

The Right Posterior Carotid Sheath Channel: A Potential Anatomical Structure Associated With Lymph Node Metastasis in Papillary Thyroid Carcinoma

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Research Article

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Abstract

Background

Papillary thyroid carcinoma (PTC) is characterized by early lymphatic spread. During right lateral neck dissection, a potential lymphatic tissue plane posterior to the carotid sheath may be overlooked. We provisionally termed this region the posterior carotid sheath channel (PTCS).

Methods

Clinical data were prospectively collected from 33 patients with PTC who underwent right lateral neck dissection between November 2022 and June 2023. This was a single-center exploratory case series, and PTCS tissue from each patient was excised and submitted separately for histopathological examination. Preoperative ultrasonography and computed tomography (CT) findings were compared with postoperative histopathology.

Results

PTCS metastasis was identified in 4 of 33 patients (12.1%). All four patients had level VI metastasis, and three had level IV metastasis. With contrast-enhanced CT as the primary imaging assessment, there were 4 true-positive, 2 false-positive, 0 false-negative, and 27 true-negative examinations. Sensitivity was 100.0% (4/4; Wilson 95% confidence interval [CI], 51.0%–100.0%), specificity was 93.1% (27/29; 95% CI, 78.0%–98.1%), and the positive predictive value was 66.7% (4/6; 95% CI, 30.0%–90.3%).

Conclusions

Lymphatic tissue posterior to the right carotid sheath can harbor metastatic PTC. The observed co-occurrence pattern raises the possibility of a lymphatic pathway but does not establish the direction of spread or an attributable proportion. Prospective bilateral anatomical and imaging studies are required before routine exploration or dissection can be recommended.

1. Introduction

For patients with papillary thyroid carcinoma (PTC) and clinically confirmed lateral cervical lymph node metastasis, the completeness of the initial therapeutic dissection directly affects locoregional control and the risk of reoperation [1]. Current guidelines and consensus recommendations support compartment-oriented lateral neck dissection, generally encompassing levels IIa, III, IV, and Vb [2]. The prognostic significance of nodal metastasis in PTC is also influenced by metastatic-node burden and extranodal extension [3]. Standardized neck levels define the conventional extent of dissection, but they leave a practical question unresolved. Lymphatic tissue at compartmental interfaces or around major

vessels may be missed in the routine surgical field and may still harbor metastasis. Identifying such potential blind spots may improve the completeness of initial surgery. The current understanding of lymphatic spread in PTC is evolving from a strictly stepwise model toward a network of multiple routes. Multilevel nodal disease has been described in N1b PTC [4]. Anatomical pathways may connect the central compartment with lateral-neck metastasis [5]. Skip metastasis from upper-pole tumors further indicates that PTC does not invariably follow a single sequential route [6]. More recently, real-time contrast-enhanced lymphatic ultrasonography has demonstrated substantial interindividual variation, frequent cross-midline communication, side-specific differences, and predominant drainage toward levels III and IV [7]. Neck levels therefore provide a useful reporting framework, but they may not capture the actual routes of tumor spread. Previous research has largely described where metastases occur, with limited attention to whether deep tissue planes posterior to major vessels represent reproducibly identifiable, metastasis-associated regions. Involvement of lymph nodes within the right carotid sheath space (RCSS), located between the right common carotid artery and the internal jugular vein, has been reported, indicating that nonstandard perivascular spaces may be clinically relevant [8]. However, the RCSS lies between the two vessels and is distinct from tissue posterior to the carotid sheath. During right lateral neck dissection, we observed a separable tissue plane posterior to the carotid sheath near the junction of levels IV and VIb. Because it appeared to contain lymphatic tissue, we provisionally termed it the posterior carotid sheath channel (PTCS). We used this term to define a testable intraoperative target for separate pathological sampling and preoperative imaging assessment, rather than to assert the existence of a fully validated anatomical entity. Because only right-sided procedures were included and cadaveric dissection, serial histology, and lymphatic mapping were unavailable, we treat the PTCS as an intraoperative anatomical hypothesis. Its deep location adjacent to major vessels limits routine ultrasonographic assessment because of acoustic-window constraints and operator dependence. Contrast-enhanced CT may better delineate the region and its relationship to the surrounding vasculature; CT is also a useful adjunct to ultrasonography for cervical nodal assessment [9]. Meta-analytic evidence supports the diagnostic value of CT for metastatic cervical lymph nodes in thyroid cancer [10]. Quantitative techniques such as dual-energy CT may provide additional diagnostic information [11]. No standardized imaging criteria for the PTCS currently exist. We aimed to describe the intraoperative appearance and pathological involvement of the PTCS and to examine its co-occurrence with level IV and level VI metastases. We also explored whether this region is a potential blind spot during right lateral neck dissection, using contrast-enhanced CT as the primary preoperative imaging modality and ultrasonography as a supplementary method. The study was designed to generate anatomical and imaging evidence for further validation, not to establish the PTCS as an independent route of lymphatic metastasis.

