**. This helps keep the two catheter shafts **1804**, **1832** parallel and prevents tangling during delivery and as shaft **1832** is slidably advanced or retracted relative to shaft **1804**. Also, a portion of shaft **1804** is disposed under proximal portion **1822** of stent **1842**. The first catheter **1802** may be slidably advanced or retracted under the proximal portion **1822** of stent **1842** so that the shaft **1804** passes through the side hole **1820** in stent **1842**. Radiopaque markers may be placed at different locations on the shaft **1832**, often near the balloon **1840** or stent **1842**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0155] FIG. **19A** illustrates a catheter system **1900** having a dual rapid exchange design with an end to end zipper or snap fitting. FIG. **19A** is similar to the embodiment of FIGS. **15A-15B**, with the major difference being the length of the snap fitting. FIG. **19B** more clearly illustrates the features of the catheter system **1900** in FIG. **19A**. The stent delivery system **1900** includes a first catheter **1902**, and a second catheter **1930**. The first catheter **1902** includes an elongate shaft **1904** with a radially expandable balloon **1906** disposed near a distal end of the elongate shaft **1904**. A stent **1908** having a proximal portion **1922**, a distal portion **1914** and a side hole **1920** is disposed over the balloon **1906**. The distal portion **1914** is crimped to the balloon **1906** to prevent ejection during delivery, while the proximal portion **1922** is partially crimped to the balloon **1906** so the second catheter **1930** may be slidably advanced under the proximal portion **1922** of stent **1908**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **1912** extending from the distal guidewire port **1910** at the distal end of the elongate shaft **1904** to a proximal guidewire port **1911** which is closer to the distal port **1910** than the proximal end of the catheter shaft **1904**. A connector **1916** is coupled with the proximal end of the elongate shaft **1904**. The connector **1916** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **1906**. The first catheter **1902** also includes a zipper or snap fitting **1924** coupled to the elongate shaft **1904**. The snap fit tube **1924** may be coextruded with the first shaft **1904**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1924** may alternatively be coupled with the other shaft **1932**. The snap fitting **1924** includes a central channel **1926** extending therethrough and is sized to slidably receive a portion of the second catheter **1930**. An elongate slot **1945** extends along the entire length of the snap fitting **1924** and is sized so that shaft **1932** may be snapped into the central channel **1926**. FIG. **19C** illustrates a partial cross-section of FIG. **19B** taken along the line C-C and shows shaft **1904** with the snap fitting **1924**. Radiopaque markers may be placed at different locations along the shaft **1904**, often near the balloon **1906** and/or stent **1908**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0156] The second catheter **1930** includes an elongate shaft **1932** with a radially expandable balloon **1940** disposed near a distal end of the elongate shaft **1932**. A stent **1942** is disposed over balloon **1940**. The stent may have a length that matches the working length of the balloon, or the

stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1942** is shorter than the working length of the balloon **1940** so that a proximal portion of the balloon **1940** is unconstrained by the stent **1942** and this unconstrained portion of the balloon **1940** may be slidably advanced or retracted through side hole **1920** and under proximal portion **1922** of stent **1908** as will be discussed below. Stent **1942** is crimped to balloon **1940** to prevent ejection during delivery. At least a portion of balloon **1940**, and stent **1942** are distally offset relative to balloon **1906** and stent **1908** so as to minimize profile of the device. In this embodiment the distal stent **1942** may be deployed in a main branch of the vessel and the other stent **1908** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1942** may be deployed in a side branch of a vessel and the other stent **1908** may be deployed in the main branch of a vessel. The second catheter **1930** is a rapid exchange catheter (RX) having a guidewire lumen **1934** extending from the distal guidewire port **1938** at the distal end of the elongate shaft **1932** to a proximal guidewire port **1936** which is closer to the distal port **1938** than the proximal end of the catheter shaft **1932**. The proximal guidewire port **1936** is also unobstructed by the snap fitting **1924** and may be distal thereto. A connector **1944**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1932** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1932** for inflation of balloon **1940**. A portion of shaft **1932** is snapped into the central channel **1926** of the snap fitting **1924** via slit **1945**, and thus shaft **1932** may slide in channel **1926**. This helps keep the two catheter shafts **1904**, **1932** parallel and prevents tangling during delivery and as shaft **1932** is slidably advanced or retracted relative to shaft **1904**. Also, another portion of shaft **1932** is disposed under proximal portion **1922** of stent **1908**. The second catheter **1930** may also be slidably advanced or retracted under the proximal portion **1922** of stent **1908** so that the shaft **1932** passes through the side hole **1920** in stent **1908**. Radiopaque markers may be placed at different locations on the shaft **1932**, often near the balloon **1940** or stent **1942**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0157] FIG. **20A** illustrates a catheter system **2000** having a dual over the wire design with an end to end zipper or snap fitting. FIG. **20A** is similar to the embodiment of FIGS. **16A-16B**, with the major difference being the length of the snap fitting. FIG. **20B** more clearly illustrates the features of the catheter system **2000** in FIG. **20A**. The stent delivery system **2000** includes a first catheter **2002**, and a second catheter **2030**. The first catheter **2002** includes an elongate shaft **2004** with a radially expandable balloon **2006** disposed near a distal end of the elongate shaft **2004**. A stent **2008** having a proximal portion **2022**, a distal portion **2014** and a side hole **2020** is disposed over the balloon **2006**. The distal portion **2014** is crimped to the balloon **2006** to prevent ejection during delivery, while the proximal portion **2022** is partially crimped to the balloon **2006** so the second catheter **2030** may be slidably advanced under the proximal portion **2022** of stent **2008**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2012** extending from the distal guidewire port **2010** at the distal end of the elongate shaft **2004** to the proximal end of the elongate shaft **2004** into Y-adapter **2014** having a connector **2016**. The connector **2016** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2012** exits via connector **2016**. A second connector **2018**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2006** via an inflation lumen (not shown) in the elongate shaft **2004**. The first catheter **2002** also includes a zipper or snap fitting **2024** coupled to the elongate shaft **2004**. The snap fit tube **2024** may be coextruded with the first shaft **2004**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **2024** may alternatively be coupled with the other shaft **2032**. The snap fitting **2024** includes a central channel **2026** extending therethrough and is sized to slidably receive a portion of the second catheter **2030**. An elongate slot **2045** extends along the entire length of the snap fitting

2024 and is sized so that shaft **2036** may be snapped into the central channel **2026**. FIG. **20C** illustrates a partial cross-section of FIG. **20B** taken along the line C-C and shows shaft **2004** with the snap fitting **2024**. Radiopaque markers may be placed at different locations along the shaft **2004**, often near the balloon **2006** and/or stent **2008**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0158] The second catheter **2030** includes an elongate shaft **2032** with a radially expandable balloon **2040** disposed near a distal end of the elongate shaft **2032**. A stent **2042** is disposed over balloon **2040**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2042** is shorter than the working length of the balloon **2040** so that a proximal portion of the balloon **2040** is unconstrained by the stent **2042** and this unconstrained portion of the balloon **2040** may be slidably advanced or retracted through side hole **2020** and under proximal portion **2022** of stent **2008** as will be discussed below. Stent **2042** is crimped to balloon **2040** to prevent ejection during delivery. At least a portion of balloon **2040**, and stent **2042** are distally offset relative to balloon **2006** and stent **2008** so as to minimize profile of the device. In this embodiment the distal stent **2042** may be deployed in a main branch of the vessel and the other stent **2008** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2042** may be deployed in a side branch of a vessel and the other stent **2008** may be deployed in the main branch of a vessel. The second catheter **2030** is an over-the-wire (OTW) catheter having a guidewire lumen **2034** extending from the distal guidewire port **2038** at the distal end of the elongate shaft **2032** to the proximal end of the elongate shaft **2032** into Y-adapter **2046** having a connector **2048**. The connector **2048** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2034** exits via connector **2048**. A second connector **2044**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **2040** via an inflation lumen (not shown) in the elongate shaft **2032**. A portion of shaft **2032** is snapped into the central channel **2026** of the snap fitting **2024** via slit **2045**, and thus shaft **2032** may slide in channel **2026**. This helps keep the two catheter shafts **2004**, **2032** parallel and prevents tangling during delivery and as shaft **2032** is slidably advanced or retracted relative to shaft **2004**. Also, another portion of shaft **2032** is disposed under proximal portion **2022** of stent **2008**. The second catheter **2030** may also be slidably advanced or retracted under the proximal portion **2022** of stent **2008** so that the shaft **2032** passes through the side hole **2020** in stent **2008**. Radiopaque markers may be placed at different locations on the shaft **2032**, often near the balloon **2040** or stent **2042**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0159] FIGS. **21A**, **22A**, **23A**, and **24A** illustrate catheters that can be used with an alternative embodiment where the mother catheter is provided to the operator with a mother stent that is crimped on the distal portion of the mother catheter balloon. The proximal portion of the mother stent is uncrimped or partially crimped. The operator can mount any commercially available catheter or balloon on a wire through the mother stent proximal end and exit out the side hole of the mother stent. The operator can align the catheters to suit the patient's anatomy and crimp the proximal portion of the mother stent. The operator can crimp the stent tightly so that the catheters do not move relative to each other. It is possible for the operator to place the catheters at the bifurcation and if necessary pullback on the commercially available catheter to adjust the alignment if necessary. Then the operator can gently push the system distally to ensure complete apposition.

