Recanalization of Total Coronary Occlusions Using a Laser Guidewire (The European TOTAL Surveillance Study)

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The success rates of coronary angioplasty for the treatment of chronic total occlusions are less favorable than for coronary stenosis. Therefore, a new laser guidewire (LW) was designed to facilitate the crossing of chronic total occlusions. We report on the results of a European multicenter surveillance study, evaluating the laser guidewire performance. Between May 1994 and July 1996, 345 patients (age 59 ± 10 years, 291 men) with chronic total occlusions were enrolled in 28 European centers. The median age of occlusion was 29 weeks (range 2 to 884), the occlusion length 19 ± 10 mm. LW recanalization was successful in 205 patients (59%). LW perforation occurred in 73 patients (21%), with hemodynamic consequences in 4 (1%). There were no deaths, emergency coronary artery bypass graft surgery, or Q-wave myocardial infarctions. In a multivariate regression analysis an occlusion age of <40 weeks ($p = 0.001$, RR = 1.34) and an occlusion length <30 mm ($p = 0.01$, RR = 1.59) were independent predictors of success. Results indicate that the LW is an effective and safe tool in the treatment of chronic total occlusion refractory to conventional guidewires. ©1997 by Excerpta Medica, Inc.

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Chronic total occlusions remain the ''enfant terrible'' of coronary angioplasty, as the success rates still lag behind those of angioplasty for coronary stenosis.[1–6] Because total occlusion is estimated to be present in one third of the angioplasty population,[7,8] an attempt was made to improve on the procedural success rates in this specific patient category. Thus, a steerable guidewire with forward debulking properties, the laser wire (LW), was developed. Following a single center pilot study[9] in May 1994, a multicenter surveillance study evaluating the performance of the Spectranetics Prima Total Occlusion System (Spectranetics, Colorado Springs, Colorado) was initiated. In this report we discuss the final outcome of the European Multicenter TOTAL Surveillance Study, which served as a preamble for the currently ongoing multicenter randomized trial, the ''TOTAL trial.''

METHODS

The laser wire: The LW and the technique of the LW procedure have been described elsewhere.[10–12] In short, the Prima Total Occlusion System consists of an 0.018-inch guidewire containing 12 silica fibers with a 45-μm diameter and a support catheter providing additional coaxial backup support. Since its introduction in 1993, the LW has been subject to a number of technical improvements. It changed from a nonsteerable straight wire to a steerable guidewire, designed to function as an exchange wire (model 018-003, generation 2B), which is the currently used model.

The laser: The laser was the Spectranetics CVX 300 XeCl excimer laser. The fluence typically used during a LW procedure was 60 mJ/mm^2, with a pulse repetition rate of 25 Hz. If any resistance prohibited sufficient wire progression, the pulse repetition rate was increased to 40 Hz, thus increasing the LW ablation rate. During pulse trains with a maximum of 5 seconds the wire was gently advanced at a rate of up to 1 mm/s.

Patient population: Data of patients with a total occlusion (Thrombolysis In Myocardial Infarction [TIMI] trial 0 and I flow)[13] existing for >2 weeks who underwent a procedure using the LW were prospectively collected. A written informed consent was obtained from all patients, according to local medical ethics committee recommendations. Lesions typically unfavorable for an attempt at recanalization, such as bridging collaterals or a major side branch originating from the occlusion stump, were deliberately not excluded. However, a visible entry point and visualization of the distal vessel through collateral flow were mandatory. The study protocol did not provide restrictions as to whether an attempt with a mechanical guidewire should be made before the LW attempt. All data regarding clinical history, preprocedural angiographic assessment, angioplasty procedure, and eventual serious adverse effects were recorded in a standard case report form. The reference diameter of the

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* See appendix for list of participating investigators in the European Multicenter Laser Guidewire Surveillance Study.

