The latest wire technique for chronic total occlusion

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If patency is restored after chronic total occlusion (CTO), it can be maintained over the long term by implanting drug-eluting stents. The cause of unsuccessful percutaneous coronary intervention is usually failure of the wire to cross the site of CTO. The objective of this article is to describe the latest wire techniques for CTO. As for wire selection, CTO should generally be treated with hard-tipped spring wires, preferably Conquest Pro series (Asahi Intec). According to the penetrating strategy, the course of a blood vessel with CTO is established preoperatively and the wire is advanced based on the imaging data with minimum rotation (a torque of ± 90° or less). If the operator encounters divergence between the preoperative CTO image and the actual course of the coronary artery, the parallel wire technique should be used. With this method, a wire which enters the subintimal space is left there, and a second wire is inserted along it to find a new channel. When this technique is successful, the following findings are often noted: 1) the second wire crosses over the first one in the CTO; 2) the second wire shows more acute curve than the first wire; 3) the second wire penetrates the lesion from the outer curvature of the coronary artery and then is advanced along the same curvature of the vessel. Indeed, the second wire should be operated intentionally to achieve these findings so that the probability of success increases and the duration of the procedure is shortened.

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Introduction

Chronic total occlusion (CTO) is now attracting attention as the most serious obstacle to successful percutaneous coronary intervention (PCI), because the problem of restenosis (once called the Achilles' heel of PCI) has almost been solved satisfactorily by the development of drug-eluting stents (DES). CTO not only influence symptoms and left ventricular function[1], but also affects survival[2]. Suero et al.[2] reviewed the prognosis of 2007 CTO patients, and found that the 10-year survival rate was 84.7% after successful PCI, while it was only 72.8% when PCI failed. Furthermore, the BARI studies have indicated that the presence of CTO is the most important factor for selecting bypass as the mode of coronary vascular reconstruction[3]. The initial success rate of PCI is as low as 60-70% in patients with CTO and the restenosis rate after restoration of patency is higher than non-CTO lesions despite stenting[4-10]. On the other hand, it has been reported by some authors that the restenosis rate can be reduced to very low levels by use of DES in CTO patients[11-13]. Thus, if patency is restored after CTO, it can be maintained over the long term by implanting DES.

The cause of unsuccessful PCI is usually failure of the wire to cross the site of CTO. However, a high success rate of 85-90% may be obtained if a recently developed spring wire dedicated for CTO[14,15] is used appropriately. This article describes the latest wire techniques for CTO.

Types and selection of wires

The wires used during PCI for CTO can be classified into two types, which are plastic wire and hard-tipped spring wire for CTO only. The plastic wire has the advantage of extremely low friction with the vessel walls, because it is coated from base to tip with a polymer and then also covered with a hydrophilic coat. When this type of wire is rotated in contact with an occlusion under low pressure, the wire finds a relatively soft part of the lesion and enters it spontaneously. However, there is little room for this wire being manipulated intentionally by the operator, because an encounter with hard tissue may cause it automatically to enter the surrounding subintimal space which is relatively soft. Therefore, we do not recommend use of this type of wire. CTO should generally be treated with the hard-tipped spring wire, while the plastic wire should only be used on special occasions with a clear understanding of its expected advantages and limitations.

