



# Intravascular ultrasound guidance in superior vena cava stenting for malignant superior vena cava obstruction: solving the landing zone dilemma

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## PURPOSE

Patients with superior vena cava (SVC) obstruction (SVCO) are referred for stenting to alleviate symptoms such as plethora and dyspnea. Accurate visualization and measurement of the central veins are essential for appropriate stent selection and optimal placement. This is critical to avoid extension into the right atrium, which can lead to arrhythmias or stent migration. However, in cases of severe SVCO, the sinoatrial junction (SAJ) often cannot be opacified on angiograms. Altered flow dynamics cause suboptimal perfusion and distention, complicating precise measurements and challenging stent planning—especially when the tumor encroaches near or beyond the SAJ.

## METHODS

We integrated intravascular ultrasound (IVUS) into our procedural workflow and evaluated its utility in a series of 27 cases involving malignancy-related SVCO between November 2023 and March 2025. We measured the distance from the midpoint of the stenosis to the SAJ (stenosis-to-SAJ distance) and identified cases requiring IVUS for accurate assessment of the caudal landing zone.

## RESULTS

Parametric testing revealed a stronger correlation between stenosis-to-SAJ distance measurements on IVUS and computed tomography (CT) than between digital subtraction angiography and CT. Statistical analysis determined that a stenosis-to-SAJ distance of  $\leq 40$  mm was significantly associated with the need for IVUS ( $P = 0.008$ ), whereas the association at  $\leq 50$  mm was not statistically significant ( $P = 0.069$ ).

## CONCLUSION

Stenting becomes particularly challenging when tumors invade the SAJ. Our findings suggest that IVUS provides valuable visualization and measurement, particularly in cases with a stenosis-to-SAJ distance of  $\leq 40$  mm, making it a useful adjunct for safe and effective SVC stent placement.

## CLINICAL SIGNIFICANCE

Visualization of venous anatomy and the exact extent of SVC stenosis is difficult in cases of severe obstruction, especially when the tumor encroaches upon the SAJ, making stent selection and deployment challenging. The use of IVUS facilitates visualization of the precise extent of the stenosis and delineates the location of the SAJ. A stenosis-to-SAJ distance of  $\leq 40$  mm significantly benefits from the concomitant use of IVUS for accurate stent placement.

## KEYWORDS

Intravascular ultrasound, superior vena cava obstruction, stenting

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Superior vena cava (SVC) obstruction (SVCO) is a relatively common clinical condition, with reported incidence rates ranging from approximately 1 in 650 to 1 in 3,100 patients.<sup>1</sup> This condition is particularly prevalent in our hospital due to our status as a tertiary care center with a specialized oncology department. Many patients presenting with SVCO are diagnosed with malignancies that compress or invade the SVC, leading to symptoms such as facial and upper limb swelling (plethora), shortness of breath (dyspnea), and dilated superficial veins. These patients are often referred to interventional radiology for diagnostic venograms and therapeutic procedures, such as SVC stenting, to alleviate these distressing symptoms.<sup>2</sup>

Accurate visualization and precise measurement of the central veins are critical in planning and executing successful stent placement. Selecting a stent with the appropriate length and diameter ensures optimal coverage of the obstruction while minimizing complications. It is particularly important to avoid extending the stent into the right atrium, as this can increase the risk of arrhythmias and may cause the stent to migrate into the heart, with potentially severe consequences.

However, in cases of tight or severe SVCO, visualizing the SAJ on angiograms can be challenging because the occlusion impedes contrast flow, preventing clear opacification of this critical area. Additionally, altered hemodynamics caused by the tumor mass and the obstruction can lead to abnormal flow patterns, resulting in suboptimal perfusion and distention of the SAJ. These factors complicate the accurate measurement of vascular structures on computed tomography (CT) imaging, making precise assessment more difficult.

To address these challenges, we have incorporated intravascular ultrasound (IVUS)

into our procedural protocol for SVC stenting. IVUS provides real-time, high-resolution imaging from within the vessel lumen, allowing for detailed visualization of the vessel wall and surrounding structures. This study conducts a series of cases to evaluate the utility of IVUS in improving the safety and accuracy of stent placement, especially in complex scenarios. The hypothesis is that when there is tumor extension toward the caudal end of the SVC, particularly encroaching upon or involving the SAJ, IVUS would be essential to ensure safe and effective stent deployment. This approach aims to prevent complications such as inadvertent injury to the heart or improper stent positioning, ultimately enhancing patient outcomes.

