2 IVUS Artifacts and Image Control

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2.1 Artifacts

2.1.1 Post-acoustic Shadowing (Severe Calcified Lesions, Metal Stent Struts, and Guidewires)

Since IVUS is a type of ultrasound, when scanning severe calcified lesions, post-acoustic shadowing frequently occurs due to poor penetration of the ultrasound beam into calcium. Due to shadowing, underlying plaque beyond the calcium cannot be evaluated or measured (Fig. 2.1a). In addition, calcified lesion can cause other types of artifacts such as reverberations and side lobes. A large coalesce of calcium seen on IVUS is often revealed to actually be many small calcifications upon histopathologic study [1]. Metal stent struts can also cause a typical sunburst pattern of post-acoustic shadows compromising the plaque evaluation underneath (Fig. 2.1b). Guidewires, at times, cause significant artifacts, especially during bifurcation lesion intervention. The dual guidewires make dual postshadows obscuring significant lesions (Fig. 2.1c). A long monorail catheter could be used as a preventive method. However, when dealing with highly movable vessels that have calcified lesions or even depending on the composition of guidewire tips, these artifacts can be worsened [1].

2.1.2 Ring-Down Artifacts

A luminous ring of false images surrounding the transducer or the catheter of IVUS, which presents as several layers around the catheter that compromise evaluation of the area adjacent to the catheter (Fig. 2.2). Often it is called near-field artifacts when using other medical ultrasound devices. Digital subtraction of a reference mask can suppress ring-down artifact; however, it also limits the ability to distinguish extremely near tissue from the surface of the catheter [2].

2.1.3 Nonuniform Rotational Distortion (NURD)

NURD is the unique motion artifact that can only be observed in IVUS system. It results from hindered constant rotational as well as fullback velocity of the transducer due to nonuniform friction of the coronary artery lumen [1, 3]. It can be

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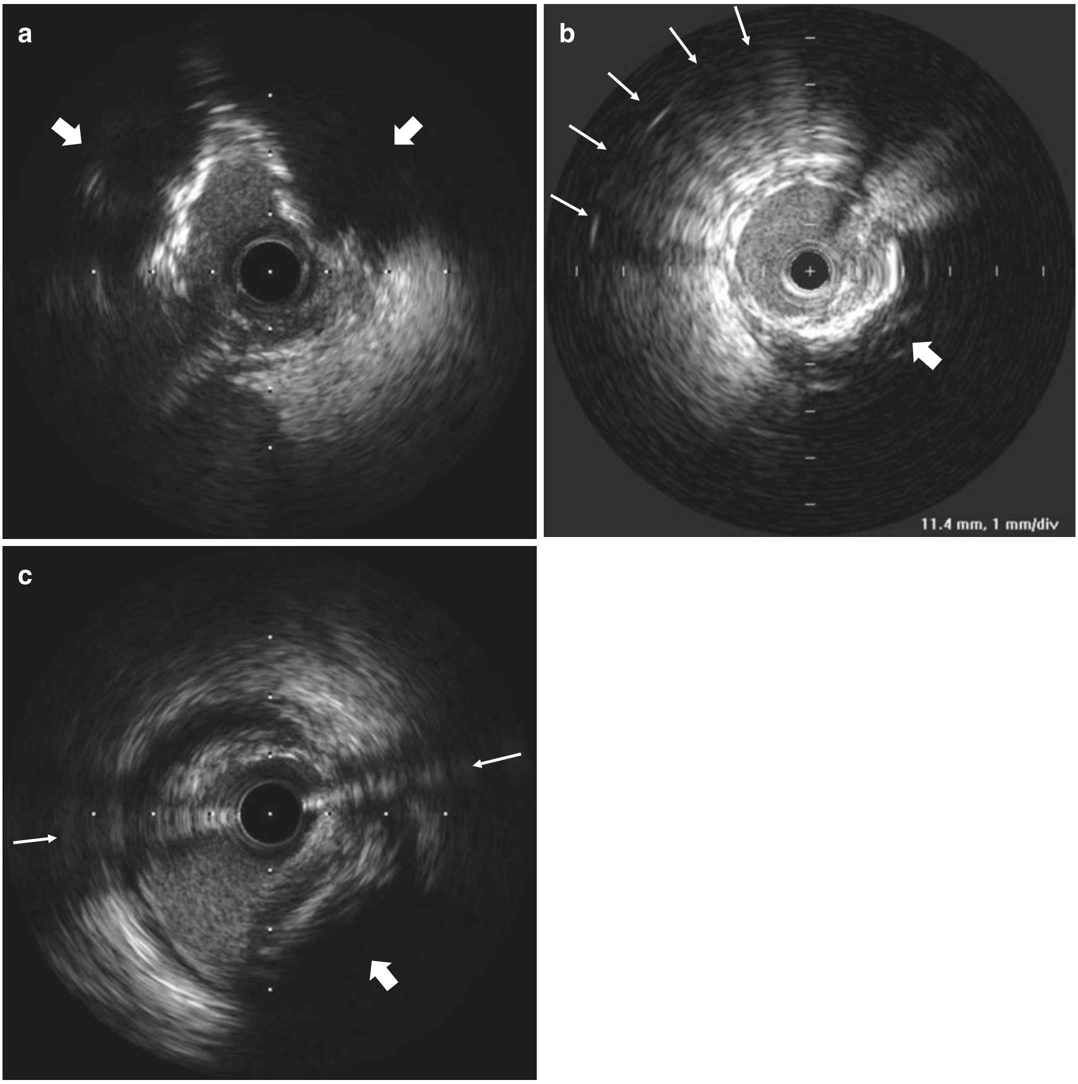

