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TECHNICAL NOTE

Techniques in adrenal vein sampling: Multipurpose catheter shape facilitates sampling of cranially oriented right adrenal veins

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ABSTRACT

Adrenal vein sampling (AVS) failure is often attributed to difficulty in sampling the right adrenal vein (RAV). Normally, the RAV is caudally oriented; however, cranial orientation of the RAV is not uncommon. In such cases, use of a multipurpose catheter may facilitate sampling. Between 2014 and 2019, 351 patients underwent AVS and RAV sampling, with a multipurpose catheter used in 23 patients (7%, 10 male, 13 female patients). Data regarding pre-AVS imaging, procedural details, and AVS results were collected, the RAV vertical angle was measured on venography using the inferior vena cava (IVC) right lateral wall as the craniocaudal axis (0° defined as caudal, 180° cranial), and correlation between the number of catheters used until successful sampling with the multipurpose catheter and various procedural measures was assessed. Twenty-four technically successful AVS procedures were performed in 23 patients, all of whom had cranially oriented RAVs on intra-procedural venography. A multipurpose catheter was the first choice in 2 patients with previously known cranially oriented RAVs. In the remaining patients, the multipurpose catheter was the second choice in 21% (n = 5), third choice in 50% (n = 12), and up to the eighth choice (n = 1). Early utilization of the multipurpose catheter correlated with lower fluoroscopic time (r = .71, *P* = .0001) and lower contrast volume (r = .77, *P* < .0001). These results support the use of the multipurpose catheter when sampling cranially oriented RAVs. Multipurpose catheters should be readily considered when cranially oriented RAVs are present and when caudally oriented catheters fail to identify the RAV.

Adrenal vein sampling (AVS) is associated with high failure rates, often attributed to difficulty in sampling the right adrenal vein (RAV) due to its short course and variable anatomic relationship to the inferior vena cava (IVC).[1-3] Normally, the RAV is caudally oriented (Figure 1), with typical first-line catheters including the renal double-curve (RDC), Cobra, and reverse-curve catheters, all of which have caudally oriented tips.[2-6] However, cranially oriented RAVs have been reported in 11%-38% of patients and have been known to be particularly problematic.[2,4-7] In such cases, use of a multipurpose catheter––which has a cranially oriented tip––when performing AVS via femoral venous access (Figure 1) may facilitate sampling. This report describes successful multipurpose catheter use for RAV sampling in 23 patients with cranially oriented RAVs.

Technique

Institutional review board approval was obtained, and this study was performed in full compliance with the Health Insurance Portability and Accountability Act. Of 351 patients who underwent AVS at the study institution between June 2014 and October 2019, 23 patients (7%) (mean age, 57.8±11.6 years; 10 male, 13 female patients) in whom a multipurpose catheter was used to successfully sample the RAV were identified through a review of procedural notes, dictated reports, an electronic inventory system (Qsight, Owens and Minor), and procedural images. The number of catheters used prior to the multipurpose catheter was determined similarly. Data regarding patient characteristics, pre-AVS imaging, procedural details, and AVS results were obtained from the electronic medical record. If repeat AVS was performed, the reason for repetition was identified.

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AVS was performed after cosyntropin stimulation by a single operator with more than 25 years' experience in AVS, as has been previously described.[1] Dedicated pre-AVS cross-sectional imaging was not performed. RAV sampling was initially attempted using standardized catheters, consisting of an RDC catheter (Cook Medical) variably followed by a Cobra (Imager, Boston Scientific), Mikaelsson (Cook), HS2 (Cook), and/or additional catheters, until a multipurpose catheter (Cook) was employed. All catheters had a single 0.024- to 0.025-inch hole punched on their cephalad aspect approximately 1-2 mm from the tip (0.025-inch Hole Punch, Cook [now discontinued] or 0.032 × 0.024 × 1.5 inch Standard Hole Punch, Syneo). Samples were obtained first from the RAV, followed by the left adrenal vein and infrarenal IVC. Samples with selectivity index (SI = adrenal cortisol/IVC cortisol) >3 (>5 preferred) were considered diagnostic and a lateralization index (LI = higher aldosterone-to-cortisol ratio/lower aldosterone-to-cortisol ratio) >4 was considered an indication for adrenalectomy.[8] Technical success was defined as obtaining diagnostic samples bilaterally.