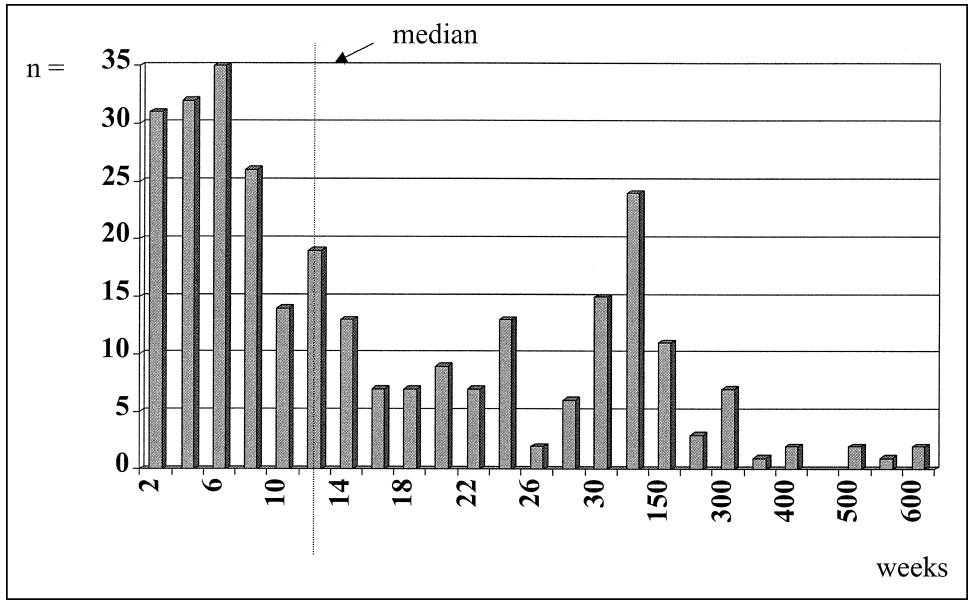

FIGURE 1. Distribution of the angiographically documented age of occlusion. As the distribution is ''non-normal,'' the median (at 12 weeks), rather than the mean age of occlusion, is given.

occluded segment and the length of occlusion were determined by visual assessment.

Definitions: LW success was defined as angiographic evidence of reaching the true lumen of any branch distal to the occlusion. This was subdivided into ''total success,'' meaning the LW reached the true distal lumen, and ''partial success,'' referring to patients in whom a combination of LW and mechanical guidewire was used to achieve reconstitution with the parent neolumen. Procedural success was defined as an average diameter stenosis of <50% in 2 orthogonal views at completion of the procedure. Clinical success was defined as procedural success without death, myocardial infarction, emergency coronary artery bypass graft surgery, or repeat percutaneous transluminal coronary angioplasty during the hospital stay.

Adjunctive angioplasty: After successful crossing of a guidewire, the nature of the ensuing angioplasty was at the discretion of the investigator. For excimer laser coronary angioplasty (ELCA), the 1.4-, 1.7-, or 2.0-mm Vitesse (Spectranetics) rapid exchange coronary catheters were available. For ELCA procedures it was advised to use a saline flush. The removal of contrast medium and blood before and during laser activation diminishes vascular wall damage resulting from fast expanding water vapor bubble formation with subsequent shock wave formation[14,15] and thereby reduces the incidence of coronary dissection.[16]

Statistical analysis: A multivariate regression analysis using SAS statistical software was performed to identify independent predictors of success. Incidents with a p value ≤0.05 were considered significant.

RESULTS

Between May 1994 and July 1996, in 28 centers, 345 patients (age 59 ± 10 years, 291 men, previous myocardial infarction 217 [63%] with a TIMI 0 flow [n = 284] or TIMI I flow [n = 61] coronary occlusion) who were treated with the LW entered the study. In 16% of cases (n = 54), a previous failed attempt at recanalization using mechanical wires was reported. The median angiographic age of occlusion was 12 weeks (range 2 to 728) or 29 weeks (range 2 to 894) according to clinical history (Figure 1). The occlusion length was 19 ± 10 mm (Table I). The enrollment per center was ≤10 patients in 13 centers, 11 to 20 patients in 14 centers, and 66 patients in 1 center.