Fig. 2.1 Post-acoustic shadows due to severe calcified lesions, metal stent struts, and guidewires. (**a**) Heavy calcified lesions mask the plaque underneath between the 9 and 3 o'clock positions (*arrowheads*). (**b**) Multiple post-shadows (*arrows*) by stent struts combined with calcification (2–7 o'clock, *arrowhead*) can be observed. (**c**) Dual postshadows are present due to dual guidewires (*arrows*) with calcified plaque (*arrowhead*)

present especially in bending or tortuous vessels, sometimes being influenced by small guided catheter lumens, the kinking of coronary wires in the same catheter, instability of catheter engagement, and the hub or drive machine itself. One of the other problems is the transducer can move up to 5 mm longitudinally according to systolic and diastolic movement of the heart. This movement can also cause significant motion artifacts. NURD is critically limited for the quantitative analysis of IVUS use (Fig. 2.3).

2.1.4 Side Lobes

Outside of main and high energy ultrasound beams, there are low energy beams called side lobes [1]. If there is a strong echo reflector such as calcium or

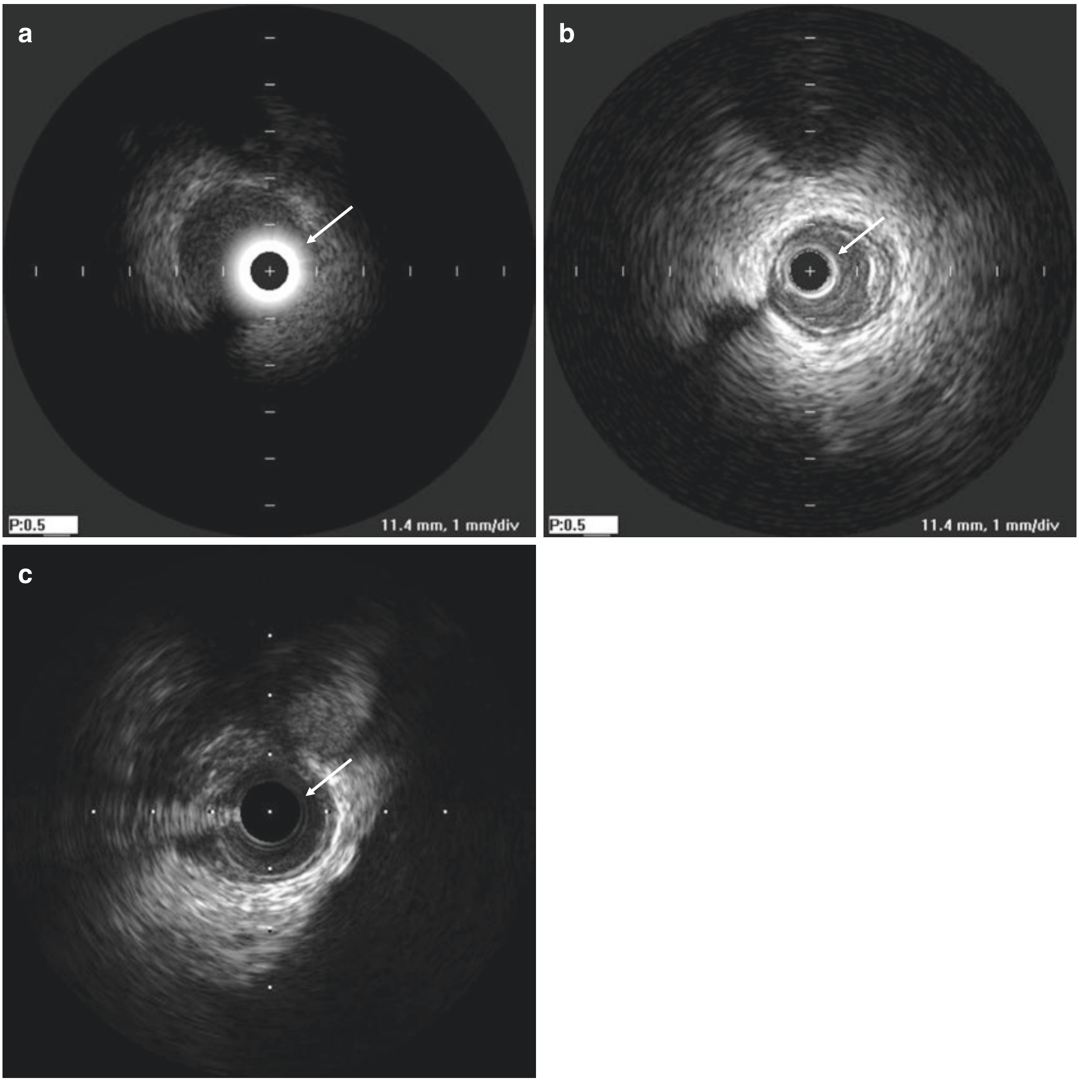