## Methods

Between November 2023 and March 2025, a total of 27 cases involving SVC venography were performed on patients presenting with symptomatic malignancy-related SVCO. Diagnostic venograms and IVUS [0.035" Opti-Cross™ catheter (Boston Scientific, Marlborough, MA, USA)] were performed in all cases to assist in the assessment and planning for stent placement. All of these patients were hemodynamically stable, and IVUS was on standby for immediate use to ensure it did not incur considerable additional procedural time. All cases were performed by two radiologists with 8 and 20 years of experience. For each case, the distance from the midpoint of the SVCO to the SAJ—coined the stenosis-to-SAJ distance—was measured on CT, IVUS, and digital subtraction angiography (DSA). The two radiologists independently

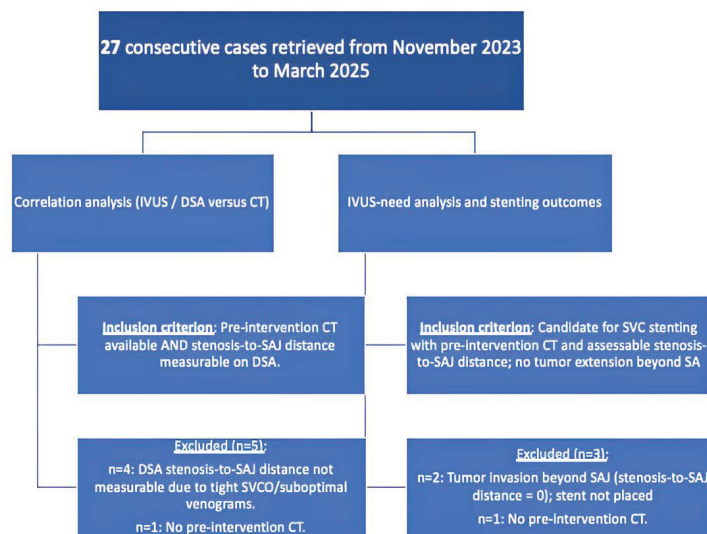
performed the measurements on CT (using coronal multiplanar reformatted images) and DSA (using pre-stent SVC venograms), resolving any discrepancies by consensus. The IVUS measurements were documented during the procedure by noting the length the catheter traversed using its centimeter markings. The SAJ is defined as the transition point between the lowest point of the SVC and the superior border of the right atrium on CT. On DSA, the SAJ is identified as approximately two vertebral body units below the carina. On IVUS, the SAJ is identified as the point where wall morphology transitions from the thicker, relatively uniform echogenic venous wall of the SVC to the thinner, highly compliant wall of the right atrium, marked by cardiac pulsatility. In particular, the measurement on IVUS is made by noting the length the IVUS catheter has traversed, making use of the centimeter markings on the catheter itself. Taking the CT measurements as the gold standard, the distances measured on IVUS and DSA were tested against the CT measurements to determine their respective correlations. Parametric tests were performed for 22 sets of data out of the 27 cases. In four cases, the stenosis-to-SAJ distances could not be measured on DSA due to tight SVCO causing suboptimal venograms. In one case, there was no pre-intervention CT for correlation (Figure 1). The imaging and interpretation process is detailed in Supplementary Figure 1.

## Statistical analysis

The focus was turned to identifying which cases required the use of IVUS to better de-

**Main points**

- In severe superior vena cava obstruction, defining the venous anatomy and the true distal extent of stenosis is challenging—particularly when the tumor approaches the sinoatrial junction (SAJ)—which complicates stent selection and deployment.
- Intravascular ultrasound (IVUS) improves visualization of the precise length of the stenosis and clearly identifies the SAJ.
- When the stenosis-to-SAJ distance is  $\leq 40$  mm, concurrent IVUS use markedly aids in accurate stent sizing and placement.



