# Introduction:

Guidewires were initially invented and used by Dotter and Judkins to cross a disease segment of the artery for further intervention. However, the initial wire used for coronary intervention was a spring coil guidewire over which a series of large rigid dilators were advanced. Andreas Gruentzig replaced these dilators with inflatable balloons, which were introduced percutaneously, hence pioneering the era of percutaneous coronary angioplasty. After Gruentzig pioneered the first angioplasty, a group of cardiologists met and formed a registry under The National Heart, Lung, and Blood Institute. Since then, significant improvement in different types of equipment and techniques were made.

The original dilatation catheter with a short tip of guidewire could not be modified once the catheter was introduced, providing the operator with no control to maneuver the catheter/wire inside the vessel. In 1981, Dr. Simpson developed a new catheter system with an independently steerable guidewire located in the balloon catheter’s central lumen, replacing the short fixed non-steerable wire tip (5 mm) manufactured by Andreas Grüntzig.1 The introduction of the coaxial steerable guidewire was the first revolution in the history of coronary angioplasty. Compared to the early version of guidewires, modern guidewires are designed to combine tip softness, trackability around curves, precise torque control, which allow the guidewire to be steered through tortuous vessels and side branches.

# Wire Basics:

Guidewire components

Image1.jpg

1. Core**:** It is the stiffest and innermost part of the wire. It provides stability and steer ability and extends through the wire’s shaft from the proximal to the distal portion where it tapers.

* Core Material: The core is usually made of stainless steel, which provides excellent support with excellent torque transmission but is less flexible and not kink resistant. On the other hand, nitinol core, a super-elastic alloy of nickel and titanium, has more flexibility, excellent resiliency, and kink resistance. Newer wires (hybrid type) are made of stainless steel and nitinol distal tip for better torque transmission and excellent flexibility with kink resistance. (I.e. Run through, Minamo, Maestro, Specter).

stainless-steel-1.jpg

stainless-steel-nitinol.jpg

* CoreDiameter**:** It is the part of the wire that tapers to the tip, not the wire’s overall size, and determines the flexibility (smaller diameter) and support (larger diameters).

core-diameter-3.jpg

* Core Taper**:** This is the part of the wire that extends from the core to the tip. The ability to transmit torque depends on the taper’s length; shorter tapers tend to prolapse but provide more support, while longer tapers offer less support but track successfully.

core-taper-4.jpg

1. Tip**:** It is the distal tip of the wire. Various tip designs could affect the steer ability of the wire.

* Core to Tip**:** Core extends to the tip of the wire. This design provides precise tip control and increases the wire’s diameter, enhancing the wire’s stiffness to help cross-resistant lesions.

core-to-tip-5.jpg

* Shaping Ribbon: Core does not reach the distal tip of the wire but is wrapped in a ribbon of flexible metal to make the tip more flexible, atraumatic, and allows shape retention.

shapping-ribbon-6.jpg

* Composite Core (CC) or Inner Coil Technology (ICT): Composite core (Dual Core and Dual coil) is made of multiple wire components to enhance durability and 1:1 torque transmission. The distal part of the composite core wire consists of core and twist wires, whereas the proximal portion of the wire is composed of rope coil, twist, and core wires.

composite-core-7.jpg

## Composite Core (Asahi)

Function of Rope Coil

1.Excellent Torque Transmission

2.Wire protection for durability

Function of Twist Wire

1.Allow smaller, more flexible core

2.Provide excellent tip durability

Inner coiltechnology is composed of a stainless steel inner coil affixed directly to the distal portion of the stainless steel core enhances the shape retention and durability of the distal tip, reduces whipping, and provides exceptional torquability.

inner-coil-8.jpg

1. Body (Coil, Cover, and Sleeve): The body of the wire surrounding the core is usually made up of coils or polymers (plastic). Coils help maintain constant diameter, torque control, and tactile feedback. Various coil forming technologies have evolved in the contemporary era. Weaving multiple small wires into a coil is the most popular one, resulting in increased strength and a better torquability and torque response than a single coil.

