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Impact of Contrast Agent Viscosity on Coronary Balloon Deflation Times: Bench Testing Results

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Abstract

Objectives—To assess the impact of viscosity on angioplasty balloon deflation times.

Background—Lower contrast viscosity could result in more rapid coronary balloon deflation times.

Methods—We performed a bench comparison of coronary balloon deflation times using 2 contrast agents with different viscosity (ioxaglate and iodixanol), 3 contrast dilutions, and 2 inflation syringe filling volumes. Ten identical pairs of coronary angioplasty balloons were used to conduct each comparison after balloon inflation to 12 atmospheres. Simultaneous deflations were performed under cineangiography. The time to full contrast extraction and the area of contrast remaining after 5 seconds of deflation (quantified by opaque pixel count) were compared between groups.

Results—The mean time to full contrast extraction during balloon deflation was 8.3 ± 2.5 seconds for ioxaglate (lower viscosity) vs. 10.1 ± 2.9 seconds for iodixanol (higher viscosity) (17.4% decrease, $P=0.005$), with a 35.6% ($P=0.004$) reduction in contrast area at 5 seconds. Compared to 1:1 ioxaglate-saline mixture, 1:2 and 1:3 ioxaglate/saline mixes resulted in 26.7% ($P<0.001$) and 39.0% ($P<0.001$), respectively reduction in mean balloon deflation time, but at the expense of decreased balloon opacity. Filling the inflation syringe with 5 vs. 15 mL of contrast/saline solution was associated with 7.5% decrease in balloon deflation time ($P=0.005$), but no difference in contrast area at 5 seconds ($P=0.749$).

Conclusions—Use of a lower viscosity contrast agent and higher contrast dilution significantly reduced coronary balloon deflation times, whereas use of lower syringe filling volume had a modest effect. Rapid coronary balloon deflation could improve the safety of interventional procedures.

Keywords

percutaneous coronary intervention; balloon; contrast; viscosity

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Introduction

Multiple contrast agents are currently available with different viscosities, osmolalities, and charge (ionic vs. non-ionic).(1, 2) Reduction in contrast osmolality has been linked to improved safety.(1–4) Older contrast agents had an osmolality up to 8 times that of blood and carried increased risk of procedural complications.(2) Newer agents are categorized as low-osmolar contrast media (LOCM, that have 2–3 times the osmolality of blood), or iso-osmolar contrast media (IOCM, that have similar osmolality with blood).(1–3, 5) Unlike osmolality, high viscosity has not been shown to have adverse clinical consequences(4, 5) but its impact on cardiac catheterization procedures has received limited study.(6–8) The impact of contrast viscosity may increase with increasing utilization of smaller French catheters and lower profile angioplasty balloons.

Higher viscosity may prolong coronary balloon deflation times which could be detrimental during interventions when vessel occlusion times should be minimized. To combat the effects of high contrast viscosity on deflation, angioplasty balloon manufacturers recommend a 1:1 contrast-saline mix, however this arbitrary ratio may not be optimal. We sought to evaluate strategies for reducing coronary balloon deflation times, including the use of a lower viscosity contrast agent, increased contrast dilution, and higher negative aspiration pressure during deflation.

Methods

We inflated and deflated 10 identical pairs of coronary angioplasty balloons of various sizes (Trek Rx, Abbott Laboratories, Abbott Park, IL, USA) using either ioxaglate (Hexabrix 320, Guerbet LLC, Bloomington, IN, USA) or iodixanol (Visipaque 320, GE Healthcare, WI, USA). Ioxaglate is a LOCM with an osmolality of 600 mOsm/kg H₂O and a viscosity of 7.5 cPs at body temperature (37° C). Iodixanol is the only clinically available IOCM and has an osmolality of 290 mOsm/kg H₂O and a viscosity of 11.8 cPs at 37° C. Both agents were mixed in a 1:1 ratio with heparinized 0.9% sodium chloride solution to simulate our current cardiac catheterization laboratory practice, according to the manufacturer's instructions for use. Each balloon catheter was filled with the contrast-saline mix by initially applying negative suction with a 20 mL syringe. If air was identified in the balloons after inflation under fluoroscopy, the balloon preparation was repeated. Two identical inflation syringes (BasixCOMPAK, Merit Medical, UT, USA) were then attached to the balloon catheters and filled with equal amounts (10 mL) of the contrast-saline mix. Each matching pair of balloons was placed under fluoroscopy and inflated to 12 atmospheres followed by simultaneous deflations under negative suction while cineangiography images were obtained. The experiment was repeated with additional balloons using varying dilutions of ioxaglate. Multiple sets of three identical 3.0 x 28 mm balloons were inflated to 12 atm then deflated simultaneously with 1:1, 1:2, and 1:3 ioxaglate-saline mixes while cineangiography images were obtained.

To assess the impact of greater negative aspiration pressure, we used 10 pairs of matched balloons of various sizes and used a 1:1 ioxaglate-saline solution. A comparison was performed between two preparations of the inflation syringes. A greater vacuum effect was created with deflation of a syringe loaded with only 5 mL of contrast-saline mixture compared with a second syringe filled with 15 mL of solution (20 mL inflation syringe). Each balloon was again inflated to 12 atmospheres then simultaneously deflated to the maximum extent while cineangiography images were obtained.

We used 2 metrics to evaluate the speed of balloon deflation: (1) time to contrast extraction past the proximal marker and (2) percent of area of contrast (measured in pixel count)

remaining after a fixed time interval. The first measurement was performed using Philips Xcelera viewer (Philips, Amsterdam, Netherlands). We measured the time from the onset of deflation until the last visible contrast passed the more proximal radiopaque marker. Each pair of balloons were timed from the identical point where simultaneous deflations were initiated. All measurements were made by a blinded reviewer.