2. Materials and Methods

2.1 Study Design and Participants

Patients with PTC who underwent thyroid lobectomy or total thyroidectomy combined with lateral neck dissection at The Second Hospital of Dalian Medical University between November 2022 and June 2023 were assessed. This was a prospective, single-center, exploratory observational case series using convenience sampling. A total of 105 patients with secondary malignant neoplasms of cervical lymph nodes were screened. Of these, 49 were excluded because no definite metastatic lesion was identified in the right lateral neck, 4 because they did not undergo surgery, and 19 because the procedure was not performed by the designated surgical team. The final cohort comprised 33 patients.

2.2 Surgical Assessment, Imaging, and Histopathology

Eligible patients had a postoperative histopathological diagnosis of PTC, underwent right therapeutic lateral neck dissection for metastatic disease, and were operated on by the designated institutional team. Complete exploration of the region posterior to the carotid sheath was also required, with tissue from this region excised and submitted separately for pathological examination. The exclusion criteria were as follows: (1) no definite metastatic lesion in the right lateral neck, including patients with metastasis confined to the left lateral neck; (2) no surgical treatment; and (3) surgery not performed by the designated team.

Of the 105 patients screened with secondary malignant neoplasms of cervical lymph nodes, 49 had no definite metastatic lesion in the right lateral neck and 4 did not undergo surgery. A further 19 were excluded because their procedures were not performed by the designated surgical team. Thus, 33 patients were included.

All procedures were performed by the designated thyroid surgery team at The Second Hospital of Dalian Medical University. A chief surgeon performed each operation with the assistance of two senior surgeons. We defined the posterior carotid sheath channel (PTCS) intraoperatively as a fibrofatty tissue plane between the posterior wall of the carotid sheath and the prevertebral fascia. The plane could contain lymphatic tissue and extended obliquely from level VIb toward level IV. At its level VIb end, the plane lay between the trachea and the medial border of the carotid sheath, deep to the recurrent laryngeal nerve. At its level IV end, it extended toward the supraclavicular fossa to approximately 1–2 cm above the clavicle, adjacent to the lateral border of the carotid sheath. Three surgeons jointly inspected the operative field and confirmed the PTCS by consensus based on its anatomical location, trajectory, extension at both ends, and tissue composition.

A sterile ruler was not used, and no standardized protocol for quantitative intraoperative measurement was prespecified. The estimated PTCS dimensions of approximately 1.5–2 cm in length and 1–1.5 cm in width were based on visual assessment by the three surgeons using the exposed operative field and adjacent anatomical landmarks. These measurements were used only for descriptive anatomical observation and were not included in quantitative statistical analyses.

All included patients underwent preoperative cervical CT and ultrasonography. Imaging assessment was based primarily on contrast-enhanced CT, with conventional ultrasonography used as a supplementary

modality. The CT acquisition covered the neck through the thoracic inlet, with 1-mm axial reconstructions and coronal and sagittal reformatted images. A dual-phase contrast-enhanced protocol was used, with arterial- and venous-phase images acquired approximately 25 and 60 seconds after contrast administration, respectively. All 33 patients in the cohort completed contrast-enhanced CT. For patients with contraindications to iodinated contrast material, nonenhanced CT was used; such findings were described only and were excluded from the primary diagnostic-performance analysis of contrast-enhanced CT.