XTRAND Coil technology, used in Gaia Next series, is multiple wires braided together to create a coil, and the design avoids coil stretching, and its anti-trapping feature avoids coil damage.

body-9.jpg

image15.jpg

xtand-coil-10.jpg

The polymer could either cover the core over the coil or cover the core itself and provides a smoother surface for tracing tortuous vessels. The wire with both polymer jacket and hydrophilic coating has a reduction of wire’s surface resistance approximately 70% than the one with coil and hydrophilic coating.

Hybrid wire consists of polymer cover of the body, leaving the distal free coils at the tip uncovered, referred to as sleeves.

types-of-coils-11.jpg

image18a.jpg

image19.jpg

**Various Guidewire Construction based on different form of coils and Covers**

Full Spring Coil Tip: Spring coil covering the distal core provides tip resiliency and tactile feedback.

Polymer Jacket over the Spring Coil: A wire with a polymer jacket covering over the spring coil: spring coil promotes tip resiliency while polymer jacket enhances cross ability and smooth device tracking.

polymer-spring-coil-12.jpg

Full Polymer Tip: Polymer jacket covering the entire distal core’s length and facilitates cross ability and smooth device tracking, especially in tortuous vessels.

full-polymer-tip-13.jpg

Spring Coil Tip with Polymer Jacket: Polymer jacket covers over the entire wire except for the tip covered by Spring Coil, called hybrid design. The hybrid design increases tactile feedback and resiliency at the distal end while providing smooth device delivery.

spring-coil-tip-14.jpg

Micro-Cut Nitinol Sleeve: It provides efficient transmission of torque energy for more precise turn-by-turn response and control than conventional spring-coil guidewires. The nitinol distal core and hydrophilic coating are designed to enhance wire durability, tactile response, and device delivery for improved overall performance.

micro-cut-nitinol-sleeve-15.jpg

**iv.** Coating: The wire body is coated by an overlay, a specific material that can reduce the surface friction

and improve device interaction and guidewire tracking.

* **Hydrophilic coating** attracts water to create a slippery ‘gel-like’ surface when wet and non-slippery when dry. It reduces friction, increases lubricity of the wire that enhances tracking and crossing, although, on occasion, could unintentionally go into false sub intimal spaces with increased risk of causing perforation.
* Hydrophobic wires are usually made of silicone and repel water to create a ‘wax-like’ surface, enhancing tactile feedback but decreasing slipperiness and tractability.
* Hybrid wire combines the hydrophobic tip for better tactile feedback with hydrophilic coating for smooth device delivery. In the contemporary era, the vast majority of guidewires have a hydrophilic coating. Put merely, hydrophilic wires increase lubricity, and hydrophobic wires increase tactile feedback.
* There are many proprietary coatings available in the market (e.g., M-Coat, Hydro-Track, or Slip-Coat (Asahi), etc.)

hydrophilic-coating-16.jpg

## Terminology of Different Wire’s Part:

Coil Length: The spring coil length can vary significantly from as low as 2.2cm upwards to 30cm. Generally, shorter coils are found on devices intended for high support and longer coils on track ability and flexibility devices.

Radiopaque length: The distal tip, an opaque part under x-rays, is usually about 30mm in length except for specialized CTO wires. It helps to make a measurement of the diseased segment and recognize for easy wire location. Some specialty wires have multiple radiopaque segments, such as the Medtronic Zinger Marker and Boston Scientific Forte Support Marker for more accurate measurements.

# Wire characteristics:

Changes in the composition of wire components could provide distinct characteristics and properties of the wire. Hence, appropriate wire selection heavily depends on the understanding of the various wire properties. The following terminologies can describe the specifications of the guidewire.

