



The Diagnostic Accuracy of MRI and non-enhanced CT for High-risk Vertebral Artery Anatomy for the Safety in Anterior Cervical Spine Surgery

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Introduction

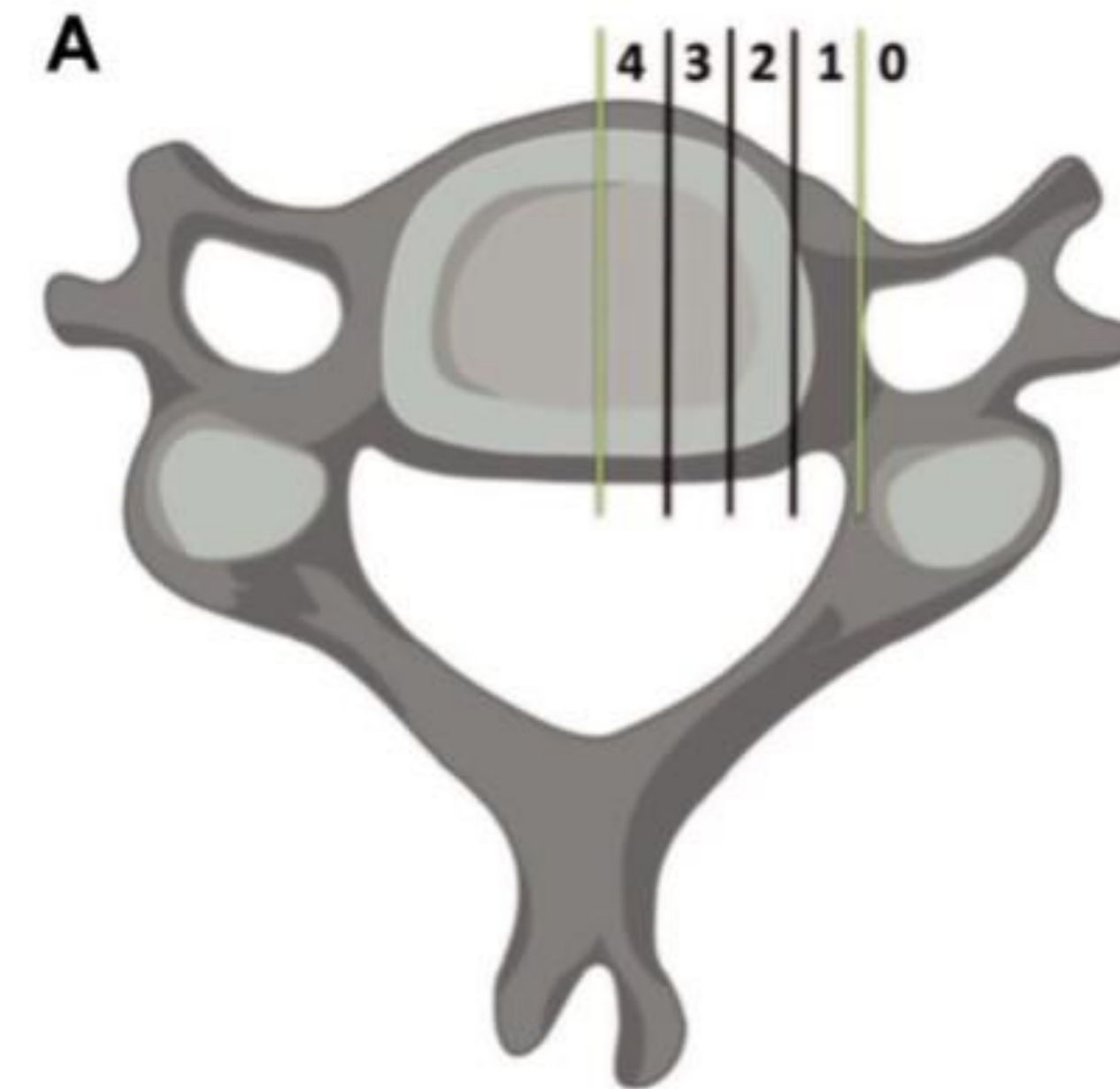
- Iatrogenic vertebral artery injury (VAI) is one of the most devastating complications in spine surgery.
- Reportedly, anomalous medial migration of the vessel can be a risk factor for VAI during anterior procedures.
- Computed tomography angiography (CTA) has been considered the gold-standard for the evaluation of various arterial anatomies, including the vertebral artery (VA).
- MRI and non-enhanced CT are more commonly utilized as routine preoperative imaging studies, but it is still unclear if these modalities can safely exclude the risk for intraoperative VAI due to the anomalous course of the VA.
- The aim of this cross-sectional observational study is to evaluate the diagnostic accuracy of MRI and non-enhanced CT for high risk VA anatomy in the subaxial cervical spine.