The RAV vertical angle was measured on venographic images using the IVC right lateral wall as the craniocaudal axis (0° defined as caudal, 180° as cranial). RAV angles were grouped as caudally oriented (0°-90°) or cranially oriented (>90°-180°) due to potential inaccuracies in exact measurement related to fluoroscopic technique and C-arm orientation.

Main points

- Sampling of the right adrenal vein (RAV) during adrenal vein sampling is often difficult due to the vein's short course and variable anatomic orientation.
- Typical first-choice catheters for RAV sampling are caudally oriented; however, the RAV may be cranially oriented in up to 40% of patients.
- The multipurpose catheter has a cranially oriented tip configuration, facilitating sampling of cranially oriented RAVs.
- Multipurpose catheters should be considered when typical catheters fail to identify the RAV or when cranially oriented RAVs are identified but cannot be sampled with typical catheters.

Statistical analysis

Continuous variables are presented as mean ± standard deviation or median with range depending on whether a normal distribution was present. Correlation of the number of catheters used to sample the RAV (inclusive of the multipurpose catheter), fluoroscopy time, and contrast volume were determined using Pearson correlation coefficient. Statistical analyses were performed using Excel 2018 (Microsoft).

Results

Twenty-four technically successful AVS procedures using a multipurpose catheter for RAV sampling were performed in 23 patients, with SI >5 (mean SI, 25 ± 13; range, 9.8-54.9) obtained in all procedures.

Three repeat AVS procedures (13%) had prior AVS for comparison; one AVS was repeated on the request of the referring physician to confirm results (despite being technically successful using the multipurpose catheter), and 2 patients underwent prior AVS without a multipurpose catheter, both of whom had results consistent with bilateral adrenal suppression (BAS), prompting repeat AVS.[9,10] Fifteen patients (65%) had no pre-AVS cross-sectional imaging available, 7 (30%) had non-dedicated imaging, including combinations of unenhanced computed tomography (CT) (n = 5), contrast-enhanced CT (n = 2), and magnetic resonance imaging (n = 1). One patient with BAS on initial AVS underwent CT venogram to delineate RAV anatomy prior to repeat AVS (Figure 2).

All patients had cranially oriented RAVs (Figure 1). The median number of catheters used in RAV sampling attempts, including the multipurpose catheter, was 3 (range, 1-8). A multipurpose catheter was the first choice in 2 patients (8%), both of whom had prior AVS. In the remaining patients, the multipurpose catheter was the second choice in 21% (n = 5), third choice in 50% (n = 12), and at most the eighth choice (n = 1, 4%) (Figure 3). Median fluoroscopy time was 13 min (range, 3-39 min) and median contrast volume was 45 mL (range,