**Figure 1.** Data acquisition flowchart. IVUS, intravascular ultrasound; DSA, digital subtraction angiography; CT, computed tomography; SAJ, sinoatrial junction; SVCO, superior vena cava obstruction; SVC, superior vena cava; SA, superior aorta.

lineate the position of the SAJ, thereby facilitating more precise SVC stent placement. To evaluate this, various cut-off values for the stenosis-to-SAJ distance—specifically  $\leq 40$  mm and  $\leq 50$  mm—were examined to test their association with the need for IVUS. The need for IVUS was decided when both operators reported uncertainty in delineating the extent of SVC stenosis and the position of the SAJ. This decision reflects operator-perceived necessity instead of externally validated criteria. Chi-square and Fisher's exact tests were employed to assess whether these relationships were statistically significant.

Three cases were excluded from this analysis. Two of these had tumor invasion extending beyond the SAJ, resulting in a stenosis-to-SAJ distance of zero; in these instances, stent placement was not performed. One case did not have a pre-intervention CT scan for measurements. In the remaining 24 cases, Wallstents (Boston Scientific) of the appropriate length and diameter were placed with technical and clinical success. Technical success was defined as the successful placement of a stent in the SVC with improvement in luminal diameter; ancillary features included the closure of venous collaterals. Clinical success was defined as improvement in any SVCO-related symptomatology, such as dyspnea, oxygen requirement, or upper limb and facial congestion.

This retrospective study was exempt from review by the Queen Elizabeth Hospital, Kowloon Central Cluster, Hospital Authority Ethics Committee Board. We generally do not require submission of retrospective studies to our local ethics committee, hence no protocol number is provided. Informed consent was not required due to the retrospective nature of this study.

## Results

Bland-Altman plots correlating IVUS and DSA measurements against the reference standard measurements made on CT were performed (Supplementary Figure 2). The Bland-Altman plot for SAJ measurements on DSA against CT showed a mean bias of  $-2.81$ , with wide limits of agreement ( $-36.6$  to  $+31.0$  mm). This suggests DSA tends to measure a slightly longer SAJ distance than CT on average. In contrast, the Bland-Altman plot for SAJ measurements on IVUS against CT showed a mean bias of  $+0.28$ , indicating a negligible systematic difference between IVUS and CT. Narrow limits of agreement ( $-4.1$  to  $+4.7$  mm) with tight clustering suggest excellent agreement. Overall, these

findings suggest IVUS provides measurements that align better with CT and reduces uncertainty regarding the SAJ.

Analysis also revealed a significant correlation between shorter stenosis-to-SAJ distances and the likelihood of requiring IVUS during the intervention. Specifically, cases where the distance from the most stenotic point of the SVC to the SAJ was  $\leq 40$  mm showed a markedly increased need for IVUS, with a highly significant  $P$  value of less than 0.008 by Fisher's exact test [odds ratio (OR): 20.0 95% confidence interval (CI): 2.29–174.7] (Table 1). However, when the stenosis-to-SAJ distance was  $\leq 50$  mm, the association did not demonstrate statistical significance, with a  $P$  value of 0.069 [OR: 5.60 (95% CI: 0.82–38.5)] (Table 2). These findings indicate that in cases with very short distances—particularly those at or below 40 mm—the use of IVUS is more likely to be necessary to accurately assess the anatomy and ensure safe and effective stent deployment. In contrast, beyond 50 mm, the predictive value diminishes, and the necessity for IVUS becomes less certain based solely on this measurement.

Overall, these results underscore that shorter stenosis-to-SAJ distances are associated with the requirement of IVUS during planning. Furthermore, we found a stenosis-to-SAJ distance of  $\leq 40$  mm to be a reasonable cut-off value for IVUS to be

considered during SVC stent placement. This information may assist in clinical decision-making, helping interventionalists anticipate when IVUS will be most beneficial to achieve precise stent placement and optimize patient outcomes in the context of malignant SVCO. The authors acknowledge that possible reporting bias may overstate the generalizability of these results; biases are further discussed in the subsequent section.