Methods

- The records of 248 patients who underwent CTA for any reason at a single academic institution between 2007 and 2018 were reviewed.
- Poor imaging quality or incomplete CTAs, cases with congenital anomalies in the subaxial cervical spine that made positional assessment difficult such as hemivertebra, were excluded. All CTAs were performed utilizing a 64-slice CT scanner (GE Healthcare, Chicago, IL, USA).
- We included MRI and non-enhanced CT taken within 1 year before or after CTA.
- An axial VA position classification was used to grade VA anomalies in the subaxial cervical spine.

VA Position Classification

- The classification consists of a number (0-4) that characterizes the location of the VA from the medio-lateral aspect of the vertebral body.
- “0” indicates no shift of the VA towards the midline of the vertebral body; “1” describes a midline shift of 0-25%; “2” 25-50%; “3” 50-75%; and “4” 75-100%, respectively.



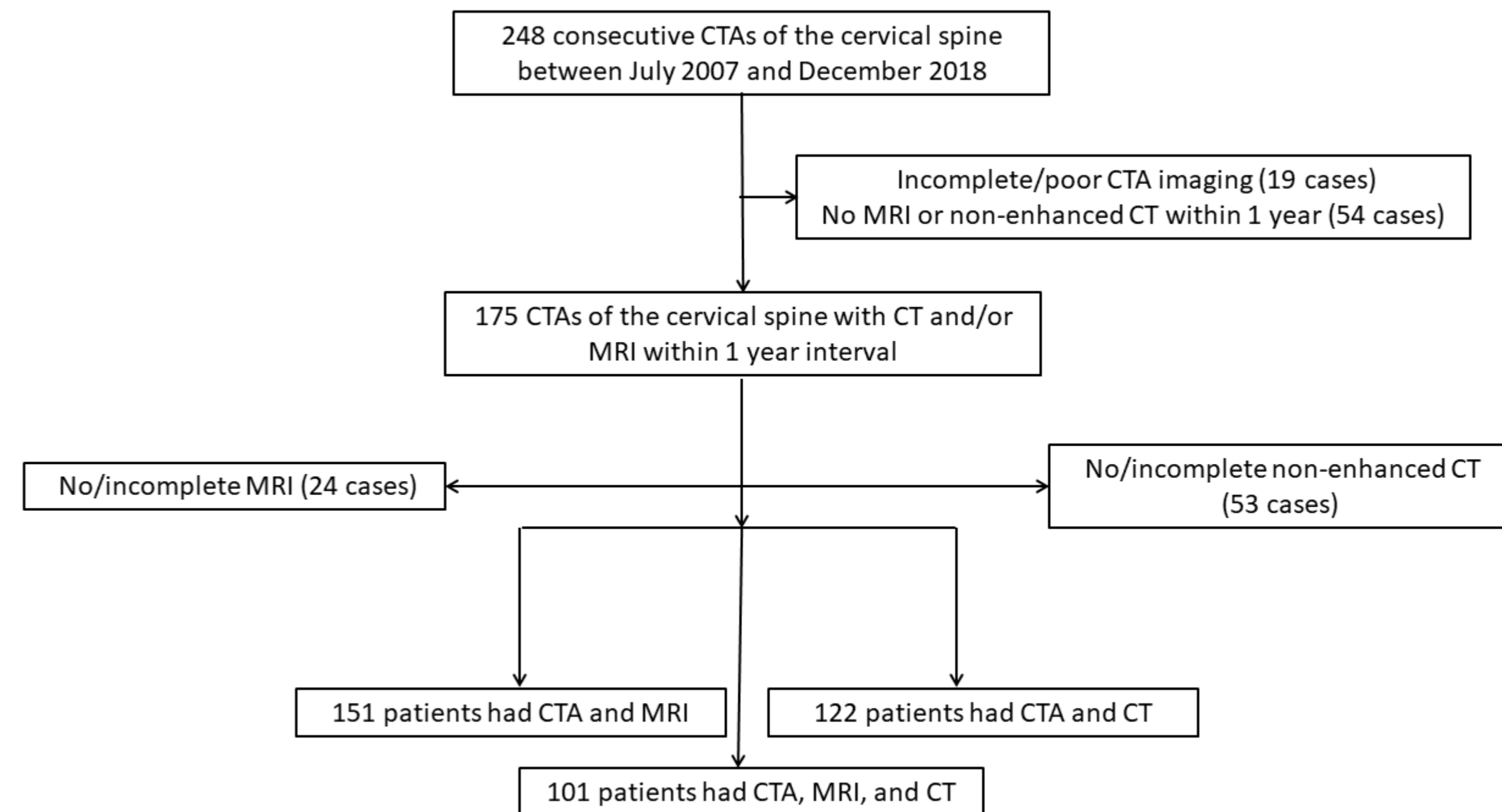
From Winter F, Okano I, Salzman SN, et al. “A Novel and Reproducible Classification of the Vertebral Artery in the Subaxial Cervical Spine.” Oper Neurosurg (Hagerstown). 2019. doi:10.1093/ons/onz310.

Methods (Cont.)

- We assessed all V2 (intraforaminal) segment VA anatomy in three slices (disc, pedicle, subpedicle levels) for each vertebral level between C2/3 disc to C7 subpedicle level.
- The sensitivity, specificity, and diagnostic likelihood ratios of MRI and non-enhanced CT for high risk VA position were calculated.

Results

- A total of 175 CTAs met the inclusion criteria.
- The mean (SD) age was 63.8 (14.9), 53.1% of the patients were female.
- Among them, 151 patients had MRI and 122 patients had non-enhanced CT. 101 patients had both MRI and non-enhanced CT.
- On CTA, the prevalence of an “at risk” VA position defined as grade 1 or over and “high risk” VA position defined as grade 2 was 4.3 and 0.4%, respectively. There were no slices showing grade 3 or 4.