A CT examination was considered suspicious when a discrete nodule was identified within the defined PTCS boundaries. At least one of the following features was required: cystic change or necrosis, calcification, marked or heterogeneous enhancement, or an irregular margin. Nonspecific soft-tissue density without these suspicious features was classified as negative or indeterminate.

Ultrasonography was performed with a high-frequency linear transducer, with the patient supine, the neck mildly extended, and the head turned to the left. Particular attention was paid to right neck levels IV and VIb and the region surrounding the carotid sheath. A lesion was considered evaluable only when its relationship to the common carotid artery, internal jugular vein, and carotid sheath permitted confident localization to the PTCS. Lesions showing microcalcifications, cystic change, focal or diffuse hyperechogenicity, or abnormal peripheral vascularity were considered suspicious. When the region could not be clearly visualized because of its depth or a limited acoustic window, the examination was recorded as nonevaluable rather than negative.

CT and ultrasonographic images were reviewed by two readers according to the criteria described above. Disagreements were resolved by consensus. No combined decision rule based on either modality being positive or both modalities being positive was applied. Contrast-enhanced CT was the primary imaging method for preoperative localization and assessment of suspected PTCS involvement; ultrasonographic findings were used only for supplementary and exploratory analyses.

All tissue excised from the PTCS region was labeled separately and submitted for histopathological examination. The pathologist first determined whether the specimen contained lymphatic tissue or lymph nodes and then assessed the presence of metastatic PTC. Pathological positivity was defined as a metastatic PTC lymph node within the separately submitted PTCS specimen. Fibrofatty tissue alone, nonmetastatic lymphatic tissue, or reactive lymph nodes were classified as negative. Histopathological findings from the separately submitted PTCS specimens served as the reference standard for preoperative imaging assessment.

2.3 Outcomes and Statistical Analysis

Analyses were performed using SPSS version 29.0. The primary outcome was the proportion of patients with pathologically confirmed PTCS metastasis. Imaging findings, nodal co-occurrence patterns, and BRAF status were secondary exploratory outcomes. Categorical variables are presented as counts and percentages, and continuous variables as means and standard deviations. Between-group comparisons

of metastatic lymph node counts were performed using the Mann–Whitney U test, and the association between PTCS metastasis and level IV metastasis was assessed using Fisher's exact test. BRAF V600E was analyzed descriptively without hypothesis testing. Exact P values are reported. Imaging results were summarized in a 2×2 contingency table, with sensitivity, specificity, accuracy, positive predictive value, and negative predictive value reported. Wilson 95% confidence intervals were calculated for binomial proportions. Because only four patients had PTCS metastasis, all between-group comparisons were considered hypothesis-generating.

3. Results

3.1 Patient Characteristics

The cohort comprised 33 patients (22 women and 11 men) aged 26–72 years, with a mean age of 47.36 ± 13.04 years. Postoperative histopathology demonstrated level VI metastasis in 31 patients (93.9%), level IV metastasis in 23 (69.7%), and PTCS metastasis in 4 (12.1%). All patients underwent right lateral neck dissection; the left side was not systematically explored. Among the 23 patients with level IV metastasis, 3 also had PTCS metastasis (13.0%; Wilson 95% CI, 4.5%–32.1%). This proportion reflects co-occurrence only and should not be interpreted as the attributable proportion of spread from level VI to level IV (Table 1).

3.2 Imaging Findings

Contrast-enhanced CT was used as the primary assessment, with ultrasonography serving only as a supplementary modality. Among all 33 patients who underwent contrast-enhanced CT, 6 examinations were positive and 27 were negative. Postoperative histopathology confirmed PTCS metastasis in 4 imaging-positive patients; the remaining 2 were false positives. All 27 imaging-negative patients were negative by the reference standard. Accordingly, the 2×2 classification comprised 4 true positives, 2 false positives, 0 false negatives, and 27 true negatives. Sensitivity was 100.0% (4/4; Wilson 95% CI, 51.0%–100.0%), and specificity was 93.1% (27/29; 95% CI, 78.0%–98.1%). Accuracy was 93.9% (31/33; 95% CI, 80.4%–98.3%), the positive predictive value was 66.7% (4/6; 95% CI, 30.0%–90.3%), and the negative predictive value was 100.0% (27/27; 95% CI, 87.5%–100.0%) (Figure 1).