There were no major periprocedural complications in any of the 27 cases. One minor incident occurred where kinking during manipulation of the IVUS catheter caused breakage at the catheter-cannula interface. This was promptly resolved by replacing the broken IVUS catheter with a new one. In the 24 cases where stents were successfully placed, technical success and clinical success both reached 100%. All patients reported immediate symptomatic relief, with improvement in dyspnea, oxygen requirement, and upper limb or facial distention. Follow-up was calculated from the index procedure date to the last clinical or imaging contact, with administrative censoring on March 12, 2025. Median follow-up, estimated by the reverse Kaplan-Meier method, was 291 days (interquartile range: 105–433 days; 95% CI: 126–421 days). The potential follow-up window ranged from 1 day (for patients treated on March 11, 2025) to 497 days (for patients treated on November 1, 2023), corresponding to approximately 0.0–16.3 months.

**Table 1.** Chi-square and Fisher's exact tests for a stenosis-to-SAJ distance of  $\leq 40$  mm

		Need for IVUS		
		Yes	No	Total
SAJ $\leq 4$ mm	Yes	8	2	10
	No	2	10	12
	Total	10	12	22
		chi <sup>2</sup>	df	$P$
SAJ $\leq 4$ mm and need for IVUS		8.82	1	0.003
Left-sided		1		
Two-sided		0.008		
Right-sided		0.005		

IVUS, intravascular ultrasound; SAJ, sinoatrial junction.

**Table 2.** Chi-square test for a stenosis-to-SAJ distance of  $\leq 50$  mm

		SAJ $\leq 5$ mm		
		Yes	No	Total
Need for IVUS	Yes	8	2	10
	No	5	7	12
	Total	13	9	22
		chi <sup>2</sup>	df	$P$
Need for IVUS and SAJ $\leq 5$ mm		3.32	1	0.069

IVUS, intravascular ultrasound; SAJ, sinoatrial junction.

## Discussion

The endovascular approach to SVC stenting begins with gaining vascular access, typically via the right femoral vein. Once access is established, a diagnostic venogram is performed to delineate the anatomy, identify the location and extent of the stenosis or obstruction, and assess for collateral circulation. In cases of malignant SVC syndrome, careful evaluation of the lesion's relationship to critical landmarks, such as the SAJ, is essential. After lesion assessment, a guidewire is advanced across the stenosed segment under fluoroscopic guidance, often facilitated by the use of hydrophilic wires for navigating occluded vessels. Pre-dilation with a balloon catheter may be performed to facilitate stent delivery, particularly in tight or fibrotic lesions. The stent—usually a self-expanding or balloon-expandable metallic stent—is then carefully positioned so that the stenosis is located near the midpoint of the stent, with the caudal extent not extending below the SAJ. This ensures adequate coverage of the stenosis while avoiding injury to the right atrium. In some cases, IVUS is employed to confirm the exact length of the lesion, determine optimal stent positioning, and assess luminal diameters. Once properly positioned, the stent is expanded with a balloon to ensure adequate apposition to the vessel wall. Post-deployment, venography and IVUS are used to verify correct placement, patency, and the absence of complications, such as extravasation or stent malapposition. This minimally invasive technique provides rapid symptomatic relief and has become the standard of care in appropriately selected patients with malignant SVCO.

Difficulty is often encountered in cases where the tumor encroaches upon the SAJ (Figure 2) and in cases of severe SVCO. In these instances, the SAJ often cannot be visualized or opacified effectively on angiograms. Additionally, the altered hemodynamics caused by SVCO lead to abnormal flow patterns, which can result in suboptimal perfusion and distention of the SAJ (Figure 3). This distortion occasionally hampers accurate vascular measurements on CT images, complicating stent selection and the determination of the distal landing zone. To address these challenges, we integrated IVUS into our SVC stenting procedures and systematically evaluated its utility across a series of cases. This is a novel indication for the use of IVUS. Although the 0.018" IVUS system has been used mainly in coronary<sup>3,5</sup> and peripheral artery disease<sup>4</sup> angioplasties,