[0160] FIG. **21A** illustrates a catheter system **2100** having a distal daughter catheter with a rapid exchange configuration and a proximal mother catheter with an over-the-wire configuration. FIG. **21B** more clearly illustrates the features of the catheter system **2100** in FIG. **21A**. The stent delivery system **2100** includes a first catheter **2102**, and a second catheter **2130**. The first catheter

2102 includes an elongate shaft **2104** with a radially expandable balloon **2106** disposed near a distal end of the elongate shaft **2104**. A stent **2108** having a proximal portion **2122**, a distal portion **2114** and a side hole **2120** is disposed over the balloon **2106**. The distal portion **2114** is crimped to the balloon **2106** to prevent ejection during delivery, while the proximal portion **2122** is partially crimped to the balloon **2106** so the second catheter **2130** may be slidably advanced under the proximal portion **2122** of stent **2108**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2112** extending from the distal guidewire port **2110** at the distal end of the elongate shaft **2104** to the proximal end of the elongate shaft **2104** into Y-adapter **2114** having a connector **2116**. The connector **2116** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2112** exits via connector **2116**. A second connector **2118**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **2106** via an inflation lumen (not shown) in the elongate shaft **2104**. Radiopaque markers may be placed at different locations along the shaft **2104**, often near the balloon **2106** and/or stent **2108**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0161] The second catheter **2130** includes an elongate shaft **2132** with a radially expandable balloon **2140** disposed near a distal end of the elongate shaft **2132**. A stent **2142** is disposed over balloon **2140**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2142** is shorter than the working length of the balloon **2140** so that a proximal portion of the balloon **2140** is unconstrained by the stent **2142** and this unconstrained portion of the balloon **2140** may be slidably advanced or retracted through side hole **2120** and under proximal portion **2122** of stent **2108** as will be discussed below. Stent **2142** is crimped to balloon **2140** to prevent ejection during delivery. At least a portion of balloon **2140**, and stent **2142** are distally offset relative to balloon **2106** and stent **2108** so as to minimize profile of the device. In this embodiment the distal stent **2142** may be deployed in a main branch of the vessel and the other stent **2108** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2142** may be deployed in a side branch of a vessel and the other stent **2108** may be deployed in the main branch of a vessel. The second catheter **2130** is a rapid exchange catheter (RX) having a guidewire lumen **2134** extending from the distal guidewire port **2138** at the distal end of the elongate shaft **2132** to a proximal guidewire port **2136** which is closer to the distal port **2138** than the proximal end of the catheter shaft **2132**. A connector **2144**, preferably a Luer connector is connected to the proximal end of the elongate shaft **2132** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **2132** for inflation of balloon **2140**. Having a portion of shaft **2132** disposed under proximal portion **2122** of stent **2108** helps keep catheter shafts **2104**, **2132** parallel and prevents tangling during delivery and as shaft **2132** is slidably advanced or retracted relative to shaft **2104**. Also, another portion of shaft **2132** is disposed under proximal portion **2122** of stent **2108**. The second catheter **2130** may also be slidably advanced or retracted under the proximal portion **2122** of stent **2108** so that the shaft **2132** passes through the side hole **2120** in stent **2108**. Radiopaque markers may be placed at different locations on the shaft **2132**, often near the balloon **2140** or stent **2142**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0162] FIG. 22A illustrates a catheter system **2200** having a proximal mother catheter with an over the wire design and a distal daughter catheter with an over-the-wire configuration. FIG. 22B more clearly illustrates the features of the catheter system **2200** in FIG. 22A. The stent delivery system **2200** includes a first catheter **2202**, and a second catheter **2230**. The first catheter **2202** includes an elongate shaft **2204** with a radially expandable balloon **2206** disposed near a distal end of the

elongate shaft **2204**, and a stent **2208** disposed over the balloon **2206**. The stent **2208** may be the same length as the working length of the balloon **2208**, or it may be shorter. In preferred embodiments, the stent **2208** is shorter than the working length of balloon **2206** such that a proximal portion of balloon **2206** remains unconstrained by stent **2208**. The proximal portion of balloon **2206** may be slidably advanced and retracted under stent **2242** via side hole **2220**. Stent **2208** is crimped to the balloon **2206** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2212** extending from the distal guidewire port **2210** at the distal end of the elongate shaft **2204** to the proximal end of the elongate shaft **2204** into Y-adaptor **2214** having a connector **2216**. The connector **2216** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2212** exits via connector **2216**. A second connector **2218**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **2206** via an inflation lumen (not shown) in the elongate shaft **2204**. Radiopaque markers may be placed at different locations along the shaft **2204**, often near the balloon **2206** and/or stent **2208**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0163] The second catheter **2230** includes an elongate shaft **2232** with a radially expandable balloon **2240** disposed near a distal end of the elongate shaft **2232**. A stent **2242** having a proximal portion **2222**, a distal portion **2214**, and a side hole **2220** is disposed over balloon **2240**. The distal portion **2214** is crimped to balloon **2240** to prevent ejection during delivery, while the proximal portion **2222** is partially crimped to balloon **2240** so elongate shaft **2204** may be slidably advanced or retracted under the proximal portion **2222** of stent **2242**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **2206**, and stent **2208** are distally offset relative to balloon **2240** and stent **2242** so as to minimize profile of the device. In this embodiment the distal stent **2208** may be deployed in a main branch of the vessel and the other stent **2242** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2208** may be deployed in a side branch of a vessel and the other stent **2242** may be deployed in the main branch of a vessel. The second catheter **2230** is a rapid exchange catheter (RX) having a guidewire lumen **2234** extending from the distal guidewire port **2238** at the distal end of the elongate shaft **2232** to a proximal guidewire port **2236** which is closer to the distal port **2238** than the proximal end of the catheter shaft **2232**. A connector **2244**, preferably a Luer connector is connected to the proximal end of the elongate shaft **2232** and allows an Inflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **2232** for inflation of balloon **2240**. Having a portion of shaft **2204** disposed under proximal portion **2222** of stent **2208** helps keep catheters **2202**, **2232** parallel and prevents tangling during delivery and as shaft **2204** is slidably advanced or retracted relative to shaft **2232**. The first catheter **2202** may be slidably advanced or retracted under the proximal portion **2222** of stent **2242** so that the shaft **2204** passes through the side hole **2220** in stent **2242**. Radiopaque markers may be placed at different locations on the shaft **2232**, often near the balloon **2240** or stent **2242**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0164] FIG. **23A** illustrates a catheter system **2300** having a dual rapid exchange design. FIG. **23B** more clearly illustrates the features of the catheter system **2300** in FIG. **23A**. The stent delivery system **2300** includes a first catheter **2302**, and a second catheter **2330**. The first catheter **2302** includes an elongate shaft **2304** with a radially expandable balloon **2306** disposed near a distal end of the elongate shaft **2304**. A stent **2308** having a proximal portion **2322**, a distal portion **2314** and a side hole **2320** is disposed over the balloon **2306**. The distal portion **2314** is crimped to the balloon **2306** to prevent ejection during delivery, while the proximal portion **2322** is partially