Fig. 2.2 Ring-down or near-field artifacts. (**a**) An extremely displayed ring-down artifact can be noted due to ultrasound element defect (*arrow*). (**b**) Presented here is ring-down artifact of around 10 mm diameter with several bright layers at the center of IVUS image (*arrow*). (**c**) Reduced ring-down artifact is noted (*arrow*)

stent strut, where the side lobe beams should pass, it will reflect these low energy echoes back to the transducer. Hence, false images of circumferential sweep will present adjacent to the calcium or stents. These false images mimic dissection flaps and may compromise precise evaluation of true lumen border (Fig. 2.4). One tip to overcome side lobe artifact is to reduce gain setting.

2.1.5 Reverberations

Reverberations are the production of repetitive false echo images due to reflections between two interfaces with a high acoustic impedance mismatch [2]. When the ultrasound beam bumps into strong reflectors such as calcium, metal stents, guide wires, and guiding catheters, it may

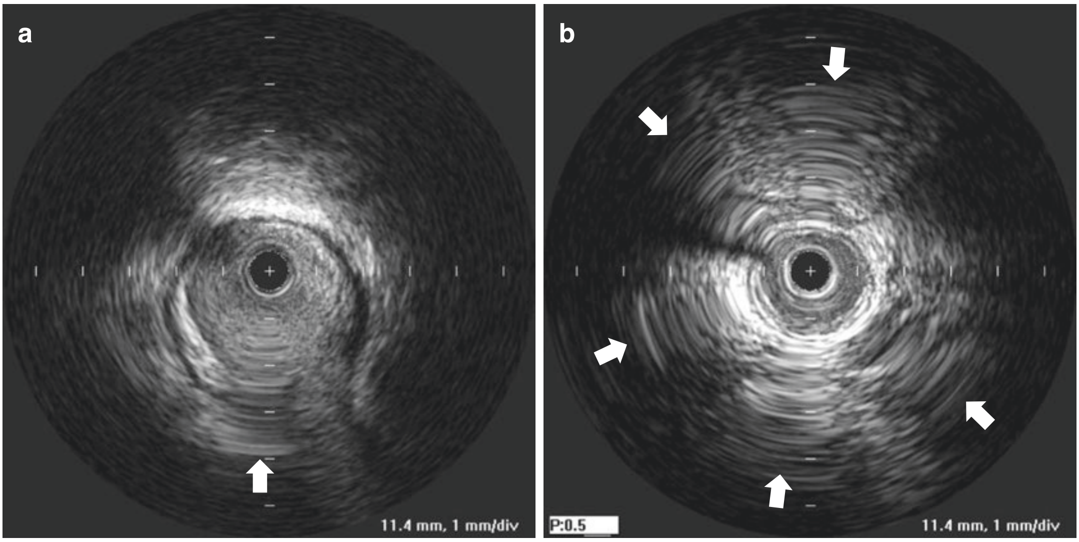

Fig. 2.3 Nonuniform rotational distortion (NURD). (**a**) NURD artifact is present between 5 and 7 o'clock with distortion of the underlying plaque (*arrowhead*). (**b**) Multiple NURD artifacts occurred in a small-sized vessel (less than 2.5 mm diameter, *arrowheads*)