3.3 Co-occurrence of PTCS, Level IV, and Level VI Metastases

All four patients with PTCS metastasis had level VI metastasis (4/4, 100.0%), and three had level IV metastasis (3/4, 75.0%) (Table 2). Among the 23 patients with level IV metastasis, 3 also had PTCS metastasis (13.0%; Wilson 95% CI, 4.5%–32.1%). These cross-sectional observations cannot determine the direction, sequence, or attributable proportion of lymphatic spread. PTCS metastasis was not significantly associated with level IV metastasis (Fisher's exact test, $P = 1.000$).

Patients with PTCS metastasis had higher mean numbers of metastatic lymph nodes at both level VI (5.75 ± 5.68 vs 3.21 ± 3.20) and level IV (3.25 ± 2.22 vs 1.59 ± 1.59). The exact P values were 0.254 for

level VI and 0.084 for level IV (Table 3). Given that only four patients were PTCS-positive and that lymph node counts may have been skewed, these comparisons are exploratory and should not be interpreted as evidence of a trend or causal relationship.

3.4 Exploratory Analysis of BRAF V600E

All four patients with PTCS metastasis who underwent molecular testing harbored BRAF V600E. Among the 14 tested patients without PTCS metastasis, 11 (78.6%) were BRAF V600E-positive. BRAF results were available for only 18 of the 33 patients, with data missing for 15. Because testing was not performed systematically and the missingness may not have been random, this analysis is exploratory and cannot establish an association between BRAF V600E and PTCS metastasis.

3.5 Intraoperative Findings

During right lateral neck dissection, an obliquely oriented tissue plane was observed posterior to the carotid sheath between the lower central compartment and level IV. The plane contained fibrofatty and lymphatic tissue. Its dimensions were estimated visually from the exposed operative field and adjacent anatomical landmarks and were used only for descriptive observation. The proposed level IV and level VIb boundaries should be described using reproducible anatomical landmarks and validated by cadaveric dissection, serial histology, or other anatomical methods. Its relationships to the vagus nerve, sympathetic trunk, phrenic nerve, anterior scalene muscle, vertebral artery, and recurrent laryngeal nerve should be documented systematically. Because nerve injury, vascular injury, operative time, and other complications were not recorded prospectively, the available data cannot establish the safety of routine PTCS dissection. Representative intraoperative appearances are shown in Figures 2 and 3.

4. Discussion

In this cohort of 33 patients with PTC who underwent right therapeutic lateral neck dissection, metastatic lymph nodes were identified in tissue posterior to the carotid sheath in 4 patients (12.1%). All four PTCS-positive patients had level VI metastasis, and three also had level IV metastasis. Involvement of this tissue plane shows that metastatic disease can extend beyond conventional neck-level boundaries. In our series, PTCS involvement occurred mainly in patients with multilevel disease in the lower central and lower lateral neck.

Metastatic PTC lymph nodes have previously been reported in the recurrent laryngeal nerve–carotid recess [12]. Anatomical studies have also identified lymphatic tissue between the recurrent laryngeal nerve and the right common carotid artery [13]. Other unusual perivascular nodal metastases have been described in differentiated thyroid cancer [14]. The RCSS lies primarily between the right common carotid artery and the internal jugular vein, whereas we examined tissue located predominantly posterior to the carotid sheath. A recent study of lymph nodes between the right innominate artery and vein similarly indicates that conventional neck levels may not encompass all deep lymphatic tissue at risk of metastasis [15]. Our observations extend this anatomical question to the region posterior to the carotid

sheath. Contemporary thyroid-cancer guidelines standardize the reporting and management of nodal disease [16]. Central-compartment consensus terminology further supports structured anatomical reporting [17]. Standardized neck-dissection classifications provide a complementary framework for lateral-neck disease [18]. However, these systems are based on defined compartments and do not exclude clinically relevant lymphatic tissue at their interfaces. Cadaveric dissection and serial histology are needed to determine whether the PTCS is anatomically continuous with these adjacent spaces.