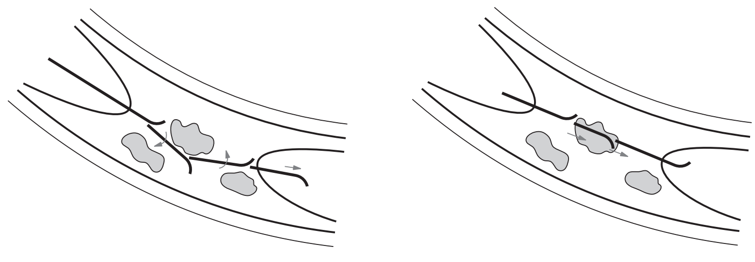
Fundamental strategy

We have to realize that the fundamental strategy for treating CTO has recently shown a considerable change. A "drilling strategy" was common in the past. Accordingly, the wire was advanced and retracted with active rotation, and discrimination of the true from false lumen was based on the extent of resistance (especially during pull-back). The wire was advanced along the lumen that was considered to be true on this basis. However, if the wire encountered tissue that was very hard and penetration was difficult (Fig. 1A), it was necessary to repeat subtle rotation, advancement, and retraction of the wire to bypass it, without increasing the force on the wire aimlessly. However, discrimination between true and false lumens was not always accurate because it depended on the sensation of resistance transmitted from the tip of the wire. Therefore, it was not uncommon for such repeated rotation to cause enlargement of the subintimal space, resulting in failure of the procedure.

In recent years, we have come to regard the "penetration strategy" as the fundamental method, because the spring wire for CTO has shown marked improvement, particularly since the Conquest Pro series (Asahi Intec, Nagoya, Japan) with the advantages of high penetration and torque transmission have come into clinical use. For this strategy, the course of a blood vessel with CTO is established preoperatively and the wire is advanced based on the imaging data under biplane fluoroscopy. Even when the tip of the wire encounters hard tissue, it is not bypassed, but is penetrated (Fig. 1B). As mentioned above, the wire tends to stray into the subintimal space, because it is softer than calcified tissue in the true lumen. Therefore, a wire with a high penetrance should be used from the early stage of treatment so that obstruction by hard tissue can be overcome.

The spring wire for CTO should always be used together with a microcatheter or an over-the-wire balloon. If such a support device is used, movement of the wire inside a guiding catheter associated with rotation is decreased, and operatability, especially transmission of torque to the tip is markedly improved. Furthermore, if the double-bend method is combined (Fig. 2), the stiffness and curvature of the wire can be changed freely. When the support device is inserted toward the proximal site of CTO, a floppy wire should be used in place of the hard-tipped spring wire to avoid causing coronary artery damage.

With the "penetration strategy," a torque of ± 90° or less is applied with the right hand to rotate the tip of the



A B

Figure 1. *Differences between the drilling and penetration strategies. Drilling strategy: when the tip of a wire encounters hard tissue, the wire is advanced and retracted repeatedly to find a relatively soft part of the chronic total occlusion lesion and is pushed through it* (A). *Penetration strategy: a stiff wire is used from the start of the procedure and is advanced in the planned direction through hard tissue in the chronic total occlusion lesion* (B).

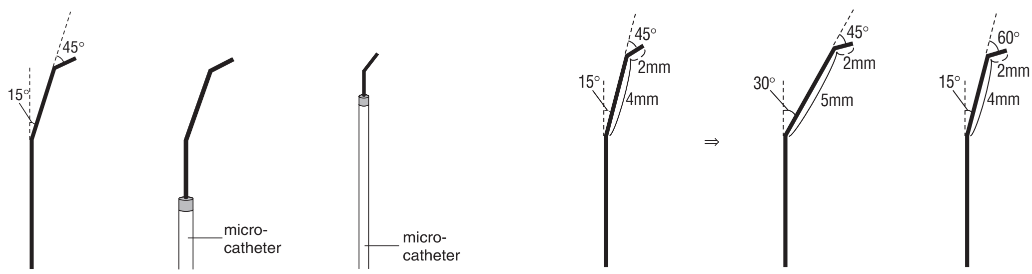


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Figure 2. *Double-bend method. In addition to the first small curve (approximately 2 mm) made at the tip of a wire to find a true lumen, a larger shallow curve (approximately 4-5 mm) is added to cope with the curvature of the blood vessel. It is possible to use or extend the second curve at the tip of a microcatheter* (A). *When the parallel wire technique is used, it is possible to advance the second wire along a different channel by making the first or second curve different from that of the first wire* (B).

wire. Then the wire is pushed forward with the left hand while the direction of its tip is correct in biplane fluoroscopy. At the beginning, the wire should be pushed very gently, i.e., a so-called feather touch should be used. If penetration cannot be achieved, then the force should be increased gradually so that the wire moves ahead in the desired direction. It is not uncommon that some divergence is admitted between the preoperative CTO image and the actual course of the coronary artery. In this case, the parallel wire technique is used to correct such divergence, and the wire can be advanced into the distal segment of the coronary artery.