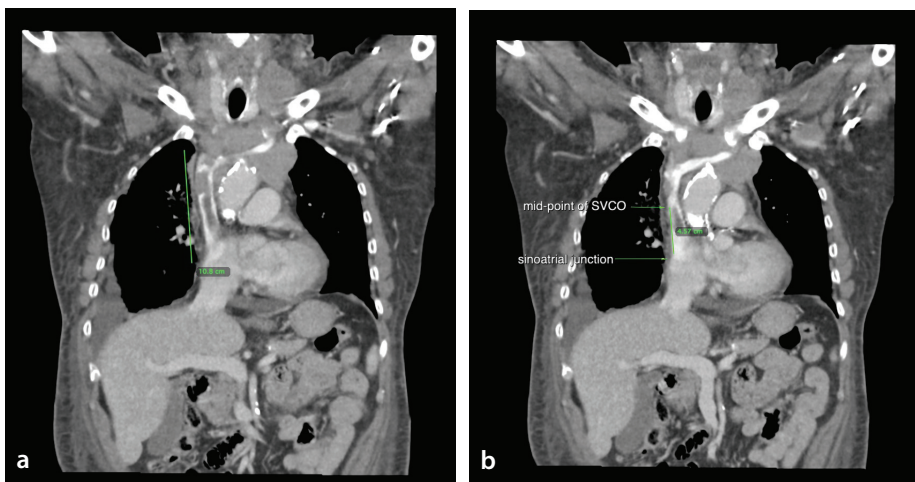
applications for the 0.035" IVUS system are even more limited, having been used almost exclusively for aortoiliac interventions. To our knowledge, there is limited<sup>6</sup> literature delineating the use of IVUS to aid in SVC stent insertion.

We specifically focused on the relationship between the stenosis-to-SAJ distance and the need for IVUS guidance during stent placement. Over our study period, we analyzed 27 cases involving symptomatic malignancy-related SVCO, utilizing venography and IVUS for detailed assessment. Our primary aim was to identify anatomical predictors that could guide the use of IVUS, thereby optimizing procedural safety and efficacy.

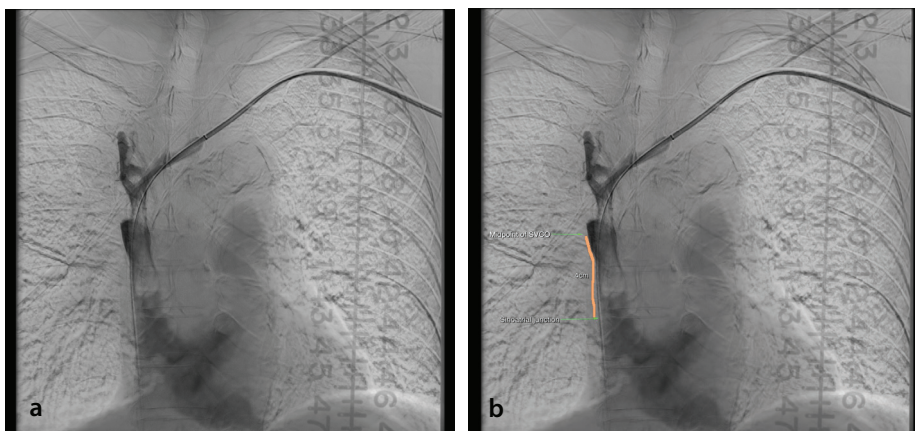
The key finding from our analysis is that shorter stenosis-to-SAJ distances—particularly those  $\leq 40$  mm—are significantly associated with the need for IVUS guidance. Statistically, cases with a stenosis-to-SAJ distance

of  $\leq 40$  mm showed a significant correlation with IVUS requirement ( $P = 0.008$ ). Conversely, the association for distances  $\leq 50$  mm was not statistically significant ( $P = 0.069$ ), indicating that the predictive value diminishes beyond the 40 mm threshold.

