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Diagn Interv Radiol 2023; DOI: 10.5152/dir.2022.21010

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Prediction of common hepatic artery catheter insertion based on celiac trunk morphology

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Received 18 January 2021; revision requested 1 February 2021; last revision received 26 October 2021; accepted 3 November 2021.

Epub: 05.12.2022

Publication date: 31.01.2023

DOI: 10.5152/dir.2022.21010

PURPOSE

This study aimed to predict the ability to insert a 4–5 French (Fr) catheter insertion with a guidewire into the common hepatic artery (CHA) based on celiac trunk morphology.

METHODS

This retrospective study included 64 patients who underwent balloon-occluded transcatheter arterial chemoembolization (n = 56), transcatheter arterial chemotherapy (n = 2), or were fitted with an implantable port system (n = 6) between June 2019 and December 2019 in our institution. The morphology of the celiac trunk was classified into three types (upward, horizontal, and downward) based on celiac angiography. The aortic–celiac trunk angle was measured on sagittal images of preprocedural contrast-enhanced computed tomography (CT). We reviewed whether a 4–5-Fr shepherd's hook catheter could advance beyond the CHA using a 0.035-inch guidewire (Radifocus® Guidewire M; Terumo). Three patients were diagnosed with median arcuate ligament syndrome (MALS) based on the characteristic hook shape of the celiac artery on sagittal images of contrast-enhanced CT. The predictive ability of celiac angiography and preprocedural CT for CHA insertion success was evaluated. In unsuccessful cases, the balloon anchor technique (BAT) was attempted as follows: (1) a 2.7/2.8-Fr microballoon catheter (Attendant Delta; Terumo) was placed beyond the proper hepatic artery, and (2) the balloon was inflated as an anchor for parent catheter advancement.

RESULTS

Upward, horizontal, and downward celiac trunk types were noted in 42, 9, and 13 patients, respectively. The median CT angle was 122.83° (first quartile–third quartile, 102.88°–136.55°). Insertion in the CHA using the guidewire was successful in 56 of 64 patients (87.50%), and the success rate in the downward type was significantly lower than that in the upward type [42/42 (100%) vs. 7/13 (53.85%), $P < 0.001$]. The CT angle was significantly larger downward in the unsuccessful group than in the successful group (121.03° vs. 140.70°, $P = 0.043$). Celiac angiography had a significantly higher area under the curve (AUC) than preprocedural CT (AUC = 0.91 vs. AUC = 0.72, $P = 0.040$). All three cases of MALS showed unsuccessful CHA insertion. In all eight patients with unsuccessful insertion, the catheter could be advanced using the BAT [8/8 (100%)].

CONCLUSION

Celiac angiography and preprocedural CT could predict CHA catheter insertion using a guidewire, and celiac angiography had high predictability. CT could detect MALS, a risk factor for unsuccessful CHA insertion.

KEYWORDS

Balloon anchor technique, balloon-occluded transcatheter arterial chemoembolization, celiac trunk morphology, common hepatic artery insertion, the aortic-celiac trunk angle

You may cite this article as: Saiga A, Yokota H, Akutsu A, et al. Prediction of common hepatic artery catheter insertion based on celiac trunk morphology. *Diagn Interv Radiol.* 2023;29(1):161-166.

A stable backup of the parent catheter is required when performing ultraselective transcatheter arterial chemoembolization (TACE) for hepatocellular carcinoma (HCC). However, common hepatic artery (CHA) insertion using a 0.035-inch guidewire is difficult or impossible in some cases because of the vessel's tortuous anatomy and severe stenosis of the celiac artery due to arteriosclerosis and median arcuate ligament syndrome (MALS). There are no studies on predictors of the success rate of CHA insertion.

We focused on the association between the success rate of CHA insertion and celiac trunk morphology. The morphology of the celiac trunk can be assessed by celiac angiography and computed tomography (CT). The former is similar to the technique used when performing CHA insertion, while the latter is useful in preprocedural planning and MALS assessment.