crimped to the balloon **2306** so the second catheter **2330** may be slidably advanced under the proximal portion **2322** of stent **2308**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **2312** extending from the distal guidewire port **2310** at the distal end of the elongate shaft **2304** to a proximal guidewire port **2311** which is closer to the distal port **2310** than the proximal end of the catheter shaft **2304**. A connector **2316** is coupled with the proximal end of the elongate shaft **2304**. The connector **2316** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **2306**. Radiopaque markers may be placed at different locations along the shaft **2304**, often near the balloon **2306** and/or stent **2308**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0165] The second catheter **2330** includes an elongate shaft **2332** with a radially expandable balloon **2340** disposed near a distal end of the elongate shaft **2332**. A stent **2342** is disposed over balloon **2340**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2342** is shorter than the working length of the balloon **2340** so that a proximal portion of the balloon **2340** is unconstrained by the stent **2342** and this unconstrained portion of the balloon **2340** may be slidably advanced or retracted through side hole **2320** and under proximal portion **2322** of stent **2308** as will be discussed below. Stent **2342** is crimped to balloon **2340** to prevent ejection during delivery. At least a portion of balloon **2340**, and stent **2342** are distally offset relative to balloon **2306** and stent **2308** so as to minimize profile of the device. In this embodiment the distal stent **2342** may be deployed in a main branch of the vessel and the other stent **2308** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2342** may be deployed in a side branch of a vessel and the other stent **2308** may be deployed in the main branch of a vessel. The second catheter **2330** is a rapid exchange catheter (RX) having a guidewire lumen **2334** extending from the distal guidewire port **2338** at the distal end of the elongate shaft **2332** to a proximal guidewire port **2336** which is closer to the distal port **2338** than the proximal end of the catheter shaft **2332**. A connector **2344**, preferably a Luer connector is connected to the proximal end of the elongate shaft **2332** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **2332** for inflation of balloon **2340**. Having a portion of shaft **2332** disposed under proximal portion **2322** of stent **2308** helps keep catheters **2302**, **2332** parallel and prevents tangling during delivery and as shaft **2332** is slidably advanced or retracted relative to shaft **2304**. The second catheter **2330** may also be slidably advanced or retracted under the proximal portion **2322** of stent **2308** so that the shaft **2332** passes through the side hole **2320** in stent **2308**. Radiopaque markers may be placed at different locations on the shaft **2332**, often near the balloon **2340** or stent **2342**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0166] FIG. **24A** illustrates a catheter system **2400** having a dual over the wire design. FIG. **24B** more clearly illustrates the features of the catheter system **2400** in FIG. **24A**. The stent delivery system **2400** includes a first catheter **2402**, and a second catheter **2430**. The first catheter **2402** includes an elongate shaft **2404** with a radially expandable balloon **2406** disposed near a distal end of the elongate shaft **2404**. A stent **2408** having a proximal portion **2422**, a distal portion **2414** and a side hole **2420** is disposed over the balloon **2406**. The distal portion **2414** is crimped to the balloon **2406** to prevent ejection during delivery, while the proximal portion **2422** is partially crimped to the balloon **2406** so the second catheter **2430** may be slidably advanced under the proximal portion **2422** of stent **2408**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2412** extending from the distal guidewire port **2410** at the distal end of the elongate shaft **2404** to the proximal end of the elongate shaft **2404** into Y-adapter **2414** having a connector **2416**. The connector **2416** is preferably a Luer connector and this allows easy coupling

with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2412** exits via connector **2416**. A second connector **2418**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **2406** via an inflation lumen (not shown) in the elongate shaft **2404**. Radiopaque markers may be placed at different locations along the shaft **2404**, often near the balloon **2406** and/or stent **2408**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0167] The second catheter **2430** includes an elongate shaft **2432** with a radially expandable balloon **2440** disposed near a distal end of the elongate shaft **2432**. A stent **2442** is disposed over balloon **2440**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2442** is shorter than the working length of the balloon **2440** so that a proximal portion of the balloon **2440** is unconstrained by the stent **2442** and this unconstrained portion of the balloon **2440** may be slidably advanced or retracted through side hole **2420** and under proximal portion **2422** of stent **2408** as will be discussed below. Stent **2442** is crimped to balloon **2440** to prevent ejection during delivery. At least a portion of balloon **2440**, and stent **2442** are distally offset relative to balloon **2406** and stent **2408** so as to minimize profile of the device. In this embodiment the distal stent **2442** may be deployed in a main branch of the vessel and the other stent **2408** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2442** may be deployed in a side branch of a vessel and the other stent **2408** may be deployed in the main branch of a vessel. The second catheter **2430** is an over-the-wire (OTW) catheter having a guidewire lumen **2434** extending from the distal guidewire port **2438** at the distal end of the elongate shaft **2432** to the proximal end of the elongate shaft **2432** into Y-adapter **2446** having a connector **2448**. The connector **2448** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2434** exits via connector **2448**. A second connector **2444**, also preferably a Luer connector allows attachment of an Inflator or other device to the catheter for inflation of the balloon **2440** via an inflation lumen (not shown) in the elongate shaft **2432**. Having a portion of shaft **2432** disposed under proximal portion **2422** of stent **2408** helps keep catheters **2402**, **2430** parallel and prevents tangling during delivery and as shaft **2432** is slidably advanced or retracted relative to shaft **2404**. The second catheter **2430** may also be slidably advanced or retracted under the proximal portion **2422** of stent **2408** so that the shaft **2432** passes through the side hole **2420** in stent **2408**. Radiopaque markers may be placed at different locations on the shaft **2432**, often near the balloon **2440** or stent **2442**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

[0168] In any of the embodiments disclosed herein, commercially available catheters and commercially available stents may be matched up to form the systems illustrated. In still other embodiments, commercially available catheters that are single use devices for treating a single vessel may be mated together in various combinations and coupled together with a polymer sleeve. The operator chooses the two catheters for the patient's anatomy then slides a sized polymer sleeve over both catheters from the distal ends. Once the operator has the catheters aligned the polymer sleeve can be treated with a heat or light source to shrink and bond the two catheters together with friction. The polymer sleeve is made of typical polymers that can act as shrink wrap when treated with a heat or light source. The polymer of the polymer sleeve for example could be manufactured with polyolefin, a chemical used in manufacturing shrink wrap. The polymer sleeve would not crosslink or covalently attach to the catheters, several types of polymers are commercially available and have the requisite properties, thin, strong, not adhesive, and reaction times to their source of ten minutes or less. The polymer sleeves are typically 15 centimeters in length and have various

diameters to suit typical catheter diameters 4 French to 20 French. The operator can test that the bond is holding by applying slight pressure prior to the procedure. If the polymer sleeve does not hold tightly the operator may elect to use a smaller diameter polymer sleeve or use more than one polymer sleeve by placing the polymer sleeves adjacent to each other. Alternatively, several smaller sleeves from 1 to 10 centimeters in length could be placed over several different portions of the catheters.

[0169] In any of the embodiments discussed herein, a therapeutic agent may be disposed on the stent or balloon and eluted therefrom in a controlled manner into the target treatment area such as a stenotic lesion. Exemplary therapeutic agents help inhibit restenosis, hyperplasia or have other therapeutic benefits. Exemplary anti-hyperplasia agents include anti-neoplastic drugs, such as paclitaxel, methotrexate, and batimastat; antibiotics such as doxycycline, tetracycline, rapamycin, everolimus, biolimus A9, novolimus, myolimus, zotarolimus, and other analogs and derivatives of rapamycin, and actinomycin; amino suppressants such as dexamethasone and methyl prednisolone; nitric oxide sources such as nitroprussides; estrogen; estradiols; and the like. Methods for applying the therapeutic agent to the stent or balloon are well known to those skilled in the art, and have been described in the patent and scientific literature.

Stent Delivery:

[0170] FIGS. 25A-30B illustrate an exemplary delivery sequence of a preferred embodiment in eight steps. Step 1 illustrates the introduction of a 0.035 inch guidewire up to the bifurcation. Step 2 illustrates the tracking of a guide catheter over the guidewire. Step 3 illustrates the removal of the guidewire and placement position of the guide catheter. Step 4 illustrates the tracking and placement of a rapid exchange compatible wire in the daughter vessel and an over the wire compatible wire in the mother vessel. Step 5A & 5B illustrate tracking of the catheter system distally over both the guidewires. Step 6A illustrates the inflation of the daughter balloon and placement of the daughter stent and partial deployment of the mother stent. Step 6B illustrates the inflation of the mother balloon to place the distal portion of the mother stent in the mother vessel. Step 7A illustrates mother stent in the main branch with side hole facing the daughter vessel. Step 7B illustrates the bifurcated stent partially in the daughter vessel and daughter ostium completely opened and continuing on to the mother vessel.

[0171] In an alternative embodiment the delivery catheter mother balloons having tapered ends to accommodate balloons and stents with non-uniform profiles. For example, the proximal end of the daughter vessel stent may be designed to have a larger circumference than the distal end to compensate for the natural bifurcation anatomy. The daughter vessel balloon would likewise have a taper to properly expand the stent and ensure complete apposition. Additionally, it is possible to design the mother stent to expand differentially along its profile to compensate for a larger arterial diameter at the carina or ostium. In other words, the proximal and distal ends of the mother vessel balloon and mother vessel stent would be smaller in circumference while the center portion of the mother vessel stent would have a larger circumference. In an alternative embodiment the mother vessel balloon has tapered ends to accommodate the distal balloon catheter portion and guidewire lumen. Further, the mother vessel balloon may be designed for differential expansion to accommodate natural vessel anatomy.