1. Torquability**:** It is an ability to transmit rotating elements applied on the proximal end of the wire (outside of the guiding catheter) to the tip of the wire. It is the crucial determinant of the operator’s ability to steer the wire through the vessel precisely. An ideal wire should provide a 1:1 torque, which can be affected by core composition, tip stiffness, and surface coating.
2. Flexibility**:** Ability of the wire to flex on its longitudinal axis while maintaining its track ability and torquability. It is the critical determinant of the tip strength. Flexible wires are soft and generally atraumatic. A wire’s flexibility can be labeled extra floppy/light, floppy/soft, and stiff.
3. Shape ability: The ability to modify the guidewire’s distal tip before the procedure to access difficult anatomies or perform intentional drilling through a CTO.
4. Shape Retention: A wire’s ability to retain an intended shape after being exposed to deformation and stress. Different strategies improve shape retention, including Asahi’s composite core, which uses an additional coil and wire inside.
5. Nitinol wires such as Terumo’s Run through, as an inherent characteristic of the metal, have better shape retention than stainless steel.
6. Tactile Feedback: Any physical sensation felt through the wire’s proximal end during wire advancement inside the coronary artery. Hydrophobic coatings offer the best feedback, but such wires advance with more difficulty than slippery hydrophilic wires. An additional polymer sleeve could further reduce feedback.
7. Track ability or deliverability or crossing: It is an ability to follow the tip and advanced smoothly along the vessel through stenosis or occlusion. Track ability is improved by nitinol core material and longer taper length, hydrophilic coatings, and polymer sleeves. Asahi Sion Black and conventional guidewires are advanced track ability-focused guidewires into an artificial vessel. A comparison of guidewire surface roughness in jacketed wire vs. spring coil wire is illustrated.

Image25.jpg

trackability-and-deliverability-17.jpg

1. Tip Load: Tip load can be determined by advancing the wire into a standard surface until it deflects the tip, at 2mm from the tip. A high tip load can help when crossing a resistant or highly stenotic lesion, while a low tip load makes the tip very soft and atraumatic. Tip load is predominantly determined by core material and thickness, with stainless steel core-to-tip style used for the highest tip loads.

tip-load-18.jpg

\*There are various ways to measure the tip load depending on the manufacturer. The method shown here is used by Abbott.

1. Support**:** It is a measure of a guidewire’s resistance to a bending force. A more supportive wire can aid in device delivery and vessel straightening, while a less one could assist in accessing through tortuous anatomy. Support and propensity for wire prolapse are directly related.
2. Whip**:** A smooth torque input from the operator results in a sudden jerk at the wire’s distal end. This effect can be minimized through hydrophilic coatings and polymer covers/sleeves. In the chart below, the dotted line shows a whip response plotted. The y = x line demonstrates an ideal guidewire with a 1:1 torque response contrasted with the erratic whip visualized by the dotted line.

Image-28.jpg

**Characteristics and Functionality of the Guidewires**

|  |  |
| --- | --- |
| **Components** | **Function** |
| Core | Stability, give tactile feedback, continuous force transmission and tip control |
| Tip | Steerability. Provide direct force transmission and maneuvering |
| Body | Trackability |
| Coating | Hydrophilicity and trackability |
| No Coating | Tactile feedback |

**Wire selection:**

Knowing the properties of guidewire and the specifics of the different types are crucial in selecting appropriate guidewire. However, it is strongly recommended to choose and master only a few wires instead of having superficial knowledge about multiple wires.

a) **Wire tip configuration and manipulation:**

The majority of guidewires are straight tipped and can be modified/shaped according to the vessel contour. The tip can be shaped with either the introducer needle or the shaping needle that comes along with the wire. Usually, a simple J shaped curve at the wire’s distal end will help track the wire through the vessel. The wire should be advanced gently through the stenosis segment. Forceful pushing of the wire can result in plaque disruption, leading to acute thrombus formation and occlusion of the vessel. It is recommended that 180 degrees clockwise or counterclockwise rotations of the wire should be performed during advancement in order to avoid wire advancement into smaller branches.5 However, the wires 360-degree rotations should be avoided, particularly when a second wire is required to prevent wires’ entanglement.

