after Bonzel had developed the monorail technique did the bare-wire principle became the standard.

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REFERENCES

1. Grüntzig A, Hirzel H, Goebel N, Gattiker R, Turina M, Myler R, Stertzer S, Kaltenbach M. Die perkutane transluminale Dilatation chronischer Koronarstenosen [Percutaneous transluminal dilatation of chronic coronary stenoses]. Schweiz Med Wochenschr 1978;108:1721–3.

2. Kaltenbach M. Transluminal angioplasty of coronary arteries. Ter Arkh 1982;54:8–15.

3. Kaltenbach M. Neue Technik zur steuerbaren Ballondilatation von Kranzgefäßverengungen [New technic for guidable balloon dilatation of coronary vessel stenoses]. Z Kardiol 1984;73:669–73.

4. Kaltenbach M. The long wire technique: a new technique for steerable balloon catheter dilatation of coronary artery stenoses. Eur Heart J 1984;5:1004–9.

RESEARCH CORRESPONDENCE

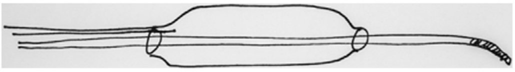
40 Years of Percutaneous Coronary Intervention

A Historical Remark on the Development of the Monorail Technique

The first steps to percutaneous coronary intervention (PCI) with Grüntzig's ground-breaking balloon catheter and the innovative separate use of guidewires and balloon catheters introduced by Martin Kaltenbach are well described in his letter to the editor in this issue of *JACC: Cardiovascular Interventions* (1). This development continued and evolved with the introduction of the monorail-balloon catheter system (including stenting) (2,3).

Our group started PCI at the University Hospital of Freiburg in 1980 after installing a new high-resolution x-ray system. It is important to remember that in the early years, the dilatation success was judged by the decrease of the trans-stenotic pressure gradient. Coronary images were insufficient because of limited radiographic systems and bulky PCI catheters hindering contrast flow through the guide catheter. Thin balloon-on-wire catheters without distal pressure measurement (described by Geoffrey Hartzler and Spencer King) improved contrast flow but had drawbacks in steerability and balloon exchange.

FIGURE 1 1984 Sketch of a "Sliding-Rail Balloon Catheter"



Guidewire with a curved tip. The balloon sits on the guidewire as on a rail. The guidewire is not in a concentric fit within the shaft, but runs parallel to the shaft.

Therefore, the long-wire technique with the concept of "bare wire first" fulfilled many requirements for better PCI procedures. In my view, however, as in the view of others, the evolution of PCI still suffered from lack of ease and from long laboratory working hours. For maximum safety and larger patient numbers, procedures had to be simpler, safer, and shorter. After weeks of thoughts, I came up with a seemingly simple solution, the "sliding-rail system," later called "monorail system." This consisted of a newly designed balloon catheter with a short tube through the balloon segment and a single-lumen shaft, and a short separate guidewire. The relevant inventory step was to desert the long-standing tradition of coaxial catheters (Figure 1). The Schneider Medintag company (Zürich, Switzerland) produced a first version of my catheter to be tested on the kitchen table within 2 weeks!

The monorail catheter dispensed with distal pressure measurement, but could easily slide on any bare wire, also for rapid balloon exchange. To visualize the dilatation result, the thin shaft permitted high contrast flow through the guide catheter, and the balloon could also be pulled back out of the stenosis, whereas it had to stay there to measure the pressure gradient. The other major advantage was the rapid exchange of balloon catheters. The controversy "pressure gradient versus visualization" was debated in many PCI conferences for several years, mostly in the United States, where the acceptance of the monorail technique took longer than in Europe. I remember, at the 10th Anniversary of PTCA Conference in Atlanta in 1987, Richard Myler, in opposition to my arguments, vehemently defended trans-stenotic pressure measurements.

