



ORIGINAL ARTICLE

Emergency coronary angioplasty with stenting using Cordis® diagnostic coronary catheters when there is difficulty in engaging guide catheters and bench evaluation of diagnostic and guide catheters



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KEYWORDS

Emergency angioplasty;
Difficulty in engagement;
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Distal tip flexion;
Three-point bending tests;
Pushability and trackability

Abstract

Introduction and Aims: Difficulty in engaging with guide catheters is not uncommon in acute emergencies. We aimed to evaluate the use of Cordis® INFINITI diagnostic catheters to perform angioplasty in patients in whom the coronaries cannot be engaged using standard guide catheters.

Methods: In 34 cases of acute coronary syndrome, when difficulty in engagement with two standard guide catheters was encountered with reasonable manipulations, angioplasty was performed using diagnostic catheters. In total, 40 stents were placed by this technique. Pushability and trackability, distal tip flexion and three-point bending tests were performed to evaluate the performance of the guide and diagnostic catheters.

Results: Angioplasty was performed easily in a setting where it would have been very difficult to perform. Coronary dissection occurred in one patient, treated by a stent. The stent and dilatation balloons were easily passed through the diagnostic catheters. Pressure tracings were clearly preserved with certain stent delivery systems, and at angioplasty, although there was slightly reduced opacification of the respective artery, the coronary anatomy was sufficiently visualized to perform angioplasty. No periprocedural target lesion complications were seen in any cases.

Pushability and trackability tests showed good force transmission along a tortuous path with diagnostic catheters, and balanced force-displacement curves from three-point bending tests and distal tip softness tests.

Conclusion: Angioplasty with stenting can be performed safely through 6F Cordis® infinity diagnostic catheters when difficulty in engaging guide catheters is encountered.

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PALAVRAS-CHAVE

Angioplastia de emergência;
Dificuldade de progressão;
Cateteres de diagnóstico;
Flexão distal da ponta;
Testes de curvatura em três pontos;
Suporte e traceabilidade

Angioplastia coronária de emergência com *stents* usando cateteres coronários diagnósticos no contexto de entubação difícil pelos cateteres-guia e avaliação prática de cateteres guias e de diagnóstico

Resumo

Introdução e objetivos: Avaliar o papel dos cateteres diagnósticos para efetuar angioplastia em doentes em que se verifica incapacidade de entubar seletivamente as artérias coronárias com os cateteres-guia padrão.

Métodos: A entubação difícil pelos cateteres-guia não é rara no contexto de emergência. Em 34 casos de síndromes coronárias agudas, quando se encontrou dificuldade na entubação com dois cateteres-guia padrão através das manipulações habituais, a angioplastia foi realizada com cateteres diagnósticos. No total, 40 *stents* foram implantados com essa técnica. O suporte e a traceabilidade, a flexão da ponta distal e de três pontos da curva foram usados para avaliar o comportamento dos cateteres-guia e de diagnóstico.

Resultados: A angioplastia foi efetuada facilmente num contexto em que era aparentemente muito difícil de fazer. Observou-se disseção coronária num caso, tratada com um *stent*. Os *stents*, tais como as dilatações por balão, foram facilmente implantados através de cateteres de diagnóstico. As curvas de pressão mantiveram-se claramente preservadas com alguns sistemas de entrega de *stents* e na angioplastia verificou-se uma ligeira redução da opacificação da artéria. Contudo, a anatomia coronária foi efetivamente visualizada para efetuar a angioplastia. Não se observou qualquer complicação nas lesões-alvo em qualquer dos casos intervencionados. Os testes de apoio e a traceabilidade revelaram uma força de transmissão através de trajetos tortuosos com cateteres de diagnóstico com curvas equilibradas da força-deslocação nos três pontos da curva em teste e na agressividade da ponta distal.

Conclusão: As angioplastias com *stent* puderam ser feitas com segurança através de cateteres de diagnóstico (Cordis® *infiniti*) quando se verificou uma dificuldade na entubação pelos cateteres-guia.

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Introduction

Difficulty in engaging standard guide catheters when performing angioplasty can be life-threatening in acute coronary syndromes (ACS), especially in acute myocardial infarction (MI), in which the speed and success of the procedure with limited contrast usage are paramount¹⁻³ and shorter fluoroscopy and procedural times are desirable. In such settings, prolonged manipulation of guide catheters is frequently required, or sizes or models of multiple guide catheters need to be changed. In general, diagnostic catheters tend to engage better than guide catheters, due to better stiffness and recoil properties.⁴ In the setting of MI, this can have significant consequences.