The wire tip should be placed as distal as possible, so the wire’s stiff part is across the lesion, providing adequate support and can track interventional devices.

b)  **Tip to wire specific blood vessel (LAD, LCx, RCA):**

1) **Left anterior descending (LAD):**

The left anterior oblique (LAO) caudal view is the best initial view to wire the LAD. Once the wire position is confirmed in the proximal LAD, further advancement into the mid and distal LAD should be carried out in the right anterior oblique (RAO) cranial view.

2) **Left Circumflex (LCx):**

A broader tip helps with entry into the LCx, and a smaller curve supports advancement into the Obtuse marginal (OM).

3) **Right Coronary Artery (RCA):**

If the RCA’s origin is relatively normal, a conventional soft wire with good steer ability to avoid side branches is chosen first.

Reference (right-coronary-artery-19.jpg)

c**) Desirable wire characteristics:**

d) **Non-CTO guidewire selection:**

1) **Simple/Uncomplicated Lesion:**

* To treat simple, concentric stenosis of the artery, the vital element of the wire is safety.
* As these wires are not required to go through difficulty or extreme anatomies, unique properties are not required.
* The wire should have an atraumatic tip, good torquability, and favorable track ability with a spring coiled nitinol wire.
* The choice of wires should include Run through, Balance Middleweight, and Sion blue.

2) **Tortuous Vessel:**

* In dealing with tortuous anatomy, the workhorse wires aren’t designed to tackle this challenging lesion and often fail to navigate through the lesion.
* The presence of wire’s flexibility, lubricity, and excellent track ability is essential to tackle this challenging anatomy.
* The optimal wire should have a soft tip, polymer/hydrophilic cover, moderate support, or a hybrid type with a hydrophilic body and hydrophobic distal tip.
* The choice of wires includes Fielder, Whisper, Pilot 50 and CHOICE Floppy.

3) **Calcified Lesion:**

* Two distinct components involve in a calcific lesion wiring: 1) crossing the lesion and 2) delivering the devices.
* The ideal wire to cross a heavy calcified lesion should have a soft tip with polymer/hydrophilic cover or a hybrid type of wire (hydrophobic tip and hydrophilic body). The wire choice will be Run through, Fielder, Whisper, and Pilot 50.
* To deliver PCI devices through calcified lesion, the wire’s crucial characteristics include high support, good tactile feedback, and excellent torquability/track ability for device delivery in a calcified lesion.
* The wires selection includes Iron man, Mailman, Hi-Torque Balance Heavyweight, the Hi-Torque All-Star, or the CHOICE Extra Support with the buddy wire technique.

4) **Bifurcation Lesion:**

* The guidewire properties to tackle the lesion should include slippery, excellent track ability, and slightly stronger tip load. It is paramount not to choose those with a higher risk of wire retrieval damage (e.g., non-polymer-coated wires) as the wire might be jailed during the procedure.9
* The choice of wires for bifurcation intervention includes a workhorse wire (Run through, BMW, CHOICE Floppy) in the main branch and polymer-coated wire in the jailed side branch (Fielder, Pilot 50, Whisper MS).
* Occasionally, aggressive wire with more tip stiffness (Gaia 2 or MiracleBros 3) along with a micro catheter may require to enter the side branch in a challenging case.

5) **Thrombotic Occlusion:**

* In a setting of an acute thrombotic lesion, the wire shouldn’t have significant resistance while traversing a lesion.
* The main objective is to cross the occlusion and advance the wire to the distal lumen softly and a traumatically.
* A soft wire would be the choice rather than a stiffer one with the hydrophilic or coated property. The operator can use any workhorse wire in this situation.
* In subacute occlusions, the thrombus material could have become more organized and may require a stiffer tip and higher tip load to facilitate in crossing the lesion. The wires choice should be Fielder, Gaia series, and MiracleBros 3.

6) **Angulated Lesion:**

The wire properties to navigate the angulated lesion is torquability, track ability, and wire flexibility. The ideal wire would be a soft tip with polymer jacketed and hydrophilic cover.

Our choice of wire are Fielder, Whisper, and Pilot 50.

