CHAPTER 1

Coronary Wiring Fundamentals: Wire Design, Engineering and Selection

Bina Ahmed, MD[1]

[1]Santa Barbara Cottage Hospital, Santa Barbara, CA

Introduction

Since the first coronary balloon dilation in 1979,[1] which was completed without the use of a guidewire, there has been considerable evolution in the procedural aspects of coronary intervention. One key development was the use of a removable coronary guidewire to facilitate passage of balloons[2] and eventually stents. Over the last two decades, there has been continued improvement in the construct of coronary guidewires allowing and facilitating treatment of a broad spectrum of coronary disease. In addition to providing support, the guidewire should be trackable, torqueable and provide good tactile feedback (**Table 1**). Selection of the correct guidewire should be determined by an operator's familiarity with the wire and tailored to the coronary and lesion anatomy being treated. The operator should have a solid understanding of basic wire components and construction which in turn can be very helpful in safe treatment of a broad spectrum of coronary lesions.

Basic guidewire construction

The standard coronary guidewire is 0.014 inch (0.36 mm) in diameter. There are exceptions such as some atherectomy-specific wires that have a distal tip measuring 0.009 inches, and chronic total occlusion (CTO) wires that have tapered tips to engage the cap of total occlusions. In addition, standard length ranges between 175-190 cm with longer lengths up to 330 cm needed for specialty wire or anatomy requiring over the wire balloons. The weight at the tip of the wire, or tip load, is an important aspect of wire design and ranges from less than one gram to 15 grams.

Although wires can appear the same, they can vary widely based on materials used for construction and overall design (**Figure 1**). Minor changes to any component of the wire can affect wire performance. The main components of a guidewire are: 1) a central shaft (core) made of stainless steel or nitonol; 2) body which surrounds the core and is usually made of coils or polymers; 3) a distal flexible tip made with platinum or tungsten alloy and 4) surface coating.

Core tapers and the diameter of the distal tip affect wire flexibility and amount of support provided. In general, when the core extends and tapers gradually across the shaft, the wire tends to be more trackable at the expense of support. On the other hand, a short taper enhances support but makes for a wire that is less trackable and more likely to prolapse. In addition, a smaller core diameter is associated with increased flexibility as compared to larger diameters, which provide more support and torque control. Core material also affects wire performance. Wires with a nitinol core are kink resistant compared to stainless steel core wires. The nitinol core also allows for balanced force transmission and makes navigating acute turns and take-offs easier. One limitation of the nitinol core is that it tends to store torque. A stainless steel core can also provide improved torque, push and excellent support.

The distal tip is usually a radiopaque platinum or tungsten alloy with a shaping ribbon or an extension of tapered core extending into the distal tip. When the core extends up to the wire tip, it is known as core-to-tip design. This provides excellent tactile feedback, as well as tip and torque control. If the core does not reach the tip, a shaping ribbon extends to make the tip (**Figure 2A and 2B**). This type of design provides good shape retention and flexibility.

Coating on the wire is usually over the distal half. Hydrophobic coating such as silicone or Teflon repel water and offer increased control but less trackability. Hydrophilic coating, which attracts water, creates a slippery surface and can help reduce surface tension and increase ease of wire advancement. Hydrophilic wires are kink resistant and flexible, and the polymer coating results in low thrombogenicity. Use of hydrophilic wires allows for easier navigation; however, they are associated with increased risk of dissection and/or perforation.

Guidewire classification

There is no uniform classification for guidewires. However, there are some common themes and several different ways coronary guidewires are categorized. Categorization based on clinical scenario can be helpful.

A **workhorse**, or everyday wire, should provide 1:1 torque and moderate support, while also providing excellent tip shape retention and durability. They are relatively low risk wires suitable for rapid, uncomplicated interventions. Lesion sets that require more finesse due to tortuosity or other anatomic features may call for a workhorse wire with a single core that offers better support and trackability. Workhorse wires usually have a hydrophilic coating to facilitate crossing over more angulated segments. Another wire category is a **stiff guidewire** designed to provide extra support. They can straighten a curved segment and facilitate stent delivery. However, they may also be prone to kinking and "pseudolesions," which can hinder stent delivery. Removal of the stiff part of the wire from the tortuous segment will usually resolve this phenomenon. Lastly, **specialty guidewires** may offer crossability for chronic total occlusions. A detailed discussion in the nuanced differences in all wire types is beyond the scope of this review.