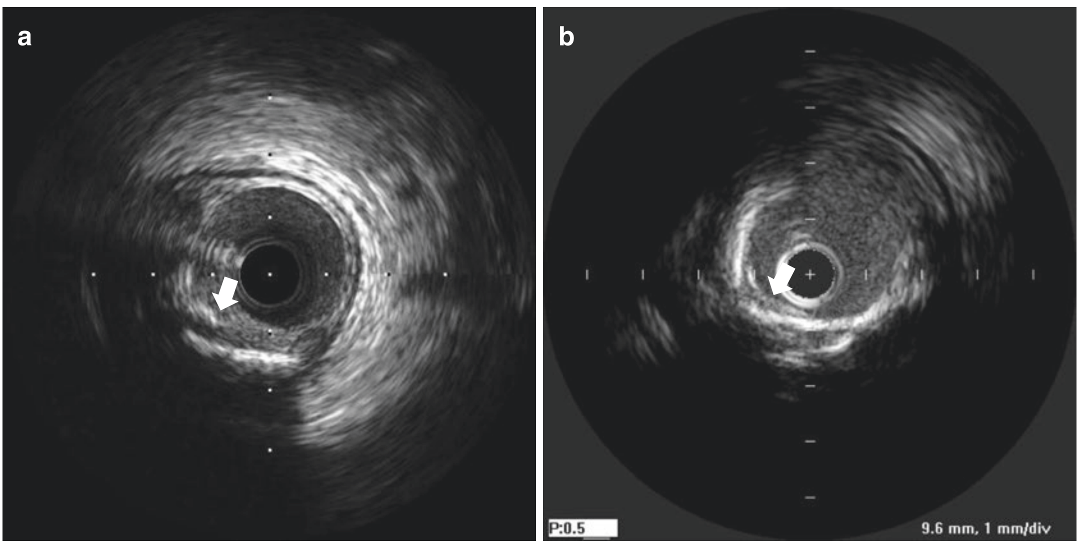

Fig. 2.4 Side lobes. (**a**) False images of circumferential lines are showing between 7 and 8 o'clock (*arrowheads*). (**b**) Slices of circumferential lines are present between 6 and 9 o'clock positions being confused with the dissection flap of the intima (*arrowheads*)

be repeatedly reflected back and forth before returning to the transducer. These repeated reflections are displayed as multiple equidistantly spaced circumferential layers on IVUS (Fig. 2.5).

2.1.6 Ghosts

Stent "ghost" artifacts are false reflected images that present on the opposite side of where the stent metal truly is [2]. They frequently appear after