However, we may require stiffer tip with hydrophobic coating at the tip to have a better tactile feedback with torquability such as MiracleBros and Provia.

Sometimes, we may require additional devices (i.e., angulated micro catheter or dual lumen catheter) to navigate an angulated lesion or re-crossing a jailed side branch.

**CTO approach and wires selection:**

a) **Strategies of CTO-PCI (Algorithm):**

There is no single guidewire that can be universally used in all CTO lesions and all possible circumstances. Familiarity with various CTO guidewires, proper selection based on angiographic features, and proper wiring techniques are necessary for CTO PCI success.

Reference (cto-chart-20.jpg)

**Wire Selection in CTO-PCI:**

Essential features to consider when selecting a guidewire include 1. tapered tip or not; 2) tip load and stiffness; 3) coated or non-coated polymer; 4) track ability.

**1) Ante grade Approach:**

Although multiple guidewires can be used in the CTO intervention, the principle on how to choose the wire is mostly unchanged.

* For a focal lesion (<10–20 mm length), tapered, straight CTO without a side branch, the first choice is a soft, tapered, polymer-coated wire for initial (micro) channel tracking.
* However, it is essential to aware that wire manipulation is often tricky, and linear force transmission can be attenuated.
* Ante grade wire escalation (AWE) is mostly recommended in the ante grade approach by penetration or drilling.
* When a wire passes the proximal cap of CTO, it is advisable to exchange the wire for a softer, steerable wire to minimize any inadvertent damage (expansion of sub intimal space), called wire step down or escalation-de-escalation.
* The parallel wiring method can be used under the ante grade approach. When the first wire fails to enter the true distal lumen, the second wire (tapered and stiffer wire) is advanced, while the first one can be used as a road map, thereby avoid entering into the sub intimal space created by the first wire.

**Our choice of wires for Ante Grade Wire Escalation (AWE) (Stepwise approach) include:**

* Fielder (Non tapered polymer jacket tip), Fielder XT/XT-A/XT-R (Tapered polymer jacket tip)
* MiracleBros (Open Coil, Straight tip, high tip stiffness > facilitate for drilling and can create the curve) or Gaia/Gaia Next series (Tapered, hydrophilic coating, composite core with 1:1 torque, high tip stiffness)
* Confianza 9/12 (Tapered, hydrophilic coating, high tip stiffness)

**Wire for microchannel tracking:**

* Fielder, Fielder XT, Fielder XT-A
* Gaia/Gaia Next series
* High Torque Pilot 50/150

**Wire for Drilling:**

* MiracleBros 6/12
* Confianza Pro 9, 12
* Pilot 200
* Progress 200T

**If the vessel course is ambiguous:**

* Pilot 200
* Confianza Pro
* Hornet 10, 14

**Wire selection based on the location**

**Crossing the proximal cap:**

* Fielder, Fielder XT/XT-A/XT-R (find microchannel)
* Gaia/Gaia Next series
* MiracleBros 3, 4.5, 6
* Confianza Pro

Choice of CTO wires based on angiographic features8

**Navigating through the vessel:**

* Gaia/Gaia Next series
* MiracleBros 4.5, 6
* Confianza Pro
* Ultimatebros 3
* Progress 140T, 200T

**Distal entry into the lumen:**

* Confianza Pro 12 (calcified distal cap)
* Progress 200T
* Hornet 14
* Astato 20, 40 (calcified distal cap)

b**) Retrograde Approach:**

The operator’s ability to manipulate the wire is even more crucial in the retrograde or antegrade-retrograde CTO approach. Steering the guidewire through collateral channels to reach the CTO’s distal end and re-entering the other side of the true lumen is challenging for the operator. This category’s primary requirement is that the wire should be longer, with the lowest tip load and very low friction, hydrophilic/polymer jacket coating.