Specific anatomic and lesion considerations

Tortuosity

There may be significant resistance when trying to navigate and establish wire position in the distal portion of a tortuous vessel. Many factors can lead to poor steerability. Emphasis should be placed on using a lubricious, flexible and trackable wire. It can be helpful to use a floppy, hydrophilic tipped long wire with the help of an over the wire balloon to provide extra support and steerability. Use of an over the wire system can also allow the operator to exchange for a more supportive, non-hydrophilic wire once the lesion has been traversed. An alternative to using long wires and over the wire balloons is the use of flexible microcatheters.

Calcified lesions

Severely calcified lesions may call for the use of hydrophilic coated wires with softer tips and smaller diameters. The risk of dissection across a calcified lesion is increased and very careful maneuvering with the correct wire can make the difference.

Bifurcations

Extreme angulation or need to access acutely angled bifurcations may require alteration of the shapeable wire tip. One such approach is applying a hairpin technique where the tip of the wire is given an extreme curve to allow retrograde access into side branch. In addition, the use of a deflectable catheter or pre-shaped microcatheter with a standard workhorse wire can assist in accessing angulated side branches.

Guidewire associated complications

Guidewire-induced perforations are uncommon but remain the most common cause of coronary perforations. [3] Migration of wires into the distal end vessels can go unrecognized resulting in signs and symptoms of pericardial effusion and tamponade several hours after the completion of the case. Hydrophilic wires pose the highest risk, although both patient and procedural factors can increase this risk with the use of any guidewire. Awareness and vigilance regarding distal wire positioning is key, and final angiography should ensure a thorough evaluation that does not miss even a small area of extravasation. Treatment of a wire-related perforation should be considered at the time of the index procedure, given that unabated bleeding may result in pericardial effusion and tamponade. Most perforations can be addressed with balloon occlusion above the area of perforation. Reversal of anticoagulation may be considered based on the context of the situation (e.g. weigh against risk of stent thrombosis if recent drug eluting stent placement).

Entrapment of coronary guidewires is rare but can occur. This risk may be increased when navigating calcified and tortuous vessels, and when excessive wire manipulation is applied. [4] Forceful attempts at freeing up the wire can result in wire fracture and retention. When the wire is intact, passage of an over the wire balloon may help facilitate removal. If the wire has fractured, the use of snares and other retrieval devices may be necessary. Conservative management can be considered if the patient is clinically stable and the risks of further manipulation exceed the benefits.

Although guidewire-induced pseudolesions (or concertina effect) is not a true complication, [5,6] recognizing wire straightening artifact is necessary to avoid unnecessary treatment. The use of a stiff wire to straighten a tortuous segment of vessel can lead to kinking and give the appearance of a pseudostenosis. Removing the stiff part of the wire while leaving the more flexible, radiopaque end will abolish the finding and allow the vessel to return to its natural state.

Conclusion

The use of the correct guidewire is key to safely completing a successful coronary intervention. There is an abundance of options when it comes to choosing the correct guidewire. Familiarity with guidewire design and construction is necessary, especially when tackling lesions that are more challenging. Operators should consider developing a 'feel' and familiarity with 3-5 wires that offer different advantages, including a work-horse wire for simple coronary lesions, a wire which requires more finesse through challenging lesions, and wires that provides extra support when needed.

Chapter 1: Coronary Wiring Fundamentals: Wire Design, Engineering and Selection

Table 1: Key properties of a coronary guidewire

Table 1: Key properties of a coronary guidewire
Torquability: Ability of the shaft to overcome turning resistance. For each 360 degree turn at the proximal end, there is a 360 degree turn at the distal end.
Trackability: Ability to deliver wire along the vessel and stenosis
Tactile Feedback: Response the operator feels while maneuvering the wire.
Wire Support: Determined by thickness of the core materials
Tip Load: Measured by the amount of force it takes to buckle the tip. Heavier tip load aids in crossing more resistant lesions.