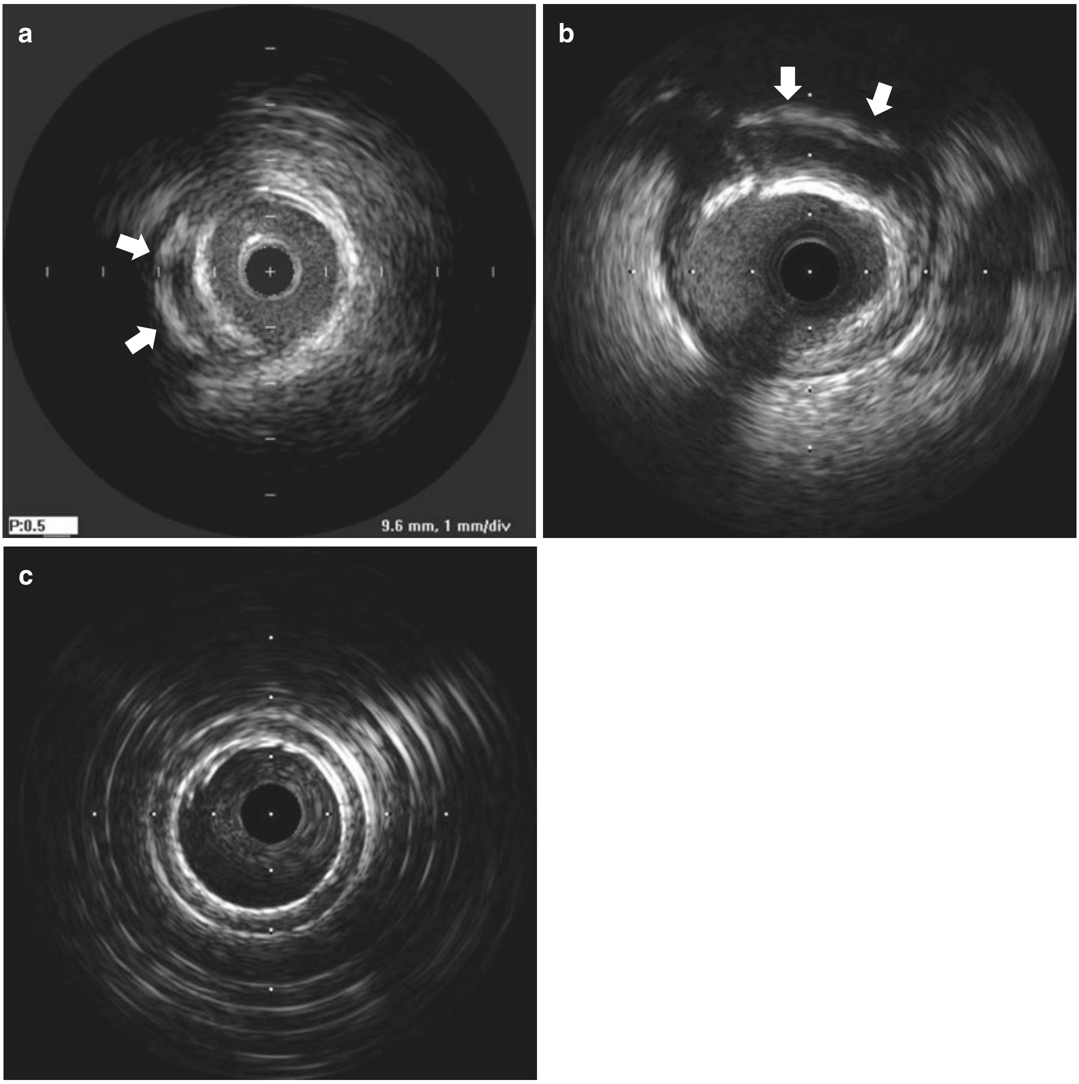

Fig. 2.5 Reverberations. Repetitive false echo images (*arrowheads*) are showing outside the calcified lesion between 7 and 10 o'clock (**a**) and 11 and 1 o'clock (**b**). (**c**) Multiple equidistantly spaced circumferential layers are present due to catheter-derived reverberations

stenting implantation and make it difficult to distinguish the true stent apposition (Fig. 2.6). Ghost artifact can be decreased by reducing overall gain.

2.1.7 Blood Speckle Artifact

High intensity of blood speckles in the coronary lumen make it difficult to distinguish between lumen and plaque (Fig. 2.7). The speckles are the result of decreased velocity of blood due to severe luminal stenosis or at times from using higher than conventional transducer frequencies such as when using 40 MHz [1–3]. Saline or contrast dye flushing would immediately resolve this artifact. Adjusting the time gain control is another option.

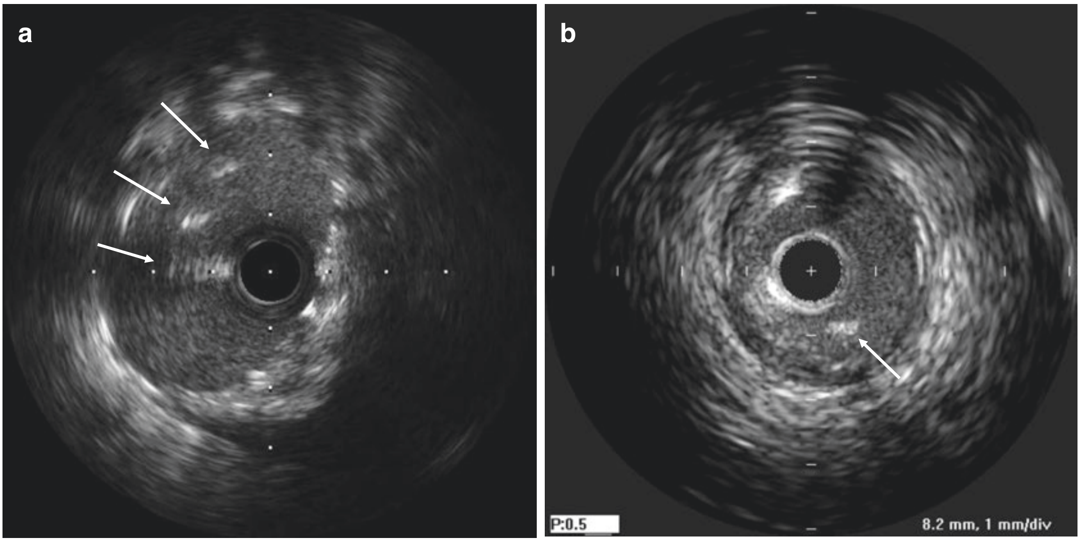

Fig. 2.6 Ghosts (**a**) Circular false images are shown opposite of implanted stent between 9 and 11 o'clock (*arrows*). (**b**) Ghost artifact caused by dense calcium is present (*arrow*)