[0172] In a preferred embodiment the distal (daughter) balloon catheter portion is crimped with a half stent on a rapid exchange catheter. The daughter vessel stent is about 4-20 millimeters long and the daughter vessel balloon is approximately twice as long in length. The mother vessel stent is about 10-30 millimeters long, and is differentially crimped to allow independent operation of the daughter balloon catheter portion. The distal portion of the mother vessel stent is crimped tightly enough to keep the entire stent from unintentionally dislodging during the procedure. The proximal portion of the mother vessel stent is crimped just tightly enough to reduce the crossing profile and to allow the daughter balloon catheter portion to be moved distal or proximal relative to the mother balloon catheter portion. The proximal (mother) balloon catheter portion is an over the wire type

design with the mother vessel balloon preferably about 3 centimeters proximal to the daughter vessel balloon. In an alternative embodiment a stent is designed to allow differential expansion of the middle portion of the stent relative to the proximal and distal ends. In particular, the design facilitates the placement of the stent across a bifurcation lesion in the mother vessel because it has a larger circumference in the middle portion relative to the ends than a stent with a constant profile. Further, the profile can be adjusted so that the largest circumference can be placed proximal or distal to the midpoint of the stent. In the particular embodiment the largest circumference is distal to the midpoint of the stent, but could be easily reversed for variable patient anatomy. Partial crimping has the following features that make it possible to maintain sufficient stent retention during delivery and placement and still allows the secondary system adjustability and deliverability.

[0173] FIG. **31** shows a partially crimped bifurcation stent prior to placement on any balloon catheter. FIG. **32-34** illustrate an embodiment of the present invention in three steps. First, the bifurcation stent is partially crimped over approximately one-third its distal portion onto the mother catheter balloon and the daughter catheter is loaded through the mother catheter and mother stent where the daughter stent can be crimped separately. Second, the daughter stent is crimped and pulled back proximally to align the daughter stent proximal end near the mother stent distal end. Third and final the proximal portion of the mother stent can be crimped to reduce the outer diameter; yet still allow independent movement of the two catheters relative to each other.

[0174] FIG. **35** illustrates a cross section of a mother and daughter balloon catheter system without a daughter stent. The daughter catheter is on top of the mother catheter. The mother stent is differentially crimped around the mother catheter balloon and daughter catheter because the daughter catheter profile is smaller than the mother catheter. The differential crimping is non-uniform and can create various cross sectional shapes to accommodate different catheter designs, balloon designs, and stent designs. For example, pear shaped or a figure eight are possible configurations. The current embodiment is designed to reduce the profile as much as possible. In one preferred method of manufacturing a protective sheet is placed between the two catheters. The protective sheet only needs to cover the portions that will come in contact during the crimping process, then the protective sheet can be removed.

[0175] FIG. **36** Illustrates a side view of the mother stent mounted on the mother catheter balloon and the daughter catheter mounted on the mother catheter through the mother stent. The distal portion of the mother stent will be crimped under standard conditions to hold the stent firmly to the mother balloon and mother catheter. The proximal portion of the mother stent is partially crimped to reduce the profile; but still allows the daughter catheter freedom to move proximal or distal relative to the mother catheter. This embodiment illustrates that the stent is differentially crimped in both the circumferential and longitudinal direction. The amount of crimping will be determined by the stent design and size, catheter dimensions, and balloon dimensions; thus the crimping is differential along the longitudinal axis.

[0176] FIG. **37** illustrates a side view of the mother stent mounted on the mother catheter balloon and the daughter catheter mounted on the mother catheter through the mother stent. The daughter catheter also includes a stent that can be crimped under standard conditions. The distal portion of the mother stent will be crimped under standard conditions to hold the stent firmly to the mother balloon and mother catheter. In one experiment, this arrangement was tested to determine the strength of the distal crimping of the mother stent by pulling the daughter catheter and stent proximally; the results were that the daughter catheter successfully passed through the crimped mother stent and still retained the daughter stent as well. Additional features may be utilized during the crimping process such as adding a slight positive internal pressure to the balloon so that the final balloon surface pillows about 0.002 inch beyond the outer diameter of the stent. This process can yield a design that protects the stent from engaging with the vessel thus reducing friction and improving stent retention at the same time.

[0177] Further, this process improves safety and reduces trauma to the vessel. While the above embodiment discloses a bifurcation stent that is crimped at or about its distal half; this is not a limitation. The stent could be differentially crimped along its axis depending upon stent design, for example; if a hole in the side of a stent was not centered along the axis. It may be preferential to have the distal crimped portion of the bifurcation stent extend just distal of the hole that the daughter catheter to pass through. Alternatively, the distal crimped portion could extend partially or entirely over the hole that the daughter catheter passes through.

[0178] FIGS. **38A-38M** more clearly illustrate an exemplary method of treating a bifurcated vessel such as a bifurcated coronary artery. In FIG. **38A** the bifurcated vessel BV includes a side branch vessel SB and a main branch vessel MB. The main branch has a main branch lesion ML, and the side branch has a side branch lesion SL. The angle between the side branch and the main branch is referred to as the bifurcation angle, and is indicated by θ . When the bifurcation angle θ is less than about 60 to 70 degrees, the distal most stent of the system can be effectively positioned in the side branch. However, when the bifurcation angle is greater than or equal to about 60 to 70 degrees, it becomes more challenging to position the distal most stent in the side branch. Moreover, when the distal stent is retracted proximally toward the stent having the side hole (discussed below), the catheter shaft may bind against the side hole resulting in damage to the catheter shaft and/or stent. Therefore, in preferred embodiments, when the bifurcation angle is less than about 60 to 70 degrees, the distal most stent is preferably positioned in the side branch and the proximal most stent is advanced into the main branch. When the bifurcation angle is greater than or equal to about 60 to 70 degrees, the distal most stent is positioned in the main branch and the other stent is positioned partially in the main branch and partially in the side branch. This is not intended to limit the use of the catheter system, and either stent may be placed in either side branch or main branch depending on operator preference. In FIG. **38B**, a guide catheter **3802** is advanced distally until its distal end is adjacent the bifurcation. A pair of guidewires GW1, GW2 are then advanced from the guide catheter **3802** distally toward the bifurcation such that the first guidewire GW1 is advanced into the side branch SB and so that the distal tip of the first guidewire GW1 is distal of the side branch lesion SL. Similarly, the second guidewire GW2 is also advanced distally in the main branch MB until the distal tip of the second guidewire GW2 is distal of the main branch lesion ML. In FIG. **38C**, a stent delivery system having a first catheter **3804** and a second catheter **3824** are advanced distally from the guide catheter **3802** toward the bifurcation. The first delivery catheter **3804** includes an elongate catheter shaft **3806** and a radially expandable balloon **3808** disposed over a distal portion of elongate shaft **3806**. A balloon expandable stent **3816** is disposed over the balloon **3808**. In this exemplary embodiment, the stent is shorter than the working length of the balloon **3808**, therefore a proximal portion **3810** of the balloon **3808** and a distal portion **3812** are 30 unconstrained by the stent **3816**. The proximal portion **3810** may be retracted under a portion of the second stent **3842** and thus when balloon **3808** is inflated, it will radially expand stent **3816** and a portion of stent **3842**. However, this is not intended to be limiting, and the stent length may be substantially equal to the working length of the balloon, or it may have shorter length as previously discussed. Proximal radiopaque marker **3820** and distal radiopaque marker **3818** help define proximal and distal ends of the stent **3816** as well as proximal and distal ends of the balloon **3808**. The radiopaque markers will also be used to help align the two catheters during treatment of the bifurcation, as will be discussed below. The distal tip **3814** may be a soft durometer polymer thereby minimizing trauma to the vessel during delivery. A distal guidewire port **3822** extends from the distal tip **3814** and allows guidewire GW1 to exit or enter a guidewire lumen (not shown) in the elongate shaft **3806**. The first catheter **3804** may be a rapid exchange catheter or an over-the-wire catheter, examples of which have been disclosed above. The second catheter **3824** (best seen in FIG. **38D**) includes an elongate catheter shaft **3826** with a radially expandable balloon **3828** disposed over a distal region of the elongate shaft **3826**. A stent **3842** having a side hole **3844** is disposed over the balloon **3828**. The length of the stent **3842** may be substantially the same as the

working length of the balloon **3828** or it may be less than the working length. In this exemplary embodiment, the stent **3842** has a length shorter than the working length of the balloon **3828** thus a proximal portion **3830** and a distal portion **3832** remain unconstrained by the stent **3842**. Proximal radiopaque marker **3836** and distal radiopaque marker **3834** help define the proximal and distal ends of the stent **3842** as well as the proximal and distal ends of the balloon **3828**. The radiopaque markers will also be used to help align the two catheters during treatment of the bifurcation, as will be discussed below. The distal tip **3838** may be a soft durometer polymer thereby minimizing trauma to the vessel during delivery. A distal guidewire port **3840** extends from the distal tip **3838** and allows guidewire GW2 to exit or enter a guidewire lumen (not shown) in the elongate shaft **3826**. The second catheter **3824** may be a rapid exchange catheter or an over-the-wire catheter, examples of which have previously been disclosed above.