A few stabilized catheterization techniques, such as the balloon anchor technique (BAT),[1] the wire anchoring technique,[2] and the AMPLATZE™ Vascular Plug anchoring technique,[3] have been described previously. Among these techniques, Shibuya et al.[1] reported that the BAT is most effective in cases wherein CHA insertion using a guidewire is difficult during TACE. A microballoon catheter is placed beyond the proper hepatic artery, and the balloon is inflated as an anchor for parent catheter advancement. The parent catheter can be inserted along the fixed microballoon catheter.

This study aimed to evaluate the ability to predict the advancement of a 4–5 French (Fr) catheter to the CHA based on celiac trunk morphology. The morphological characteristics of the celiac artery were compared between successful and unsuccessful cases of CHA insertion with a guidewire.

Main points

- Common hepatic artery (CHA) insertion tends to be difficult in the downward type on celiac angiography.
- The predictive power of preprocedural computed tomography (CT) was inadequate compared with that of celiac angiography with respect to CHA insertion success.
- Median arcuate ligament syndrome was a risk factor for CHA insertion using a guidewire and was detectable on preprocedural CT.

Methods

This study was approved by the institutional review board of our hospital (ethics approval number: 3,972) and was not supported by any funding. Written informed consent was obtained from all patients.

Patients

This study retrospectively included 90 consecutive procedures in 90 patients who underwent contrast-enhanced CT and at least one of three treatments for HCC between June 2019 and December 2019: balloon-occluded TACE (B-TACE), transcatheter arterial chemotherapy, and an implantable port system. As described in a previous study from our institution,[4] the decision to treat patients with Barcelona Clinic Liver Cancer (BCLC) stage-B HCC[5] was based on the following steps. We initially considered whether the most common curative treatment, such as surgical resection and local ablation, could be performed. All remaining patients were considered for TACE, the first-line non-curative treatment for BCLC stage-B HCC. We routinely performed B-TACE to accumulate more dense iodized oil emulsion in HCC than conventional TACE. Because the pressure gradient between the occluded artery and the portal vein was decreased by balloon occlusion, the iodized oil emulsion was limited to the liver parenchyma, and accumulation in the HCC nodules was relatively increased.[6] Balloon occlusion enables the injection of iodized oil emulsion under higher pressure without a backflow of iodized oil.[7]

A total of 26 patients were excluded due to the following reasons: absence of branching of CHA from the celiac artery (n = 18), brachial artery approach (n = 5), coaxial implantable port system (n = 2), and celiac artery dissection (n = 1). A total of 64 consecutive patients (50 men and 14 women; median age, 73.00 years; first quartile–third quartile, 67.00–77.00 years) were included in the analyses.

Classification of celiac trunk morphology on angiography

Celiac trunk morphology was classified into three types (upward, horizontal, and downward) according to celiac angiography (Figure 1a-c) by a radiologist with 13 years' experience in interventional radiology. Celiac angiography was performed from an anteroposterior view at end expiration. The upward type was defined when the celiac artery had an upward course from the level of the catheter tip in the celiac trunk. The downward type was defined in the opposite way. The horizontal type was defined when the catheter tip and celiac trunk overlapped.

Measurement of the celiac arterial branching angle on CT

Five-phase (non-contrast, early arterial, late arterial, portal venous, and delayed phases) dynamic CT (Aquilion ONE ViSION or Aquilion PRIME; Canon Medical Systems) for liver assessment was performed at end inspiration with a dose of 2 mL/kg of iodinated contrast medium (iopaque, 300-mg iodine/mL; Fuji Pharma Co., Ltd. or iopromide, 300-mg iodine/mL; Fujifilm Toyama Chemical Co.). The contrast medium was injected at a rate of 2.5–3.5 mL/s via mechanical injection (Dual Shot GX7; Nemoto Kyorindo Co., Ltd.). The anterior side of the abdominal aorta was defined as the baseline, and we measured the celiac arterial branching angle from the cranial side to the baseline using reconstructed sagittal images of the early arterial phase on preprocedural contrast-enhanced CT (Figure 2). Two radiologists (with 13 and 6 years' experience in abdominal radiology) individually assessed the angle, and the average angles were calculated. Additionally, the radiologists diagnosed MALS by consensus from a characteristic hook shape of the celiac artery on sagittal images of contrast-enhanced CT.