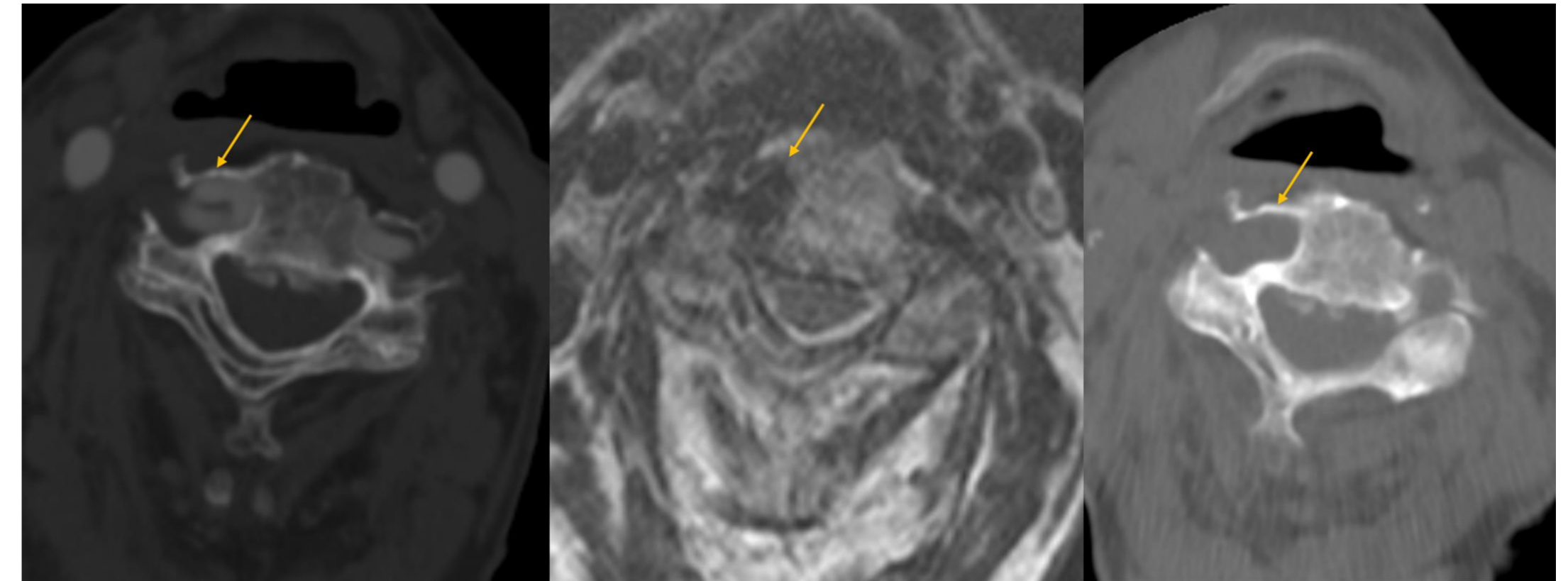
Results

- The C5/6 disc level showed the highest prevalence of “at risk” VA position (7.2%).
- The left sided VA showed significantly more medialized VA (5.7% vs 3.0%, $p < 0.001$).
- In multivariate analysis including demographic factors, **advanced age, disc and pedicle levels, lower cervical levels,** and **left side** were independent risk factors for medially migrated VA position on CTA.
- VA positions were not measurable in 4.2% of MRIs and 0.5% of CT slices ($p < 0.001$).

Variable		OR (95% CI)	p-value
Age		1.05 (1.01-1.08)	0.005
Sex	Female	1.88 (0.90-3.93)	0.096
Slice	Disc	2.24 (1.38-3.64)	0.001
	Pedicle	2.11 (1.29-3.46)	0.003
	Subpedicle	Ref.	
Level	C3	0.32 (0.18-0.60)	<0.001
	C4	1.03 (0.64-1.64)	0.907
	C5	Ref.	
	C6	0.85 (0.51-1.40)	0.516
	C7	1.45 (0.36-5.94)	0.603
Side	Left	Ref.	
	Right	0.46 (0.32-0.68)	<0.001
Prior cervical spine surgery		0.82 (0.39-1.68)	0.575

Results

- Among measurable slices, the sensitivities of MRI and non-enhanced CT for the detection of grade 1 or over VA position were only fair.
- The sensitivity of MRI was lower than that of non-enhanced CT (0.31 vs 0.37, $p < 0.001$).
- The specificities were similarly high in both modalities (0.97 vs 0.97).
- With the combination of MRI and non-enhanced CT, the sensitivity significantly increased to 0.50 ($p < 0.001$ vs MRI and vs CT alone) with a minimum decrease of specificity (0.95).



Examples of Grade 2 vertebral artery on CTA (Left), MRI (Middle), and non-enhanced CT (Right). Medially located VAs are indicated with arrows.