Balloon angioplasties performed using diagnostic catheters have been reported. There is one report of two cases of stenting with diagnostic catheters,⁵ and two of routine primary angioplasty or in acute coronary syndromes predominantly through radial access.^{6,7} We present a retrospective study of 34 patients who underwent angioplasty using diagnostic catheters as an urgent measure when there was difficulty in engaging guide catheters. The aim of the study was to evaluate the role of Cordis® *INFINITI* diagnostic catheters in reducing procedure time and difficulty in catheter manipulations, and in improving safety by reducing contrast load and hence procedural complications.

Methods**Engagement of diagnostic catheters**

A standard angiogram was performed and angioplasty was planned in all cases of ACS. Difficulty in engaging standard guide catheters was encountered in 34 cases. The femoral route was the preferred method for the operator in primary angioplasty for ACS. Difficulty in engaging guide catheters was defined as difficulty with two or more standard guide catheters in engaging the target artery with reasonable manipulations using discretion. The catheters chosen were predominantly Judkins catheters. The operator (i.e. the author) performed the procedures. Only 6F guide catheters were used in all cases. For the left coronaries, a 3.5 cm Judkins Left (JL) was used initially. If engagement failed, a 4.0, 4.5 or 5.0 cm JL was tried, depending on aortic dilation and curvature. In younger patients and with a less arched aorta, a 3.0 Judkins Left (JL) was used for engagement of the ostia. If this failed, Cordis® Extra Backup (XBU) catheters of similar dimensions were tried. For the right coronary system a 3.5 cm JR was used in the majority of cases. If engagement failed, a Cordis® JR 4 or Cordis® Amplatz Right (AR) 1 or 2 was used, depending on the patient's age and the shape of the aorta. If the catheter was approaching the ostium, another JR 3.5 was tried, depending on the