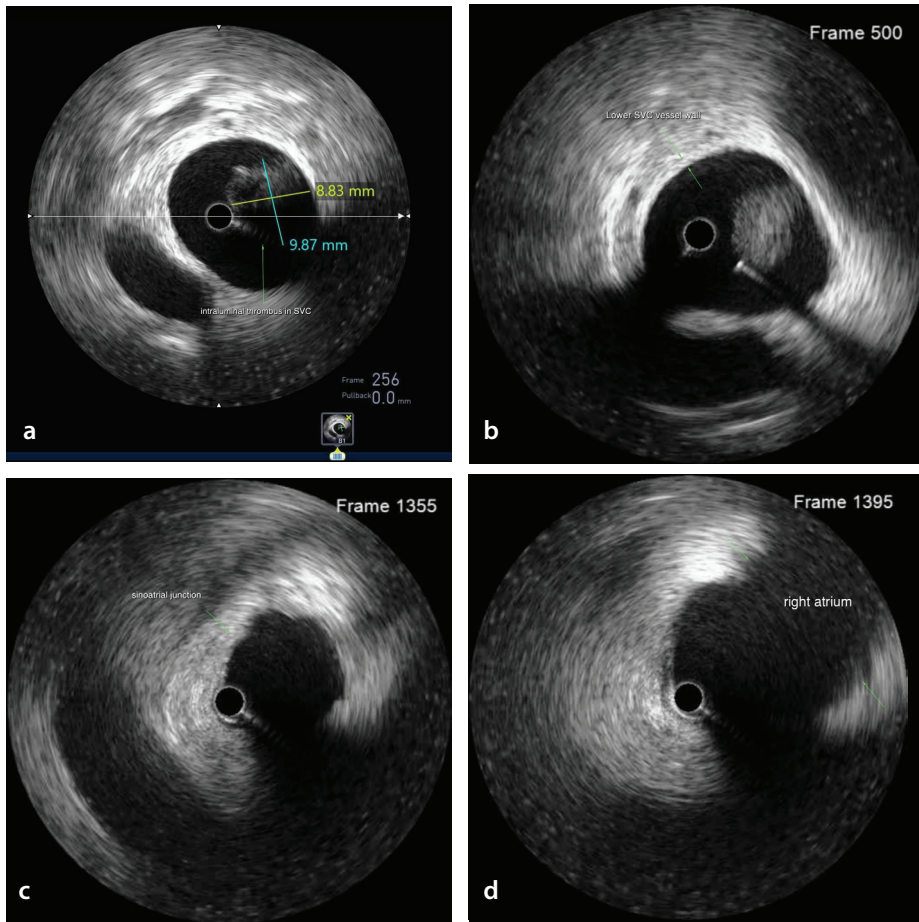
These findings suggest that when the stenosis is located very close to the SAJ—specifically 40 mm or below—there is an increased likelihood that IVUS will be necessary to accurately delineate the caudal landing zone. This is critical because precise stent deployment depends on correct landmark identification, particularly in cases where tumor invasion or anatomical distortion may obscure traditional fluoroscopic and CT visualization. IVUS provides high-resolution cross-sectional imaging, allowing for better assessment of the vessel lumen, wall invasion, and the position of the SAJ relative to the stenosis, thereby reducing the risk of malposition or inadequate coverage (Figures 4 and 5).



**Figure 2.** (a) Coronal contrast CT of a patient with squamous cell carcinoma of the lung causing SVCO. The intraluminal component of the cancer extends to encroach upon the SAJ. (b) Measurement of the SAJ is taken from the midpoint of the SVCO to the SAJ. CT, computed tomography; SVCO, superior vena cava obstruction; SAJ, sinoatrial junction.



**Figure 3.** (a) Initial venogram delineating SVC wall infiltration and luminal narrowing. The suboptimal opacification of the lower SVC made accurate delineation and measurement of the SAJ difficult. (b) SAJ measurement on DSA. SVC, superior vena cava; SAJ, sinoatrial junction; DSA, digital subtraction angiography.