	Diagnosis of grade 1 or over		
	MRI	CT	MRI and CT
Number of observation	145	129	169
Number of observation on CTA	143	136	103
Apparent prevalence (%)	4.1	4.6	7.1
True prevalence (%)	4.0	4.8	4.4
Sensitivity (95% CI)	0.308 (0.233-0.390)	0.368 (0.287-0.455)	0.495 (0.396-0.595)
Specificity (95% CI)	0.971 (0.964-0.976)	0.971 (0.963-0.977)	0.948 (0.939-0.957)
Positive predictive value (95% CI)	0.303 (0.230-0.385)	0.388 (0.303-0.477)	0.306 (0.238-0.381)
Negative predictive value (95% CI)	0.971 (0.965-0.976)	0.968 (0.961-0.974)	0.976 (0.969-0.982)
Diagnostic accuracy (95% CI)	0.944 (0.936-0.951)	0.941 (0.932-0.950)	0.929 (0.918-0.939)
Positive likelihood ratio (95% CI)	10.56 (7.63-14.36)	12.49 (9.07-17.03)	9.61 (7.40 -12.48)
Negative likelihood ratio (95% CI)	0.71 (0.63-0.79)	0.65 (0.57-0.73)	0.53 (0.44-0.64)
Pairwise p-values	MRI vs CT	MRI vs MRI&CT	CT vs MRI&CT
Sensitivity	<0.001	<0.001	<0.001
Specificity	0.633	<0.001	<0.001

Discussion

- Our results showed that a medially migrated VA was observed in 4.3% of slices.
- There have been no studies that specifically investigated the diagnostic ability of MRI and non-enhanced CT for medialized VA.
- CT shows more accurate measurements of bony structures. In one small study, researchers compared the accuracies of lumbar pedicle length/width measurements on CT and MRI. (Omar Pacha et al. *Int J Spine Surg.* 2020;14(5):671-680)
- The high resolution of CT likely contributed to better diagnostic ability of CT than MRI for medialized VA in our study.

Discussion

- In our study, the results indicated that MRI and non-enhanced CT are useful to rule in medialized VAs, but the imaging modalities could not completely rule out them out even with negative findings.
- CTA is inevitably associated with higher cost, radiation exposure, and risk for contrast medium side effects. Furthermore, it is clear that medialized VAs do not always cause a devastating VAI if there is no issue in surgical technique, especially when considering the high prevalence of medialized VA and low incidence of VAI.
- The indication of CTA should be based on its risk to benefit ratio for the patient. Also, the present study only utilized axial images since other reconstruction images were not available in all cases.
- Further studies are required to answer the question of how other reconstruction images might improve the diagnostic ability of MRI and non-enhanced CT for medialized VA.

Limitations

- Cross-sectional observational study design
- Our study population included patients who underwent CTA for any reason at an academic orthopaedic institution. The prevalence of VA anomalies might be overestimated in our population due to confounding by indication compared to general anterior cervical surgery candidates.
- The manufacturers and machines utilized for our MRIs and non-enhanced CTs, which might affect the diagnostic ability of these modalities, were not standardized.
- Our patient population mainly consisted of Caucasians/white racial group. Anatomical characteristics might be different in other racial groups.
- This study focused on the intraforaminal VA position at the V2 segment and did not look at the extraforaminal VA position at the V1 segment.

Conclusions

- Axial images of MRI and non-enhanced CT demonstrated high specificities but only fair sensitivities to detect medialized VA in the subaxial spine.
- Non-enhanced CT demonstrated better diagnostic values than MRI. Combining both modalities, the sensitivity was improved, but a substantial proportion of medialized VA could not be diagnosed.
- Adding other imaging modalities, such as MRA, reconstruction images and/or thinner cut axial images on CT, might be beneficial, especially in cases with certain risk factors, such as advanced age, left side lesion, or multilevel surgeries.

The presenter has nothing to disclose.