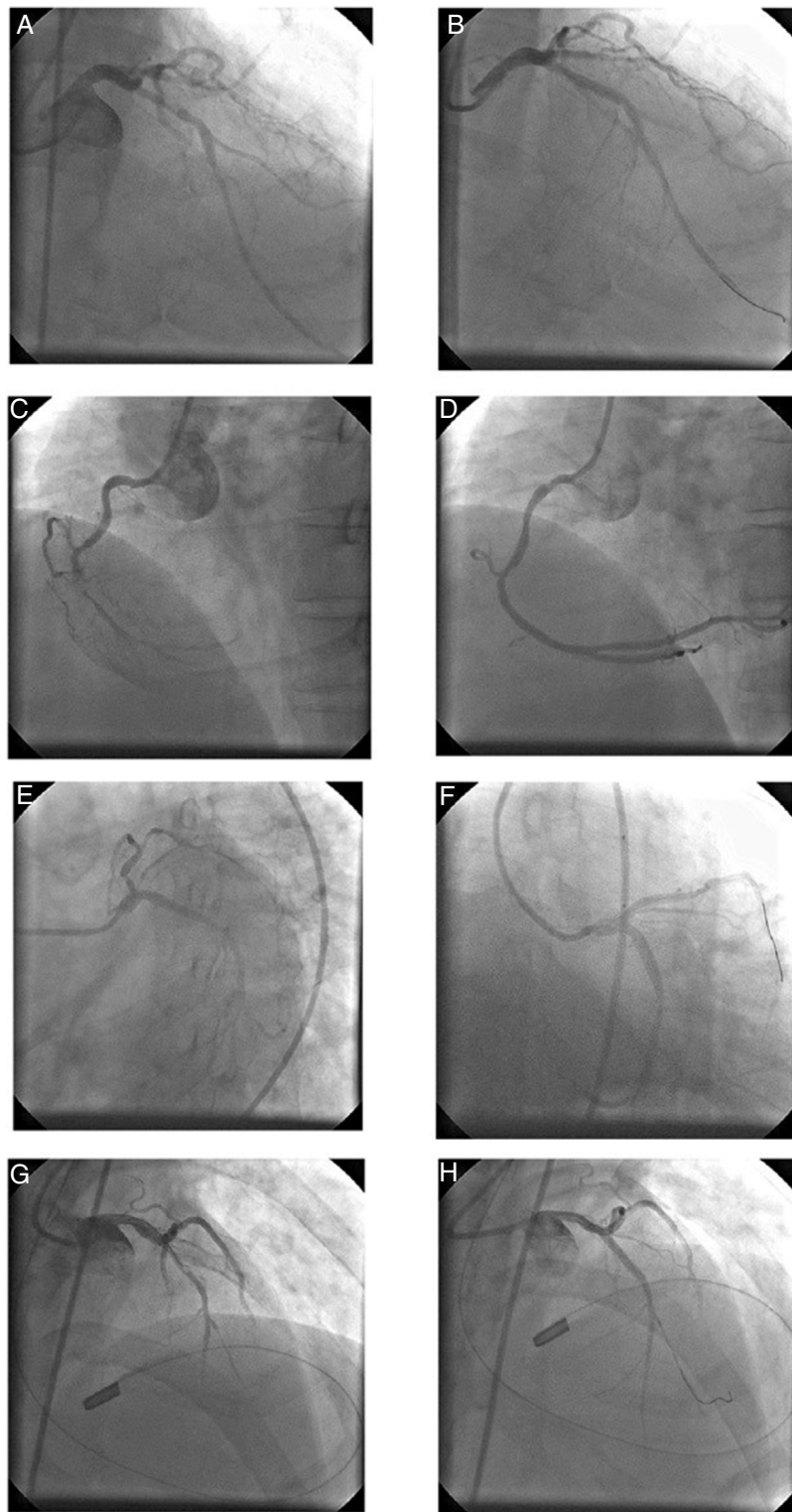


Figure 1 Angiograms of angioplasties and stenting performed using diagnostic catheters: angioplasty in the proximal left anterior descending (LAD) artery (A and B); angioplasty in the mid right coronary artery with clots (C and D); angioplasty of the proximal LAD in a patient in cardiogenic shock (E and F), and angioplasty of the proximal LAD in a critically ill patient (G and H).

procedural circumstances. Also, in all these cases insertion of a 0.014" wire was attempted into the coronaries even when the guide catheter did not engage or was placed near the coronary ostium. However, in all cases, the diagnostic

catheters engaged very well during the initial angiogram, so the same 6F Cordis® INFINITI diagnostic catheter was used to perform angioplasty. Figure 1 shows angiograms of angioplasty performed using diagnostic catheters. The diagnostic

catheters have a luminal diameter of 1.4 mm, and the guide catheters have a luminal diameter of 1.8 mm.

The mean age of the patients was 60 ± 14 years, and 27 were male. The main causes of difficulty in engaging guide catheters encountered were tortuosity of iliofemoral arteries (12), mildly dilated aorta (9), slightly posterolateral origin of the right coronary (5), tortuous abdominal-thoracic aorta (4), and high origin of the left main artery (3). However, a combination of multiple factors in various degrees was the reason for difficulty in engaging guide catheters more often than any isolated cause. All injections were given by hand only; a power injector was not used for coronary visualization in any of the cases. Two patients had cardiogenic shock, in one of whom intra-aortic balloon counterpulsation was used, and the other patient was managed with inotropes. No mortality was encountered during the procedures. BMW (Abbott) wires were used in 30% of cases, All Star (Abbott) in 57.5% of lesions and Runthrough NS (Terumo) in the remaining 12.5%.

Lesion characteristics

The lesions were discrete and critical, and caused 90-100% stenosis by visual assessment, predominantly with associated soft clots. In 16 cases, angioplasty was performed in the proximal left anterior descending (LAD) artery, eight in the circumflex artery and in the right coronary artery (RCA) in the other 10 patients. Calcified lesions were seen in six cases, three of them heavily calcified.

Stent and balloon characteristics

The stent length used was between 12 and 20 mm in 27 patients, 24 mm in four patients, 28 mm in two cases, and 8 mm in one patient. A total of 40 stents were used in these 34 cases. Direct stenting was the preferred technique. It was left to the operator's discretion to use the shortest possible stent length to avoid redundancy. In nine cases predilatation was performed. Tazuna semi-compliant balloons (2 mm \times 10 mm) were used in three cases, a 1.5 \times 10 mm Sprinter balloon in one patient and Fast Track semi-compliant balloons (2 mm \times 10 mm and 2.5 mm \times 10 mm) were used in four other cases. The stent widths mainly ranged from 2.25 mm to 3.0 mm. In four cases, 3.5 mm stents were deployed without difficulty. The balloons were easily withdrawn into the catheter after stent deployment. Post-dilatation was performed in three cases with 3 mm \times 12 mm Fast Track semi-compliant balloons and a 2.75 mm \times 10 mm iTrack balloon.