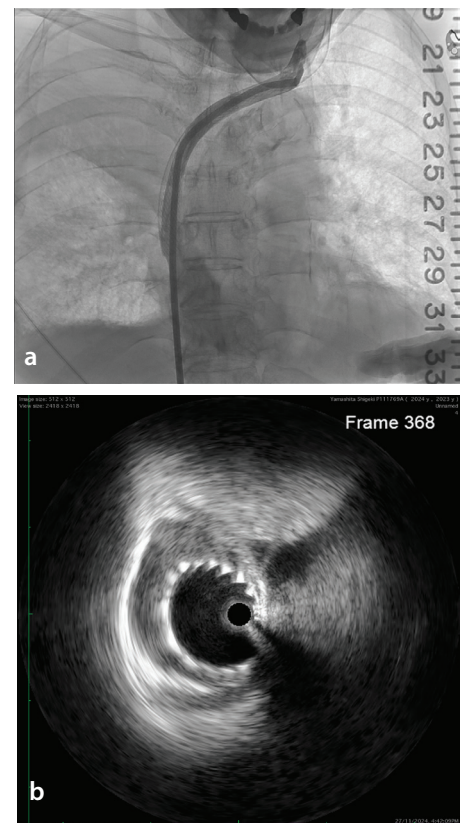
**Figure 4.** IVUS delineation of the (a) intraluminal tumor thrombus and (b) uniform echogenic wall with round luminal appearance of the lower SVC. (c) The sinoatrial junction is depicted by a sudden increase in lumen size, loss of uniform SVC wall echogenicity circumferentially, and thin, highly pulsatile atrial wall behavior. (d) Once the IVUS catheter traverses past the sinoatrial junction, the right atrium is immediately visualized. IVUS, intravascular ultrasound; SVC, superior vena cava.

The clinical implications of these results are significant. Incorporating a stenosis-to-SAJ distance threshold into pre-procedural planning can streamline decision-making, reserving IVUS for cases where anatomical predictors indicate a higher likelihood of benefit. This targeted approach could enhance procedural success rates, minimize contrast and radiation exposure, and potentially reduce procedure times and complications.

Limitations of this study include the relatively small sample size and its retrospective nature, which may limit the generalizability of the findings. Future prospective studies with larger cohorts are warranted to validate these cut-off values and further refine guidelines for IVUS use in malignant SVC.

Another key source of bias is that the same two operators determined the need for IVUS, performed the procedures, and generated the intra-procedural measurements.

This introduces incorporation and observer-expectancy bias. The decision to use IVUS and its subsequent findings are not independent, as knowledge of CT/DSA findings and procedural plans could consciously or unconsciously influence IVUS utilization and measurements. It also creates selection bias toward more complex or uncertain cases, potentially exaggerating the perceived benefit of IVUS, and limits generalizability to centers with different venography/CT protocols or operator thresholds. The absence of blinding and objective, pre-specified criteria for uncertainty (e.g., non-diagnostic venogram, ambiguous distal margin, motion/overlap, or heavy collaterals) further amplifies subjectivity, whereas learning-curve effects may affect both the propensity to deploy IVUS and measurement precision. To mitigate these issues, we acknowledge these limitations explicitly. For future studies, we propose objective triggers for IVUS deployment, recommend blinded core-lab measurement of SAJ dis-



**Figure 5.** (a) Venogram post-stent insertion aided by IVUS, showing satisfactory stent position and apposition. (b) IVUS image showing good stent expansion pushing against the intraluminal thrombus. IVUS, intravascular ultrasound.

tances where feasible, and suggest reporting interobserver agreement.

The authors acknowledge that IVUS may not be readily available in all interventional radiology centers; the cut-off value determined in this study may serve as a guide with which to consider IVUS when possible. For centers without routine IVUS, the practical takeaway is to treat a short stenosis-to-SAJ distance (e.g.,  $\leq 40$  mm) as a red flag for high placement risk near the right atrium. When IVUS is unavailable, clinicians should optimize pre-procedural CT (venous phase timing, thin slices, and electrocardiogram-gating in borderline cases), standardize DSA views and magnification, and adopt conservative landing margins to avoid atrial extension. If available, adjuncts such as cone-beam CT and intracardiac or transesophageal echocardiography can help refine the caudal landing zone.

In conclusion, our findings demonstrate that a stenosis-to-SAJ distance of  $\leq 40$  mm is a strong predictor for the need for IVUS guidance in SVC stenting procedures. Incorporating this measurement into clinical practice can aid in pre-procedural planning, improve stent placement precision, and ultimately enhance patient outcomes in the management of malignant SVCO.

#### Footnotes

#### Conflict of interest disclosure

The authors declared no conflicts of interest.

**Supplementary Figures 1-2:** <https://d2v96fx-pocvxx.cloudfront.net/688d2d00-d207-464d-89b6-73f393f4f50c/content-images/64ee6092-8877-45d0-b12f-2a87929c77ee.pdf>

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