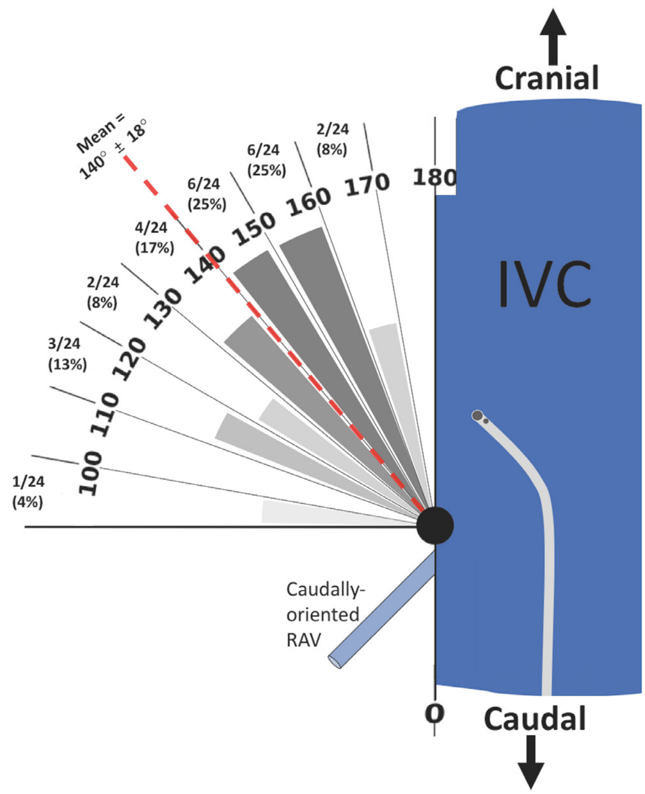

Figure 1. Distribution of craniocaudal orientation of the right adrenal vein in 24 procedures performed in 23 patients, with 0° defined as caudal and 180° defined as cranial. Frequency is reported in 10°-intervals ranging from 90° to 100° and 170° to 180°. The *red dotted line* represents the mean RAV vertical angle. A multipurpose catheter, with its cranially oriented tip, is displayed in the mid-IVC. Note the proximal sidehole added to facilitate sampling. A caudally oriented RAV is shown in the bottom left of the figure for comparison.

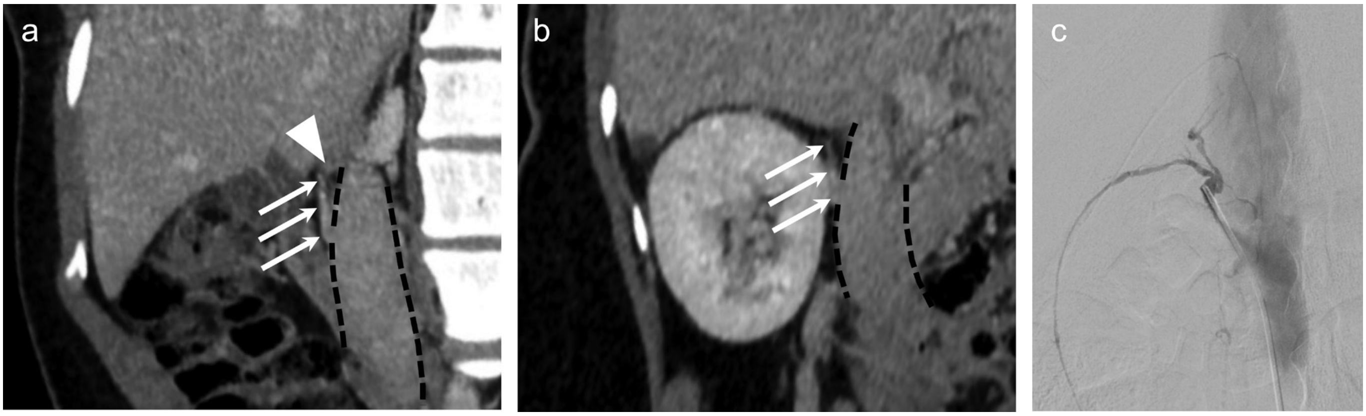

Figure 2. a-c. A 37-year-old female with hyperaldosteronism and initial AVS with difficulty in sampling the RAV; AVS results reveal bilateral adrenal suppression. CT venogram was subsequently performed prior to repeat AVS, which revealed a cranially oriented RAV. AVS using a multipurpose catheter for RAV sampling was successful, with lateralization to the right adrenal gland, consistent with right-sided aldosterone-producing adenoma. Panel (**a**) shows CT venogram using multiplanar reformatted images revealing a cranially oriented RAV (*white arrows*) draining the right adrenal gland, which is partially visualized on this image (*white arrowhead*). The IVC is outlined by the *black dotted line*. Orthogonal view (**b**) redemonstrating the cranially oriented RAV (*white arrows*) and further delineating the venous anatomy. Panel (**c**) shows successful RAV sampling (SI = 37.4) using the multipurpose catheter, which readily cannulated the cranially oriented RAV (vertical angle = 154°). Note the prominent inferior emissary vein, a reliable indicator for the RAV.

10-250 mL). A higher number of catheters used for RAV sampling was positively correlated with increased fluoroscopic time (r = .66, *P* = .0008) and contrast volume (r = .77, *P* < .0001), excluding those in whom the multipurpose catheter was the first choice (n = 2).

Fourteen patients (61%) had LI >4 indicating aldosterone-producing adenoma (5 right-sided, 10 left-sided) and 8 patients (35%) had LI <4 indicating bilateral adrenal hyperplasia. One patient (4%) with BAS on initial AVS had similar results on repeat AVS using the multipurpose catheter and was lost to follow-up. No complications of AVS occurred.