PTCS-positive cases showed a pattern of concurrent involvement of level VI, the PTCS, and level IV. Surgical series show that lateral nodal disease often clusters at levels III and IV [19]. Central-compartment tumor burden has been associated with lateral cervical lymph-node metastasis [20]. Meta-analytic evidence further supports characteristic patterns of lateral nodal prevalence, risk factors, and location in PTC [21]. Skip metastasis can occur without pathological central-node involvement [22]. These patterns may jointly reflect a greater overall cervical nodal burden. Intraoperatively, the PTCS extended from level VIb toward level IV. This orientation, together with concurrent nodal involvement, raises the possibility that the region is a transition zone between the lower central and lower lateral neck. Interpretation is limited because level VI and level IV metastases were already highly prevalent in this cohort (31/33 and 23/33, respectively), and only four patients were PTCS-positive. The pattern is therefore a signal for further study, not evidence of an established sequential metastatic route.

Reported variability, bilateral communication, and side-to-side asymmetry in thyroid lymphatic drainage offer one anatomical context for metastatic lymph nodes in the PTCS region. PTCS involvement could reflect an uncommon drainage variant or synchronous disease in several adjacent regions in patients with a high nodal burden. Because the predominant thyroid lymphatic drainage route is generally anterior to the carotid artery, the specific role of the PTCS in thyroid lymphatic drainage requires region-directed lymphatic mapping and serial histological investigation.

Clinically, our observation draws attention to deep tissue near the boundaries of standard compartment-oriented dissection. Standard compartment-oriented therapeutic lateral neck dissection for clinically evident lateral nodal disease generally encompasses levels IIa, III, IV, and Vb, but does not include the region posterior to the carotid sheath as a routine target. Meta-analytic evidence identifies central-node burden among the predictors of occult lateral metastasis [23]. Recurrence studies also emphasize the importance of adequate compartment-oriented treatment when lateral disease is clinically evident [24]. Targeted assessment may be considered when contrast-enhanced CT shows a suspicious nodule in this region. It may also be considered when high level VI and level IV tumor burden is accompanied by abnormal tissue posterior to the carotid sheath intraoperatively. Surgeons undertaking this assessment should be familiar with the regional anatomy, and suspicious tissue should be submitted separately for histopathology. In the absence of imaging or intraoperative abnormalities, routine extension of the dissection should be weighed against the potential benefits and the risks of neural and vascular injury associated with deep dissection in this region.

All four PTCS-positive patients with available molecular testing harbored BRAF V600E; however, testing was available for only 18 of 33 patients and was not performed systematically. Meta-analytic evidence has associated BRAF V600E with cervical lymph-node metastasis and other adverse clinicopathological features [25]. Cohort evidence has also linked BRAF V600E with central-compartment lymph-node metastasis in PTC [26]. Given the incomplete testing and very small PTCS-positive subgroup, these data cannot establish a specific association with PTCS involvement. Using contrast-enhanced CT as the primary preoperative imaging modality and ultrasonography as a supplement, we observed 4 true-positive, 2 false-positive, 0 false-negative, and 27 true-negative examinations. Although sensitivity was 100%, this estimate was based on only four pathologically positive patients and had a wide 95% confidence interval (51.0%–100.0%); the positive predictive value was 66.7%. Contrast-enhanced CT identified all four pathologically positive cases. However, reactive lymph nodes, fibrofatty tissue, and adjacent perivascular structures may still produce false-positive interpretations. Arterial-phase CT and protocol optimization may improve the conspicuity and diagnostic assessment of lateral cervical nodal metastases from PTC [27]. Thus, our data support the feasibility of CT assessment but do not validate its diagnostic performance. Future studies should use a standardized thin-section contrast-enhanced CT protocol, prespecified imaging criteria, blinded independent interpretation, and assessment of interobserver agreement.