[0179] Referring back to FIG. **38C**, the bifurcation angle is less than about 60 to 70 degrees, and the first catheter **3804** and the second catheter **3824** are further advanced distally so that the first catheter tracks over the first guidewire GW1 into the side branch SB while the second catheter **3824** tracks over the second guidewire GW2 in the main branch MB toward the main branch lesion ML. Because the first catheter **3804** is coupled with the second catheter **3824** via stent **3842**, both catheters are advanced distally simultaneously thereby reducing procedure time, although this is not meant to be limiting, as each catheter may be advanced independently of the other. In this embodiment the first balloon **3808** and first stent **3816** are distal to the second balloon **3828** and second stent **3842**. This axial offset minimizes the system profile.

[0180] In FIG. **38D**, both catheters **3804**, **3824** are advanced further distally toward the bifurcation until the first stent **3816** is distal to the side branch lesion SL and the second stent **3842** traverses the main branch lesion M L and the side hole **3844** is adjacent the ostium of the side branch SB. Advancement of both catheters **3804**, **3824** is again performed simultaneously, although they could also be advanced independently of one another. The operator will feel resistance against further advancement of the catheters **3804**, **3824** because as the catheters are advanced further distally, the two catheter shafts **3806**, **3826** will spread apart relative to one another as they are forced against the carina of the bifurcation. However, a portion of the first elongate shaft **3806** is disposed under a portion of the second stent **3842**, therefore the two shafts **3806**, **3826** can only spread apart so far. Thus, when an operator feels resistance against further advancement of the catheter shafts, the operator knows that both catheters **3804**, **3824** and their associated stents and balloons are properly positioned relative to the bifurcation.

[0181] In FIG. **38E**, the first catheter **3804** is retracted proximally relative to the second catheter **3824**. Because a portion of the first catheter shaft **3806** is disposed under a portion of the second stent **3842**, the first shaft **3806** is slidably retracted into side hole **3844** and the first shaft **3806** and proximal portion **3810** of balloon **3808** are slidably retracted under a portion of second stent **3842**. The first shaft is proximally retracted until proximal radiopaque marker **3820** lines up with proximal radiopaque marker **3836** so that a proximal end of the first stent **3816** will be aligned with the side hole **3844** in the second stent **3842**. An operator may feel resistance during retraction of the first elongate shaft **3806** relative to the second elongate shaft **3826** when the ends of the stents **3816**, **3842** engage one another. Stent **3842** has a distal portion crimped to balloon **3828** to prevent ejection during delivery, and a proximal portion is partially crimped thereto or uncrimped to allow catheter **3804** to slide thereunder. Crimping of the stent is disclosed in greater detail in U.S. patent applications previously incorporated by reference above. The ends of the stents may butt up against one another, overlap with one another, interleave with one another, or combinations thereof. Additional details related to the engagement of the stents is disclosed in U.S. patent applications previously incorporated by reference above. Both stents **3816**, **3842** are disposed adjacent their respective lesions SL, ML, and the side hole **3844** is in rough alignment with the ostium to the side branch SB and the side branch stent **3816**.

[0182] In FIG. **38F**, the balloon **3808** is radially expanded, often with contrast medium, saline, or a

combination thereof thereby radially expanding the first stent **3816** into engagement with the side branch lesion SL and the walls of the side branch. A proximal portion **3810** and a distal portion **3812** of the balloon **3808** will also expand, thus a proximal portion of the second stent **3842** will also be radially expanded. Expansion of the stents occurs simultaneously. Since a portion of balloon **3808** also passes through side hole **3844**, expansion of balloon **3808** also partially expands the side hole **3844** and also aligns the side hole **3844** with the ostium of the side branch.

[0183] In FIG. **38G** the balloon **3808** is contracted, and then in FIG. **38H** the other balloon **3828** is radially expanded, with contrast medium, saline, or a combination thereof, thereby further radially expanding the second stent **3842**. Expansion of balloon **3828** expands the proximal portion of the stent **3842** into engagement with the main branch vessel wall and main branch lesion ML, and the distal portion of the stent **3842** is also radially expanded into the main branch vessel wall as well as the main branch lesion ML. The side hole **3844** is also further aligned with the ostium of the side branch SB.

[0184] Referring now to FIG. **38I**, balloon **3828** is contracted and then both balloons are simultaneously inflated in a “kissing balloon” technique as seen in FIG. **38J**. Both balloons **3808**, **3828** are inflated with contrast medium, saline, or combinations thereof until they engage one another and are fully expanded in the main branch MB and side branch SB. The kissing balloon technique ensures that both stents **3816**, **3842** are fully expanded and in full apposition with their respective vessel wall and lesion. Additionally, the kissing balloon technique lines up the proximal end of the first stent **3816** with the side hole **3844** in the second stent **3842**, thereby ensuring that continuous and smooth scaffolding from the main branch MB into the side branch SB. Also, the kissing balloons technique ensures that the side hole does not block the ostium to the side branch thereby avoiding “stent jailing,” or disrupting blood flow into the side branch.

[0185] In FIG. **38K**, both balloons **3808**, **3828** are contracted, and in FIG. **38L** both catheters **3804**, **3824** are retracted proximally. The catheters may be retracted simultaneously or independently of one another. The first catheter **3804** is retracted through both stents **3816**, **3842** and also passes through the side hole **3844**. The second catheter **3824** is retracted through the second stent **3842**. In FIG. **38M**, both catheters **3804**, **3828** have been removed, as well as the guide catheter **3802** and both guidewires GW1, GW2. Stents **3816**, **3842** remain implanted in at the bifurcation. Optionally, the stents or balloons may contain therapeutic agents such as those previously discussed, and these may elute out into the lesion at a controlled rate in order to help prevent restenosis.

[0186] FIGS. **39A-39M** more clearly illustrate another exemplary embodiment of a method for treating a bifurcated vessel. This method is similar to that previously disclosed, with the major difference being that the distal-most catheter is used to treat the main branch vessel, and the proximal-most catheter is used to treat the side branch vessel. In the previous embodiment, the distal-most catheter is used to treat the side branch vessel and the proximal-most catheter is used to treat the main branch.

[0187] In FIG. **39A**, the bifurcated vessel BV includes a side branch vessel SB and a main branch vessel MB. The main branch has a main branch lesion ML, and the side branch has a side branch lesion SL. The angle between the side branch and the main branch is referred to as the bifurcation angle, and is indicated by θ . When the bifurcation angle θ is less than about 60 to 70 degrees, the distal most stent of the system can be effectively positioned in the side branch. However, when the bifurcation angle is greater than or equal to about 60 to 70 degrees, it becomes more challenging to position the distal most stent in the side branch. Moreover, when the distal stent is retracted proximally toward the stent having the side hole (discussed below), the catheter shaft may bind against the side hole resulting in damage to the catheter shaft and/or stent. Therefore, in preferred embodiments, when the bifurcation angle is less than about 60 to 70 degrees, the distal most stent is preferably positioned in the side branch and the proximal most stent is advanced into the main branch. When the bifurcation angle is greater than or equal to about 60 to 70 degrees, the distal most stent is positioned in the main branch and the other stent is positioned partially in the main