Catheter testing

Further catheter testing was performed in vitro to study the mechanisms of engagement by evaluating catheter pushability and trackability characteristics and by three-point bending and distal tip flexion tests. Eleven catheters were selected and analyzed in the testing laboratory. Lists of the diagnostic and guide catheters are shown in [Figure 2](#). For three-point bending and distal tip flexion tests five catheters – diagnostic JL and JR, 6F JL and JR guide catheters and 5F

XBU – were selected ([Supplementary Table 3](#)). The catheters used for distal tip flexion testing are listed in [Supplementary Table 4](#).

Intravascular ultrasound catheter evaluation

The OptiCross (Boston Scientific) intravascular ultrasound (IVUS) catheter was chosen, and the ability of this catheter to pass through the diagnostic catheters was assessed in both JL and JR 6F catheters.

Results

Procedure

All the diagnostic catheters used were 6F Cordis®. The angioplasty procedure with stenting was successfully performed using diagnostic catheters, stents being easily placed in the lesion site in the coronaries. In total, 40 stents were used: Endeavor Resolute (1), Excel (6), Biomatrix Flex (1), Endeavour Sprint (11), Onyx (1), Ultimaster (4), Nobori (6), Yukon Choice PC Flex (5), Resolute Integrity (3) and Xience Alpine (2). A slight dampening of pressure tracings was observed during the procedure except in newer-generation stent delivery systems, in which the pressure tracings could be visualized more clearly. This could be due to the thinner shafts of these delivery systems. Standard procedures were followed during the angioplasty. During the procedure, a second wire could be taken through the diagnostic catheter if required and parked in the coronaries. However, in none of the cases was bifurcation stenting performed. During the angioplasty, opacification of the coronaries was less than with guide catheters, but even so the coronaries and the lesion location were clearly visualized. Immediately after stent placement, the coronaries were visualized by contrast injection, and the stent was visualized clearly. The stent could be easily and safely taken inside the diagnostic catheter and then to the lesion. In an emergency setting, complex interventional cases can also be tackled with this technique, as shown in [Figure 3](#).

Thrombus aspiration was not performed in any of the cases. Peri-procedural complications or no-reflow phenomenon was not seen in any of the cases and none of these 34 patients suffered reinfarction in a one-month follow-up. One patient had a coronary artery dissection at the distal edge of the stent, which was stented. No dissection was observed at the site of coronary ostial engagement. There were no deaths, and contrast-induced nephropathy (32% increase in creatinine from baseline) was seen in only one patient, in whom creatinine levels improved over the following few days.

Pushability and trackability

The trackability tests measured the force required to advance the catheters along a tortuous femoral path. The displacement forces required to advance the catheter were measured. Pushability was measured as the ratio of distal to proximal forces. Results of the pushability and trackability tests are given in [Figures 4 and 5](#).

Description	Type	I.D. (")	Ref	Lot	PTM ID
Cordis® guide catheter, VISTA BRITE TIP 6F, 100 cm	JL 3.5	0.07	670-002-00	17347512	GC1
Cordis® guide catheter, VISTA BRITE TIP 6F, 100 cm	JL 4	0.07	670-004-00	17267465	GC2
Cordis® guide catheter, VISTA BRITE TIP 6F, 100 cm	XB 3.5	0.07	670-054-00	17347927	GC3
Cordis® guide catheter, VISTA BRITE TIP 5F, 100 cm	XB 3.0LBT	0.056	SM7328	17323131	GC4
Cordis® guide catheter, VISTA BRITE TIP 6F, 100 cm	JR 3.5	0.07	670-080-00	17288033	GC5
Cordis® guide catheter, VISTA BRITE TIP 6F, 100 cm	XB 3.5	0.07	670-054-00	17183398	GC6
Cordis® guide catheter, VISTA BRITE TIP 6F, 100 cm	JR 3.5	0.07	670-080-00	17288033	GC7
Cordis® diagnostic catheter, INFINITI Thrulumen 6F, 100 cm	JR 3.5	0.057	534-619T	17196317	DC7
Cordis® diagnostic catheter, INFINITI Thrulumen 6F, 100 cm	JR 3.5	0.057	534-619T	17196317	DC2
Cordis® diagnostic catheter, INFINITI Thrulumen 6F, 100 cm	JL 3.5	0.057	534-618T	17150489	DC3
Cordis® diagnostic catheter, INFINITI Thrulumen 6F, 100 cm	JL 3.5	0.057	534-618T	17150489	DC4