CHA insertion strategy

Right or left femoral artery catheterization was performed under local anesthesia using the Seldinger technique. A 4–5-Fr shepherd's hook diagnostic catheter (4-Fr catheter in B-TACE and transcatheter arterial chemotherapy, and 5-Fr catheter in the implantable port system) was placed in the celiac trunk, and angiography was performed (three images/s, 25 mL, with 5 mL/s). Initially, we advanced the parent catheter beyond the CHA using a 0.035-inch. guidewire (Radifocus® Guidewire M; Terumo; 150 cm) to achieve high-quality images of CT during hepatic arteriography and stable backup by the parent catheter in selective B-TACE.

In unsuccessful cases of CHA insertion, the coaxial system was inserted through the parent catheter using a 2.7-Fr microballoon catheter (130 cm) (Attendant Delta; Terumo), and the BAT was attempted as follows (Figure 3a-c, and Video 1): 1) The microballoon catheter was placed beyond the proper hepatic artery with a 0.016-in. micro guidewire (ASAHI Meister; Asahi Intecc), 2) the balloon was

Figure 1. Celiac angiography was classified into three types: **(a)** upward, **(b)** horizontal, and **(c)** downward.

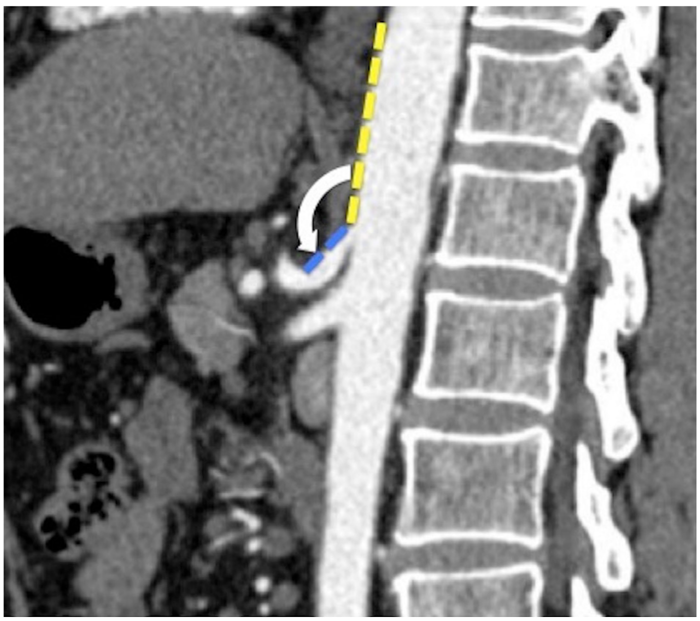

Figure 2. An aortic–celiac trunk angle (curved arrow) between the anterior side of the abdominal aorta (dotted yellow line) and the anterior side of the celiac trunk (dotted blue line) was measured on sagittal contrast-enhanced computed tomography.

inflated as an anchor at a non-tumor feeding artery, and 3) the parent catheter was advanced while pulling the balloon catheter in the negative direction.

