Section: Miscellaneous

Original Research Article

ANATOMICAL VARIATION AROUND THE ATLAS TRANSVERSE PROCESS ON HEAD AND NECK CT

Raghu Jetti[1], Mayank Arya[2], Kishore Chandra Thakur[3]

[1]*Assistant Professor, Department of Basic Medical Sciences, College of Applied Medical Sciences, King Khalid University, Abha, Kingdom of Saudi Arabia*
[2]*Assistant Professor, Department of Anatomy, Graphic Era Institute of Medical Sciences, Dehradun, Uttarakhand, India*
[3]*Professor, Department of Anatomy, Graphic Era Institute of Medical Sciences, Dehradun, Uttarakhand, India*

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Corresponding Author:
Dr. Raghu Jetti,
Assistant Professor, Department of Basic Medical Sciences, College of Applied Medical Sciences, King Khalid University, Abha, Kingdom of Saudi Arabia.
Email: rjetti@kku.edu.sa

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ABSTRACT

Background: The transverse process of the atlas (C1) may help orient upper neck dissection, but its relationship with adjacent vessels and the styloid process varies. This study assessed those relationships on computed tomography (CT).

Materials and Methods: In this retrospective, cross-sectional study, head and neck CT examinations of 87 eligible patients from a North Indian tertiary care centre were reviewed. Image-based distances from the lateral tip of each C1 transverse process to the internal carotid artery, internal jugular vein, vertebral artery, occipital artery and styloid process were recorded where structures were adequately visible. Right–left measurements were compared as paired observations.

Results: Mean age was 49.5 ± 15.2 years, 49 patients (56.3%) were male, and 64 (73.6%) had contrast-enhanced CT. Bilateral measurements were available for 59 patients for the internal carotid artery, 52 for the internal jugular vein, 56 for the vertebral artery, 42 for the occipital artery and 87 for the styloid process. The median nearer-side jugular distance was 8.06 mm (interquartile range, 5.83–9.78); 6 of 52 patients (11.5%) had a distance below 5 mm. Small right–left differences were found for jugular distance (8.66 versus 8.25 mm; $p = 0.018$) and styloid distance (16.64 versus 15.87 mm; $p < 0.001$). No significant sex differences were found.

Conclusion: C1 is a useful CT reference for describing upper neck anatomy, but measured distances vary among patients. The findings support individual image review and do not establish fixed surgical safety margins.

Keywords: Atlas; C1 transverse process; surgical anatomy; internal jugular vein; upper neck.

INTRODUCTION

Surgery in the upper lateral neck requires dissection within a narrow space containing the internal carotid artery, internal jugular vein, vertebral artery and several cranial nerves. Injury to these structures can have serious consequences during neck dissection, parotid surgery and approaches to the jugular foramen. A reliable anatomical reference is therefore valuable when tissue planes are obscured by a tumour, scarring or previous surgery. The transverse process of the atlas (C1) is a prominent bony structure that can be identified in the upper neck and has long been used to guide high ligation of the internal jugular vein.[1]

Anatomical studies have described the C1 transverse process in relation to the internal jugular vein, internal carotid artery and spinal accessory nerve during conservative neck dissection.[2] Cadaveric work has also used it to orient dissection towards the styloid process, carotid canal and jugular foramen.[3] Its position relative to the facial nerve trunk has been examined as a potential aid in parotid surgery.[4] More recent skull base studies have incorporated C1 into surgical models for approaching the jugular foramen and, together with the asterion, for estimating the course of the sigmoid sinus and jugular vein.[5,6]

These relationships cannot be assumed to be identical in every patient. For example, CT angiography has demonstrated internal jugular vein compression

between the C1 transverse process and an elongated styloid process.[7] In a CT study of 50 individuals, the reported mean distance from C1 to the internal jugular vein was 9.06 mm, while the minimum observed distance was 1.49 mm.[8] These findings support measuring both the position and variation of adjacent structures rather than relying on a single expected distance. The present CT assisted study assesses the spatial relationships of the C1 transverse process with structures relevant to head and neck surgery, with the aim of providing anatomical information for preoperative planning.[8]

MATERIALS AND METHODS

Study design and setting: This retrospective, cross-sectional imaging study was conducted in the Departments of Anatomy and Radiodiagnosis at a tertiary care centre in North India. Head and neck computed tomography (CT) examinations performed between January 2023 and December 2024 were reviewed to assess the relationship of the transverse process of the atlas (C1) with structures relevant to upper neck and lateral skull base surgery. The images had been acquired for clinical indications, and no additional imaging was performed for the study. Approval was obtained from the Institutional Ethics Committee.