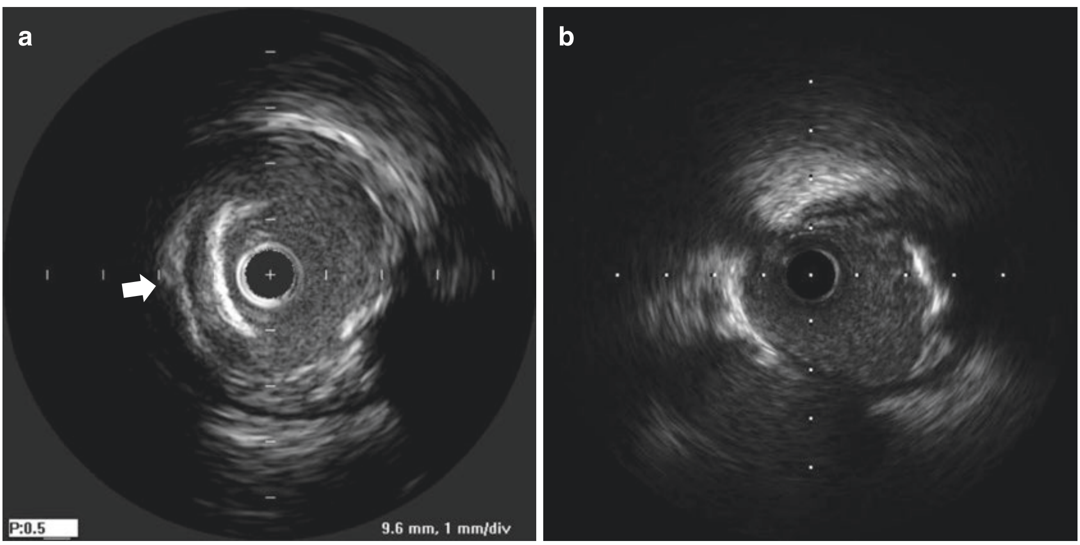

Fig. 2.7 Blood speckle artifact. (**a**) Highly accumulated blood speckles in lumen make it difficult to distinguish between lumen and plaque (9–3 o'clock and 4–6 o'clock). Reverberation artifact is also noted between 7 and 11 o'clock (*arrowhead*). (**b**) Dense blood speckles are shown between 2 and 7 o'clock

2.1.8 Air Bubble Artifact

Air bubble artifact is simply caused by improper catheter saline flushing [2]. Therefore, remaining air bubbles reduce the resolution of IVUS images (Fig. 2.8a). Complete flushing of air bubbles in the catheter with saline will be enough to resolve this problem (Fig. 2.8b). However, it is important to prevent an air embolism from occurring, and thus it is best to remove the IVUS catheter and reintroduce it to the coronary upon successful completion of flushing to remove the air bubbles.

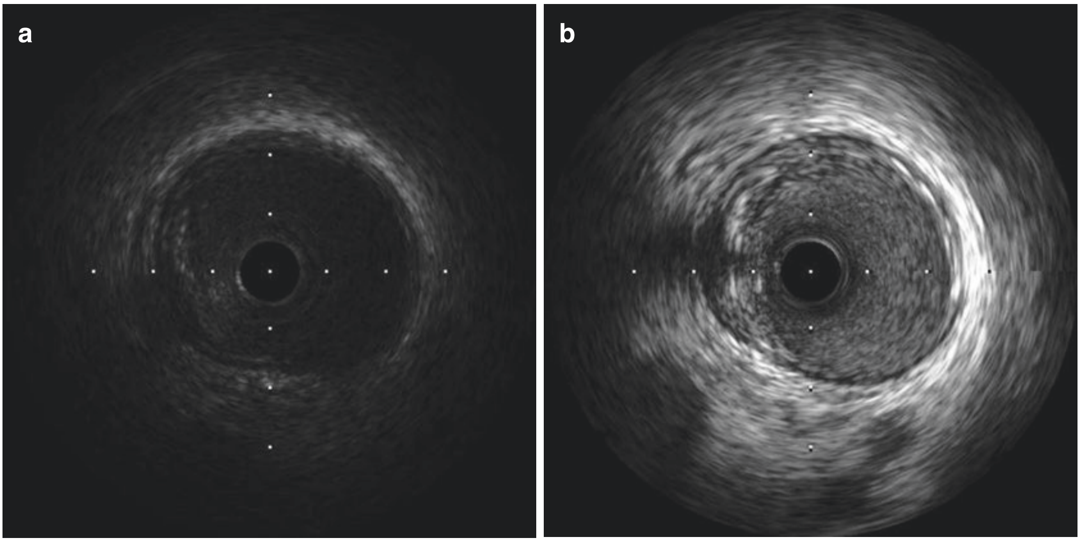

Fig. 2.8 Air bubble artifact. (**a**) Air bubble artifacts are present due to improper catheter saline flushing. (**b**) Upon completion of proper air bubble flushing, an improved image was achieved

