Introduction. Since the introduction of coronary angioplasty by Gruentzig in 1977, this revascularization technique has been applied to an increasing number of patients and in different clinical scenarios. However, chronic total occlusions are still considered to be a challenge for the interventional cardiologist. It has been estimated that approximately 10% of all angioplasty procedures are currently undertaken for chronic total occlusions. Percutaneous coronary intervention of chronic total occlusions has been limited by a relatively low angiographic success rate between 42–73% and a high restenosis rate ranging from 43–77% during follow-up.1–4 However, a successful recanalization of an occluded artery can improve clinical symptoms and left ventricular function and can even reduce coronary artery bypass graft surgery in this type of patient.

Over the past years, several new materials and devices, such as guidewires, smaller-profile balloons, laser technology, mechanical drills, and stenting, have been developed to treat chronic total coronary occlusions. These devices can either facilitate the attempted recanalization, reduce restenosis rates after successful recanalization, or both. Likewise, new pharmacological adjunctive treatments such as glycoprotein IIb/IIIa platelet inhibitors have demonstrated a reduction in the ischemic complications of percutaneous interventions of complex coronary lesions.5

Angiographic predictive factors in chronic total occlusions. Success rate is higher in functional occlusions compared to chronic total occlusions. Functional occlusion is defined as the presence of only faint, late anterograde flow in the absence of a discernible lumen, with Thrombolysis in Myocardial Infarction (TIMI) grade 1 and major filling of the distal vessel predominantly by collateral channels. In contrast, total occlusion is defined as the absence of any anterograde opacification, corresponding to TIMI grade 0 flow. Angiographic chronic total occlusion frequently corresponds to less than complete occlusion by histologic criteria. The failure rate is also known to increase with the duration of the occlusion, the length of the occluded segment, the presence of bridging collateral circulation, and the absence of vessel stump.

Patients with recent occlusions or acute total occlusions during impending myocardial infarction behave differently than those with chronic occlusions.6 A fresh and soft thrombus is an easy obstacle to pass through. In total occlusions, the recanalization equipment should be passed through the atherosclerotic plaque, and its texture is crucial for the success or failure of the intervention. Therefore, attempts to recanalize older total occlusions are hampered by a lower success rate and higher recurrence rate. On the other hand, serious complications are rare, although they do occur. In general, the success rates in the literature range from 42–73%.7,8 The extent of fibrosis of the thrombus is the decisive factor in determining the chance of successful recanalization. The duration of occlusion emerges as a key factor for success in most studies.9 The most rapid decline in the chance of success occurs within the first 4–6 weeks after the occlusion. Some angiographic features, such as bridge collaterals, suggest the presence of an older occlusion. Previous studies reported that occlusion duration of < 12 weeks had an acute success rate of 68%.10 Similar findings were shown by other authors reporting a 67% success rate when the duration was < 20 weeks and an 18% success rate when the duration was > 20 weeks.10 Other studies observed a success rate of 69%, 50%, and 11% for occlusion durations of < 1 month, 1–6 months, and > 6 months, respectively.10 Age-related
changes in histologic composition and neovascular channel pattern of chronic total coronary artery occlusions may explain the variable success rates. Cholesterol and foam-cell laden intimal plaque is more frequent in younger lesions ($p < 0.001$), whereas fibrocalcific plaque increases with more chronic occlusions ($p = 0.008$). Therefore, age-related changes in intimal plaque composition from cholesterol laden to fibrocalcific may explain the adverse revascularization profile of older occlusions.

The length of the occluded segment strongly influences the success rate of the intervention. The estimated length of the occlusion is measured from the point of the chronic occlusion to the most proximal point of the distal vessel, which is visualized by antegrade or retrograde collateral filling with contrast. A shorter occluded segment corresponds with a greater chance of crossing with the coronary guidewire and angioplasty materials without developing any angiographic complications such as coronary dissection or perforation.

The presence of a tapering stump appears to be associated with a higher success rate. This factor is usually associated with a more recent total occlusion. An occlusion at a sidebranch point results in a technically more difficult intervention because the coronary guidewire tends to direct toward the lower resistance pathway.