Penetration of the proximal fibrous cap

CTO is caused by organization of coronary artery thrombus, but the process of organization is not uniform[16-18]. Briefly, it occurs rapidly at the edges of the occlusion, but slowly in the central portion. Therefore, hard tissue rich in fibrous and calcified components, called the proximal and distal fibrous caps, often forms at the proximal and distal borders where organization is more rapid. Penetration through these caps is often difficult.

The proximal border of a CTO lesion is classified as abrupt or tapered. At a bifurcation, no protrusion is noted in the former type, while a cone-shaped protrusion is observed in the latter type. From the standpoint of the wiring technique, the latter type is classified with respect to the presence or absence of an entrance into the lesion, which is called a stump.

In abrupt and tapered lesions without a stump, there is a hard proximal fibrous cap at the margin that can be seen by angiography. It is usually impossible to penetrate this cap with a moderately stiff wire, such as an Intermediate or a Miracle 3gr (Asahi Intec). Therefore, we start the procedure with a very stiff wire, such as the Conquest Pro or Miracle 12gr (Asahi Intec).

An abrupt type CTO at a side branch is a kind of bifurcation lesion. It has been shown by intravascular ultrasonography that plaques are mainly distributed on the side opposite to the side branch. Based on this rule, the site of penetration is narrowed to the commencement of the side branch (Fig. 3).

In the tapered type with a stump, a proximal fibrous cap is not necessarily present at the margin that can be seen by angiography. Instead, resistance (presumably due to the proximal fibrous cap) is usually felt after the wire has been advanced a few millimeters into the lesion. If the duration of occlusion is several months, penetration is usually possible using a moderately stiff wire. However, if the duration of occlusion is unknown or if it is estimated to be longer from the extent of development of collateral vessels, a moderately stiff wire may be redirected by the proximal fibrous cap and enter the subintimal space. In such cases, the wire should be immediately changed to a Conquest Pro. When the wire needs to be changed, the parallel wire technique mentioned below should be used in principle (Fig. 4).

Penetration of the distal fibrous cap and the parallel wire technique

In the past, if a wire entered the subintimal space adjacent to a CTO lesion, it was removed and a new wire (usually stiffer one) was inserted to find a new channel.