All procedures were performed by a designated team. In every patient, tissue posterior to the carotid sheath was labeled and submitted separately, providing a pathological reference for the intraoperative and imaging findings. The principal limitations were the single-center, selected-case design; small sample size; only four PTCS-positive patients; and lack of systematic assessment of the left side. Excluding 19 patients whose procedures were performed by other surgical teams improved consistency of intraoperative assessment but may have introduced selection bias. In addition, the anatomical boundaries of the PTCS have not been validated by cadaveric dissection or serial histology, image interpretation was not strictly blinded, and operative time, neurovascular injury, lymphatic leakage, recurrence, and survival were not recorded prospectively.

In this series, metastatic lymph nodes were found in tissue posterior to the carotid sheath in a subset of patients undergoing right therapeutic lateral neck dissection for PTC. Targeted imaging and intraoperative assessment of the PTCS could be considered in patients with a high level VI and level IV tumor burden, particularly when contrast-enhanced CT shows suspicious tissue in this region. Bilateral, multicenter prospective studies incorporating standardized imaging, cadaveric dissection, serial histology, and lymphatic mapping are needed to clarify the anatomical basis, risk of involvement, and clinical management implications of this region.

5. Conclusions

In this single-center exploratory case series of 33 patients with PTC undergoing right lateral neck dissection, metastasis was identified in lymphatic tissue posterior to the carotid sheath in 4 patients (12.1%). All four had level VI metastasis, and three had level IV metastasis. This co-occurrence raises the

possibility of a lymphatic pathway but does not establish the direction of spread or an attributable proportion. With only four PTCS-positive cases, estimates of imaging performance were imprecise. Before routine exploration or dissection can be recommended, prospective bilateral anatomical studies are needed. These studies should use standardized imaging, separate pathological submission of PTCS tissue, and systematic recording of surgical safety and outcomes.

Abbreviations

The following abbreviations are used in this manuscript:

B-Raf proto-oncogene

confidence interval

computed tomography

papillary thyroid carcinoma

posterior carotid sheath channel

right carotid sheath space

standard deviation

Declarations

Author Contributions: Conceptualization, J.Z.W., J.H., J.X. and Y.Z.; methodology, J.Z.W., J.H., J.X. and Y.Z.; investigation, J.Z.W. and J.H.; data curation, J.Z.W., J.H. and J.R.W.; formal analysis, J.Z.W. and J.H.; validation, J.R.W. and J.X.; visualization, J.Z.W., J.H. and J.R.W.; writing—original draft preparation, J.Z.W. and J.H.; writing—review and editing, J.X. and Y.Z.; supervision, J.X. and Y.Z.; project administration, Y.Z. All authors have read and agreed to the published version of the manuscript. J.Z.W. and J.H. contributed equally to this work. J.X. and Y.Z. jointly supervised the study and share corresponding-author responsibilities.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of The Second Hospital of Dalian Medical University.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available from the corresponding authors upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Tables

Tables 1-3 are available in the Supplementary Files section.

