Useful Respiratory Maneuvers Aiding Left Heart Cardiac Catheterization and Intervention. A Comprehensive Review

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November 25, 2023

Short title: Respiratory Maneuvers during Invasive Cardiac Procedures

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Keywords: Cardiac Catheterization; Coronary angiography; left heart catheterization; Percutaneous coronary intervention; Stents; Respiration; Inhalation; Exhalation

Abstract: Left heart catheterizations, coronary angiography, and coronary interventions are important common cardiac procedures. Performing a successful cardiac catheterization and intervention and proper catheterization and device delivery is not always without difficulties, especially in the context of calcification or vessel tortuosity. Although there are some techniques to overcome this issue, performing respiratory maneuvers (inspiration or expiration) can be simply tried as the first step to increasing successful procedures which is underreported and underutilized. The goal of this manuscript is to review current literature regarding useful respiratory maneuvers that can aid in successful left heart catheterization, coronary angiography, and intervention for a successful procedure. Introduction: Left heart catheterization and percutaneous coronary intervention (PCI) are very common cardiac procedures performed in patients with valvular heart disease, suspected coronary artery disease, or heart failure, patients. Although significant advances have been done in terms of instrument designs and improved technology to improve the success rate, respiratory maneuvers are helpful to achieve higher success rates (1, 2). In terms of PCI, engaging coronary artery ostium and advancing balloons or stents can be challenging. Stent delivery difficulties still occur with an incidence of 2.7% - 3.3% (3). Both inspiration and expiration could be utilized to improve cardiac catheterization and device delivery during PCI due to the mediastinal motion of the heart in each respiratory cycle. The goal of this manuscript is to summarize respiratory maneuvers that can aid physicians in improving diagnostic and interventional cardiac procedures during a left heart catheterization, coronary angiography, and intervention. This manuscript will not discuss respiratory maneuvers that can be used
during a right heart catheterization, structural heart intervention, or electrophysiological studies. **Respiratory maneuvers that can aid during cardiac catheterization** Inspiration is also a practical method to pass the brachiocephalic trunk and vertebral artery as two critical points with probable catastrophic adverse events including cerebral athero-embolic or thrombo-embolic complications. By asking the patient to inspire deeply, the mediastinum and heart would be caudally displaced leading to the strengthening of the aorta and coronary arteries leading to facilitate passage of catheters or devices, particularly during trans-radial catheterization. Engaging the ostium of the right coronary artery (RCA) and certain left main take-offs can improve with deep inspiratory maneuvers. Dahm and colleagues suggested Amplatz II catheter in the central position of ascending aorta adjacent to the aortic valve can be successfully advanced by asking the patient to take a deep breath and hold it and turning right the catheter into the right sinus of Valsalva leading to the appropriate RCA cannulation (Figure 1) (4). The same strengthening of the left main ostium can be achieved but taking a deep breath particularly when the left main take-off has a superior angle. This can not only aid Amplatz catheters but any catheters. Di Mario et al. indicated for proper RCA intubation, breath-holding during deep inspiration can help cannulation after appropriate engagement using 4.0 right Judkins catheter in left anterior oblique view with rotation and slow pull-back catheter movement from a right coronary sinus (5). The same maneuver can aid to engage the left main when the catheter tip does not enter the left coronary cusp. In difficult cases, deep inspiration can also facilitate pigtail catheter advancement into the left ventricle for performing ventriculography. After the advancement of the Pigtail catheter to the level of the aortic valve and loop positioning to the left in the right anterior oblique (RAO) projection and making a U shape by pushing the Pigtail catheter against the aortic valve, deep inspiration can facilitate ventricular entry. By taking a deep breath, the heart will be displaced in a more vertical position, making it easier to advance the Pigtail catheter (6). Respiratory maneuvers that are useful during the percutaneous coronary intervention: Tortuosity is one of the most challenging anatomical obstacles that can cause great difficulty during wire and stent advancement (7). Many techniques have been developed to overcome this obstacle such as using buddy wire, stiffer wire, or extension catheters with the deep sitting of the extension catheters. All the above methods are other not mentioned complex interventions that are time and cost-consuming and can cause vessel injury (8-11). Simple respiratory maneuvers such as inspiration or expiration can easily overcome this obstacle in the majority of cases that should be attempted first before proceeding with more advanced techniques due to ease of use without much additional time or cost utilization. In the following paragraphs, inspiratory and expiratory maneuvers are separated based on the vessels that needed intervention. Native vessel tortuosity can be reduced by deep inspiration while vein graft tortuosity can be reduced using expiration. Detailed descriptions and reviews of cases are described in the following two paragraphs. **Deep inspiratory maneuver to overcome vessel tortuosity in native vessel coronary intervention:** Inspiration has been reported to be a simple procedure associated with a higher likelihood of stent delivery in tortuous coronary vessels. Attaran et al. implemented this technique in four cases with successful outcomes (12). The first case was a 61-year-old man with prior coronary artery bypass grafting (CABG) surgery of the left internal mammary artery and saphenous vein to the left anterior descending (LAD) and obtuse marginal (OM) branch, respectively. A 90% stenosis in the left circumflex (LCx) artery was found. After wiring, and ballooning the lesion, the 2.5x18-mm Endeavor® stent could not be advanced due to the presence of tortuosity. After performing deep inspiration by the patient, successful stent advancement across the tortuosity was achieved. (Figure 2). In another case, a 79-year-old man was admitted with non-ST segment elevation myocardial infarction (NSTEMI) with significant lesions found in the proximal and mid LAD. After wiring and balloon dilatation, again stent could not be advanced until a deep inspiratory maneuver was performed. (Figure 3 A & B). In the third case, a 61-year-old man presented with NSTEMI and 99% stenosis in the proximal first OM only after deep inspiration, the stent could be advanced into the lesion. (Figure 3 C & D). In their last case, a 90% stenosis in the mid-distal RCA can only be stented after deep inspiration. (Figure 3 E & F) (12). During inspiration, coronary arteries move downward and this caudal movement is approximately equal in both left and right coronary vessels (13). Also, RCA and LAD, as two anterior coronary arteries, move to the posterior position during inspiration (13, 14). This maneuver has been reported to decrease coronary vessel tortuosity. Also, the heart and diaphragm move to a vertical position during deep inspiration resulting in facilitated device delivery (12). An expiratory maneuver that