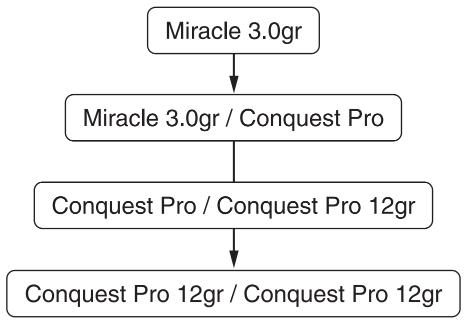

Figure 4. *Our selection of wires for chronic total occlusion.*

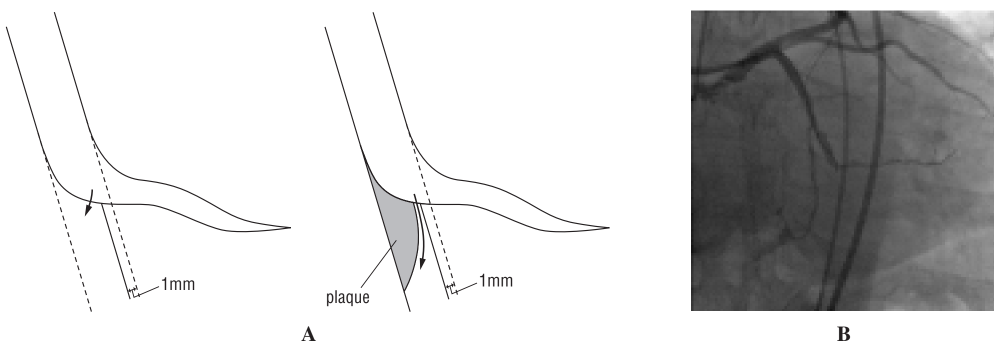

Figure 3. *Optimal site for crossing the abrupt type of chronic total occlusion at a vessel bifurcation. Extensions are drawn from both sides of the vascular trunk located on this side branch. From approximately 1 mm inside the branch vessel, a wire is advanced at a slight angle in the opposite direction* (A). *Since the vessel diameter is slightly smaller in the peripheral segment, the margin is "approximately 1 mm". Because the main plaque is located on the side opposite to the branch, while the true lumen is on the same side as the branch, the wire should be advanced in "the opposite direction to the branch". A typical example is shown at the origin of the posterolateral branch from the left circumflex artery* (B).

However, insertion of the new wire through the proximal fibrous cap was time-consuming and required the use of contrast medium. Moreover, even when another channel was created, it was not rare for the new wire to eventually enter the same subintimal space. Furthermore, it was often necessary to advance a support device beyond the proximal fibrous cap in order to change the wire, resulting in further enlargement of the subintimal space and even displacement of the true lumen of the distal segment of the coronary artery. Therefore, the parallel wire technique was developed. With this method, a wire which enters the subintimal space is left there, and a second wire is inserted along it to find a new channel.

Thus, the first wire acts as a useful landmark for insertion of the second one. The parallel wire technique also has the following advantages. Because one wire is already fixed in the blood vessel, albeit in the subintimal space, the force applied to the lesion can be increased when the second wire is inserted. Accordingly, the second wire can more easily penetrate the distal fibrous cap or other obstructions. Because continuing the procedure with a wire which has entered the subintimal space may lead to the further enlargement of the space, the parallel wire technique should be adopted as soon as it is considered difficult to move the wire from the subintimal space to a new channel. When the parallel wire technique is employed, it is convenient to insert