Discussion

RAV sampling is often considered the "Achilles heel" of AVS.[1-3] Numerous studies have sought ways to improve RAV sampling success rates, including pre-procedural and intra-procedural contrast-enhanced cross-section imaging to help delineate RAV anatomy, regimented approaches to catheter choice, and others. Many of these studies have reported the prevalence of cranially oriented RAVs, although few have highlighted its potential influence on catheter choice, leaving those performing AVS with little guidance regarding catheter choice when a cranially oriented RAV is encountered.[2-6]

Studies evaluating pre-AVS contrast-enhanced multidetector CT (MDCT) to determine RAV anatomy have reported cranial orientation of the RAV in 11%-22% of the patients and prevalence as high as 38% in anatomic studies.[3,5-7] Others have evaluated the association of the RAV vertical angle with sampling success using different caudally oriented catheter

Figure 3. a-c. Three separate patients with hyperaldosteronism undergoing AVS. In panel (**a**), attempts at RAV sampling with an RDC catheter reveal a cranially oriented RAV (vertical angle = 158°), with subsequent successful sampling with the multipurpose catheter. In panel (**b**), attempts at sampling with a Simmons catheter reveal a cranially oriented RAV (vertical angle = 143°), with subsequent successful sampling with a multipurpose catheter. In panel (**c**), attempts at RAV sampling with a Mikaelson catheter reveal a cranially oriented RAV (vertical angle = 147°), with subsequent successful sampling with a multipurpose catheter.

shapes, with greater success in cranially oriented RAVs using catheters that can be manipulated into a more cranial orientation (despite having a natural caudal orientation).[4] These authors also reported that steam-reshaped shepherd's hook or Mikaelson catheter shapes (presumably reshaped to have a more cranially oriented tip) may be useful in patients with cranially oriented RAVs.

In the current study, a multipurpose catheter, which has a natural cranial orientation, successfully sampled cranially oriented RAVs in 23 patients. While this represents only 7% of those who underwent AVS in the study cohort, utilization of the multipurpose catheter increased later in the study period as the operator more readily recognized the ability of the multipurpose catheter to easily sample cranially oriented RAVs. Given the cranial orientation of the multipurpose catheter, this is not surprising, although this catheter has typically not been included in the discussion of catheter choice for AVS. Early consideration of the multipurpose catheter within the typical catheter regimen, as measured by the number of catheters used prior to the multipurpose catheter, correlated with lower fluoroscopic time and contrast volume. The findings of this study suggest that, if RAV sampling is unsuccessful with typical catheters and/or a cranially oriented RAV is recognized, early utilization of a multipurpose catheter may facilitate successful RAV sampling. Early utilization of a multipurpose catheter in cranially oriented RAVs may not only potentially increase AVS success but may decrease procedure times and contrast volume, and decrease cost (as less money is spent on additional improperly shaped catheters). Additionally, while the study institution does not typically perform pre-procedural imaging to delineate RAV anatomy, if a cranially oriented RAV is identified on such imaging, a multipurpose catheter may be immediately considered.

Study limitations include the inclusion of only patients in whom the multipurpose catheter was successfully used; those in whom the multipurpose catheter was tried unsuccessfully and those who had cranially oriented RAVs successfully sampled without use of the multipurpose catheter were unable to be identified. Prospective studies regarding RAV vertical angle and catheter use would be required to address these limitations. Measurements of RAV angles may be affected by fluoroscopic technique, C-arm orientiation, catheter manipulation, and respiration status, and the results should be interpreted with these limitations in mind. Additionally, a number of confounding factors likely affected the recorded fluoroscopic time and contrast volume, and results regarding correlation of the number of catheters and these factors should be interpreted in this context.

In conclusion, identification and subsequent catheterization of cranially oriented RAVs with a multipurpose catheter facilitates sampling. Multipurpose catheters should be readily considered when caudally oriented catheters fail to identify the RAV or when cranially oriented RAVs are identified but cannot be sampled with those catheters.

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Conflict of interest disclosure

The authors declared no conflicts of interest.

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