TABLE I Baseline Lesion Characteristics

	No.(%)
Left anterior descending artery	125 (36)
Circumflex artery	51 (15)
Right coronary artery	168 (49)
TIMI flow	
0	284 (82)
1	61 (18)
Stump morphology	
Central funnel	125 (36)
Eccentric funnel	95 (28)
Blunt stump	125 (36)
Major side branch	126 (37)
Microcapillary refill	36 (10)
Age of occlusion (wk)	Median (range)
Angiographic age (n = 161)	12 (2–728)
Clinical age (n = 174)	29 (2–894)
Lesion measurements (mm) (mean ± SD)	
Length of occlusion (n = 198)	19 ± 10*
Reference diameter (n = 184)	2.84 ± 0.55

*Range: 2 to 50 mm.
TIMI = Thrombolyis In Myocardial Infarction trial.

Wire success: None of the primary mechanical wire attempts (n = 182, median duration 15 minutes, range 1 to 135) were successful (Figure 2). In all patients, a second attempt was performed using the LW, which was successful in 105 (58%). In patients in whom the LW was the primary guidewire (n = 163, median

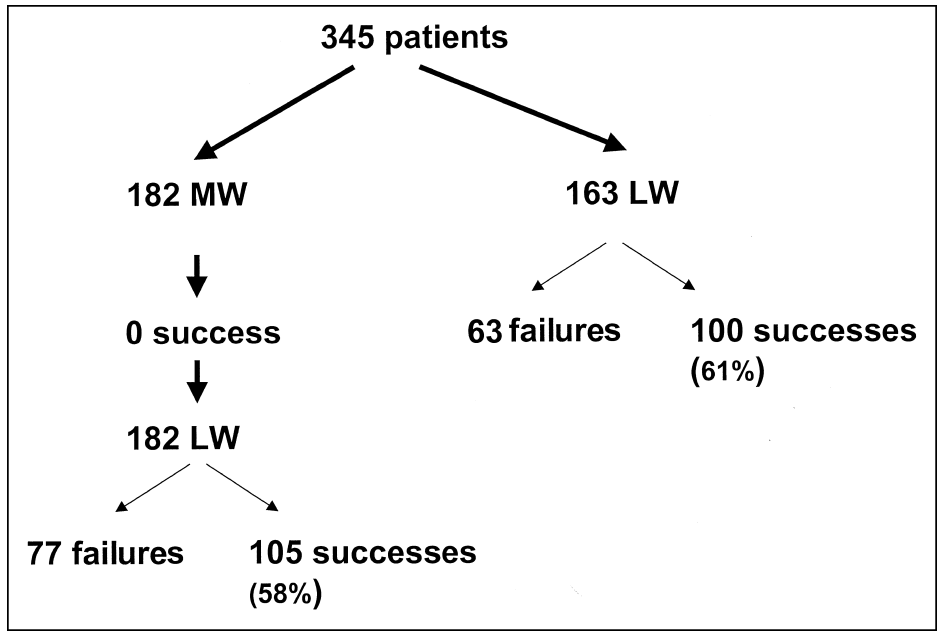

FIGURE 2. Breakdown of the results. MW = initial attempt at recanalization using a mechanical guidewire; LW1 = initial attempt at recanalization using a laser wire; LW2 = a second attempt at recanalization using the laser wire after a failed mechanical attempt.

duration 25 minutes, range 1 to 180), the attempt was successful in 100 cases (61%). From the 205 cases successfully performed with the LW, 169 cases were a ''total success,'' whereas in 36 cases (17.5%), a combination of techniques was used (''partial success''). As a result, the overall LW success rate was 59% (205 of 345 cases).