The second measurement was performed by quantifying the contrast pixel count at a fixed time interval from the onset of deflation (5 seconds for all balloons, except for the smaller 4.0 x 8 mm and 2.25 x 20 mm balloons for which 2.5 seconds was used) using Photoshop Creative Suite 6 (Adobe Systems, CA, USA) (Figure 1). A paired t-test was used to compare differences in balloon deflation time and pixel count. A p value of <0.05 was considered statistically significant.

Results

The mean time to contrast extraction past the proximal balloon marker using 1:1 ioxaglate or iodixanol solution was 8.3 ± 2.5 and 10.1 ± 2.9 sec, respectively (17.5% reduction, $P=0.005$). The mean pixel count at a fixed time from onset of deflation was 35.6% lower in the ioxaglate group ($P=0.004$, Figure 2). The mean time to contrast extraction past the proximal balloon marker using 1:1, 1:2 and 1:3 mixture of ioxaglate-saline was 15.4 ± 0.9 seconds, 11.3 ± 1.0 seconds (27% reduction, $P<0.001$ compared to 1:1 mix) and 9.5 ± 1.0 seconds (39% reduction, $P<0.001$ compared to 1:1 mix), respectively (Figure 3). Compared to 1:1 ioxaglate-saline ratio the contrast area at 5 seconds post deflation initiation was reduced by 25.4% ($P<0.001$) and 53.4% ($P<0.001$), respectively in the 1:2 and 1:3 groups (Figure 3). Balloon opacification at peak inflation decreased with reduced concentrations of contrast (Figure 4). Limiting the amount of solution in the inflation syringe resulted in a modest decrease in balloon deflation time. Time to deflation when a syringe was filled with 15 vs. 5 mL of 1:1 ioxaglate- saline mix was 11.3 ± 2.0 vs. 10.5 ± 2.0 seconds (7.5% decrease, $P=0.004$), yet pixel count at a fixed time interval was similar ($P=0.75$, Figure 5).

Discussion

Our study demonstrates that contrast solution viscosity has significant impact on angioplasty balloon deflation time. We observed this by comparing ioxaglate, an LOCM with lower viscosity, to iodixanol, an IOCM with higher viscosity. Additional reductions in balloon deflation times could be achieved with further saline dilution, however at the expense of reduced visualization. A modest reduction in deflation time could be achieved by minimizing the amount of solution contained in the deflation syringe, effectively increasing the vacuum used to deflate the balloon.

Previous studies have highlighted the effects of viscosity on flow rates during diagnostic angiography,(6–8) but to our knowledge this is the first study to evaluate the effects of viscosity on coronary balloon deflation. The “miniaturization” of interventional techniques and the increase in the use of the radial approach has the potential to magnify the impact of higher viscosity due to smaller catheter sizes. An increasing proportion of procedures are being performed with 4 and 5 French diagnostic catheters and radial percutaneous coronary interventions with guides as small as 4 French have been described.(9, 10) Brunette et al. reported that significantly higher pressure was required for iodixanol to maintain similar catheter flow rates with ioxaglate at room temperature for adequate angiography.(11) Coronary balloons are potentially more susceptible to the effects of high viscosity because of long catheter lengths and small lumen size. In our study, use of a lower viscosity contrast agent (ioxaglate) resulted in significantly shorter deflation times compared to a higher viscosity agent (iodixanol) using 1:1 dilution of contrast with 0.9% sodium chloride. This

maneuver lowers viscosity, but at the expense of worsening visibility, a factor not insignificant with rising obesity rates and challenging coronary visualization. We also found that additional contrast dilution allowed additional reductions in balloon deflation times, suggesting that the 1:1 mix may not be optimal in all cases. However, further contrast dilution decreased the visibility of the balloon, which may limit its clinical utility. Reducing deflation times may reduce angina in high risk coronary interventions or reduce limb discomfort during peripheral angioplasty. In addition, long deflation times may result in premature attempts at removing balloons before complete deflation. This could result in deep guide intubation that could lead to ostial vessel dissection and/or longitudinal stent compression.(12)

Our analysis has important limitations. First, although differences in balloon deflation times were observed with ioxaglate compared to iodixanol, the clinical implications these differences require further study. Second, since viscosity is temperature dependent, if contrast is pre-heated to the body temperature of 37 degrees Celsius differences between contrast agents could be reduced. Third, our metrics for evaluating balloon deflation times and contrast extraction are new and have not been validated, although they are intuitively sound. Fourth, our analysis was limited by small sample size although significant differences were observed between contrast agents. In summary, contrast viscosity is an important factor to consider when selecting agents to fill angioplasty balloons.

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Figure 1. Measurement of contrast area at a fixed time interval

To account for some of the irregular contrast extraction from a balloon, we measured contrast area using the border selection tool (Photoshop, Adobe Systems).

Figure 2. Contrast viscosity and coronary balloon deflation

Using matched pairs of coronary dilation balloons filled with either ioxaglate or iodixanol, we measured the time from onset of deflation until withdrawal of all visible contrast passed past the proximal radiopaque marker; we also measured the area of contrast after 5 seconds of balloon deflation.

Figure 3. The effect of lower concentration of ioxaglate on balloon deflation

Dilution of ioxaglate resulted in more rapid balloon deflation by both contrast extraction time and contrast area remaining after 5 seconds of balloon deflation.

Figure 4. The effect of lower concentration on balloon visibility at peak inflation
Use of more saline in the contrast/saline mix resulted in decreased angioplasty balloon visibility.

Figure 5. Inflation syringe volume and balloon deflation times

Modest decreases in balloon deflation were observed by limiting the volume of contrast/saline mix within the inflation syringe. No differences were observed in contrast area after 5 seconds of balloon deflation.