Statistical analysis

Continuous variables are presented as median and first quantile–third quantile range and were compared using the Mann–Whitney U test. Categorial variables are shown as frequencies and percentages and were compared using Fisher's exact test. The success rate of CHA insertion using a guidewire during angiography was compared among the three celiac trunk morphology groups using Fisher's exact test. When further comparisons were performed to find which pairs in the three groups had significant differences, the *P* value was adjusted to triple according to the Bonferroni method. Fisher's exact test was also used to compare the success rate of CHA insertion between 4-Fr and 5-Fr catheters using a guidewire. The celiac arterial branching angles on CT between the groups with successful and unsuccessful CHA insertion with a guidewire were compared using the Mann–Whitney U test. Spearman's rank correlation coefficient was calculated between the classification of the angiography morphology and CT angles. The intraclass correlation coefficient (ICC) for CT angle measurements was calculated to evaluate the intra-rater reliability of the two radiologists. Receiver operating characteristic (ROC) curves were created for the predictability of CHA insertion with a guidewire, and the area under the curve (AUC) values were computed using the angiography morphology and CT angles. The numbers corresponding to the types of angiography morphology (0= upward, 1= horizontal, and 2= downward type) and CT angles were input to the ROC analysis. The difference between the two ROC curves was evaluated using DeLong's test. A two-sided value of $P < 0.050$ was considered significant. All statistical analyses were performed using R software v. 3.5.1 (R Foundation for Statistical Computing; Vienna, Austria). The ICC was calculated using the psych package (https://cran.r-project.org/web/packages/psych/), and a ROC analysis was performed using the pROC package (https://cran.r-project.org/web/packages/pROC/). The R Base Package was used for all other analyses.

Results

The technical success rate of CHA insertion using a guidewire was 56/64 (87.50%). No technique-related complications were observed. A balloon derived from the defective product did not deflate in one case. We retrieved the catheter after the intended rupture of the balloon.

The relationship between the morphology type of angiography and CT angles is presented in Table 1. There was a significant correlation between the morphology of the celiac trunk on angiography and the branching angle of the celiac trunk on CT ($r_s = 0.40$, $P = 0.001$) (Figure 4). The ICC for CT angle measurement by the two radiologists was 0.94 (95% confidence interval: 0.91–0.96; $P < 0.001$). The morphological assessment of the celiac angiography showed that the success rates of CHA insertion using a guidewire were 42/42 (100%), 7/9 (77.78%), and 7/13 (53.85%) in the upward, horizontal, and downward types, respectively. A significant difference was observed among the three groups ($P < 0.001$). The success rate in the downward type was significantly lower than that in the upward type [7/13 (53.85%) vs. 42/42 (100%), $P < 0.001$]. However, no significant difference was noted in the success rates between the upward vs. horizontal and the horizontal vs. downward types [42/42 (100%) vs. 7/9 (77.78%), $P = 0.085$; 7/9 (77.78%) vs.