branch and partially in the side branch. This is not intended to limit the use of the catheter system, and either stent may be placed in either side branch or main branch depending on operator preference. In FIG. 39B, a guide catheter **3902** is advanced distally into the vessel until it is adjacent the bifurcation and the lesions ML, SL. A first guidewire GW1 is advanced distally in the main branch MB until it is distal of the main branch lesion M L. A second guidewire is also advanced distally until it enters the side branch SB and it is distal of the side branch lesion SL. [0188] In FIG. 39C, a treatment system having a first catheter **3904**, and a second catheter **3924** are advanced distally through the guide catheter **3902** toward the bifurcation. The two catheters **3904**, **3924** may be advanced independently of one another, or the two catheters may preferably be advanced simultaneously. The first catheter **3904** includes an elongate shaft **3906** with a radially expandable balloon **3908** on a distal portion of the elongate shaft **3906**. A stent **3922** is disposed over the balloon **3908**. The length of the stent **3922** may substantially match the working length of the balloon **3908**, or the length of the stent **3922** may be less than the working length of the balloon **3908** such that a proximal portion **3910** and a distal portion **3912** of the balloon remains unconstrained by the stent **3922**. A proximal radiopaque marker **3916** and a distal radiopaque marker **3914** may be used to help determine the proximal and distal ends of the balloon **3908** as well as the proximal and distal ends of the stent **3922**. A soft durometer polymer tip may be used on the distal portion of the catheter shaft **3906** so as to prevent trauma to the vessel during delivery, and the catheter shaft **3906** has a distal guidewire port **3920** to allow a guidewire GW1 to enter or exit a guidewire lumen (not shown) in the catheter shaft **3906**. The first catheter **3904** may be a rapid exchange catheter or it may be an over-the-wire catheter. The second catheter **3924** (best seen in FIG. 39D) includes an elongate shaft **3926** having a radially expandable balloon **3928** on a distal portion thereof. A second stent **3934** is disposed over the second balloon **3928**. The stent length may substantially match the working length of the balloon, or it may be less. In this embodiment, the length of stent **3934** is less than the working length of balloon **3928**, thus a proximal portion **3930** and a distal portion **3940** of the balloon remain unconstrained by the stent **3934**. A portion of the first elongate shaft **3906** is disposed under a proximal portion of the second stent **3934**, and the stent **3934** also has a side hole **3936** so that the first elongate shaft **3906** may exit therefrom. The first elongate shaft **3906** may slide under the stent **3934** relative to the second elongate shaft **3926**, thus a proximal portion **3910** of balloon **3908** is also disposed under stent **3934**. When balloon **3908** is expanded, a proximal portion of stent **3934** will also be expanded. The second catheter shaft **3926** also includes a proximal radiopaque marker **3932** and a distal radiopaque marker **3938** that help identify the proximal and distal ends of the balloon **3928** and the proximal and distal ends of the stent **3934**. The second catheter **3924** also has a soft durometer polymer tip **3942** that helps minimize trauma to the vessel during delivery, and a distal guidewire port **3944** allows a guidewire to be inserted or to exit from a guidewire lumen (not shown) in the elongate shaft **3926**. The second catheter **3924** may be an over-the-wire catheter or it may be rapid exchange. The first stent **3922** and balloon **3908** are distal to the second stent **3934** and second balloon **3928**.

[0189] In FIG. 39D, the bifurcation angle θ is greater than about 60 to 70 degrees. Both catheters **3904**, **3924** are further advanced distally toward the bifurcation until the first stent **3922** is distal to the main branch lesion ML, and the second stent **3934** is partially disposed in the side branch SB adjacent the side branch lesion SL, and the stent **3934** is also disposed in the main branch MB adjacent the main branch lesion ML. The side hole **3936** also faces generally in the direction of the main branch vessel MB. Advancement of both catheters is preferably performed simultaneously, although they could also be advanced independently of one another. The operator will feel resistance against further advancement of the catheters **3904**, **3924** because as the catheters are advanced further distally, the two catheter shafts **3906**, **3926** will spread apart relative to one another as they are forced against the carina of the bifurcation. However, a portion of the first elongate shaft **3906** is disposed under a portion of the second stent **3934**, therefore the two shafts **3906**, **3926** can only spread apart so far. Thus, when an operator feels resistance against further

advancement of the catheter shafts, the operator knows that both catheters **3904**, **3924** and their associated stents and balloons are properly positioned relative to the bifurcation.

[0190] In FIG. **39E** the first catheter **3904** is retracted proximally relative to the second catheter **3924** so a proximal portion **3910** of balloon **3908** is disposed under stent **3934**. Stent **3934** has a distal portion crimped to balloon **3928** so that it will not be ejected during delivery, and a proximal portion is partially crimped or uncrimped over balloon **3928** to allow shaft **3906** to slidably pass thereunder. Stent crimping is described in greater detail in U.S. patent applications previously incorporated by reference above. Because a portion of the first catheter shaft **3906** is disposed under a portion of the second stent **3934**, the first shaft **3906** is slidably retracted into side hole **3936** and the first shaft **3906** is also slidably retracted under a portion of second stent **3934**. The first shaft is proximally retracted until proximal radiopaque marker **3916** lines up with proximal radiopaque marker **3932** so that a proximal end of the first stent **3922** will be aligned with the side hole **3936** in the second stent **3934**. An operator may feel resistance during retraction of the first elongate shaft **3906** relative to the second elongate shaft **3926** when the ends of the stents **3922**, **3934** engage one another. The ends of the stents may butt up against one another, overlap with one another, interleave with one another, or combinations thereof. Additional details related to the engagement of the stents are disclosed in U.S. patent applications previously incorporated by reference above. Both stents **3922**, **3934** are disposed adjacent their respective lesions SL, ML, and the side hole **3936** is in rough alignment with the main branch vessel MB.

[0191] In FIG. **39F**, the balloon **3908** is radially expanded, often with contrast medium, saline, or a combination thereof thereby radially expanding the first stent **3922** into engagement with the main branch lesion ML and the walls of the main branch. A proximal portion of the second stent **3934** is also expanded into engagement with the main branch lesion ML and the walls of the main branch, while a distal portion of the second stent **3934** remains unexpanded in the side branch SB. The first stent **3922** and the proximal portion of the second stent **3934** are radially expanded simultaneously. The inner surfaces of both stents form a smooth lumen for blood flow through the main branch.

Since a portion of balloon **3908** also passes through side hole **3936**, expansion of balloon **3908** also partially expands the side hole **3936** and also aligns the side hole **3936** with the main branch lumen.

[0192] In FIG. **39G** the balloon **3908** is contracted, and then in FIG. **39H** the other balloon **3928** is radially expanded, with contrast medium, saline, or a combination thereof, thereby further radially expanding the second stent **3934**. Expansion of balloon **3928** expands a distal portion of stent **3934** into engagement with the side branch vessel wall and side branch lesion SL. The proximal portion of stent **3934** and side hole **3936** may also be further expanded and aligned with the first stent **3922**. The side hole is also further aligned with the lumen of the main branch.

[0193] Referring now to FIG. **39I**, balloon **3928** is contracted and then both balloons are simultaneously inflated in a “kissing balloon” technique as seen in FIG. **39J**. Both balloons **3908**, **3928** are inflated with contrast medium, saline, or combinations thereof until they engage one another and are fully expanded in the main branch MB and side branch SB. The kissing balloon technique ensures that both stents **3922**, **3934** are fully expanded and in full apposition with their respective vessel wall and lesion. Additionally, the kissing balloon technique lines up the proximal end of the first stent **3922** with the side hole **3936** in the second stent **3934**, thereby ensuring that continuous and smooth scaffolding from the main branch MB into the side branch SB. Alignment of the two stents is disclosed in greater detail in U.S. patent applications previously incorporated by reference above. Also, the kissing balloons technique ensures that the side hole does not block the main branch or disrupting blood flow across the bifurcation.

[0194] In FIG. **39K**, both balloons **3908**, **3928** are contracted, and in FIG. **39L** both catheters **3904**, **3924** are retracted proximally. The catheters may be retracted simultaneously or independently of one another. The first catheter **3904** is retracted through both stents **3922**, **3934** and also passes through the side hole **3936**. The second catheter **3924** is retracted through the second stent **3934**. In FIG. **39M**, both catheters **3904**, **3924** have been removed, as well as the guide catheter **3802** and

both guidewires GW1, GW2. Stents 3922, 3934 remain implanted in at the bifurcation. Optionally, the stents or balloons may contain therapeutic agents such as those previously discussed, and these may elute out into the lesion at a controlled rate in order to help prevent restenosis.

[0195] Any of the methods described above may use any of the stents disclosed herein in any of the system configurations described. Additionally, any of the features previously described above may also be used. Therefore, one of skill in the art will appreciate that any number of combinations may be made. For example, catheter systems may have any combination of rapid exchange or over-the-wire configurations, with any of the stents disclosed herein, with or without a therapeutic agent on a stent or a balloon, and with or without any of the hollow exchange port, capture tube, removable capture tube, or snap fittings described above.