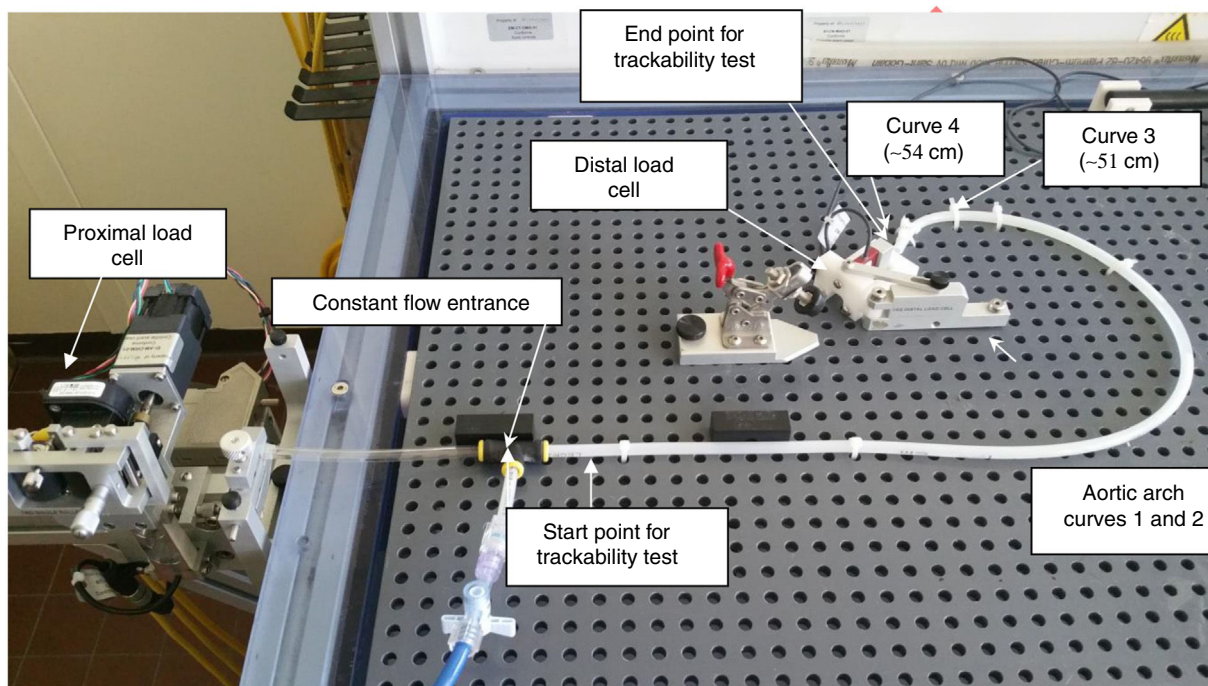


Figure 2 Lists of diagnostic and guide catheters and their identification names used in the study. I.D.: inner diameter.

The force transmission parameters are shown in Supplementary Tables 1 and 2. The diagnostic catheters require more force (mean 7.83 ± 1.57 vs. 4.06 ± 2.29 N). However, the ratio between proximal and distal forces was 0.28 for diagnostic catheters, and for guide catheters it was 0.51. The diagnostic catheters have more maneuverability, as reflected by the maximal force parameters (10.03 vs. 7.73 N), but the guide catheters have high force transmission ratios.⁸⁻¹² To ensure successful procedures in real time, better maneuverability parameters enable easier engagement of catheters in the coronary ostium.⁸⁻¹²

Distal tip flexion test

Figure 6 summarizes the results of distal tip flexion testing on five catheters. The distal tip flexion of the diagnostic catheters show balanced force displacement curves. The

area inside the curve shows the hysteresis between elasticity and plasticity. The 5F XBU shows large displacement with small forces, whereas the 6F JL and 6F JR guide catheters show less displacement with large forces. The slope of the curve represents the stiffness of the catheters. The diagnostic catheters show optimal stiffness; the guide catheters have more stiffness and the 5F XBU catheter is less stiff.⁸⁻¹²

Three-point bending tests

The three-point bending tests were performed at 4.5 cm and 10 cm from the distal tip of the catheters. The force displacement curves of the catheters are shown in Figure 7A and B. The diagnostic catheters have a balanced force displacement compared to the guide catheters, with less plastic deformation as shown by a smaller area inside the curves.



Figure 3 Complicated stenting of right coronary artery performed with diagnostic catheters. The proximal right coronary artery (RCA) was 100% occluded (A), and the lesion was crossed with a BMW wire with balloon support, and balloon dilatation was performed (B). A dissection was observed in the mid RCA (C), and stenting was performed from proximal to mid RCA (D and E).