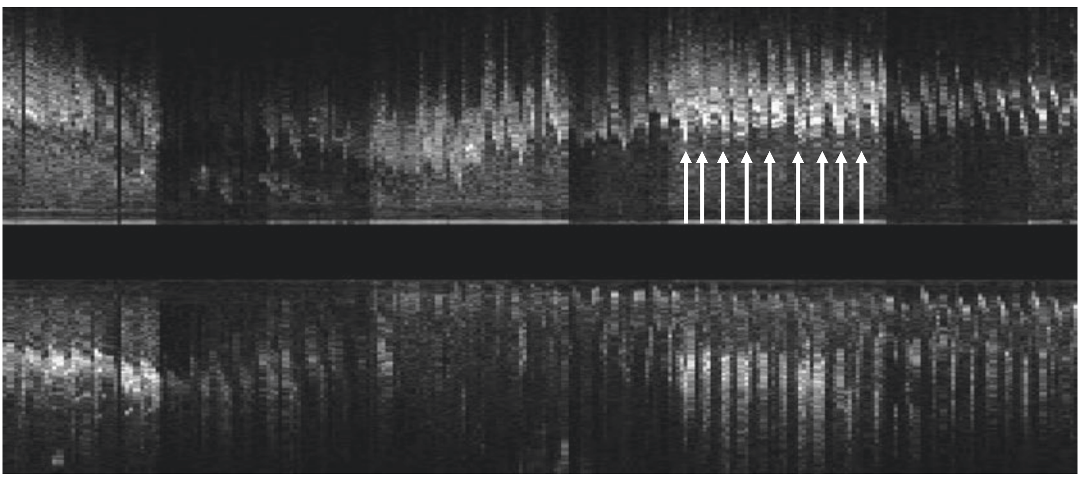

Fig. 2.9 Sawtooth artifact. "Sawtooth" appearance is present on the longitudinal reconstructed image due to a rapid swinging coronary artery (*arrows*)

2.1.9 Sawtooth Artifact

This artifact appears when the transducer is excessively swung during the pullback period. Due to this, a "sawtooth" appearance shows on the longitudinal reconstructed image (Fig. 2.9). It frequently happens in tortuous vessels, rapid beating hearts, or rapid moving coronary arteries such as right coronary arteries [2].

2.2 Image Control

2.2.1 Gain Control (Overall Gain and Time Gain Compensation)

Overall gain control is used to increase or decrease the overall brightness of the image through amplification of the return signal without changing the transmitted pulse (Fig. 2.10).

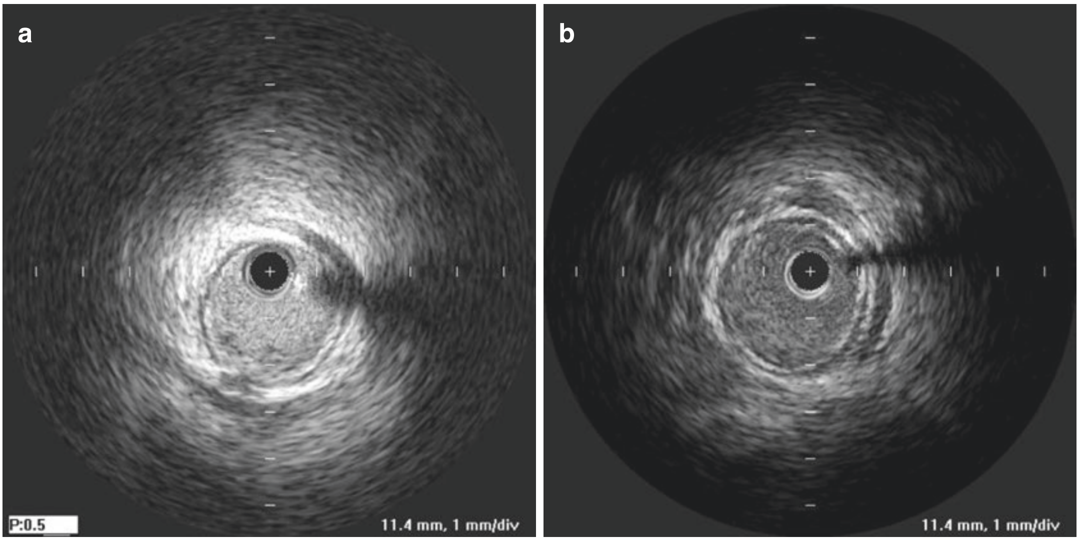

Fig. 2.10 Overall gain control. (**a**) A gain setting being set too high caused amplified noise signals in the lumen. (**b**) In this image, a properly adjusted gain setting can be seen