can facilitate stent deliverability in tortuous vein grafts: In terms of expiration, this respiratory maneuver has been associated with successful device delivery in tortuous vein grafts. The so-called Reverse Movahed maneuver was successfully published. The first case reported a 61-year-old man with prior CABG presenting with unstable angina. The OM graft had a significant lesion requiring intervention. Several attempts failed to advance a Promus stent (3.5x16 mm) (Boston Scientific). The patient was instructed to perform a deep expiration leading to straightened saphenous vein graft (SVG) and successful stent delivery (Figure 4) (15). In Figure 5, a schematic illustration of the “Reverse Movahed Maneuver” is depicted (16). A full expiration results in the upward motion of the aorta and aortic arch containing the vein grafts consequently causes strengthening the grafts and thereby facilitating stent delivery while deep inspiration would have the opposite negative effect. (15). Laramee et al. reported the effects of respiration on SVG stenosis in two cases. The first patient was a 69-year-old man with prior 11 years CABG history (SVG to LAD, OM branch of LCx, and posterior descending branch of RCA with successful dilation of stenosis at proximal anastomosis of the latter graft presented with unstable angina. 90% tubular stenosis at the proximal anastomosis and 60% stenosis at the graft body were successfully dilated using appropriate balloon catheters. However, a dynamic 80% tubular narrowing adjacent to the proximal segment was observed when the patient held his breath in full inspiration. This narrowing was unrelated to the cardiac cycle and was not affected by the administration of nitroglycerine or verapamil and was just associated with the respiratory cycle (Figure 6 A & B). The second case was a 61-year-old man with prior 15 years of CABG history in addition to previous PCI for stenosis in the SVG to RCA and native RCA lesion distal to the graft site. Prior to angioplasty, 80% tubular obstruction was found adjacent to the proximal anastomosis of SVG to RCA when the patient was inspired deeply. This dynamic obstruction disappeared during exhalation and was not relieved either after nitroglycerine intra-graft injection or balloon dilation (Figure 6 C & D). They suggested diaphragm descent during inspiration can produce linear traction to a fixed area near the anastomosis in the context of pre-existing pericardial adhesions or local scarring and fibrosis (17). In another case, a 52-year-old man presented with persistent exertional chest pain. He had CABG two years prior to his current admission. Left internal mammary artery was grafted to LAD and the saphenous vein was anastomosed to diagonal and intermediate branches. Due to hemodynamic instability, another vein graft was implemented in LAD distal to the anastomosis of the left internal mammary artery with anastomosis of the proximal end to the bypass supplying diagonal and intermediate branches as well as another vein graft to RCA. Within two years of post-operation, he was admitted two times for recurrent chest pain with no identifiable causes. CAG in current admission revealed chronic obstruction of bypass to the diagonal branch and left internal mammary artery bypass. Interestingly, dynamic stenosis in the vein graft supplying distal LAD was observed during deep inspiration but resolved in expiration (Figure 7) (18). Respiration associated risksUsing this maneuver is not risk-free. Despite its rareness, complications are reported in the literature. Bied et al. reported coronary dissection during contrast injection in a 37-year-old man. The patient underwent coronary intervention because of significant coronary lesions. During contrast administration, the patient was inspired deeply leading to the downward movement of the Amplatz catheter in the left main coronary artery causing sub-intimal dissection. Fortunately, he survived and was discharged from the hospital without complications (19). Future perspectivePerforming a respiratory maneuver (either inspiration or expiration) is a relatively simple and inexpensive task that can be used in clinical settings to increase device deliverability in difficult tortuous coronary vessels. These maneuvers can reduce intervention time as well as radiation exposure. However, some considerations should be made. The first and most important issue is patient cooperation. Making deep inspiration might not be practical, especially among patients sedated heavily. On the other hand, the procedure itself must be taken into account. Inspiration can be a useful technique for the intervention of naïve coronary arteries. However, this maneuver can be associated with higher failure rates when performing coronary interventions in vein grafts. Thereby, the patient should be instructed to avoid a deep inspiration and perform a gradual inhalation to prevent additional vessel kinking of vein graft prior to full exhalation. Furthermore, extra caution should be done during coronary interventions if the catheter tip moves excessively and perform contrast injection after the completion of inspiration, but not during the active phase of respiration, in order to prevent a rare but significant complication, named arterial dissection. It should be also kept in mind that the detection of vessel tortuosity in vein grafts might not be completely obvious from two-dimensional angiographic images. Thus,
a high index of suspicion is required, especially in terms of difficult device delivery in relatively normal cine images. **Summary:** Cardiac catheterization and device delivery during coronary interventions might not always be feasible, especially in calcified lesions or tortuous vessels. Although several techniques have been already proposed, they are associated with complications and are invasive. However, performing inhalation or exhalation during the procedure, as appropriate, and requested by the interventionist might be associated with a higher successful balloon and/or stent delivery and this simple and safe technique can be done at the first step if a device delivery is encountered with difficulties.