* For collateral crossings, the wire choice should be tapered tip polymer-coated wire (Fielder XT, Fielder XT-R) or non-tapered polymer-coated one (Sion Black, Fielder FC) or stainless steel composite core with shaping wire to tip (SUOH 03).
* CTO crossing can be done by many different strategies [direct retrograde crossing, controlled ante grade and retrograde sub intimal tracking (CART), and reverse CART].
* The most frequently used retrograde wires are Gaia/Gaia Next series with micro catheter and MiracleBros 3.
* Confianza Pro 9 and Confianza Pro 12 are useful to cross a hard segment, while others could use Fielder XT and fighter as a retrograde ‘knuckle’ wiring to facilitate sub intimal passage in a prolonged, calcified occlusion.

**The following are the most used wires for a specific purpose:**

Wires for collateral channels/Septal branches:

* Fielder, Fielder FC, Fielder XT-R (Asahi Intec)
* Sion Black (Asahi Intec)
* Suoh 03 (Asahi Intec)
* Wires for penetration:
* Gaia/Gaia Next (Asahi Intec)/MiracleBros (Asahi Intec)
* Confianza Pro (Asahi Intec)
* Wires for externalization:
* RG3 (Asahi Intec)
* R350 (Teleflex)
* Viper Wire Advance (Cardiovascular Systems Inc., St Paul, MN, USA) or RotaWire11

**Atherectomy:**

**Guidewires for Atherectomy devices;**

There are two mechanical Atherectomy devices available in the market, rotational Atherectomy and orbital Atherectomy.

**Rotational Atherectomy:**

* Rota Wire has entirely different physical properties compared to conventional guidewires. It is a thinner device with its 0.009-inch diameter (except for the more distal radio-opaque segment, which is 0.014 inches).10
* This wire’s most crucial requirement is to provide an excellent and stable support function for the rotating burr.
* It is made of homogeneous stainless steel to have a stable support function with decreased wire manipulative properties (flexibility and torquability).
* Two types of Rota Wires are available
* Rota wire Drive Floppy (one with moderate support but better track ability)
* Rota wire Drive Extra Support (one with extra support but poorer track ability)

**Orbital Atherectomy:**

* Orbital Atherectomy is performed over a 0.014” guidewire, in contrast to a 0.009” wire with rotational Atherectomy.
* Viper wire is made of stainless steel to have a better support, silicone coating, and a radiopaque distal spring tip.
* Two viper wires are available
* Viper wire Advance (stainless steel core: better support)
* Viper wire Advance with Flex Tip (Nitinol with stainless steel support coil) > better to navigate in complex anatomy.

**Micro catheter:**

Micro catheter and over-the-wire balloons are low profile and trackable systems with end-holes. It provides good wire support and allows precise wire control by preventing flexion, kinking, and prolapse of the guidewire, especially in complex coronary intervention. It is useful in navigating tortuous or angulated lesion, CTO lesion, complex bifurcation with or without acute angle side branch, and re crossing a jailed side branch. Hence, micro catheter and guidewire are used as a single unit (e.g., Fielder + Fine Cross) to navigate challenging anatomy in complex coronary intervention.

**Types of micro catheter:**

1) **Single lumen (based on size of catheter):**

a) Standard (Corsair Pro, Tornus, Turnpike, Turnpike Spiral, Nhancer Pro X, Mizuki, Mamba, Teleport control, M-Cath)

b) Small (Caravel, Turnpike LP, Fine Cross, Micro Cross 14, Mamba Flex, Teleport, Corsair XS

* Provide guidewire support in tortuous anatomy
* Facilitate guidewire placement and exchange

2**) Dual lumen (Twin-Pass Torque &Twin-Pass, Sasuke, Crusade, Fine Duo, NHancer Rx, ReCross):**

* Useful for guidewire exchange in difficult wiring cases and act like two micro catheters
* Provide support in tortuous anatomy
* Help to steer the wire through the side branch
* Facilitate to wire the bifurcation lesion
* Collateral access in CTO-PCI

3**) Angulated (Super Cross, Venture, Swift Ninja):**

* Facilitate in crossing the severely angulated side branch
* Provide great back up wire support

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