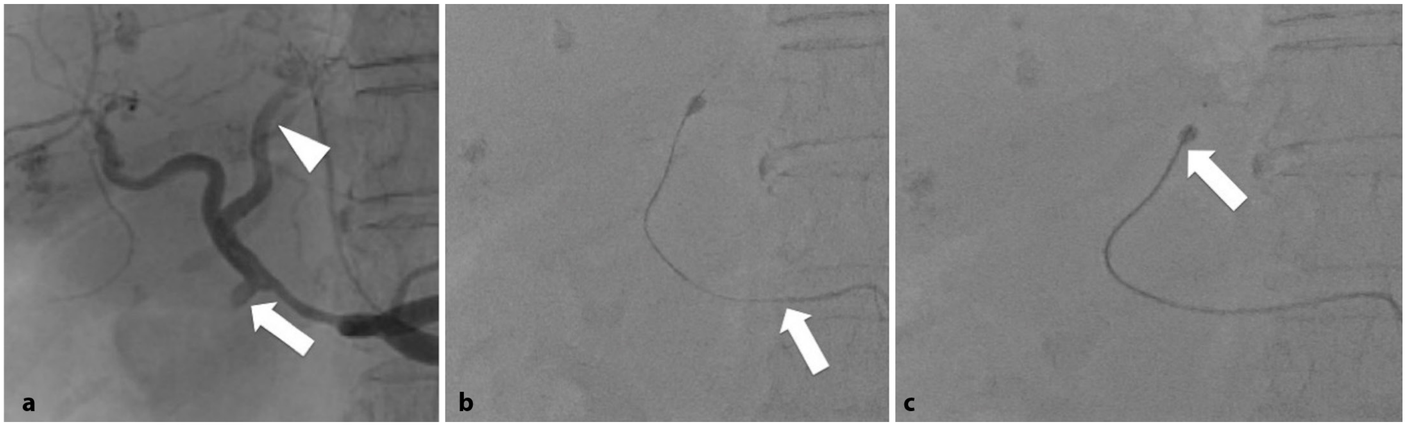

Figure 3. The balloon anchor technique was used in a 70-year-old woman with median arcuate ligament syndrome. **(a)** Although the common hepatic artery was visualized anterogradely, the gastroduodenal artery (arrow) showed stagnant flow due to the flow from the superior mesenteric artery. **(b)** The balloon was inflated as an anchor in the left hepatic artery [cf. arrowhead on **(a)**]. The arrow indicates the tip of the parent catheter. **(c)** The parent catheter was advanced into the left hepatic artery along the fixed microballoon catheter. The arrow indicates the tip of the parent catheter.

Table 1. Imaging characteristics of the celiac trunk

	Upward	Horizontal	Downward
Morphology type on celiac angiography	42 (65.63%)	9 (14.06%)	13 (20.31%)
CT angles for each morphology type on angiography*	Median 117.6° (95.5–113.5)	Median 124.3° (104.8–136.7)	Median 138.2° (134.7–146.0)

*, median (first quantile–third quantile); CT, computed tomography.

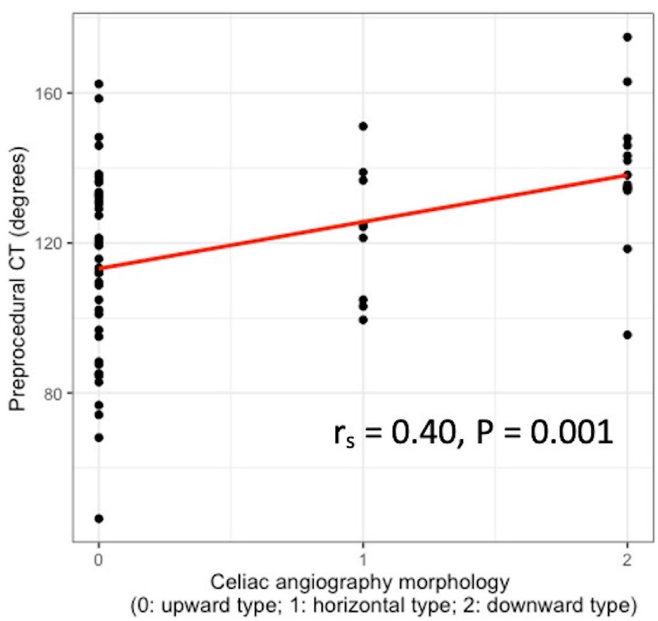

Figure 4. The correlation between celiac angiography morphology and preprocedural computed tomography. The r_s is 0.40 (P = 0.001). Celiac angiography morphology is classified into three types: upward, horizontal, and downward. Zero, 1, and 2 on the X-axis indicate the upward, horizontal, and downward types, respectively. CT, computed tomography.

7/13 (53.85%), P = 1.000].

Additionally, the success rate of CHA insertion using a guidewire was not significantly different between the 4-Fr (50/58) and 5-Fr (6/6) catheters (86.21% vs. 100%; P = 1.000). The CT angle was significantly larger downward in the unsuccessful group than in the successful group for CHA insertion using a guidewire [median 140.70° (122.84–146.49) vs. median 121.03° (100.66–134.91), P = 0.043].