Statistical analysis: The following parameters were entered in a multiple univariate analysis: the age of occlusion, the occlusion length, the reference diameter, the presence of a side branch originating from the occlusion stump, the presence of bridging collaterals, the funnel shape (central vs eccentric funnel, or a blunt stump) and the location of the occlusion (left anterior descending vs no left anterior descending). A logrithmic transformation of the age of occlusion was performed to compensate for skew due to a nonnormal distribution of parameters. A multivariate regression analysis of these variables indicated that the independent predictors of success were clinical age of occlusion ($p = 0.004$) and the occlusion length ($p = 0.0004$). When the analysis was repeated for only patients with a TIMI 0 flow coronary occlusion, again the clinical age of occlusion ($p = 0.005$) and the occlusion length ($p = 0.002$) were independent predictors of success. The respective cutoff lines of success were reached at the clinical age of occlusion of 40 weeks (crossing success 63% for age <40 weeks vs 47% for age ≥ 40 weeks, $p = 0.012$, RR = 1.34) and an occlusion length of 30 mm (crossing success 62% for length <30 mm vs 39% for length ≥ 30 mm, $p = 0.0013$, RR = 1.59).

Adjunctive angioplasty: An adjunctive angioplasty was performed after successful crossing of the total occlusion in all 205 patients. Of these, 194 were successful (procedural success rate of 95%). Only a minority of patients were treated with balloon angioplasty alone (23%). The remaining patients were treated with ELCA and adjunctive balloon angioplasty (n = 78, 38%), whereas in another 78 patients, angioplasty was completed by implantation of ≥ 1 intracoronary stent (Table II). The overall procedure duration was 105 minutes (range 20 to 330).

TABLE II Procedural Success of Adjunctive Angioplasty

Procedure	No.	Success (%)
LaLa	2	0 (0)
LaBa	47	40 (85)
LaLaBa	78	78 (100)
LaBaSt	40	39 (98)
LaLaBaSt	38	37 (97)
Total	205	194 (95)

LaBa = laser wire-assisted balloon angioplasty; LaLaBa = laser wire-assisted laser and balloon angioplasty; LaBaSt = laser wire-assisted balloon angioplasty with stenting; LaLa = laser wire-assisted laser angioplasty; LaLaBaSt = laser wire-assisted laser and balloon angioplasty with stenting.

TABLE III Reason for Failure of Laser Wire Crossing (n = 144)

	No.(%)
Misalignment	44 (31)
Wire stuck	27 (19)
Wire perforation	56 (39)
Wire fracture	1 (0.7)
Other	12 (9)

Procedure-related complications: Noteworthy is the relatively high number of LW perforations (n = 73, Table III) that were originally perceived as a reason to terminate the procedure (n = 56). In 4 patients (1.2%), the wire position was mistakenly thought to be intraluminal. In these cases, the advancement of a device over the LW caused extravasation of contrast medium leading to tamponade, which in all patients could be

treated by means of nonsurgical drainage. However, because no clinical sequelae were reported resulting from LW perforation, per se, LW perforation emerged to be a more or less benign event, thus allowing for a continuation of the procedure after withdrawal of the wire into the proximal part of the coronary artery.

Serious adverse events: Serious adverse events were reported in 12 patients (3.5%): 3 non–Q-wave myocardial infarctions, 4 repeat percutaneous transluminal coronary angioplasties, 4 tamponades, and 1 LW malfunction. Of interest is the overall benign character of these events, in the absence of Q-wave myocardial infarction, emergency coronary artery bypass graft surgery, and death. As a result of these adverse events, clinical success was obtained in 54% of the original patient cohort.

DISCUSSION

Since the early days of angioplasty, despite the introduction of various new mechanical devices,[17–19] we have not witnessed a substantial improvement in the success rates of recanalization of chronic total occluded coronary arteries. The only exception to this experience could be the results described by Kinoshita et al,[20] which were achieved with the Japanese ''Athlete'' guidewire.

Although the baseline characteristics of our study population indicated that the patient group was representative of current coronary angioplasty practice, the number of patients with a previous myocardial infarction was relatively high. As reported, 16% of the patients had a previously failed mechanical attempt at recanalization. In addition, in the study there was a 100% failure of primary mechanical attempts. Obviously, by the very nature of this device registry, cases in which a mechanical guidewire attempt was successful were not reported because in these cases the LW was not used. However, we feel that an average 59% success rate with the LW after a failed attempt with any type of mechanical guidewire is an encouraging development. Furthermore, it is conceivable that in a number of cases a failed primary attempt with a mechanical wire, causing dissection, might have negatively influenced the success rate of the LW during a subsequent attempt.