Stents:

[0196] The catheter systems and methods described above may use a commercially available stent for either the proximal or distal stent in the system. When a commercially available stent is used for the distal stent, it need only be crimped to the distal balloon catheter. When the commercially available stent is used for the proximal stent it may be partially crimped to the proximal balloon such that a portion of a second catheter shaft is slidably disposed under the stent and a portion of the second catheter shaft slidably passes through a side hole in the stent. The stent is crimped to the proximal balloon so that it is not displaced from the balloon during delivery, and also so the second catheter shaft can slide thereunder. FIGS. 40A-40E illustrate several examples of commercially available stents that may be used in catheter system configurations and methods described above, either as is, or with slight modification. For example, FIG. 40A illustrates the Abbott Vascular Xience® drug eluting stent 4102a. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap 4104a created between adjacent struts in a cell, or the gap 4106a between axially adjacent cells. FIG. 40B illustrates the Cordis Cypher® stent 4102b. Again a portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap 4104b created between adjacent struts in a cell, or the gap 4106b between axially adjacent cells. FIG. 40C illustrates the Boston Scientific Taxus® Liberte® stent 4102c. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap 4104c created between adjacent struts in a cell, or the gap 4106c between axially adjacent cells. FIG. 40D illustrates the Medtronic Endeavor® stent 4102d. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap 4104d created between adjacent struts in a cell, or the gap 4106d between axially adjacent cells. FIG. 40E illustrates a Palmaz-Schatz® stent 4104e. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap 4104e created between adjacent struts in a cell, or the gap 4106e between axially adjacent segments. Other stents have been designed with side holes that are specifically intended to treat bifurcations. These stents may also be used with the systems and method disclosed herein. For example, FIGS. 40F-40H illustrate several embodiments of stents from Boston Scientific and are disclosed in detail in U.S. Pat. No. 7,678,142. FIG. 40F shows a stent 4102f after it has been unrolled and flattened having a side hole 4106f. 40F illustrates a stent geometry (unrolled, plan view) where the struts create a side hole 4106f that allows access to a side branch, and that can accommodate a catheter shaft as described herein. The side hole may be formed by the spaces 4104f, 4108f between struts. FIG. 40G illustrates another stent geometry (unrolled, plan view) having a side hole 4106g. Alternatively, the side hole may be formed by the spaces 4104g, 4108g between struts or axial connectors. FIG. 40H illustrates still another stent geometry (unrolled, plan view) having a side hole 4106h. The side hole may also be formed by the space between struts 4104h or axial connectors 4108h. In any of these embodiments, a catheter shaft may be slidably disposed under a portion of the stent, and the catheter shaft may exit the side

hole. Additionally, any of the stents or balloons disclosed herein may carry a therapeutic agent such as those described above for local drug delivery. Also, while the stents disclosed herein are preferably balloon expandable, one of skill in the art will appreciate that self-expanding, and hybrid balloon expandable/self-expanding stents may also be used.

Stent Alignment:

[0197] FIGS. **42A-42C** illustrate various ways a side branch stent can lineup with a main branch stent. In FIG. **42A**, the side branch SB is substantially perpendicular to the main branch MB, therefore the bifurcation angle θ is about 90 degrees. In this situation, the proximal end **4206** of the side branch stent **4202** will be substantially flush with the side hole **4208** in the main branch stent **4204** (assuming proper deployment of both stents). This is desirable since there are no gaps and hence no unscaffolded regions between the two stents **4202**, **4204**. However, when the bifurcation angle θ increases (FIG. **42B**) or decreases (FIG. **42C**), a portion of the side branch will remain unstented. For example, in FIG. **42B** the bifurcation angle increases and because of the right cylindrical shape of the stent, in which the end is perpendicular to the sidewalls of the stent, a gap **4210** exists between the proximal end **4206** of the side branch stent **4202** and the side hole **4208** of the main branch stent **4204**. Similarly, in FIG. **42C**, when the bifurcation angle decreases, there is also a gap **4212** between the proximal end **4206** of stent **4202** and the side hole **4208** of stent **4204**. FIG. **42C** is typical of human anatomy, therefore the gap **4212** often is upstream of the bifurcation. Gaps are undesirable since they are unscaffolded and recoil and restenosis may occur in this region. Additionally, in the case where a stent is used for drug elution, the gap region may not receive any of the drug.

[0198] One possible solution for ensuring that the gap between a side branch stent and a main branch stent is eliminated or reduced is shown in FIG. **43A**. The side branch stent **4302** is a right cylindrical stent. The main branch stent **4304** has a side hole **4306** with struts that expand outwardly into the gap region, thereby ensuring continuous scaffolding. An alternative solution in FIG. **43B** is to fabricate the proximal end **4310** of the side branch stent **4308** with its proximal end non-perpendicular to the central axis of the stent so that the proximal end of the side branch stent lines up with the side hole in the main branch stent **4312**. Even using the geometries illustrated in FIG. **43A-43B** still requires careful alignment of the side branch stent with the main branch side hole. Therefore, it would be desirable to provide a stent geometry that facilitates alignment.

[0199] The ends of the side branch stent and the main branch stent may intersect in several different ways thereby providing continuous and uniform coverage of the bifurcation. For example, in FIG. **44**, a portion **4406** of side branch stent **4402** may be disposed inside main branch stent **4404**. FIG. **45** shows a portion **4506** of the main branch stent **4504** disposed inside the side branch stent **4502**. Neither situation in FIG. **44** or **45** are ideal as overlapping of stents may result in metal rubbing on metal as well as possibly disrupting blood flow or causing stagnation points. A more desirable interface between stents is shown in FIG. **46** where the end of the side branch stent **4602** butts up against the side hole in main branch stent **4604**. The interface region **4606** is desirable since it provides continuous scaffolding of the vessel without gaps between ends of the stents. However, depending on the stent geometry, gaps may still exist between stents. Therefore, in preferred embodiments, the ends of the stents will interleave or interdigitate with one another.

[0200] FIGS. **47A-47D** illustrate several exemplary embodiments where the ends of the side branch stent and the side hole of the main branch stent interleave with one another or interdigitate. For example, in FIG. **47A**, a proximal end **4704** of side branch stent **4702** has a series of axially extending elements or fingers **4712** which interdigitate or interleave with the laterally extending elements or fingers **4716** that extend laterally from the side hole **4708** of main branch stent **4706**. FIG. **47B** illustrates an exemplary embodiment of interdigitating axial and lateral elements. A proximal end **4704** of side branch stent **4702** has a plurality of axially extending elements **4712**. The axially extending elements **4712** are formed from a plurality of interconnected stent struts **4714**, in this case forming a triangular shape. Similarly, the side hole **4708** of the main branch stent

4706 has a plurality of laterally extending elements **4716** that are formed from a plurality of interconnected stent struts **4718**. In this case the laterally extending elements **4716** are formed into a triangular shape. Thus the apex of one triangular shaped element fits in between adjacent elements on the adjacent stent. Or alternatively, the peaks fit in the valleys, and the valleys receive the peaks.

[0201] FIG. **47C** illustrates still another exemplary embodiment of interleaving or interdigitating elements. The proximal end **4704** of the side branch stent **4702** includes a strut **4720** formed into a series of peaks and valleys. Similarly, the side hole **4708** of the main branch stent **4706** will also have a strut **4722** that has been formed into a series of peaks and valleys. Therefore, the peaks of the side branch stent will fit into the valleys of the adjacent main branch stent side hole, and similarly the valleys of the side branch stent receive the peaks of the side hole. FIG. **47D** illustrates yet another exemplary embodiment of interleaving or interdigitation of stent ends. The proximal end **4704** of side branch stent **4702** includes a strut **4724** formed into a series of rectangular peaks and valleys. The side hole **4708** of the main branch stent **4706** also has a strut **4726** formed into a series of rectangular peaks and valleys. The peaks and valleys interleave and interdigitate with one another.

Balloon Configurations:

[0202] The balloons used to radially expand the stents described herein may be cylindrical balloons having a constant diameter along the working length, or diameter may vary. When stenting a tapered vessel, it may be advantageous to use a balloon which has a variable diameter balloon that more closely matches the vessel anatomy. For example, in FIG. **41A**, a tapered balloon **5006** is attached to the distal portion of shaft **5002**. A soft durometer tip **5004** prevents vessel trauma during delivery. The balloon is tapered such that a proximal portion **5010** of the balloon has a larger diameter than a distal portion **5006**. Any taper may be used. FIG. **41B** illustrates another embodiment of a balloon **5012** having a plurality of stepped regions **5014**. The stepped regions may be incremented in any amount, and in preferred embodiments, a proximal portion **5016** of the balloon has a larger diameter than a distal portion **5018**. Any of these embodiments, or combinations thereof may be used in the systems and methods described herein to treat a bifurcation. Use of a tapered or stepped balloon allows a stent to be expanded to more closely match the vessel walls, where a proximal portion of the expanded stent has a larger diameter than a distal portion of the stent.

[0203] In addition to using catheters having rapid exchange or over-the-wire guidewire lumens, and tapered or stepped balloons, the balloon catheters may not always employ a guidewire lumen. Instead, a fixed wire may be attached to a distal end of the catheter. For example, FIG. **48** illustrates an exemplary embodiment of a fixed wire catheter **5102** having a balloon **5106** attached to a distal portion of the shaft **5104**. A section of guidewire **5108** is fixedly attached to the distal end of the catheter and this fixed wire helps the catheter track through the vessels. The fixed wire may have any number of shapes including straight, curved, J-tip, etc. This embodiment may be used with any of the systems and methods disclosed herein, and it may or may not have a stent crimped to the balloon. The fixed wire catheter may be used in the main branch, or more preferably it may be used in the side branch.