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Figures

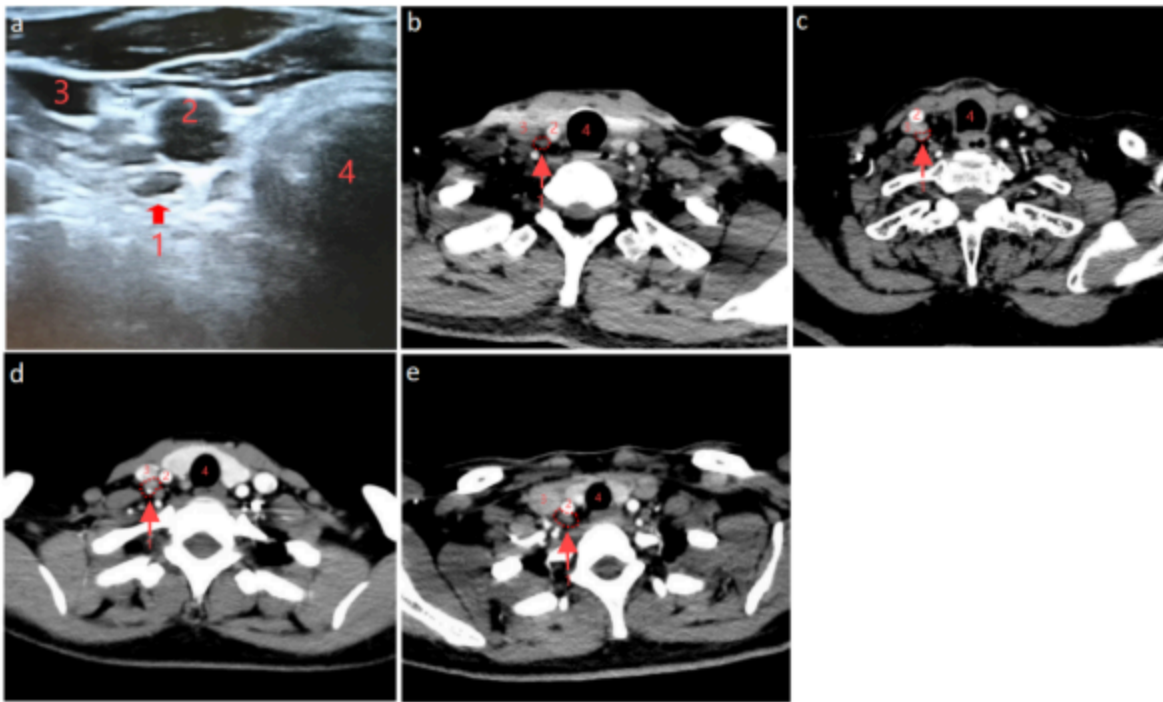


Figure 1

Preoperative imaging appearance of the proposed posterior carotid sheath channel (PTCS) region. (a) Ultrasonography shows a suspicious lymph node posterior to the right carotid sheath (red arrow). (b–e) Computed tomography (CT) images show the region posterior to the carotid sheath; dashed lines delineate its proposed extent. 1, suspicious lymph node within the PTCS region; 2, carotid artery; 3, internal jugular vein; 4, trachea.

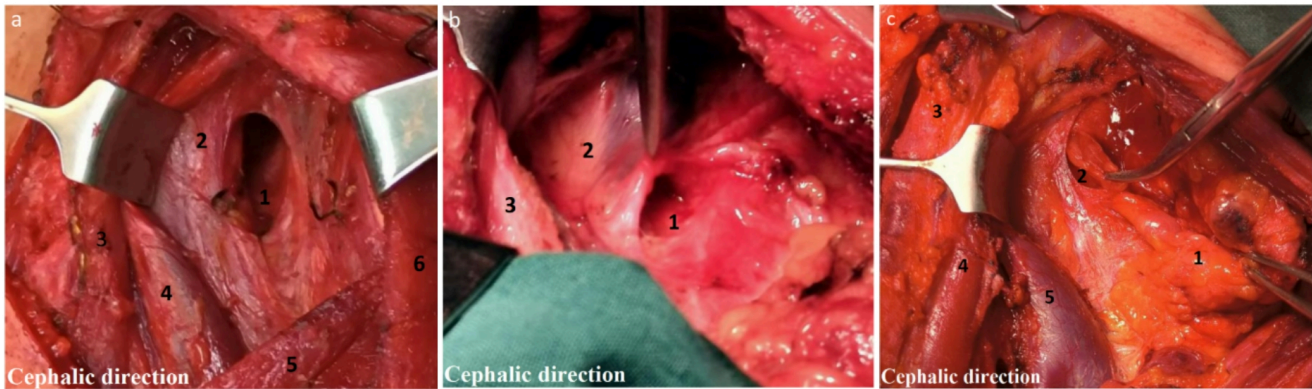


Figure 2

Intraoperative appearance of the posterior carotid sheath channel (PTCS). (a) Proposed level IV opening of the PTCS: 1, proposed opening; 2, carotid artery; 3, sternohyoid muscle; 4, internal jugular vein; 5, omohyoid muscle; 6, sternocleidomastoid muscle. (b) Proposed level IV opening of the PTCS: 1, proposed opening; 2, carotid sheath; 3, sternohyoid muscle. (c) Fibrofatty and lymphatic tissue within the proposed PTCS region: 1, lymphatic/fibrofatty tissue; 2, proposed level IV opening; 3, trachea; 4, sternohyoid muscle; 5, internal jugular vein.