On celiac angiography, six and two cases of the downward and horizontal types, respectively, were included in the unsuccessful group. All three MALS cases were also included in the unsuccessful group. The cases of MALS were classified into one horizontal and two downward types on the angiography morphology. The ROC curves are shown in Figure 5. Celiac angiography showed a significantly higher AUC than preprocedural CT (AUC = 0.91 vs. AUC = 0.72, P = 0.040). The sensitivity and specificity of angiography were 1.00 and 0.75, respectively, at the cutoff point between the downward–horizontal types and the upward type.

In all eight patients with unsuccessful insertion, the catheter could be advanced using the BAT without balloon inflation-related complications.

Discussion

This study demonstrated that the success rate of CHA insertion using a guidewire in the downward type was significantly lower than that in the upward type on angiography. The morphology of CHA on angiography was a good predictor of CHA insertion. The celiac arterial branching angle on preprocedural CT also predicted CHA insertion success with a guidewire, although its predictive power was lower than that of celiac angiography. MALS was a risk factor in CHA insertion using a guidewire, and it was detectable on preprocedural CT. In patients unsuccessfully inserted with CHA using a guidewire, the BAT may have played a complementary role. However, its effectiveness requires further investigation in the future.

The morphology of the celiac artery was evaluated using angiography and CT. Tokue et al.[8] reported that the branching angle of the celiac trunk on CT was 135° ±

23° (range, 51°–174°), and 1,027 of 1,104 (93.03%) cases had an angle between 91° and 180°. In our study, the branching angle was 123° ± 25° (range, 47°–175°), and 54 of 64 (84.38%) cases had an angle of between 91° and 180°. The result of our study was consistent with the results of Tokue at al.'s[8] study. We also demonstrated the discrepancy in celiac trunk morphology between celiac angiography and CT. We speculated the two major causes of this discrepancy were the difference in measurement points (from the tip of the catheter on celiac angiography vs. from the orifice of the celiac trunk on CT) and the difference in breathing (celiac angiography at the expiration phase vs. preprocedural CT at the inspiration phase). Suh et al.[9] reported branch angles of the celiac artery at the inspiration and expiration phases in contrast-enhanced magnetic resonance angiography. The angles were 126.4° ± 17.8° (mean ± standard deviation) and 125.0° ± 19.9° at the inspiration and expiration phases, respectively. They concluded that the celiac artery showed lower branch angle changes. The discrepancy between celiac angiography and CT may have been affected by the difference in measurement point rather than breathing. The CT angle was significantly larger downward in the unsuccessful group than in the successful group.

In all cases where CHA insertion by a guidewire was unsuccessful, the BAT was successful. The BAT might have played a complementary role in CHA insertion, although further study with a larger number of participants is needed to evaluate complication rates and clinical significance. Shibuya et al.[1] applied BAT to TACE for hepatic tumors. They used a 1.8-Fr microballoon catheter (Logos; Piolax) and applied this technique in three cases of unsuccessful CHA insertion with a guidewire. They demonstrated that the vessel's tortuous anatomy and severe stenosis of the celiac trunk due to arteriosclerosis and MALS caused unsuccessful insertion. In our experience, CHA insertion was possible in the case of the vessel's tortuous anatomy beyond the proper hepatic artery because a guidewire could be advanced to the gastroduodenal artery and a parent catheter could be followed into the CHA. In contrast, in the case of celiac artery stenosis due to the downward type and MALS, CHA insertion was difficult due to insufficient backup of the parent catheter at the celiac artery.

The balloon size in Shibuya et al.'s[1] study and our research was similar (3–5 mm vs. 4 mm, respectively). However, the tip of the microballoon catheter (1.8-Fr vs. 2.7-Fr) and the size and shape of the parent catheter (5-Fr vs. 4- or 5-Fr; cobra and modified spiral shaped vs. shepherd's hook shaped) were different. Although it is unclear which combination of the microballoon catheter and parent catheter was suitable for the BAT, our choice (a smaller parent catheter and a larger microballoon catheter) may be effective for the technique due to the smaller gap between the two catheters.