[0204] While the above is a complete description of the preferred embodiments of the invention, various alternatives, modifications, and equivalents may be used. Therefore, the above description should not be taken as limiting the scope of the invention which is defined by the appended claims.

Claims

1. A method for treating a bifurcated vessel, the method comprising: providing a first delivery catheter and a second delivery catheter, wherein the first delivery catheter comprises a first elongate shaft, a first expandable member coupled to a distal portion of the first elongate shaft, and

a first stent disposed over the first expandable member, the first stent having a collapsed configuration and an expanded configuration, in the collapsed configuration the first stent is crimped on the first expandable member, and in the expanded configuration the first stent is expanded to engage and support a vessel wall, and wherein the second delivery catheter comprises a second elongate shaft, a second expandable member coupled to a distal portion of the second elongate shaft, the second expandable member having a working length with a proximal portion and a distal portion, and a second stent disposed over the second expandable member, the second stent having a collapsed configuration and an expanded configuration, in the collapsed configuration the second stent is crimped on the second expandable member leaving a portion of the working length of the second expandable member uncovered by the second stent, and in the expanded configuration the second stent is expanded to engage and support a vessel wall; advancing the first and second delivery catheters toward a bifurcation in a blood vessel, wherein the bifurcation comprises a main branch vessel and a side branch vessel, wherein the main branch vessel and the side branch vessel form a bifurcation angle of less than 60-70 degrees, and the advancing comprises disposing the first stent into the side branch vessel, and disposing the second stent into the main branch vessel; proximally retracting the first elongate shaft under a portion of the second stent in the collapsed configuration until a proximal end of the first stent is aligned with a side hole in the second stent; radially expanding the first expandable member, thereby expanding the first stent into engagement with the vessel wall; and radially expanding the second expandable member, thereby expanding the second stent into engagement with the vessel wall, the second expandable member being distal to the first expandable member before and during delivery of the first and second expandable members.

2. A system for treating a bifurcated vessel, comprising: a first delivery catheter comprising a first elongate shaft, a first expandable member coupled to a distal portion of the first elongate shaft, and a first stent disposed over the first expandable member, the first stent having a collapsed configuration and an expanded configuration, in the collapsed configuration the first stent is crimped on the first expandable member, and in the expanded configuration the first stent is expanded to engage and support a vessel wall; and a second delivery catheter comprising a second elongate shaft, and a second expandable member coupled to a distal portion of the second elongate shaft, the second expandable member distal of the first expandable member and having a working length with a proximal portion and a distal portion, and a second stent disposed over the second expandable member, the second stent having a collapsed configuration and an expanded configuration, in the collapsed configuration the second stent is crimped on the second expandable member leaving a portion of the working length of the second expandable member uncovered by the second stent, and in the expanded configuration the second stent is expanded to engage and support a vessel wall, the second expandable member being distal to the first expandable member before and during a delivery of the first and second expandable members.

3. A method for treating a bifurcated vessel, the method comprising: providing a first delivery catheter and a second delivery catheter, wherein the first delivery catheter comprises a first elongate shaft, a first expandable member coupled to a distal portion of the first elongate shaft, and a first stent disposed over the first expandable member, the first stent having a collapsed configuration and an expanded configuration, in the collapsed configuration the first stent is crimped on the first expandable member, and in the expanded configuration the first stent is expanded to engage and support a vessel wall, and wherein the second delivery catheter comprises a second elongate shaft, a second expandable member coupled to a distal portion of the second elongate shaft, the second expandable member having a working length with a proximal portion and a distal portion, and a second stent disposed over the second expandable member, the second stent having a collapsed configuration and an expanded configuration, in the collapsed configuration the second stent is crimped on the second expandable member leaving a portion of the working length of the second expandable member uncovered by the second stent, and in the

expanded configuration the second stent is expanded to engage and support a vessel wall; advancing the first and second delivery catheters toward a bifurcation in a blood vessel, wherein the bifurcation comprises a main branch vessel and a side branch vessel, wherein the main branch vessel and the side branch vessel form a bifurcation angle of greater than 60-70 degrees, and the advancing comprises disposing the first stent into the main branch vessel, and disposing the second stent into the side branch vessel; proximally retracting the first elongate shaft under a portion of the second stent in the collapsed configuration until a proximal end of the first stent is aligned with a side hole in the second stent; radially expanding the first expandable member, thereby expanding the first stent into engagement with the vessel wall; and radially expanding the second expandable member, thereby expanding the second stent into engagement with the vessel wall, the second expandable member being distal to the first expandable member of the system before and during a delivery of the first and second expandable members.

4. The method of claim 1, wherein advancing the first and the second delivery catheters comprises slidably advancing the first delivery catheter over a first guidewire and slidably advancing the second delivery catheter over a second guidewire.

5. The method of claim 4, wherein the first guidewire is disposed in the side branch vessel, and the second guidewire is disposed in the main branch vessel.

6. The method of claim 1, wherein the advancing comprises advancing both the first and the second delivery catheters against a carina of the bifurcation until resistance to further advancement is felt by an operator.

7. The method of claim 6, wherein the resistance is provided by separation of the first elongate shaft from the second elongate shaft as both shafts are advanced against the carina of the bifurcation.

8. The method of claim 1, wherein the second elongate shaft comprises an exchange lumen, and the retracting comprises slidably retracting the first elongate shaft through the exchange lumen.

9. The method of claim 1, wherein the first delivery catheter comprises a first radiopaque marker disposed adjacent a proximal region of the first expandable member, and the second delivery catheter comprises a second radiopaque marker disposed adjacent a proximal region of the second expandable member, and wherein the retracting comprises retracting the first elongate shaft until the first radiopaque marker is axially aligned with the second radiopaque marker.

10. The method of claim 1, wherein the first expandable member comprises a balloon, and the expanding of the first expandable member comprises inflating the balloon with a fluid.

11. The method of claim 1, wherein the second expandable member comprises a balloon, and the expanding of the second expandable member comprises inflating the balloon with a fluid.

12. The method of claim 1, wherein the second elongate shaft comprises a snap fitting configured to receive and retain the first elongate shaft, and wherein the retracting comprises slidably retracting the first elongate shaft along the snap fitting.

13. The system of claim 2, wherein the first delivery catheter comprises a first guidewire lumen extending at least partially between proximal and distal ends thereof, and wherein the system further comprises a first guidewire slidably disposed in the first guidewire lumen.

14. The system of claim 13, wherein the second delivery catheter comprises a second guidewire lumen extending at least partially between proximal and distal ends thereof, and wherein the system further comprises a second guidewire slidably disposed in the second guidewire lumen.

15. The system of claim 2, wherein the first delivery catheter comprises a first radiopaque marker disposed adjacent a proximal region of the first expandable member.

16. The system of claim 15, wherein the second delivery catheter comprises a second radiopaque marker disposed adjacent a proximal region of the second expandable member, wherein when the first radiopaque marker is aligned with the second radiopaque marker, a proximal end of the second stent is aligned with a side hole in the first stent.

17. The system of claim 2, wherein the second elongate shaft comprises a snap fitting configured to

receive and retain the first elongate shaft, and wherein the first elongate shaft is slidably movable axially through the snap fitting.

18. The system of claim 2, further comprising a polymer sleeve having a proximal end, a distal end, a longitudinal axis, and a central channel extending therethrough, wherein the first elongate shaft and the second elongate shaft are slidably disposed in the central channel.

19. The system of claim 2, wherein the first expandable member comprises a balloon.

20. The system of claim 2, wherein the second expandable member comprises a balloon.

21. The method of claim 3, wherein advancing the first and the second delivery catheters comprises slidably advancing the first delivery catheter over a first guidewire and slidably advancing the second delivery catheter over a second guidewire.

22. The method of claim 21, wherein the first guidewire is disposed in the main branch vessel, and the second guidewire is disposed in the side branch vessel.

23. The method of claim 3, wherein the advancing comprises advancing both the first and the second delivery catheters against a carina of the bifurcation until resistance to further advancement is felt by an operator.

24. The method of claim 3, wherein the first delivery catheter comprises a first radiopaque marker disposed adjacent a proximal region of the first expandable member, and the second delivery catheter comprises a second radiopaque marker disposed adjacent a proximal region of the second expandable member, and wherein the retracting comprises retracting the first elongate shaft until the first radiopaque marker is axially aligned with the second radiopaque marker.

25. The method of claim 3, wherein the first expandable member and the second expandable member each comprise a balloon, and wherein expanding the first and second expandable members comprises inflating the respective balloons with fluid.