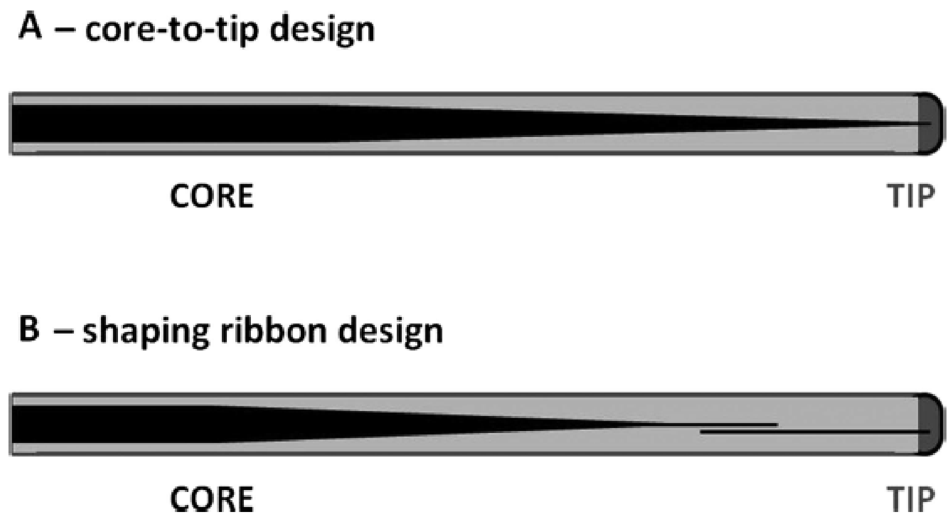
Figure 1: Detailed description of commonly used coronary guidewires

	Product	Core*	Tip	Design	Diameter	Tip load (g)	Tip coating	Radiopaque (cm)	Support
Mtr	Zinger Light	Steel	Spring coil	Shaping ribbon	0.014″ ntp	n/a	Hydrophilic	3	Light
Mtr	Cougar LS	Nitinol	Spring coil	Shaping ribbon	0.014″ ntp	n/a	Hydrophilic	3	Light
Abb	Whisper Light Support	Steel	Polymer	Core-to-tip	0.014″ ntp	0.8	Hydrophilic	3	Light
Bsc	ChoICE Floppy	Steel	Spring coil	Core-to-tip	0.014″ ntp	0.8	Hybrid†	2.8	Light
Abb	Powerturn Ultraflex	Steel	Coil	Core-to-tip	0.014″ ntp	0.9	Hydrophilic	3	Light
Bsc	PT 2 light support	Nitinol	Polymer	Shaping ribbon	0.014″ ntp	2.5	Hydrophilic	2	Light
Mtr	Zinger medium	Steel	Spring coil	Shaping ribbon	0.014″ ntp	n/a	Hydrophilic	3	Moderate
Mtr	Cougar MS	Nitinol	Spring coil	Shaping ribbon	0.014″ ntp	n/a	Hydrophilic	3	Moderate
Abb	Balance middle weight	Nitinol	Coil	Shaping ribbon	0.014″ ntp	0.7	Hydrophilic	3	Moderate
Asa	Sion	Steel	Coil	Core-to-tip	0.014″ ntp	0.7	Hydrophilic	3	Moderate
Asa	Fielder FC	Steel	Polymer	Core-to-tip	0.014″ ntp	0.8	Hydrophilic	3	Moderate
Bsc	Luge	Steel	Spring coil	Core-to-tip	0.014″ ntp	0.9	Hybrid†	3	Moderate
Abb	Powerturn flex	Steel	Coil	Core-to-tip	0.014″ ntp	0.9	Hydrophilic	3	Moderate
Abb	Whisper medium support	Steel	Polymer	Core-to-tip	0.014″ ntp	1.0	Hydrophilic	3	Moderate
Bsc	IQ	Nitinol	Spring coil	Shaping ribbon	0.014″ ntp	1.1	Hydrophobic	2	Moderate
Abb	Pilot 50	Steel	Polymer	Core-to-tip	0.014″ ntp	1.5	Hydrophilic	3	Moderate
Abb	Cross-IT 100XT	Steel	Spring coil	Core-to-tip	0.010″ tp	1.7	Hydrophilic	3	Moderate
Abb	Pilot 150	Steel	Polymer	Core-to-tip	0.014″ ntp	2.7	Hydrophilic	3	Moderate
Bsc	PT 2 moderate support	Nitinol	Polymer	Shaping ribbon	0.014″ ntp	2.9	Hydrophilic	2	Moderate
Mtr	Thunder	Steel	Spring coil	Core-to-tip	0.014″ ntp	n/a	Hydrophilic	3	Extra
Mtr	Zinger support	Steel	Spring coil	Shaping ribbon	0.014″ ntp	n/a	Hydrophilic	3	Extra
Asa	Grand slam	Steel	Spring coil	Core-to-tip	0.014″ ntp	0.7	Hydrophobic	4	Extra
Abb	Balance heavy weight	Nitinol	Coil	Shaping ribbon	0.014″ ntp	0.7	Hydrophilic	4.5	Extra
Bsc	ChoICE extra support	Steel	Spring coil	Core-to-tip	0.014″ ntp	0.9	Hybrid†	2.8	Extra
Abb	Powerturn	Steel	Coil	Core-to-tip	0.014″ ntp	0.9	Hydrophilic	3	Extra
Bsc	Choice PT extra support	Steel	Polymer	Core-to-tip	0.014″ ntp	1.2	Hydrophilic	35	Extra
Abb	Whisper extra support	Steel	Polymer	Core-to-tip	0.014″ ntp	1.2	Hydrophilic	3	Extra