Intravascular ultrasound catheter in diagnostic catheters

The IVUS catheter (OptiCross 3.1 F) could be taken inside the 6F JR and JL diagnostic catheters and could be exteriorized through the distal tip of the catheters with ease, as observed in bench testing.

Discussion

Advantages of diagnostic catheters in angioplasty

It is feasible to perform angioplasty and stenting using 6F Cordis® diagnostic catheters as an emergency procedure in

ACS. This technique could be used as a bailout procedure, although it is not advisable for routine use. Difficulty in engagement often subjects the operator to psychological stress, especially when patients have ongoing angina or MI. The major advantage of this technique is that it minimizes procedural time as well as contrast use.

Frequent exchanges of catheters are often associated with increased procedural and fluoroscopy times and thus with procedural complications,¹³ increased contrast use,^{14,15} infections or bacteremia,¹⁶ and thrombotic complications.¹³ As a bailout procedure, this technique is useful and feasible in ACS, when difficulty in engagement is encountered with guide catheters. The contrast load is reduced, in contrast to the larger contrast quantity commonly required in

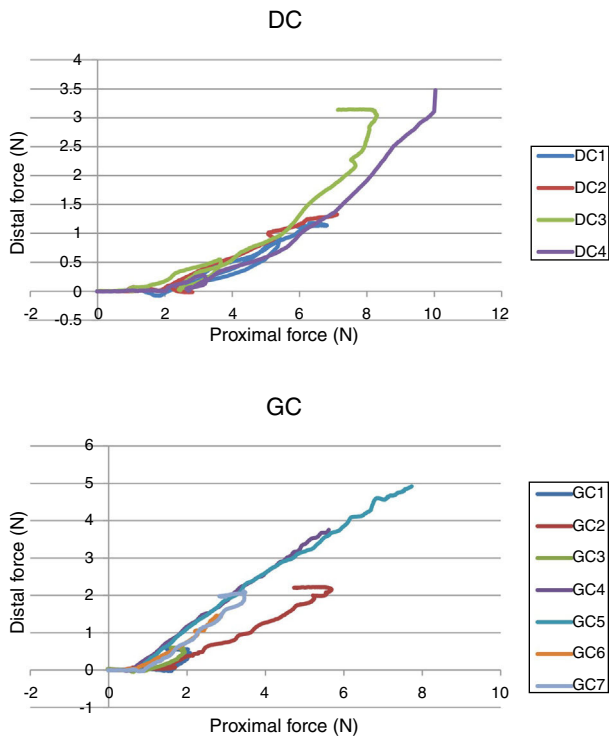


Figure 4 Results of pushability and force transmission measurements of the catheters. DC: diagnostic catheters; GC: guide catheters.