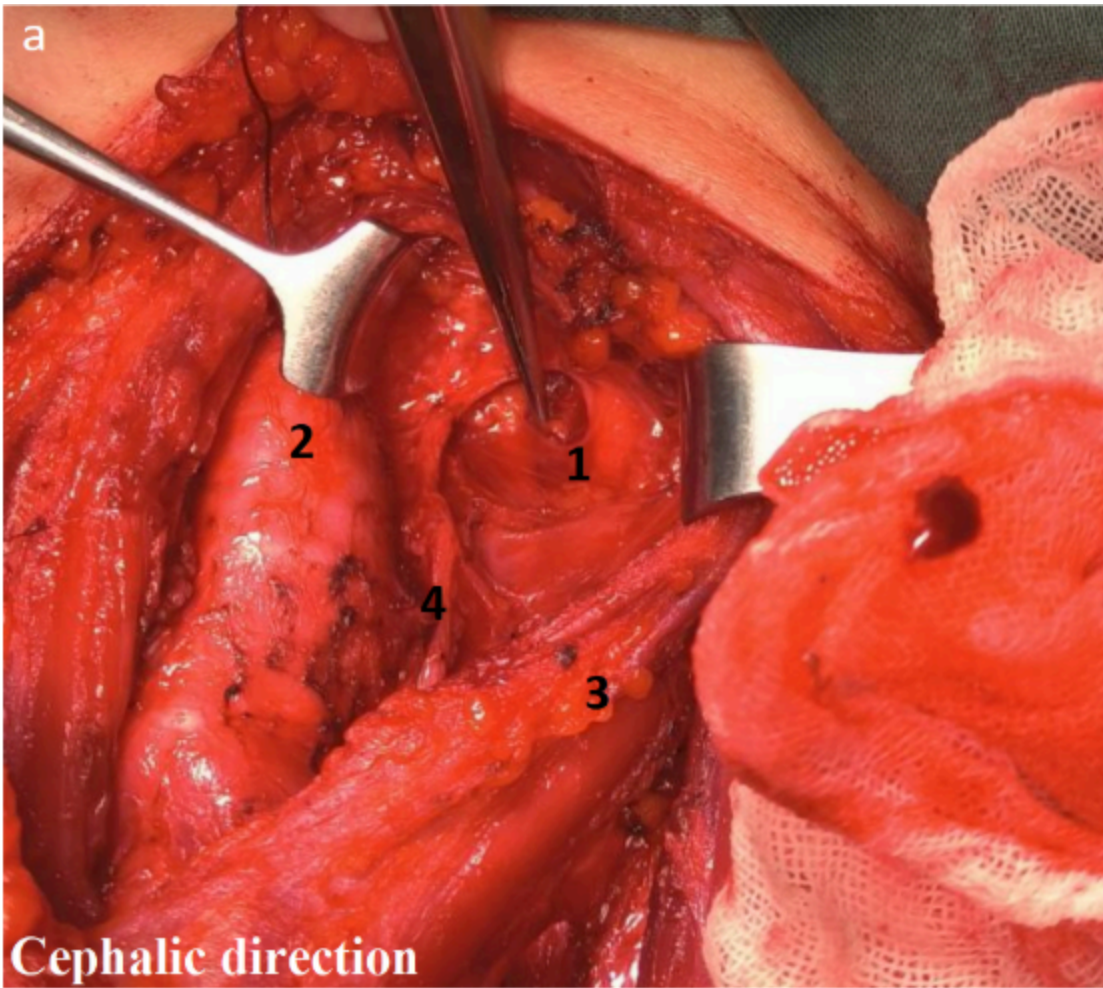


Figure 3

Proposed level VIb opening of the posterior carotid sheath channel (PTCS). 1, lymphatic/fibrofatty tissue; 2, trachea; 3, sternohyoid muscle; 4, recurrent laryngeal nerve.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Tables.docx](#)