Therefore, overall gain increase does not improve tissue penetration or resolution power. On the contrary, if overall gain is set too high, it also amplifies noise signals resulting in the reduction of the image resolution [1].

The time gain compensation (TGC) is a way to overcome ultrasound attenuation by increasing signal gain over time it is emitted from the transducer. As emitted ultrasound passes through tissue, wave amplitude becomes attenuated. Hence, TGC is a compensation technique of increasing return signal amplification while penetrating deeper [1]. This correction makes equally echogenic structures appear the same visually regardless of depth. In large vessels such as left main, increasing the far-field attenuation would be helpful. On the other hand, reducing the near-field intensity can compromise assessment of in-stent neointimal tissue, small branches, or CTO lesions.

2.2.2 Rejection

Rejection is a way of increasing image contrast by filtering-out low amplitude noise signals [1]. However, if reject level is set too high, low echogenic structures such as hematoma or small dissection flaps might be missed.

2.2.3 Compression (Dynamic Range)

Compression (also known as dynamic range) is controlling the range of echo intensities by narrowing or broadening the range of the gray scale [1]. If the compression level is set too high, fewer shades of gray will be displayed resulting in higher contrast images with more black and white [2].

2.2.4 Zoom, Depth, and Scale

According to vessel size or lesion morphology, zoom, depth, or scale adjustment should be tactfully chosen. Zoom is only magnifying the image, not providing further structural detail. Therefore, adjusting depth might be useful to gain greater detail within the structure (Fig. 2.11).

2.3 Summary

Artifacts in IVUS imaging are an infrequently inevitable phenomenon due to the inherent limitations of ultrasound modality itself. Therefore, it should be important to distinguish artifacts from

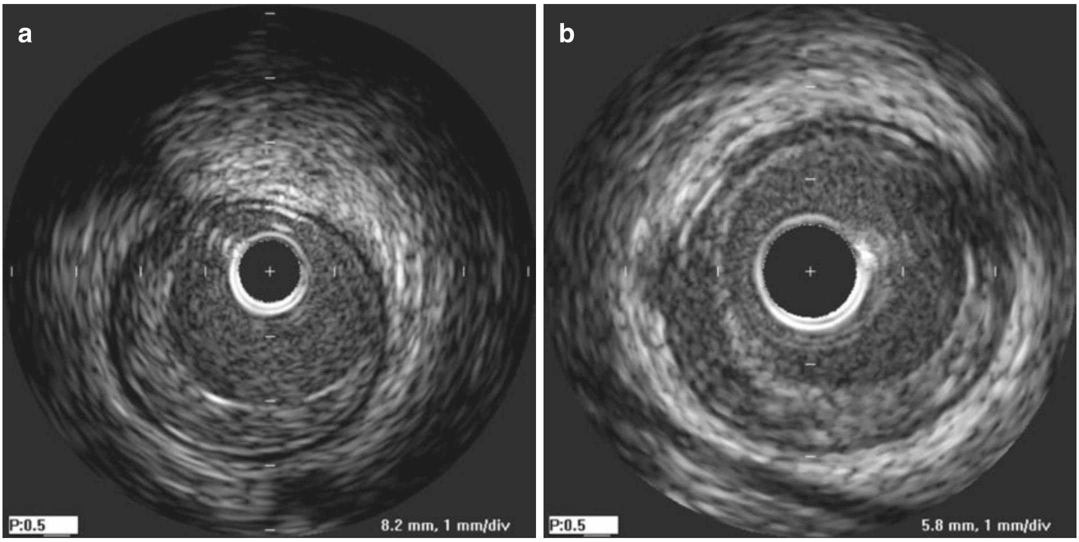

Fig. 2.11 Depth or scale control. Depth or scale was adjusted from 8 mm diameter (**a**) to 6 mm (**b**). It is noted that image resolution has not changed despite magnifying the image

true image findings at each specific clinical scenario and gain image control skills to reduce artifacts as much as possible.

References

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