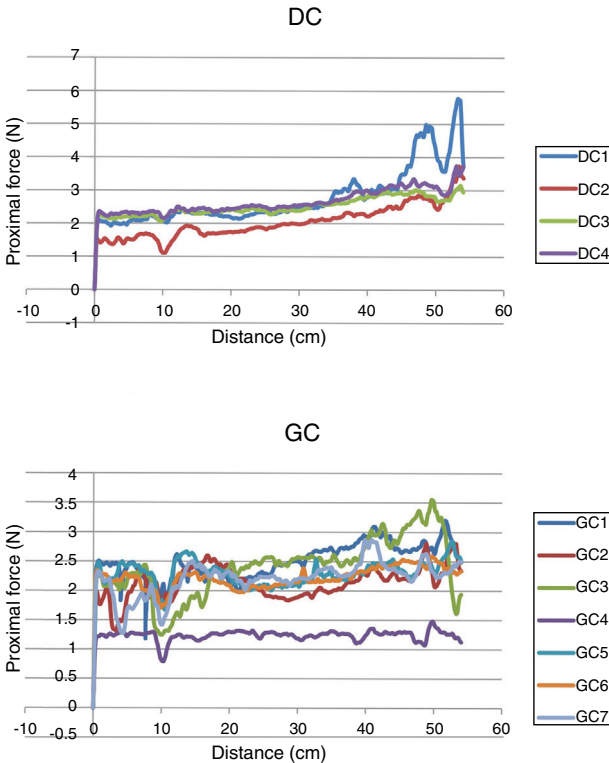
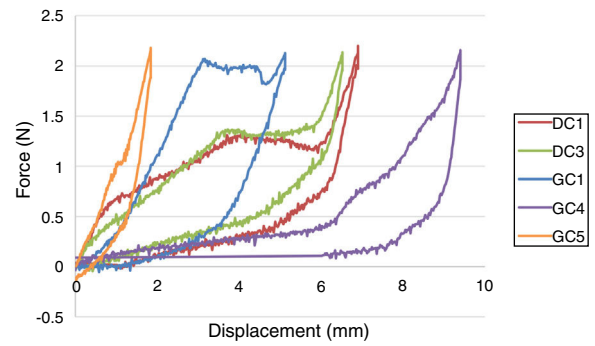
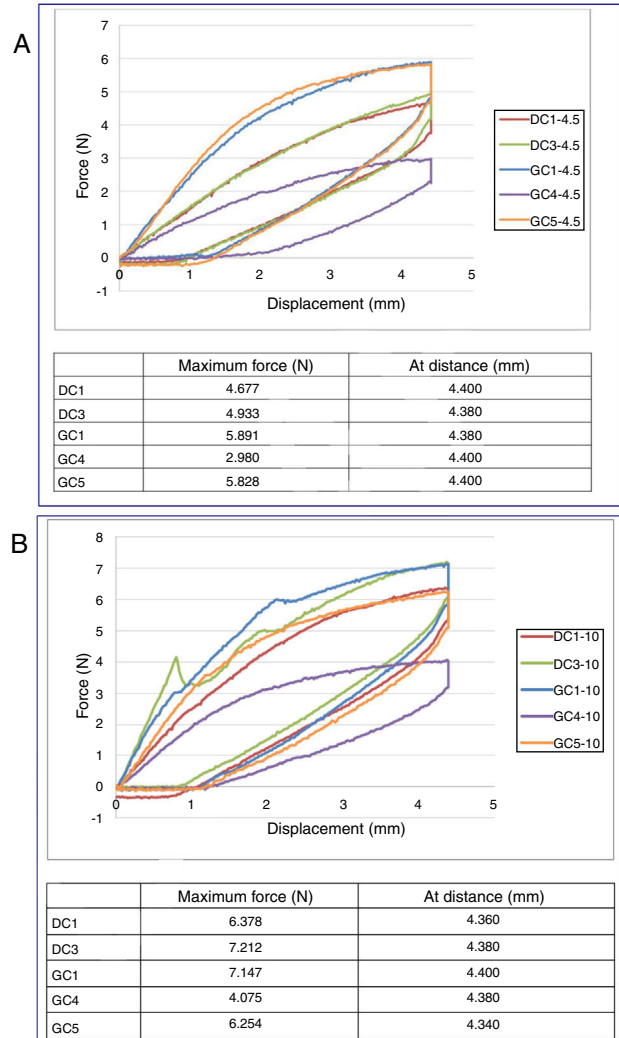


Figure 5 Results of trackability measurement of the catheters by force-distance curves. DC: diagnostic catheters; GC: guide catheters.



	Maximum force (N)	At distance (mm)
DC1	2.199	6.900
DC3	2.136	6.520
GC1	2.128	5.120
GC4	2.157	9.400
GC5	2.179	1.840

Figure 6 Results of distal tip flexion tests and maximum force distance table. DC: diagnostic catheter; GC: guide catheter.



	Maximum force (N)	At distance (mm)
DC1	4.677	4.400
DC3	4.933	4.380
GC1	5.891	4.380
GC4	2.980	4.400
GC5	5.828	4.400

	Maximum force (N)	At distance (mm)
DC1	6.378	4.360
DC3	7.212	4.380
GC1	7.147	4.400
GC4	4.075	4.380
GC5	6.254	4.340

Figure 7 Results of three-point bending test measured at 4.5 and 10 cm from the distal tip with maximum force distance parameters. DC: diagnostic catheter; GC: guide catheter.

such situations. Also, in life-threatening situations in which a perfect result is not a major concern and time is of the essence, this method can be very useful.^{6,7} In our study, in more than 50% of cases the contrast load used was less than 50 ml including the diagnostic angiogram. Maximum contrast use was 110 ml in one patient, and the mean was 45 ml.

GuideLiner and deflectable tip catheters

GuideLiner, deflectable tip or steerable catheters are some of the other options available in the present scenario for difficult cannulation.^{17,18} However, these techniques are expensive and time-consuming, and are not available in all catheterization centers.

Measurement of coronary pressures

The other difficulty is the assessment of pressures, which are damped to a certain extent; this would be a limitation on the use of diagnostic catheters as a routine technique. Although pressures are slightly damped, the pressure tracings are visible, and it is feasible to perform the procedure. As an observation, the pressure tracings were better visualized with newer-generation stent delivery systems.