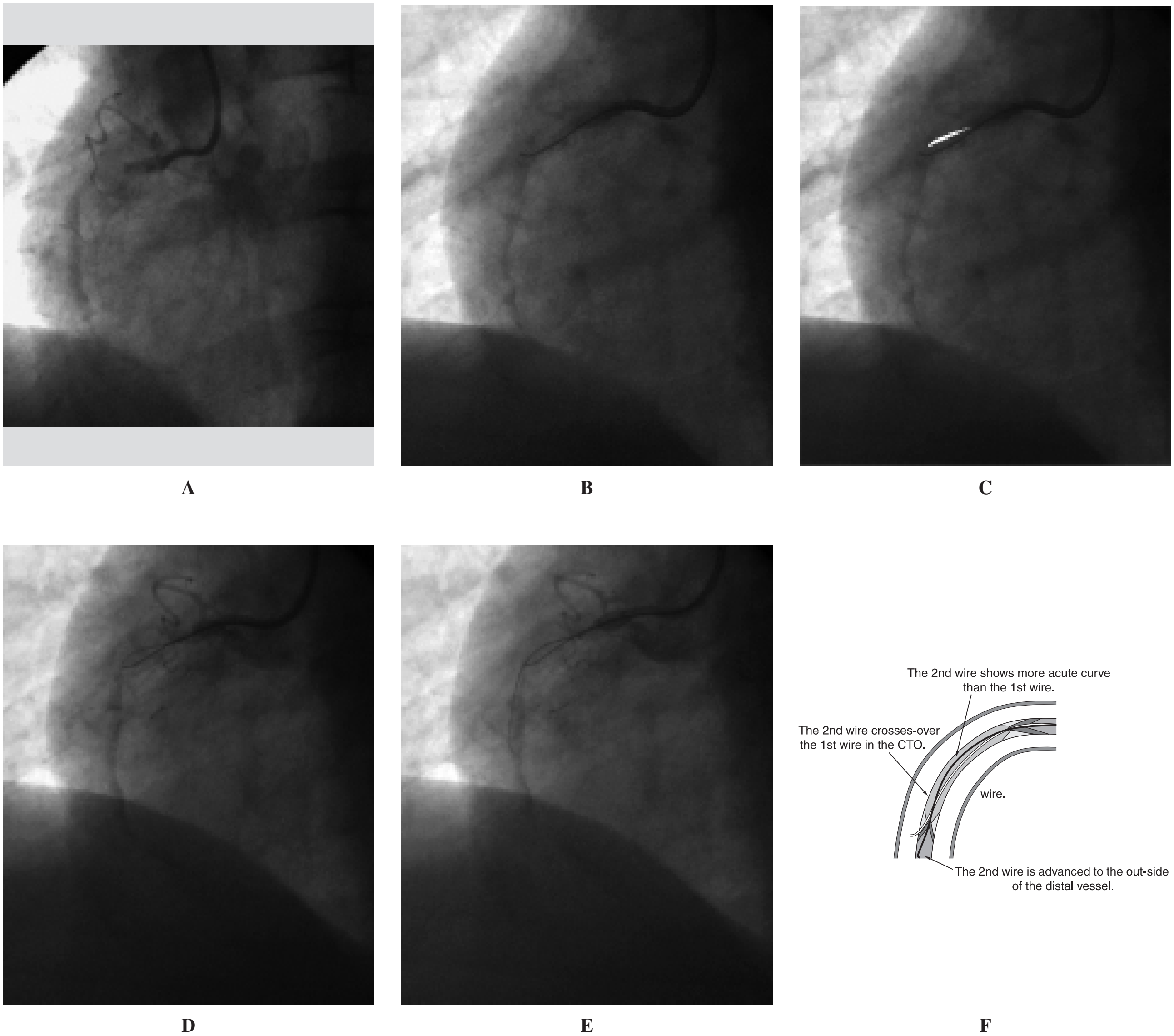

Figure 5. *Principles of the parallel wire technique. In a patient with chronic total occlusion (CTO) of unknown duration in the proximal segment of the right coronary artery, the lesion was located at the curve in the proximal segment of the vessel* (A). *A Miracle 3.0gr was initially used with Transit support. However, the wire was deviated from the course of the distal segment of the coronary artery when it was advanced close to the distal fibrous cap, indicating that it was in the subintimal space* (B). Panel C *shows the ideal route for crossing the distal fibrous cap. If the Miracle 3.0 wire is used as a landmark, it can be easily recognized by fluoroscopy without the need to perform angiography. A Conquest Pro was inserted by the parallel wiring technique and passed through the ideal route without appreciable resistance, after which it was advanced to cross the Miracle 3.0* (D). *Finally, the wire penetrated the distal fibrous cap from the outer curvature of the right coronary artery* (E). *This case demonstrates all three requirements for successful performance of the parallel wire technique* (F).

another microcatheter and then introduce the second wire using the catheter.

Since it is almost inevitable that the first wire will enter the subintimal space when treating a difficult CTO lesion, it is not necessary to become alarmed when this occurs. Excessive efforts should not be made to cross the lesion in one attempt. For the time being, the wire can be left in the subintimal space. The concept of not crossing a lesion but leaving a wire in the subintimal space temporarily is not applicable to most non-CTO lesions and it is difficult to become accustomed to it. However, it is important to remember that success can be achieved by advancing the second wire using the first wire lodged in the subintimal space as a landmark. Also if this is too difficult, the parallel wire technique can be repeated again to achieve success with a third wire.

When the parallel wire technique is successful, the following findings are often noted: 1) the second wire crosses over the first one in the CTO; 2) the second wire shows more acute curve than the first wire; 3) the second wire penetrates the lesion from the outer curvature of the coronary artery and then is advanced along the same curvature of the vessel (Fig. 5). If these principles of the successful parallel wire technique are understood, it becomes possible to operate the second wire more intentionally so that the probability of success increases and the duration of the procedure is shortened. According to this, the second wire should be advanced with the intention of crossing over the first wire inside the lesion showing more acute angle, and it should be pushed toward the outer curvature of the distal segment of the coronary artery.

After a wire crosses the CTO, balloon expansion and insertion of a stent are performed. It is not uncommon for these procedures to also be associated with problems, including failure to cross the balloon through the CTO. However, further details have to be omitted due to lack of space.

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