Case selection plays an even more important role in very old occlusions, and some angiographic features (such as a short, straight segment in a large vessel) are predictors of success. Further adverse factors are the absence of a stump or a tapered segment as an entry port, the presence of bridging collaterals (which testify to the age of occlusion), and occlusions within bypass grafts.

**Differences in long-term results between total occlusions and non-occluded lesions.** Percutaneous coronary intervention of chronically occluded arteries is associated with a lower initial success rate than angioplasty of arteries that are stenotic but not occluded. In addition, when angioplasty is successful, the frequency of restenosis and reocclusion has been reported to be considerably higher than that after angioplasty of subtotal stenoses. Recurrence rates after balloon angioplasty average 55%, ranging from 43–77% [12,13]. Complete reocclusions of recanalized lesions occur in an average of 19% [14].

Stenting has proven to be superior to balloon angioplasty in reducing the incidence of repeat revascularization procedures in patients with focal, short, non-occluded lesions of native coronary arteries [15-17]. Several recent studies demonstrated that implantation of intracoronary stents after successful recanalization of chronic coronary occlusion significantly improved the angiographic and clinical long-term outcome [19-20]. Although stenting has improved the long-term results (mainly by reducing target vessel revascularization), the incidence of restenosis is still higher among patients with totally occluded coronary arteries compared to those with non-occluded lesions. The angiographic restenosis rate after stenting in this population compares unfavorably with historical balloon angioplasty versus stenting clinical trials [15-17,20]; however, further improvement of this technique is required to reduce this still relatively high restenosis rate. Furthermore, the results might be improved with the use of intravascular ultrasound guidance to better measure the vessel size and to achieve optimal stent deployment after successful recanalization of chronic total occlusions. The higher restenosis rate might be explained by several factors, such as a greater plaque burden with consequently more pronounced elastic recoil and the diffuse atherosclerotic disease in the proximal and distal reference segment that is associated with a more aggressive neointimal proliferation, thrombosis, and negative vascular remodeling. Moreover, the frequency of reocclusion occurs more often among patients with total occlusions compared with non-occluded lesions (19% versus 7%; $p = 0.001$) [14]. However, despite the greater reocclusion rate, adverse cardiovascular events are no more frequent in such patients, and the proportion of patients that derive clinical benefit from a successful angioplasty procedure is similar in both groups of patients.

**Technical considerations.** The interventional strategy varies according to the several clinical and angiographic characteristics mentioned above. However, there are some generalizations that are worthy of note. The first consideration is the adequate selection of angioplasty materials. The over-the-wire system offers several advantages over the monorail system. The possibility of exchanging guidewires without losing the balloon position represents its principal benefit. Second, the guidewire selection will affect the efficacy and safety of the intervention. The first attempt with a softer-tip coronary wire is usually followed by a hydrophilic-coated soft wire. The latter is frequently followed by a stiffer-tip coronary wire. Caution with the use of these types of coronary guidewires is warranted due to the risk of coronary dissection or perforation.

Third, the use of intravascular ultrasound is strongly suggested to measure the vessel diameter before choosing the stent size. Fourth, and more important in acute or subacute occlusions, the use of adjunctive glycoprotein IIb/IIIa platelet inhibitors, which have demonstrated a reduction in the incidence of ischemic complications associated with these interventions, is often necessary. Finally, the use of other
mechanical ablative techniques is sometimes necessary to overcome non-dilatable lesions. In these cases, rotational atherectomy is the most frequently utilized technique.

Conclusion. Due to the lower primary success rate and higher restenosis rate, as well as increased time, expense and radiation exposure to both patients and physicians associated with angioplasty of occluded coronary arteries, a careful case selection should be performed considering several clinical and angiographic factors. The complication rate is lower than for angioplasty of subtotal occlusions. The average mortality rate associated with attempted angioplasty of occluded arteries and the frequency of emergency bypass surgery are low, averaging 2–3%. In many cases, the mortality rate and frequency of emergency bypass surgery resulting from angioplasty of occluded arteries is actually the result of complications of angioplasty of subtotally occluded arteries performed during the same procedure. Therefore, despite the higher reocclusion and restenosis rate in patients undergoing angioplasty of a chronic coronary occlusion, the frequency of adverse cardiovascular events is no greater than in patients with subtotal stenosis, and a similar proportion of patients is found to derive clinical benefit from the angioplasty procedure.

REFERENCES