In 4 patients a LW exit resulted in tamponade. In all 4 this was due to the advancement of a catheter into the free pericardial space. Therefore, it is strongly recommended not to advance any device over the LW before the intraluminal position of the wire tip has been confirmed by angiography.

In this registry there was a marked absence of serious adverse events. No LW-related deaths, Q-wave myocardial infarction, or emergency coronary artery bypass graft surgery have been reported, suggesting that recanalization of total occlusions by using a LW is a relatively safe procedure. Notwithstanding the initially positive results with this new technology in a notoriously difficult subset of patients, there are some limitations to this study. Given the protocol design, there was freedom in initial guidewire selection (mechanical wire, LW), without recording of the intention to treat. Completion of a screening log was not required. As a result, it could not be determined what percentage of patients with chronic total occlusions were enrolled in this study. Earlier, we demonstrated the influence of a ''learning curve,'' showing an increase in success rates of 50% to 85% in a single center experience.[12] Therefore, the inclusion of learning curve data (13 of the 28 participating centers enrolled ≤10 patients) and the implementation of technical changes in the LW during the study may possibly interfere with the results and their just interpretation. Finally, the limited collection of in-hospital events, in the absence of an angiographic and/or electrocardiography corelab, precludes the possibility of determining the mid- and long-term condition and prognosis of these patients. Therefore, a randomized trial with intention to treat recorded by a central telephone allocation center was initiated in 1995. This trial, with extensive and prospective collection of clinical and angiographic data, will be conducted by an independent coordinating center with corelab facilities.

APPENDIX

List of participating investigators, in order of the number of patients recruited for the European Multicenter Laser Guidewire Surveillance Study: Thoraxcenter, University Hospital, Rotterdam, The Netherlands: J.N. Hamburger, P.W. Serruys; Santa Cruz Hospital, Lisbon, Portugal: R. Gomes; Christian Albrechts Universität Kiel, Germany: R. Simon; Catherina Hospital, Eindhoven, The Netherlands: J.J. Koolen, H. Bonnier; Deutsches Herzzentrum, Berlin, Germany: E. Fleck; Kardiologisches Gemeinschaftspraxis, Hamburg, Germany: D. Mathey, J. Schofer; Bethaniën Krankenhaus, Frankfurt am Main, Germany: H. Sievert; Rudolf Virchow, Charité, Berlin, Germany: W. Rutsch; Universitätsklinik Goettingen, Goettingen, Germany: A.B. Buchwald; Clinique Pasteur, Toulouse, France: J. Marco, J. Fajadet; Armed Forces Cardiac Center, Riadh, Saudi Arabia: S. Al Kasab; Medizinisches Universitätsklinik Bonn, Bonn, Germany: L. Pizzulli; Universitätskrankenhaus Eppendorf Hamburg, Hamburg, Germany: C. Hamm; CMC Parly Grand Chesnay, Paris, France: Th. Corcos; Rotes Kreuz Krankenhaus Frankfurt, Frankfurt, Germany: N. Reifart; RWTH Aachen, Aachen, Germany: P. Hanrath; R.U. Gent, Gent, Belgium: Y. Taeymans; Harefield Hospital, London, United Kingdom: Ch. Ilsley; Hospital ''Gregorio Maranon,'' Madrid, Spain: E. Garcia; Sahlgrenska University Hospital, Götenborg, Sweden: H. Emmanualson; St. Anthonius Ziekenhuis, Nieuwegein, The Netherlands: J. Ernst, H. Plokker; Universitätsklinik Essen, Essen, Germany: M. Haude; Universitätsklinik Inselspital, Bern, Switzerland: B. Meier; Centro Cuore Columbus, Milano, Italy: A. Colombo; St. Thomas, London, United Kingdom: M. Webb-Peploe; UH Gasthuisberg, Leuven, Belgium: F. van der Werf; Clairval Hospital, Marseille, France: H. Escojido; Franz Volhard Klinik, Berlin, Germany: D.R. Waigand.

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