**Competing interests:** None

**Abbreviations:**
- CABG: Coronary Artery Bypass Grafting
- CAG: Coronary Angiography
- LAD: Left Anterior Descending
- LCx: Left Circumflex
- NSTEMI: Non-ST segment Elevation Myocardial Infarction
- OM: Obtuse Marginal
- PCI: Percutaneous Coronary Intervention
- RAO: Right Anterior Oblique
- RCA: Right Coronary Artery
- SVG: Saphenous Vein Graft

Figure 1. Right coronary artery (LAO 30°), Amplatz II located in the central position of ascending aorta plus its tip in right sinus Valsalva during deep inspiration while turning right to engage right coronary artery, reported by Dahm et al. (4). (with permission from Herz Journal)
Figure 2. A: High grade lesion located in left circumflex coronary artery and diaphragm position (white arrow) during expiration, B: Small improvement in ostial angle of left circumflex coronary artery and diaphragm position (white arrow) during inspiration, C: Successful stent advancement through the target stenosis, D: Final angiographic finding, reported by Attaran et al. (12). (with permission from Texas Heart Institute Journal)

Figure 3. A: High grade lesion in mid-left anterior descending coronary artery with slight lesion angle strengthening and diaphragm position (white arrow) during inspiration, B: Successful stent advancement through the target stenosis, C: High grade lesion located in left circumflex coronary artery and slight lesion angle strengthening and diaphragm position (white arrow) during inspiration, D: Successful stent advancement through the target stenosis, E: High grade lesion located in mid-to-distal right coronary artery and lesion angle strengthening and diaphragm position (white arrow) during inspiration, F: Successful stent advancement through the target stenosis, reported by Attaran et al. (12). (with permission from Texas Heart Institute Journal)
Figure 4. A: Two high grade lesions in saphenous vein graft supplying obtuse marginal branch, B: Vein graft location during expiration showing upward heart position and strengthening of vein graft (black arrows), C: Vein graft location during inspiration showing downward heart position and more tortuosity of vein graft (black arrows), D: Final angiographic outcome, reported by Movahed (15). (with permission from International Journal of Angiology)
Figure 5. Schematic illustration of Reverse Movahed Maneuver showing upward moving of aorta and aortic arch during expiration (straight line) results in vein graft strengthening and downward aorta movement in inspiration (dashed line) leading to increased vein graft tortuosity and kinking, reported by Movahed(15). (with permission from International Journal of Angiology)
Figure 6. A: Coronary angiogram of vein graft to posterior descending branch during expiration, B: Coronary angiogram of vein graft to posterior descending branch during a full inspiration showing inhalation induced narrowing (arrowhead), C: Coronary angiogram of vein graft to distal right coronary artery showing 30% narrowing as well as diffuse narrowing after proximal anastomosis, D: Coronary angiogram of vein graft during full inspiration showing remarkable focal narrowing in the proximal vein graft (arrowhead), reported by Laramee et al. (17). (with permission from Catheterization and Cardiovascular Diagnosis)
Figure 7. A: Coronary angiography image showing venous graft to left anterior descending coronary artery in expiration, B: Coronary angiography image showing dynamic obstruction of vein graft to left anterior descending coronary artery during inspiration suggesting respiratory dependent vein graft occlusion, reported by Wilhelm et al. (18). (with permission from The Annals of Thoracic Surgery)

References