Study population: The institutional radiology archive was screened consecutively for examinations covering both C1 transverse processes and the adjacent upper cervical region. Scans were eligible when the bony landmarks were clearly depicted and at least one adjacent structure of interest could be assessed reliably. Examinations were excluded if fracture, previous surgery, a large mass, destructive disease or substantial artefact distorted the local anatomy. Anatomical variants were retained and documented because they could alter the relationship between C1 and nearby structures. Only one examination per patient was included. All consecutive examinations meeting these criteria during the study period were considered; no separate sample-size calculation determined the number included. After screening, 87 patients were eligible. Age, sex, clinical indication and type of CT examination were obtained from the imaging record and entered into a de-identified dataset.

Image acquisition and review: Archived images were retrieved in Digital Imaging and Communications in Medicine (DICOM) format. The examinations had been acquired on the department's multidetector CT equipment using protocols selected for their original clinical indications. Source axial images and available coronal and sagittal reconstructions were reviewed on a DICOM-compatible workstation. Bone-window settings were used to identify C1 and the styloid process; soft-tissue or vascular settings were used to assess vessels. Image-calibrated workstation tools were used to record distances in millimetres.

Contrast-enhanced and noncontrast examinations were identified separately. A vascular measurement was accepted only when the vessel boundary could be distinguished sufficiently to place the measurement point. The internal jugular vein was measured only when its margin was adequately visible. Noncontrast images could contribute to bony measurements but did not contribute to a vascular measurement when the vessel could not be reliably delineated. Consequently, the number of evaluable sides could differ among structures. Multiplanar review was used to confirm the identity of each structure and avoid relying on an apparent relationship seen on a single section. Clinical head and neck CT protocols can differ in contrast use and reconstruction parameters, making this structure-specific assessment necessary.

Anatomical landmarks and measurements: The lateralmost cortical tip of each C1 transverse process was designated the reference point. On each side, the internal carotid artery, internal jugular vein, vertebral artery at its C1 course, occipital artery and styloid process were identified where visible. The linear distance from the C1 reference point to the nearest clearly visible outer margin of each vessel was measured on the multiplanar image that depicted both measurement points. The distance to the styloid process was measured to its nearest cortical margin. Measurement points were checked against the other available planes to confirm their anatomical location. These values were treated as CT image-based distances; they were not described as three-dimensional minimum distances or direct intraoperative measurements.

Right- and left-sided distances were recorded separately. The position of each structure relative to C1 was described as anterior or posterior, medial or lateral, and superior or inferior, as applicable. Anatomical variants and visible contact between the styloid process, internal jugular vein and C1 were recorded descriptively. A structure outside the scan coverage or insufficiently visible for a reliable measurement was recorded as unavailable rather than assigned an estimated distance.

Statistical analysis: Data were analysed using IBM SPSS Statistics version 20.0. Age was summarised as mean ± standard deviation, and categorical variables as frequencies and percentages. The number of patients and sides with an evaluable measurement was reported separately for each structure. Bilateral distances were summarised as mean ± standard deviation; right- and left-sided measurements from the same patient were compared using a two-sided paired t test. For each patient with bilateral measurements, the smaller of the two distances was also summarised as median, interquartile range and observed range. Sex comparisons used each patient's average bilateral distance as one independent observation and were assessed using Welch's independent-samples t test. Unavailable measurements were not imputed. All comparisons were exploratory, with unadjusted p values reported;

a two-sided p value <0.05 was used to identify statistical evidence of a difference.

RESULTS

The mean age was 49.5 ± 15.2 years (range, 18–78 years), and 49 patients (56.3%) were male. The largest age group was 45–59 years (33 patients, 37.9%). Sixty-four examinations (73.6%) were contrast-enhanced. The leading imaging indications were a suspected localised salivary or neck lesion (26, 29.9%) and cervical lymphadenopathy (20, 23.0%) [Table 1].

The styloid process was measurable bilaterally in all 87 patients. Among vascular structures, at least one side was evaluable for the internal carotid artery in 63 patients (72.4%), vertebral artery in 61 (70.1%), internal jugular vein in 58 (66.7%) and occipital artery in 50 (57.5%). Bilateral measurements were available in 59, 56, 52 and 42 patients, respectively. Occipital artery measurements had the lowest availability, with 92 evaluable sides [Table 2].

Table 1: Demographic characteristics, clinical indications and CT examination types (N = 87).

Characteristic	Frequency (%)/Mean ± SD
Age, years	49.5 ± 15.2
Age range, years	18–78
<30 years	8 (9.2%)
30–44 years	23 (26.4%)
45–59 years	33 (37.9%)
≥60 years	23 (26.4%)
Gender	
Male	49 (56.3%)
Female	38 (43.7%)
CT type	
Contrast-enhanced CT	64 (73.6%)
Noncontrast CT	23 (26.4%)
Indications	
Suspected localised salivary or neck lesion	26 (29.9%)
Cervical lymphadenopathy	20 (23.0%)
Upper neck pain or swelling	16 (18.4%)
Vascular assessment	12 (13.8%)
Other clinical indications	13 (14.9%)

CT, computed tomography.