My first public presentation took place in Germany in 1986 at the annual meeting of the German Cardiac Society and in the United States in 1987 at the Annual Scientific Session of the American College of

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Cardiology. At the very first international symposium addressing PCI technology in Freiburg, Germany, in January 1987, a major session was dedicated to guidewire technology, including long-wire and monorail techniques. Also in 1987, self-expandable stents were introduced by Ulrich Sigwart, and safe guarded PCI results. In 1987, I visited Julio Palmaz in San Antonio and had the chance to participate in animal testing of balloon-expandable stents. These stents, carried by monorail catheters, in a few years evolved as an accepted treatment standard.

The monorail principle was used for a variety of therapeutic and diagnostic instruments to be advanced into coronary arteries, but also cerebral and distal limb arteries, for example, for transfusion, drug delivery, or ultrasound catheters. In acute coronary syndromes, the reliable combination of adequate guidewires and stent-carrying monorail balloon catheters is now well established. The best example for wire versatility is its use for fractional flow reserve measurement.

Considering the evolution of wire technology for PCI, we can draw a continuous line from Simpson's moveable wire, to the separation of wire and balloon catheter by Kaltenbach, and to the monorail system, which added, together with stents, safety, ease of use, and versatility. Thus, in coronary artery disease (with a few exceptions), the combination of wire and monorail catheter technology has been the basis for instrumental treatment innovations and for the enormous propagation of PCI.

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REFERENCES

1. Kaltenbach M. 40 years of PCI: a historical remark on the development and evolution of guidewire technology. J Am Coll Cardiol Intv 2017;10:2582–3.

2. Bonzel T, Wollschläger H, Just H. Ein neues Kathetersystem zur mechanischen Dilatation von Koronarstenosen mit austauschbaren intrakoronaren Kathetern, höherem Kontrastmittelfluß und verbesserter Steuerbarkeit [A new catheter system for the mechanical dilation of coronary stenoses with exchangeable intracoronary catheters, fast flow of the contrast agent and improved control]. Biomed Tech 1986;31:195–200.

3. Bonzel T, Wollschläger H, Kasper W, Meinertz T, Just H. The sliding rail system (Monorail): description of a new technique for intravascular instrumentation and its application to coronary angioplasty. Z Kardiol 1987;76 Suppl 6:119–22.

RESEARCH CORRESPONDENCE

Mechanisms of Orbital Versus Rotational Atherectomy Plaque Modification in Severely Calcified Lesions Assessed by Optical Coherence Tomography

Rotational atherectomy (RA) and orbital atherectomy (OA) are designed to ablate calcified plaque, but differences in their mechanisms of action in vivo are not well described (1,2), despite the importance of atherectomy in treating complex coronary artery disease.

This was a retrospective observational study comparing the effects of OA ($n = 30$) versus RA ($n = 30$) on severely calcified lesions (maximum calcium angle by OCT >270°) followed by stenting from March 2014 to August 2016 at 3 centers (NewYork-Presbyterian Hospital, New York, New York: $n = 6$ [RA], $n = 6$ [OA]; Showa University Northern Yokohama Hospital, Yokohama, Japan: $n = 24$ [RA]; St. Francis Hospital, Roslyn, New York: $n = 24$ [OA]). OCT images were acquired with the ILUMIEN OPTIS system (St. Jude Medical, St. Paul, Minnesota) and the Dragonfly Duo or Dragonfly OPTIS imaging catheter (Abbott Vascular, Santa Clara, California) or the Lunawave optical frequency domain imaging system and FastView coronary catheter (Terumo, Tokyo, Japan). OCT was performed pre-intervention (if possible), post-atherectomy (RA or OA), and post-stenting.

Calcium cross-sectional area (CSA) at the maximum calcium ablation site was identified by comparing pre- and post-atherectomy images and measured by manual segmentation. Calcium angle and lumen CSA were measured every 1 mm throughout the calcified plaque in the post-atherectomy image. Calcium modification was identified as a round, concave, polished lumen surface (**Figure 1**). Noncalcified plaque modification was a round shape of the noncalcified plaque surface post-atherectomy. Stent malapposition (distance between stent strut and lumen surface >0.2 mm), asymmetry index (1 - minimum/maximum stent diameter irrespective of location), and eccentricity index (minimum/maximum stent diameter at same location) were evaluated. Calcium fracture was defined as discontinuity of the luminal surface in the calcified plaque.