Catheters and site

It is also important to mention that all these procedures were performed with Cordis[®] diagnostic catheters only. There are no other comparative studies on the use of other diagnostic catheters for this purpose. It was the operator's choice to use these catheters. It is worthwhile noting that in 10 out of 34 cases the procedures were performed for right coronary artery lesions, in which difficulty in engaging guide catheters is more frequent.

Trackability and pushability

In bench testing the trackability characteristics were better for diagnostic catheters than for guide catheters. Also, the diagnostic catheters sustained more proximal force, and the distance at maximal force was more than 53 cm in the 54 cm tortuous path defined in the study protocol (mean 53.3±0.25 cm). The mean distance for the guide catheters was 49.6±4.17 cm.

The diagnostic catheters have better pushability characteristics. The diagnostic catheters sustained more proximal force and had better distal force transmission compared to guide catheters as reflected by the ratio of proximal and distal force. Also, the guide catheters cannot sustain as much proximal force as diagnostic catheters, which is often required in tortuous or calcific iliac arteries and aortas.

Three-point bending and distal tip flexion tests

The comparisons of three-point bending tests (Figure 7A and B) show that the area under the curves, which indicates the work performed or the kinetic energy stored in the catheters during catheter deformation, is higher for diagnostic catheters than for guide catheters. Also, the area

inside the curves is less for the diagnostic catheters, which indicates less plastic deformation. The slope of the force-distance curve indicates the acceleration of the movement, which is also greater than in guide catheters.^{9,10}

The distal tip flexion tests show good characteristics in the diagnostic catheters compared to guide catheters. The 3.5 JR demonstrates large plastic deformation, while the 3.5 JL and 3.0 XBU show less elastic properties.

Intravascular ultrasound and optical coherence tomography catheters

Currently available IVUS and optical coherence tomography (OCT) catheters are about 3F or less with hydrophilic coating, and they are 5F guide compatible. Hence, these imaging catheters can also be safely used in these diagnostic catheters. Bench evaluation of the OptiCross IVUS catheter demonstrated that it could easily go through the 6F JR and JL diagnostic catheters. The OptiCross catheter's shaft is 3.1F (1 mm), and hence this is feasible. The Dragonfly[™] OCT catheter (St. Jude Medical) has a shaft diameter of 2.7 F. This is comparable to the shaft diameters of stents like Endeavor (2.8F), Onyx (2.7F), Nobori (2.5F) and Yukon Choice (2.6F). Since all these stents can pass through 6F Cordis[®] diagnostic catheters, OCT and IVUS are feasible for use in these diagnostic catheters.

Contrast-induced nephropathy

Emergency angioplasties are associated with a high incidence (15-20%) of contrast-induced nephropathy. In our series contrast-induced nephropathy was seen in only one patient, in whom creatinine increased from 1.3 mg/dl to 1.8 mg/dl, and after a few days decreased to 1.2 mg/dl. Contrast volume is a major determinant of contrast-induced nephropathy.¹⁹⁻²¹ In this series, the mean contrast volume was only about 45 ml, and no mortality was observed. However, the total number of cases was less.

Limitations

Using this method bifurcation lesion therapy and thrombosis aspiration²² before stenting cannot be performed. In our center, it is the operator's choice that thrombosis aspiration is not performed routinely in all acute emergencies, but only in cases with a very high clot burden. The routine treatment of choice in ACS is direct stenting. Predilatation and stenting are used when direct stenting is not feasible. There are increasing reports of the benefits of direct stenting.^{23,24} In bifurcation lesions in an emergency setting, provisional stenting is the preferred method. Bifurcation lesion therapy and thrombosis aspiration may not always be required in routine emergency procedures. Also, in this study a switch to a radial approach was not tried when the femoral route failed, which is another available option. This is due to the operator's choice of the femoral route in ACS. However, the diagnostic catheter technique is an easy method for the majority of lesions in an emergency setting. Simplicity of the procedure is also a common priority in most cases of

ACS, in which time and contrast load are major concerns, especially in patients with ongoing angina or MI.

Conclusion

Angioplasty can be performed successfully and safely using 6F Cordis® INFINITI diagnostic catheters, which is a useful alternative when guide catheters fail to engage during angioplasty.

Conflicts of interest

The author has no conflicts of interest to declare.

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Appendix A. Supplementary material

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.repc.2017.04.007.

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