Table 2: Availability of C1-to-structure measurements by side (N = 87).

Structure	Patients with ≥1 evaluable side	Both sides	Right only	Left only	Total evaluable sides
	Frequency (%)				
Internal carotid artery	63 (72.4%)	59 (67.8%)	2 (2.3%)	2 (2.3%)	122
Internal jugular vein	58 (66.7%)	52 (59.8%)	3 (3.4%)	3 (3.4%)	110
Vertebral artery	61 (70.1%)	56 (64.4%)	3 (3.4%)	2 (2.3%)	117
Occipital artery	50 (57.5%)	42 (48.3%)	4 (4.6%)	4 (4.6%)	92
Styloid process	87 (100%)	87 (100%)	0 (0%)	0 (0%)	174

"Both sides," "right only" and "left only" are mutually exclusive. C1, first cervical vertebra.

The internal carotid artery was located 23.43 ± 2.98 mm from C1 on the right and 23.09 ± 2.98 mm on the left (p = 0.065). The corresponding internal jugular vein distances were 8.66 ± 2.64 and 8.25 ± 2.49 mm, showing a small right–left difference (p = 0.018). Styloid process distance was also greater on the right (16.64 ± 3.12 versus 15.87 ± 3.24 mm; p < 0.001). Vertebral and occipital artery distances did not differ significantly between sides (p = 0.195 and 0.285, respectively) [Table 3].

Table 3: Paired comparison of right- and left-sided distances from the C1 transverse process.

Structure	Paired patients	Right, mm	Left, mm	Right − left, mm	Paired p value
	Frequency	mean ± SD			
Internal carotid artery	59	23.43 ± 2.98	23.09 ± 2.98	0.34 ± 1.40	0.065
Internal jugular vein	52	8.66 ± 2.64	8.25 ± 2.49	0.41 ± 1.21	0.018
Vertebral artery	56	23.71 ± 4.74	24.09 ± 4.84	−0.38 ± 2.16	0.195
Occipital artery	42	12.63 ± 4.04	12.23 ± 4.29	0.40 ± 2.41	0.285
Styloid process	87	16.64 ± 3.12	15.87 ± 3.24	0.77 ± 1.83	<0.001

Differences are calculated as right minus left; positive values indicate a greater right-sided distance. C1, first cervical vertebra.

The median nearest-side distance was 8.06 mm (IQR, 5.83–9.78 mm) for the internal jugular vein and 12.19 mm (IQR, 8.22–14.12 mm) for the occipital artery. A distance below 5 mm occurred in 6 of 52 patients (11.5%) with bilateral jugular measurements and 2 of 42 (4.8%) with bilateral occipital artery measurements. No distance below 5 mm occurred for the internal carotid artery, vertebral artery or styloid process [Table 4].

Table 4: Nearest-side distance from the C1 transverse process for patients with bilateral measurements.

Structure	Patients with bilateral measurements	Nearer-side distance, mm	Observed range, mm	Patients with a distance <5 mm
	Frequency	median (IQR)		Frequency (%)
Internal carotid artery	59	22.35 (21.24–24.19)	15.36–31.50	0
Internal jugular vein	52	8.06 (5.83–9.78)	2.43–12.58	6 (11.5%)
Vertebral artery	56	22.78 (20.64–26.06)	10.70–33.52	0
Occipital artery	42	12.19 (8.22–14.12)	2.66–21.18	2 (4.8%)
Styloid process	87	15.57 (13.09–18.00)	8.72–23.11	0

C1, first cervical vertebra; IQR, interquartile range.

Mean distances were comparable between male and female patients for all five structures. The male and female means were 23.81 ± 2.66 and 22.56 ± 3.09 mm for the internal carotid artery (p = 0.106), and 8.70 ± 2.53 and 8.12 ± 2.47 mm for the internal jugular vein (p = 0.417). No significant sex difference was found for the vertebral artery, occipital artery or styloid process (all p ≥ 0.331) [Table 5].

Table 5: Comparison of C1-to-structure distances according to sex.

Structure	Male patients	Male, mm	Female patients	Female, mm	p value
	Frequency	mean ± SD	Frequency	mean ± SD	
Internal carotid artery	33	23.81 ± 2.66	26	22.56 ± 3.09	0.106
Internal jugular vein	30	8.70 ± 2.53	22	8.12 ± 2.47	0.417
Vertebral artery	31	24.25 ± 4.47	25	23.47 ± 4.95	0.541
Occipital artery	24	12.25 ± 3.63	18	12.66 ± 4.52	0.754
Styloid process	49	15.98 ± 3.12	38	16.62 ± 2.94	0.331

C1, first cervical vertebra.