The BAT has been reported previously in other fields. Sharashidze et al.[10] reported it for thrombectomy in large-vessel occlusion acute ischemic strokes. Moreover, Kawaguchi et al.[11] used this technique on endoscopic retrograde cholangiopancreatography with a large balloon catheter. In the field of abdominal surgery, we reported the BAT as a "balloon anchoring and squeezing technique" (Saiga et al.[12], p. 403) in a case of renal artery aneurysm exclusion using a stent graft. This technique is extremely effective in preventing the risk of vessel injury and facilitating distal advancement of the guiding sheath.[12]

Miyayama et al.[13] reported that ultraselective TACE was effective in controlling local recurrence, especially when accumulating dense iodized oil emulsion in HCC with a greater grade of portal vein visualization. As we routinely tried to advance the microballoon catheter as much as possible to the distal portion of the feeding artery (e.g., the distal subsegmental and distal sub-subsegmental tumor feeding branches), we performed CHA insertion in all patients. Thus, CHA insertion in B-TACE may partially help improve the treatment effect. However, further studies should be conducted in the future.

This study has some limitations: it was retrospective in nature, and the sample size was small. Thus, technique-related complications, such as vascular injuries associated with balloon overinflation, were not fully evaluated. Although no severe complication was observed in this study, the risk should be considered. Moreover, we used only the shepherd's hook catheter as a parent catheter. In clinical practice, the shape of the parent catheter is commonly selected according to the morphology of the celiac trunk. For example, the Rosch hepatic catheter is commonly available on celiac angiography, especially the downward type.

In conclusion, this study demonstrated that CHA insertion tended to be difficult in the downward type on celiac angiography. With regard to CHA insertion success, the predictive power of preprocedural CT was inadequate compared with that of celiac angiography. However, CT could detect MALS, a risk factor for difficult CHA insertion using a guidewire.

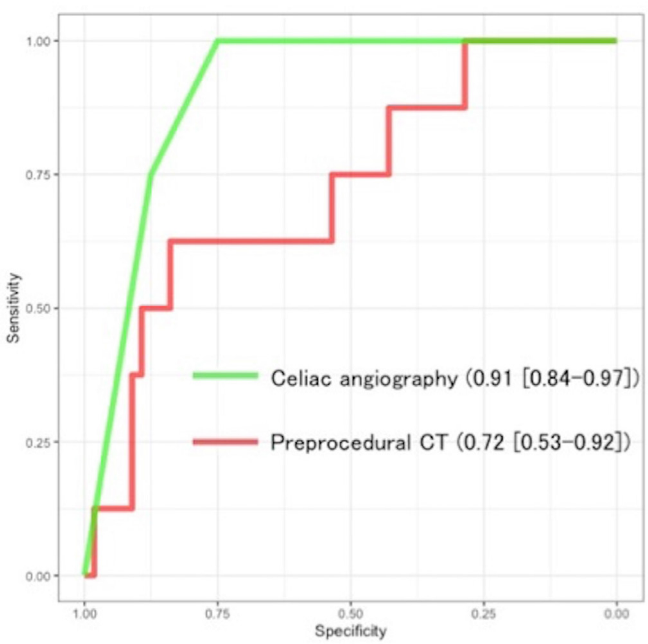

Figure 5. Receiver operating characteristic curve of common hepatic artery insertion. The area under the curve of celiac angiography morphology (green line) surpassed that of the preprocedural computed tomography angle (red line) (0.91 vs. 0.72, $P = 0.040$). CT, computed tomography.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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Video 1 link: https://youtube.com/shorts/KlHqx5ou_ag

Video 1. The balloon anchor technique was used in a 70-year-old woman with median arcuate ligament syndrome. A 2.7-Fr microballoon catheter (130 cm) (Attendant Delta; Terumo) was inflated as an anchor in the left hepatic artery. Subsequently, a 4-Fr shepherd's hook diagnostic catheter was advanced into the left hepatic artery along the fixed microballoon catheter while the balloon catheter was pulled in the negative direction. FR, French.