*Various alloys of steel, such as stainless steel, durasteel, etc, are not specified.
†Hybrid: distal 3 cm uncoated.
Abb, Abbott Laboratories, Abbott Park, Illinois, USA; Asa, Asahi Intecc Co, Aichi, Japan; Bsc, Boston Scientific Corp, Natick, Massachusetts, USA; Mtr, Medtronic Inc, Minneapolis, Minnesota, USA; ntp, non-tapered, tp, tapered; ″, inch.

Reprinted with permission. Tóth GG, Yamane M, Heyndrickx GR. How to select a guidewire: technical features and key characteristics. Heart 2015;101:645–652.

Figure 2: A: In the core-to-tip design, the core material extends to the tip. B: In the shaping ribbon design, the core is shorter and the shaping ribbon provides continuity to the tip.



Reprinted with permission. Tóth GG, Yamane M, Heyndrickx GR. How to select a guidewire: technical features and key characteristics. Heart 2015;101:645–652.

References:

1. Gruentzig AR, Senning A, Siegenthaler WE. Non-operative dilatation of coronary artery stenosis: percutaneous transluminal angioplasty. N Engl J Med 1979;301:61.
2. Simpson JB, Baim DS, Robert EW, et al. A new catheter system for coronary angioplasty. Am J Cardiol 1982;49:1216-22.
3. Witzke CF, Martin-Herrero F, Clarke SC, et al. The changing pattern of coronary perforation during percutaneous coronary intervention in the new device era. J Invasive Cardiol 2004;16:257-301.
4. Alomari, Snyder R, Ahmed B. Entrapped Devices After PCI. Cardiovascular Revascularization Medicine 2014;15(3):182-185.
5. Deligonul U, Tatineni S, Johnson R, et al. Accordion right coronary artery: an unusual complication of PTCA guidewire entrapment. Cathet Cardiovasc Diagn 1991;23:111-113.
6. Rauh RA, Ninneman RW, Joseph D, et al. Accordion effect in tortuous right coronary arteries during percutaneous transluminal coronary angioplasty. Cathet Cardiovasc Diagn 1991;23:107-110.