DISCUSSION

In the present study on 87 patients, the internal jugular vein (IJV) was the closest major vessel to the lateral tip of the C1 transverse process: its median nearer-side distance was 8.06 mm, and 6 of 52 patients with bilateral measurements (11.5%) had a distance below 5 mm. The right-sided mean exceeded the left by only 0.41 mm despite a paired p value of 0.018. This small difference is unlikely to provide a dependable side-specific guide during surgery. Jayaraman et al., examining 108 unselected neck CT angiograms, found severe bilateral extrinsic upper-IJV compression in 10 patients (9.3%).[9] Clinical reports by Li et al., and Pokeerbux et al., describe venous narrowing where the styloid process and C1 form a confined corridor.[10,11] The present distances describe proximity rather than luminal stenosis or impaired drainage; neither can be inferred from a short bone-to-vein distance alone.

The internal carotid artery lay farther from the selected C1 point, at 23.43 mm on the right and 23.09 mm on the left, without a statistically significant paired difference (p = 0.065). Nevertheless, nearer-side measurements extended down to 15.36 mm. These values support C1 as an orientation landmark, but do not define a fixed distance through which dissection is safe. Identifying C1 on CT also differs from finding it by touch: in a radiographic study of 21 participants, Cooperstein et al., reported a mean absolute palpation error of 4.34 mm, with only 57.1% of markers meeting their strict ±4 mm accuracy criterion.[12] That error exceeds the mean right–left arterial and venous differences in the present study. Image review and direct vessel identification therefore remain necessary near the carotid sheath.

The vertebral artery showed a wider spread than the carotid artery, with a nearer-side range of 10.70–33.52 mm and no significant right–left difference (p = 0.195). This variability is anatomically plausible because the V3 segment curves around C1 before entering the cranial cavity. In a South Indian cadaveric study of 40 vertebral arteries, Punja et al., documented variation in the lengths of its atlantic components.[13] Kiresi et al., demonstrated how multidetector CT angiography defines V2–V3 relationships in 33 patients,[14] while Hong et al., examined atlas-associated osseous and arterial variants in 1,013 CT angiograms.[15] Ulm et al. also described variation in V3's relationship to bony landmarks.[16] These studies used different reference points, so their measurements cannot be equated numerically with C1-tip distances. Together, they support tracing each patient's arterial course before a posterior or lateral approach.

The occipital artery was evaluable bilaterally in only 42 patients, fewer than the other arteries. Its small calibre, variable course and differences in contrast timing may explain reduced delineation on CT performed for mixed clinical indications. Mean distances were 12.63 mm on the right and 12.23 mm on the left (p = 0.285), although two patients had a nearer-side distance below 5 mm. Keser et al., detailed the artery's surgically important segments,[17] and Rafferty et al., examined its sternomastoid branch as a guide to the spinal accessory nerve.[18] Angiographic studies further caution against assuming a uniform course: Dincă et al., classified 200 occipital arteries by their relationship to the atlas and occipital sulcus,[19] while Rusu et al., described four aberrant courses, including vessels passing deep to the IJV.[20]

Styloid-process distance was greater on the right by 0.77 mm ($p < 0.001$), whereas none of the five patient-level distances showed a significant difference by sex. The styloid finding should be interpreted as a small measured asymmetry, not proof that one side offers a safer surgical route. Five side comparisons were also performed without adjustment for multiple testing. Vascular evaluability varied: although all 87 patients had bilateral bony measurements, only 42–59 had bilateral measurements for an individual vessel. These subsets may differ because of scan indication, contrast timing and vessel visibility. The present study findings therefore support patient-specific CT review for surgical orientation.

Limitations: This retrospective, single-centre study is subject to selection bias because scans were obtained for different clinical indications. Contrast timing and image quality reduced vascular evaluability, particularly for the occipital artery, and may have affected comparisons. Image-based distances do not reproduce surgical exposure or account for neck position. Measurement reproducibility and operative correlation were not established. The modest sample and multiple exploratory comparisons also limit interpretation of small side differences.

CONCLUSION

The atlas transverse process provides a consistent bony reference from which adjacent upper cervical structures can be described on CT. In this study, the internal jugular vein was the closest major vessel, with substantial patient-to-patient variation and occasional distances below 5 mm. Small right–left differences in jugular and styloid measurements should not be converted into fixed operative margins. Vertebral and occipital artery relationships also varied, supporting individual review of vessel course before upper neck or lateral skull base surgery. These findings support CT-based anatomical planning, but clinical usefulness and any effect on surgical complications require prospective assessment with standardised imaging and operative correlation.

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